UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

TRADE AND ENVIRONMENT REVIEW 2009/2010

Promoting poles of clean growth to foster the transition to a more sustainable economy

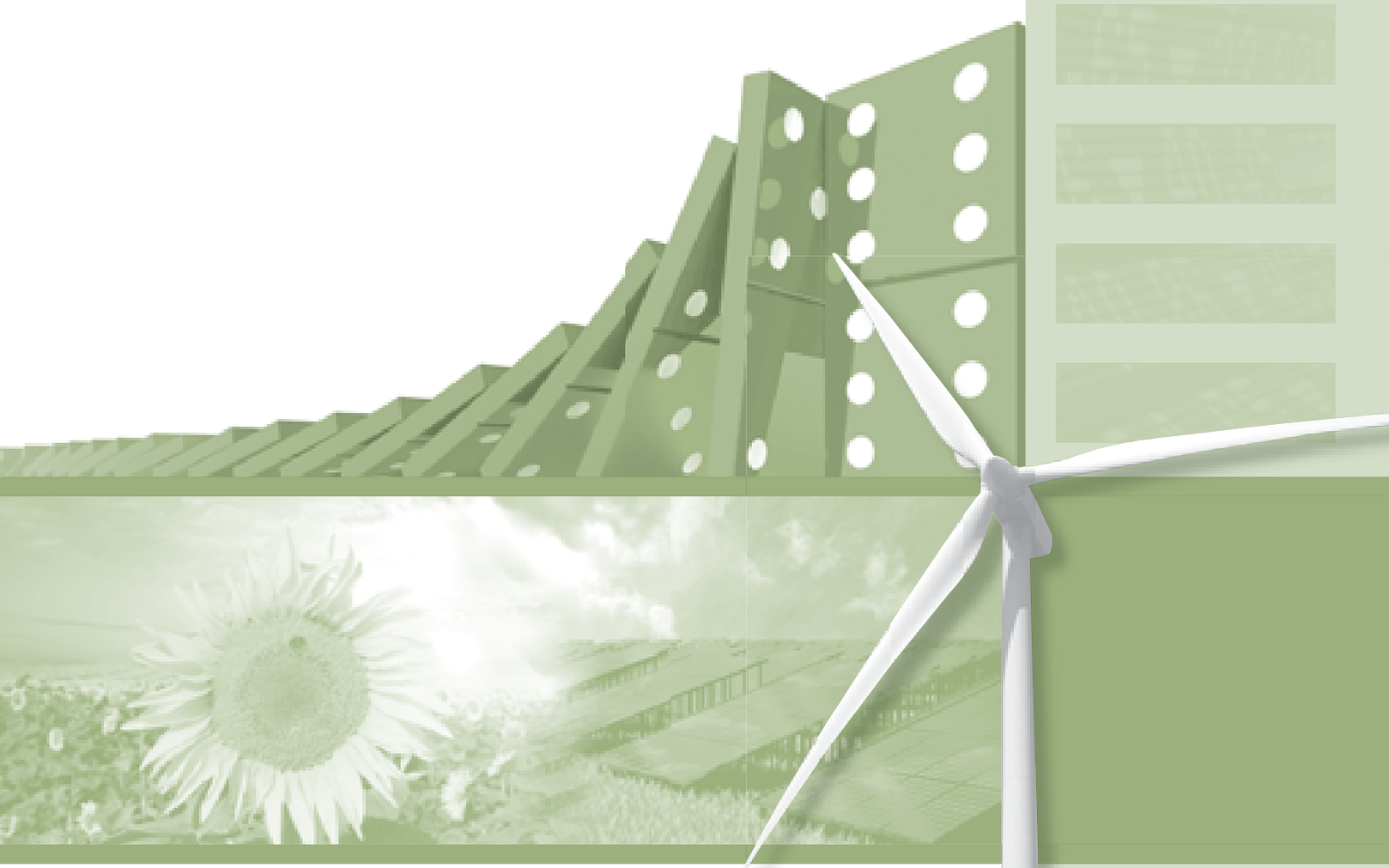


UNITED NATIONS

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Promoting poles of clean growth to foster the transition to a more sustainable economy



UNITED NATIONS
New York and Geneva, 2010

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Preface

This Trade and Environment Review is about finding a policy response to one of the defining challenges of our times – climate change. Meeting that challenge – and reducing the greenhouse gas intensity of the global economy by any meaningful amount – will require landslide changes in the approach to economic development. It will mean a thorough rethinking of national, regional and international economic and trade policymaking. The enormity of these tasks, and the complexity of the decisions ahead, is further compounded by the current economic recession, the ongoing global food crisis and the poverty-reduction imperative, all of which are interrelated.

In the light of these challenges, analysis and capacity-building activities at the interface of climate change, trade and development have assumed higher priority in UNCTAD's work. In the first six months of 2009 alone, UNCTAD hosted one expert meeting on maritime transport and climate change and another on trade and investment opportunities and challenges under the Clean Development Mechanism. In addition, the Trade and Development Report 2009 includes a chapter on the development challenges and opportunities of climate-change mitigation. In February 2010, UNCTAD will be holding an expert meeting on green and renewable energy technologies as solutions for rural development.

As UNCTAD has repeatedly argued, major crises such as the world is now experiencing can offer opportunities for rapid breakthroughs in new technologies, production and consumption patterns, and management practices. Such crises can also make it easier to effect the paradigm shifts and broader economic structural change required for humanity to master the challenges presented by climate change. According to the Review, the macroeconomic cost is not the greatest barrier to lowering the GHG intensity of growth. Rather, what is missing are the policy, regulatory, and institutional structures to support the shift towards sustainable growth poles that combine low-carbon growth in developing countries with job and income-generation opportunities leading to self-sustained and more equitable pro-poor development.

Promoting growth in relevant sectors – including energy efficiency, sustainable agriculture and renewable energies for rural electrification – will not automatically solve the current poverty and climate imperatives. It will, however, provide multiple social, economic and environmental dividends and constitute much-needed first steps towards low-carbon social and economic development. The Trade and Environment Review 2009/2010 makes a further important contribution to efforts in this area.



Geneva, November 2009

Dr. Supachai Panitchpakdi
Secretary-General of UNCTAD

Foreword

In light of the scientific evidence available, action to combat climate change is urgent, not only to protect the welfare of future generations but also to safeguard the security of our present generation. For developing countries where social and economic progress is fragile, climate change adaptation and mitigation are as much a necessity as a daunting challenge.

The longer governments delay taking action, the greater the mitigation and adaptation costs will be. These costs are measured not only as a percentage of GDP or a loss of habitat or species, but, most importantly, in terms of the millions of human lives that are at risk. Indeed, the rise of temperatures, changes in rainfall patterns and the more frequent occurrences of extreme weather conditions carry enormous threats for the security and livelihoods of the millions of struggling poor in developing countries.

South Africa finds itself in the continent most vulnerable to climate change – a continent facing major challenges to development and poverty eradication, in addition to multiple stresses and low adaptive capacity. Agricultural production in many African countries and regions, including access to food, is projected to be severely compromised by climate variability and change. The area of arable land suitable for agriculture, the length of growing seasons and the yield potential, particularly along the margins of semi-arid and arid areas, are expected to decline. This would further adversely affect food security and exacerbate malnutrition on the continent. In some countries, yields from rainfed agriculture could be reduced by up to 50 per cent by 2020. Food security might further deteriorate as a result of declining fish resources, in both the sea and large freshwater lakes, as a result of rising water temperatures and possibly exacerbated by continued overfishing.

Moreover, isolated and uncoordinated national action against climate change may further adversely affect developing countries, particularly if discriminatory trade policy measures are put in place. Agricultural exports from developing countries could face new and additional restrictions in developed countries

if the latter implement measures such as border tax adjustments, food miles, carbon standards and labelling. Such an outcome would add to the climate burden shouldered by the most vulnerable countries.

I cannot overemphasize the importance of implementing urgent and immediate adaptation actions to reduce vulnerability and build resilience of developing countries to impacts that are already occurring. Priority sectors include water, agriculture, food security, health, biodiversity, disaster management and coastal management. In the agricultural sector, key challenges include developing more drought- and flood-resistant crops and considering crop switching strategies. It is also critically important to find ways of communicating information about climate scenarios and adaptation options to subsistence farmers and rural communities.

The IPCC's overall message to policymakers is one of urgency, leadership and ambition. We need to act quickly, we need to make decisive policy shifts, and we need to be ambitious in embracing a basket of technological options both for adaptation and mitigation. Together, we must recognize that solving the climate problem and making the transition to a low-carbon economy will only be possible if it is undertaken with development priorities in mind. Collaboration should be real and based on a global and fair framework which facilitates dialogue, exchange of best practices, technology transfer and international solidarity.

Fortunately, the fight against climate change can bring several benefits for human and economic development. On the one hand, inaction on climate change will undermine sustainable development and our best efforts to achieve poverty reduction and economic growth. On the other hand, taking action on reducing greenhouse gas emissions will bring sustainable development co-benefits, such as reduced air pollution, savings in energy bills and increased employment.

If properly anticipated, the response to climate change also offers tremendous opportunities for change towards more sustainable and more resilient economic growth, especially if that response is based on international solidarity. Climate change policy will create new investment opportunities, highlight the employment potential of new dynamic economic sectors and offer new trading opportunities. The challenge is to minimize risks and seize new opportunities.

The good news is that it is technologically and financially possible to steer economies in that direction. Indeed, many of the attitudinal and production shifts required are in countries' best interests, because they can save costs and yield stronger economies. For instance, energy conservation and efficiency measures can help save costs for companies, governments and energy utilities, improve the overall competitiveness of developing economies, and enhance the energy security of the poorer countries. Governments can utilize climate policy as a tool to rethink their countries' economic and production systems, and make new and strategic investments that will gear their economies towards cleaner growth. If developing countries manage to rapidly initiate the shift towards more sustainable production, they can position themselves very competitively in the global economy: seizing opportunities now can benefit from a first- mover advantage.

The Climate Summit in Copenhagen in December 2009 must reach an agreement that mobilizes political will based on a shared vision for an inclusive, fair and effective climate regime. Our deal must give content to the sustainable development approach to climate change. If we are to reach a common understanding of a shared vision, a sense of solidarity in addressing the development challenges of the future will be required. A climate deal will depend on a development deal, and at the core of a development deal will be the technology-finance-capacity package.

As we prepare for Copenhagen, we must ask ourselves how we can simultaneously avoid the risks and seize the opportunities of the global transition to a low-carbon economy. In South Africa, our economic modelling has shown that taking early action is affordable, and that in the long term green growth is the best option for sustainable job creation and poverty eradication. We have found that, given our domestic circumstances, economic growth and welfare imperatives are fully compatible with the imperative to stabilize the climate.

We cannot allow ourselves to dither at the point when action and implementation are most critical. The decisions we have to take are tough, but I have never been more convinced that they are right, necessary, and possible.



Pretoria, November 2009

Buyelwa Sonjica
Minister of Water and Environmental Affairs,
South Africa

Foreword

I have previously described the trade-climate change linkage as a ticking time-bomb. But I also believe there is another path open to us, and real opportunities to pursue win-win-win solutions across these agendas. I therefore welcome the focus of this Review on the crucial nexus between trade, development and climate change.

The impact of the global economic crisis on the livelihoods of hundreds of millions of people, particularly in developing countries, adds further urgency and importance to the path we take. Nowhere is this more evident than in the agricultural sector. All countries, developed and developing alike, have a common interest in food security, removing impediments to trade and reducing global emissions of greenhouse gases.

We have the international negotiating frameworks to deliver this: the Doha Development Agenda and the United Nations negotiations on climate change. While one is focused on trade, and the other on the environment, both negotiations have economic development at their heart, and agriculture is increasingly important to both.

Completing the Doha Round remains the single most important issue on the international trade policy agenda. An ambitious and robust outcome from Doha could deliver economic benefits that would support countries' development aspirations. Removal of distortions in international trade in agriculture would provide more market opportunities for farmers in developing countries. Increased economic wealth would also improve the ability of countries over time to contribute to global action on climate change.

Improved trade rules could help countries shift to low-carbon economic development, including through liberalization of trade in environmental goods and services. Encouraging investment flows will be essential for enabling technology transfer.

Reducing environmentally harmful subsidies (including in agriculture) would encourage globally optimal efficient patterns of production, as well as bringing positive environmental benefits and climate impacts, by discouraging fossil fuel use and encouraging alternative energy solutions.

Internationally accepted, science-based standards to encourage efficient resource use (for example, greenhouse gas footprinting) will also be important. We must ensure that standards, as well as opportunities taken to promote "green growth", do not in themselves become barriers to trade and development.

Trade also has an important part to play at the intersection of agriculture and climate change. As changes to climate cause shifts in growing conditions, important agricultural regions may be threatened, affecting millions of farmers, many already living below the poverty line. Trade will become increasingly important for food security, as prices will fall when food can flow freely across borders.

Food production needs at least to double in the next 40 years, and at the same time global greenhouse gas emissions need to be reduced substantially. Land is a finite resource. Thus we will need to achieve the best possible global production patterns for agriculture that will meet food, development and climate needs.

The United Nations climate change negotiations in Copenhagen in December 2009 must deliver mechanisms for reducing global greenhouse gas emissions that are economically efficient and avoid perverse economic, trade and development outcomes. We need international agreement on how we are to share global efforts in tackling climate change. Failure to achieve this runs the risk of countries taking unilateral actions, such as the imposition of climate-related trade measures. As long as uneven pricing of carbon continues across economies, concerns about competitiveness and loss of economic activity (with no environmental gain) will continue.

The agricultural sector was a late entrant to multilateral trade negotiations. This is mirrored in the climate change negotiations, where agriculture has, until now, been the poor cousin to other economic sectors. Agriculture now sits at the centre of the Doha Development Agenda. With agriculture-related emissions contributing around 14

per cent of global emissions, and averaging around 27 per cent of developing-country emissions, the United Nations climate change framework needs to to pay particular attention to this critical sector.

Improving our collective understanding of the challenges faced by the agricultural sector is crucial. And there needs to be a significant scaling-up of investment in research and development aimed at finding ways to reduce emissions from agriculture. Building on New Zealand's strong tradition in agricultural sciences, my Government is establishing a virtual world research centre on agricultural greenhouse gas mitigation to help deliver solutions to this challenge.

We have an opportunity to achieve win-win-win solutions across the trade, development and climate agendas. Seizing this opportunity requires a long-term view, coherence in the direction and substance of the relevant international frameworks, and a shared commitment from developed and developing countries alike to contribute to global action on climate change. Recognizing the importance and intersection of agriculture, trade, development and climate change objectives is a good starting point.



Auckland, October 2009

Tim Groser
Minister of Trade and Associate Minister for
Climate Change Issues (International Negotiations)
New Zealand

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Acronyms and abbreviations

BTA	border tax adjustment
CAFE	corporate average fuel economy
CBTF	Capacity Building Task Force
CCS	carbon capture and storage
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CER	certified emission reduction
CERT	carbon emissions reduction target
CFL	compact fluorescent light (bulbs)
CH_4	methane
CO_2	carbon dioxide
CO_2-eq	carbon dioxide equivalent
EC	European Commission
EE	energy efficiency
EEPS	energy efficiency portfolio standard
EGS	environmental goods and services
EGs	environmental goods
EIA	Energy Information Administration (United States)
EPP	environmentally preferable product
ETS	emissions trading scheme (or system)
EuP	energy using product
FAO	Food and Agriculture Organization of the United Nations
G-8	Group of Eight
GDP	gross domestic product
GFS	green fiscal stimulus
GHG	green house gas
GND	Green New Deal
Gt	Gigaton
HS	Harmonized Commodity Description and Coding System (of the World Customs Organization)
ICT	Information and communication technology
IEA	International Energy Agency
ILO	International Labour Organization
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change

ITA	Information Technology Agreement
ITC	International Trade Centre of UNCTAD/WTO
JI	Joint Implementation
LCA	life cycle analysis
LED	light emitting diode (lamps)
LEISA	low external input sustainable agriculture
LPG	liquefied petroleum gas
LULUCF	land use, land-use change and forestry
MBI	market-based instrument
MDG	Millennium Development Goal
MEPS	Minimum Energy Performance Standard
MRV	monitoring, reporting and verification
Mtoe	million tons of oil equivalent
N_2O	nitrous oxide
NAMA	nationally appropriate mitigation action
NCAS	National Carbon Accounting System
NTB	non-tariff barrier
OECD	Organisation for Economic Co-operation and Development
PES	payment for environmental services
ppm	parts per million
PPM	process and production methods
PV	photovoltaic
R&D	research and development
RET	renewable energy technology
SD-PAM	sustainable development–policies and measures
SHS	solar home system
SME	small and medium-sized enterprise
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organization
WSSD	World Summit for Sustainable Development
WTO	World Trade Organization

Explanatory notes

Classification by country or commodity group

The classification of countries in this *Review* has been adopted solely for the purposes of statistical or analytical convenience and does not necessarily imply any judgement concerning the stage of development of a particular country or area.

The major country groupings used in this *Review* follow the classification by the United Nations Statistical Office (UNSO). They are distinguished as:

- Developed or industrial(ized) countries: the countries members of the OECD (other than Mexico, the Republic of Korea and Turkey) plus the new EU member countries and Israel.
- Transition economies refers to South-East Europe and the Commonwealth of Independent States (CIS).
- Developing countries: all countries, territories or areas not specified above.

The terms "country" / "economy" refer, as appropriate, also to territories or areas.
References to "Latin America" in the text or tables include the Caribbean countries unless otherwise indicated.
References to "sub-Saharan Africa" in the text or tables do not include South Africa unless otherwise indicated.

For statistical purposes, regional groupings and classifications by commodity group used in this *Review* follow generally those employed in the UNCTAD Handbook of Statistics 2008 (United Nations publication, sales no. E/F.08.II.D.18) unless otherwise stated. The data for China do not include those for Hong Kong Special Administrative Region (Hong Kong SAR), Macao Special Administrative Region (Macao SAR) and Taiwan Province of China.

Other notes

The term "dollar" ($) refers to United States dollars, unless otherwise stated.

The term "billion" signifies 1,000 million.

The term "tons" refers to metric tons.

Annual rates of growth and change refer to compound rates.

Exports are valued FOB and imports CIF, unless otherwise specified.

Use of a dash (–) between dates representing years, e.g. 1988–1990, signifies the full period involved, including the initial and final years.

An oblique stroke (/) between two years, e.g. 2000/01, signifies a fiscal or crop year.

A dot (.) indicates that the item is not applicable.

Two dots (..) indicate that the data are not available, or are not separately reported.

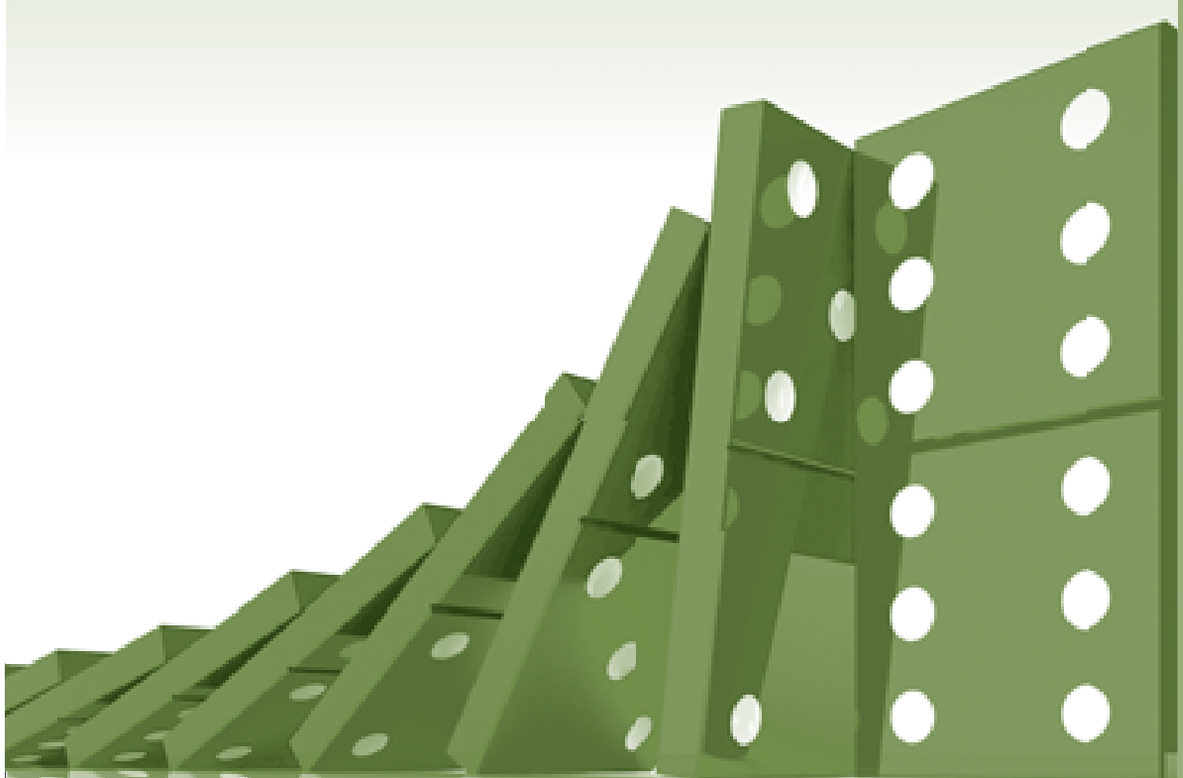
A dash (-) or a zero (0) indicates that the amount is nil or negligible.

Decimals and percentages do not necessarily add up to totals because of rounding.



CHAPTER 1

OPPORTUNITIES FROM LOW CARBON GROWTH



I. Detoxifying Finance and Decarbonizing the Economy: Opportunities for Clean and Sustainable Growth in Developing Countries

Ulrich Hoffmann
UNCTAD secretariat

» The current systemic crisis presents both a major challenge and opportunity: the challenge is to avoid locking in production and consumption methods and related technologies that are no longer economically, socially and environmentally sustainable over the long term. The opportunity is to utilize the crisis as a launching pad for steering the global economy towards a more sustainable growth path.

» A transition to a low-carbon and more resource-efficient economy provides a promising avenue for economic and social development in many countries. To initiate this transition, developing countries can gain experience through promoting pilot "poles of cleaner growth". Promoting sustainable agriculture, enhancing energy efficiency and harnessing renewable energy for sustainable rural development are but three illustrative poles that could yield a triple win: economic growth, job and income creation, as well as environmental sustainability.

» Economic stimulus packages can be used to kick-start these poles, which are economically self-sustaining once initial investment is made, even under conditions of minimal or imperfect internalization of health and environmental costs or benefits.

» While the emergence of such poles of cleaner growth cannot alone overcome the current severe economic crisis, it can, nevertheless, initiate a process of transformation, innovation and policy change in strategically important economic areas, such as sustainable agricultural practices, enhanced material, resource and energy efficiency (closely related also to waste avoidance and reduction), and drastic changes in the energy mix.

» Despite the fact that such investments are strategic and can be lucrative, the 'greening' of economies requires the elimination of perverse policy frameworks as well as the availability of public finance where private investment is deficient. It will also require the emergence of the necessary awareness, skills, capabilities and vision to mobilise the private sector, governments, and the society as a whole.

A. Introduction

The conventional wisdom seems to suggest that periods of economic crises are times for belt-tightening and cost-cutting measures. While there is some truth to that, under capitalism, periods of severe recession are also when economic distortions and asymmetries between supply and demand are temporarily overcome, when radically new economic structures emerge and breakthrough technologies are adopted. The current systemic crisis presents both a major challenge and opportunity: the challenge is to avoid locking in production/consumption methods and related technologies that are no longer economically, socially and environmentally sustainable over the long term; the opportunity is to utilize the crisis as a launching pad for steering the global economy towards a sustainable growth path, initially focusing on some very promising and sustainable 'poles of clean growth'. These poles combine measures to overcome the economic/financial crisis with measures to mitigate climate change, and to deal with increasing resource/material scarcity and the yawning gap between the rich and the poor. In other words, the crisis offers an ideal opportunity to restructure economic incentives and governance systems.

This *Trade and Environment Review* elaborates on some promising areas in which developing countries, particularly the poorest of them, can turn the current crisis-induced challenges into long-lasting and sustainable development opportunities. Promoting sus-

tainable agriculture, enhancing energy efficiency and harnessing renewable energy for sustainable rural development are but three illustrative areas among several others,[1] from which developing countries can generate a triple win: economic growth, human development and environmental sustainability. These areas can be turned into poles of clean and sustainable growth, linking cost savings with employment creation, income-generation and investment opportunities. In so doing, in addition to relaunching growth (that was brought to a halt by the economic crisis), these areas can address key issues involved in the energy, climate, food and water crises, and make substantial contributions towards meeting the Millennium Development Goals (MDGs).

Recent discussions on "green" economic stimulus packages (be they in the context of a "Green New Deal" (GND) or "Green Fiscal Stimulus" (GFS) approaches, discussed in greater detail below) by many governments represent somewhat of a paradigm shift that offers tremendous potential to ensure that the recent crisis-induced destruction is channelled creatively. However, the significance and difficulty of the choices that policymakers face cannot be exaggerated. The paradigm shift that may be emerging is leading to a conceptual transcendence of the long-accepted false dichotomy between economic health and environmental protection. The concept of valuation of "ecosystem services" that the Millennium Ecosystem Assessment[2] helped advance was an important step towards integrating environmental and economic considerations. The *Stern Review* played an important role in promoting understanding of the fact that the cost of action to reduce greenhouse gas (GHG) emissions would be less than the cost of inaction. Stern's main point was that the adverse economic impacts of climate change are expected to be so severe that stabilizing the climate is a sound investment in financial terms (Stern, 2007). The problem remains that national investments in climate mitigation offer global benefits but may not pay off without sufficient international cooperation. However, viewed from the perspective of economic development and local environmental benefits, most climate mitigation actions actually turn out to be prudent subnational and national investments as well. The transition to a low-carbon and more material/resource-efficient economy may increase annual GDP growth in many countries. This is the conceptual breakthrough that recent discussions on the GND/GFS packages represent.

As stated in a recent study by the McKinsey Global Institute (2008: 9): "the histories of the industrial and information-technology revolutions show that with the right incentives and institutional structures, dramatic levels of change and innovation in the economy can occur, driving growth, raising living standards, and creating opportunities … Research shows that most of the technologies required for a carbon revolution already exist. But creating the necessary incentives and structures on a global scale will be one of the most significant political challenges of our age."

The poles of clean growth discussed in this Review can be part of an economic and developmental paradigm shift[3] in developing countries, which, while not able to overcome the current severe economic crisis on its own, can nevertheless lay some of the groundwork for sustainable development paths in strategically important economic areas, such as low external input sustainable agricultural practices, enhanced material and energy efficiency (closely related also to waste avoidance and reduction), and drastic changes in the energy mix. However, in order to understand the need for and potential of such a profound paradigm shift, it is useful to fully understand the root causes (including their interplay) and systemic nature of the current crisis.

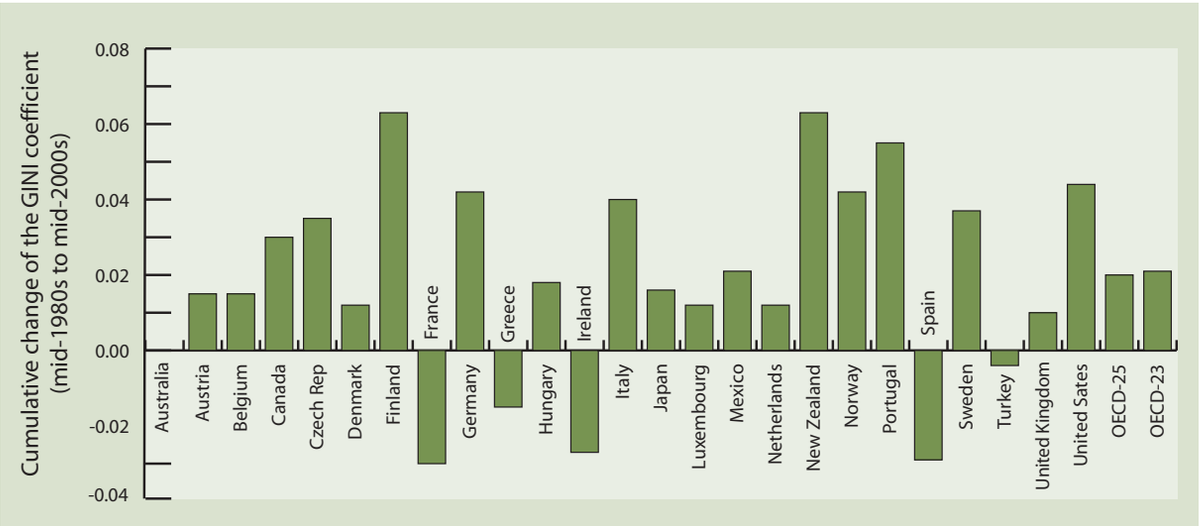
B. Root causes of the current systemic crisis and the importance of sustainable growth

The current crisis is frequently portrayed as a severe recession linked to a global financial crisis. This is a simplistic and superficial evaluation of the situation: it implicitly lends support to the perception that tightening a few screws and adjusting some bolts might be sufficient to return the world economy to its former business-as-usual economic growth path (Halle, 2009). In actual fact, the financial crisis triggered the current systemic crisis in the productive economy and amplified deep-rooted structural and social problems, but it was by no means the only or even the most important cause of the problems (for more information, see UNCTAD, 2008c, 2008d, 2009f and 2009g). So what is at the root of the crisis?

1. Inequality and poverty

Although in recent years global economic activity has thrived as seldom before, driven by technological change (in particular in transport, information technology and communications), a large and fast-growing stock of financial capital in search of lucrative invest-

Figure 1. Trends in income inequality in selected OECD countries, mid-1980s to mid-2000s
(Point changes in the GINI coefficient)



Source: OECD, 2008: 27.
Note: OECD-23 refers to all the OECD member countries shown in the figure, excluding Mexico and Turkey.

ments, and abundant and readily available labour, the fruits of this economic growth have not been equally divided – either between countries or within countries. This is borne out by a recent report of the Organisation for Economic Co-operation and Development (OECD, 2008). Income inequality was higher in most OECD countries in the mid-2000s than in the mid-1980s (figure 1). Despite strong economic growth in recent years, two thirds of OECD countries experienced greater inequality, and also, to a certain extent, a rise in poverty. The report highlights that while paid work can reduce the risk of poverty, there is no guarantee that more jobs and greater employment reduce poverty. Indeed, the rising incidence of non-standard employment has widened the gap in earnings distribution and contributed to an increase in poverty.

Two representative examples are Germany and the United States. In Germany, the total income gain of households has gone to the richest 10 per cent of households since 2003 (Parma and Vontobel, 2009: 129). In the United States, in the period 1993 to 2006, the household income (excluding capital gains) of the richest 1 per cent of the population increased annually by 10–11 per cent, whereas the household income of the rest of the population increased by only 2.7 per cent in the period 1993–2000 and by 0.9 per cent during the period 2002–2006.[4] In other words, no less than 75 per cent of the gains in household income recorded in this period accrued to the richest 1 per cent of households. The recent widening of inequalities marked a complete reversal of the previous trend. From the 1930s to the late 1970s wealth disparities in developed countries declined sharply.[5]

The International Labour Organization's *World of Work Report 2008* (ILO, 2008) analyses income inequalities in the age of financial globalization, and draws the conclusion that between the early 1990s and the mid-2000s (i.e. a period of relatively rapid economic growth and strong job creation) in about two thirds of the countries examined the total income of high-income households expanded faster than that of the low-income ones. Similar trends were found in other dimensions of income inequality, such as labour income vis-à-vis profits, or top wages vis-à-vis wages of low-paid workers. In 51 out of the 73 countries for which data were available, the share of wages in total income declined over the past two decades. Likewise, the income gap between the top and bottom 10 per cent of wage earners increased in 70 per cent of the reviewed countries.

The ILO report concludes that "financial globalization has led to a depression of the share of wages in GDP, reinforcing the downward trend recorded in most countries … This effect is over and above any trend decline in the wage share that may have resulted from sectoral shifts, rising labour demand elasticities from trade openness or changes in labour market regula-

Box 1. Evolution of poverty in developing and developed countries

Progress towards reducing extreme poverty in developing countries, 1990–2004

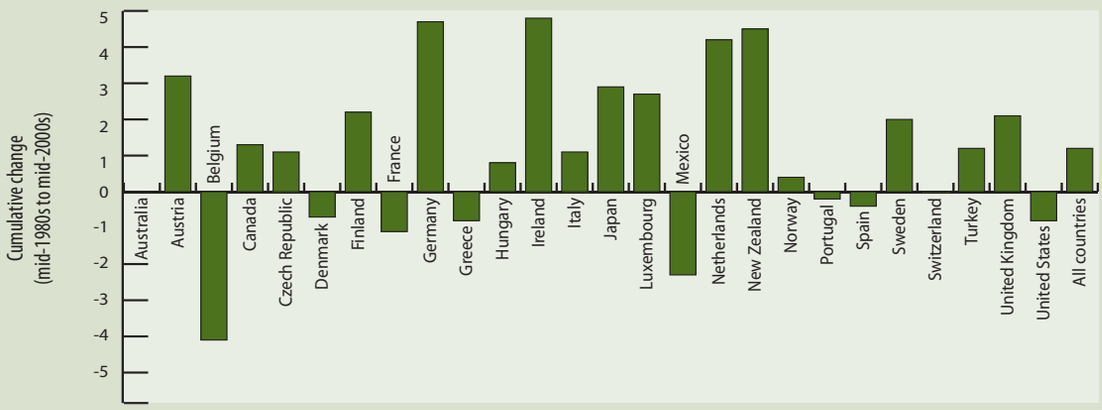
		Africa		Asia				Latin America & Caribbean
		Northern	Sub-Saharan	Eastern	South-Eastern	Southern	Western	
Current progress towards reducing extreme poverty by half		low poverty		moderate poverty	moderate poverty	very high poverty	low poverty	moderate poverty
Proportion of people living on less than $1 a day (%)	1990	2.6	46.8	33.0	20.8	41.1	1.6	10.3
	2004	1.4	41.1	9.9	6.8	29.5	3.8	8.7

Line 1 (progress). The colours show the trend towards meeting the 2015 target.

- Target met
- Almost met, or on target
- Some/ negligible progress, but insufficient to meet target
- No change or negative progress

Source: United Nations, 2008: 2.

Trends in poverty headcounts in selected OECD countries, mid-1980s to mid-2000s
(Point changes in income poverty rate at 50% median level)



Source: OECD, 2008: 129.

Note: The level of poverty in developed and developing countries in the table and chart above is measured in two different ways. For developing countries, it is based on the evolution of absolute poverty (i.e. the proportion of population living on less than $1 a day). For developed countries, poverty is measured as relative income poverty (i.e. with the threshold set as a percentage of the median income in each country in each of the years considered). Only a few OECD countries have "official" measures of poverty that rely on "absolute" standards, typically in the form of the cost of a basket of goods and services required to assure minimum living conditions and indexed for price changes over time.

tions and institutions. There is empirical evidence that financial globalization has led to an increase in income inequality owing both to a trend increase in financial assets (relative to GDP) and to a growing incidence of crises" (ILO, 2008: 39–40). In developed countries, high income inequalities have gone hand-in-hand with a greater burden of household debt.[6]

However, the situation differs between developing and developed countries. In many developing countries, poverty levels fell significantly between 1990 and 2004, notably in the countries of North Africa, East, South-East and South Asia (box 1). Furthermore, an important middle class emerged in a number of countries, particularly in the rapidly industrializing ones, although income disparities generally increased.[7] Conversely, in many developed countries, the middle class shrank and the number of people being pushed into poverty increased[8] (box 1).

In short, globally there has been progress towards a reduction of absolute poverty, but at the same time there has been an increase in income inequality. In many developing countries, absolute poverty has declined while income inequality has increased. In South Asia and sub-Saharan Africa, poverty levels have remained very high. In developed countries, income inequality has increased, and the phenomenon of the working poor has become more pronounced.

For many years, declining prices for many consumer goods (particularly food, clothing, household appliances, and electronic goods, including IT equipment) as a result of globalization of production had moderated the slide in household incomes, as outlined above. However, the recent escalation in prices of food, fuel and industrial commodities till mid-2008 largely wiped out those gains.

Rising income inequality and poverty, particularly in many developed countries, has constrained the global purchasing power of large segments of the population, thus leading to disequilibrium between supply and demand. Two prominent examples are many excessively sophisticated and expensive products in the automobile and household-appliances industries worldwide, which have experienced a massive oversupply in recent years. In order to boost demand, it is necessary to ensure that there is enough purchasing power where the physical demand exists, and that this demand is met by more affordable products for sustainable consumption.

2. Commodity price hike

A second causal factor of the current crisis is the explosion in commodity prices in recent years (box 2). Rising commodity prices by themselves are not problematic as long as they lead to material/energy efficiency and changes towards sustainable production and consumption patters. However, the classical "brown economy"[9] has a poor performance record in this regard, or, as commented by Ackerman in this Review: "the current style of industrialization has been described as 'carbon lock-in', meaning that carbon-intensive technologies gained an early lead at a time when fossil fuels were cheap and concern about global warming was not yet on the horizon."

Whereas labour productivity has increased by some 260 per cent globally in the last 30 years, energy,[10] material and resource efficiency has improved by well below 100 per cent (Müller, 2009) (as a result, the share of wages in GDP decreased, whereas the proportion of material inputs soared[11]). Therefore, the unprecedentedly high prices – both in nominal and real terms – of crude petroleum and minerals and metals have been particularly problematic for many manufacturing and service activities. Analytically speaking, these high price levels may be seen as a more appropriate reflection of the economic, social, environmental and health externalities of material and resource prices. But the "brown economy" has seemed unable to cope with it, in that material- and energy-efficiency measures have been falling short of matching the required cuts in production costs (for further details, see chapter on energy efficiency in this Review).[12]

3. Excessive "financialization" and speculation

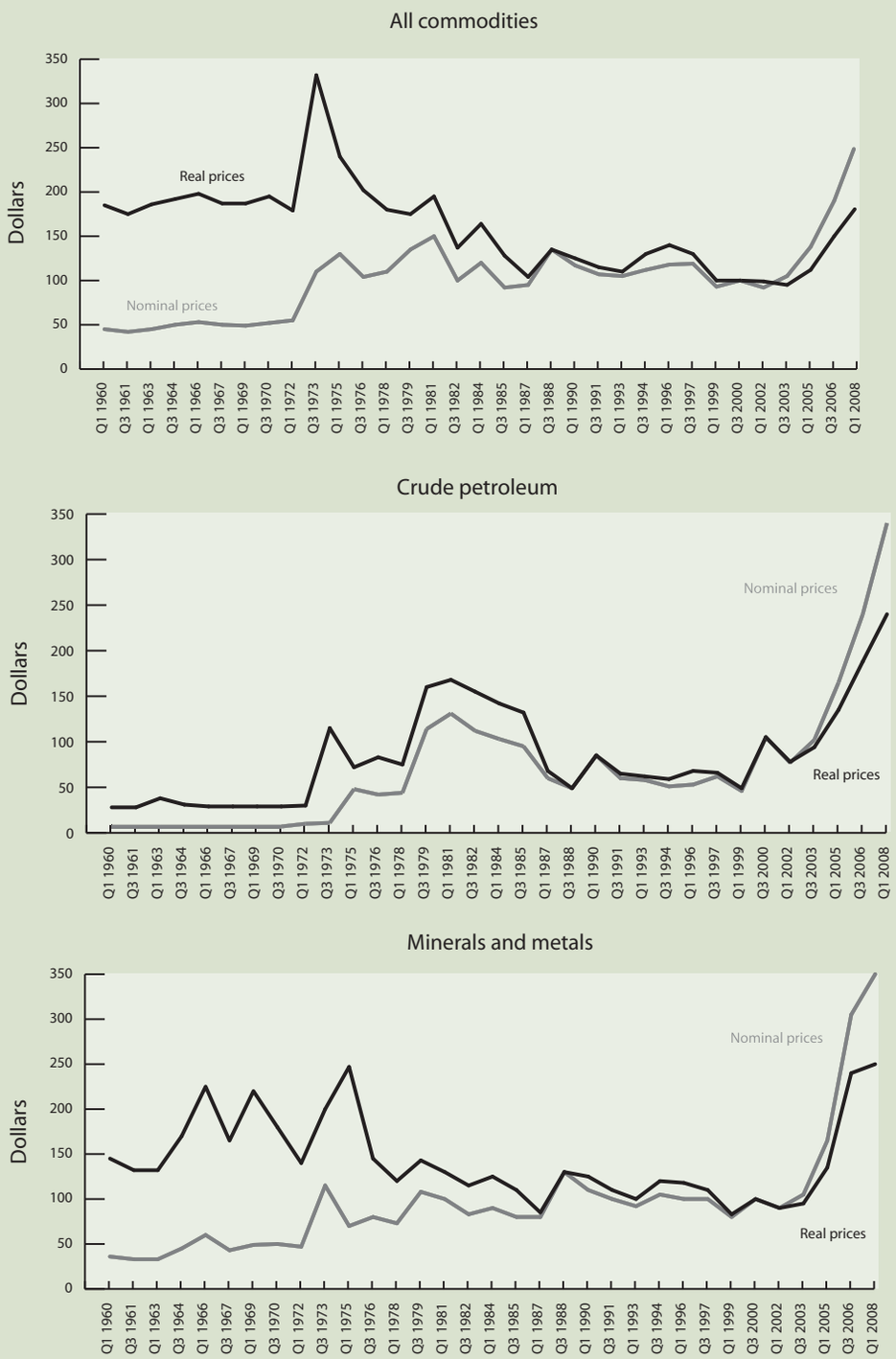
The third decisive factor at the root of the current systemic crisis was the concentration of wealth, which generated a massive volume of financial assets in search of increasingly more lucrative investment opportunities. However, the ILO report cited above concludes that the expectation that financial liberalization would help improve the allocation of savings and thus stimulate economic growth, while also relaxing credit constraints and improving income prospects of low-income groups, did not materialize. According to the ILO, financial globalization has failed to contribute to enhancing global productivity and employment (ILO, 2008).

Largely unregulated international financial markets led to a situation in which only about 10 per cent of generated profits of producing companies in many developed countries was re-invested, whereas some 90 per cent ended up in financial markets in search of speculative gains[13] – a phenomenon referred to as "financialization of non-financial corporations" (UN-DESA, 2009a).[14] This was compounded by the pressure to deliver increased shareholder value against investment analysts' expectations and the short-term reliance on profit centres for maximizing short-term corporate earnings. These developments discouraged strategic, sustainable orientation and decision-making in tangible production and service operations (see also: UNCTAD, 2008c and 2008d).

The abundance of financial capital in search of ever more lucrative investment opportunities fuelled speculation (of which derivatives and hedge funds are but two examples[15]) and excessive corporate and private debt.[16] In this way, the above-mentioned disequilibrium between supply and constrained demand, caused by greater inequality and the consequences of the recent

Box 2. Trends in commodity prices, 1960–2008

As can be seen from the figures below, in nominal terms the general commodity price level increased by 300 per cent between 2002 and mid-2008, with prices of crude petroleum and minerals and metals escalating by 400–460 per cent. However, in real terms, the general commodity price level did not reach its average of the 1970s, and remained far below the price hikes of those years. Even so, the real price level of crude petroleum and minerals and metals did reach new historical peaks in mid-2008.



Source: UNCTAD, 2009d and 2009e: 4.

commodity price boom, were temporarily bridged until the financial bubble finally burst.

It is obvious from the above that bailing out banks, reform of the international financial system, and better regulations and controls over financial institutions are necessary measures, but in themselves insufficient to address the root causes of the current crisis and re-establish a new equilibrium between supply and demand in key markets. Indeed, excessive bank bail-outs and continuing inattention to the more systemic problems by developed-country governments might render the prospects for economic recovery bleaker in the medium-term. The related escalating public debt[17] and higher reserve requirements for banks may well exert upward pressure on future interest rates, jacking up the costs of borrowing for the productive sector and fuelling inflation.

C. Poles of clean growth for new, sustainable production and consumption patterns

A recent policy brief by the United Nations Department of Economic and Social Affairs (UN-DESA, 2009) suggests two directions of policy intervention aimed at strengthening social safety nets and productive investment:

(i) Enhancing labour market support through greater spending on proactive labour market policies, and higher unemployment benefits and employment protection in order to reduce the adverse impacts of globalization on labour's share of national income. The provision of a solid set of social protection measures does not appear to have led to reduced trade competitiveness; in fact, if anything, such measures may have improved competitiveness, as workers' security is conducive to innovation and rapid productivity growth.

(ii) A share of any growth in profits must be redirected from financial assets to their reinvestment in new capacity and employment, in product and process innovation, and in skills development. Reform of the banking sector must ensure that banks get back to performing prudent credit assessment, in line with borrowers' expected earnings, and support more economically, socially and environmentally productive investment opportunities.[18]

In short, innovative policy approaches are required that generate synergies between creating new jobs (and associated income-generation opportunities), cost reductions resulting from more efficient material/resource and energy use, and lower environmental pressures (including abatement of greenhouse gases (GHGs)). This provides the very rationale for the concept of poles of clean and sustainable growth developed in this Review, which would contribute to re-establishing equilibrium between supply and demand, and moving towards patterns of production and consumption along sustainable development lines.

Such restructuring, combined with accelerated technological innovation and deployment, could help obtain four principal results:

(i) Improvements in people's quality of life and social equity, as well as the creation of new opportunities for job and income-generation;

(ii) Savings in material, energy and resources, and a drastic lowering of environmental impacts, including the reduction of GHG emissions;

(iii) Increased corporate competitiveness and the level of innovation of companies; and

(iv) A reduced degree of dependence on fossil fuels, enhanced energy security and more affordable access to energy.

All these results would make a tangible contribution to fulfilling the MDGs.

Economic stimulus packages can kick-start the required policy transition, but, as discussed later, the proposed growth poles tend to be economically self-sustaining once initial investments are made, even under conditions of minimal or imperfect internalization of health and environmental costs or benefits. What is required in the medium and long term for broadening the base and enhancing the impact of the growth-poles approach is a supportive policy framework, including, for example, the removal of perverse subsidies, public support for research and development (R&D), as well as the diffusion and operational deployment of technologies, green public procurement and government-backed green financing schemes. These should be supported by price signals (a blend of carbon/material taxes and emissions trading) to induce a shift to a low-carbon and material-efficient economy. Complex trade-offs must be carefully analysed to maximize both qualitative and quantitative employment and income-generation opportunities (Green New Deal Group, 2008: 36).

D. Decarbonizing the economy: a new industrial revolution

The economic rationale for advocating poles of clean growth coincides with the current exigencies of mitigation of and adaptation to climate change. At present, the concentration of carbon dioxide (CO_2) in the atmosphere is estimated at around 380 ppm (or about 470 ppm of CO_2 equivalent (CO_2-eq) for all GHGs), up from 280 ppm in pre-industrial times (Blasing, 2009). According to experts on the Intergovernmental Panel on Climate Change (IPCC), limiting the increase in global temperature to no more than 2–3°C would require stabilizing global GHG levels at a concentration level of 450–550 in CO_2-eq. This would necessitate a reduction of global CO_2 emissions by at least half (or 30–85 per cent, depending on countries' current emission levels) till 2050, relative to the emission levels of 1990 (IPCC, 2007; IEA, 2007: 206) (see figure 2 for the required cuts). For developed countries, these targets imply reductions of between 80 and 90 per cent of GHG emissions. In other words, what is required is nothing short of a new industrial revolution that decarbonizes the economy. While a seemingly impossible prospect, in most concerned areas appropriate new technologies already exist, and these targets could be achieved mainly through greater energy efficiency (about two-thirds), and fuel switching (about one-third), thus implying the substitution of fossil fuels to a large extent (IEA, 2007).[19]

In the light of this tall – but imperative – order, we seem to be at the dawn of a new economic era: after the revolution in transport, information and communication technologies, which has driven globalization so far, the next industrial revolution is likely to focus on enhanced energy, material and resource efficiency, increased use of renewable energy sources, and a paradigm shift towards sustainable agriculture. This ecological modernization is already seen by some analysts and policymakers (see, for instance, Müller and Thierse, 2009) as the next, the sixth long Kondratieff wave of innovation-driven industrialization.[20] It is thus important to realize that the resource/material-efficiency[21] and climate change problems[22] (as well as the interrelated food security and water problems) of today represent the strategic markets and sources of growth of the future (figure 3 illustrates the global green growth potential for energy-efficient building technologies for the next 10 years; buildings are the single-largest global energy consumer and offer a huge market potential, including for many developing countries).

Investing in these areas will not only lead to cost savings (generally very important, but particularly essential in times of crisis), but also bring environmental benefits,[23] and increase income-generation potential and employment opportunities. The potential in this regard is huge. By way of illustration, in Germany the share of labour costs in gross manufacturing output

Figure 2. Required global GHG emission cuts for the period 2020–2050

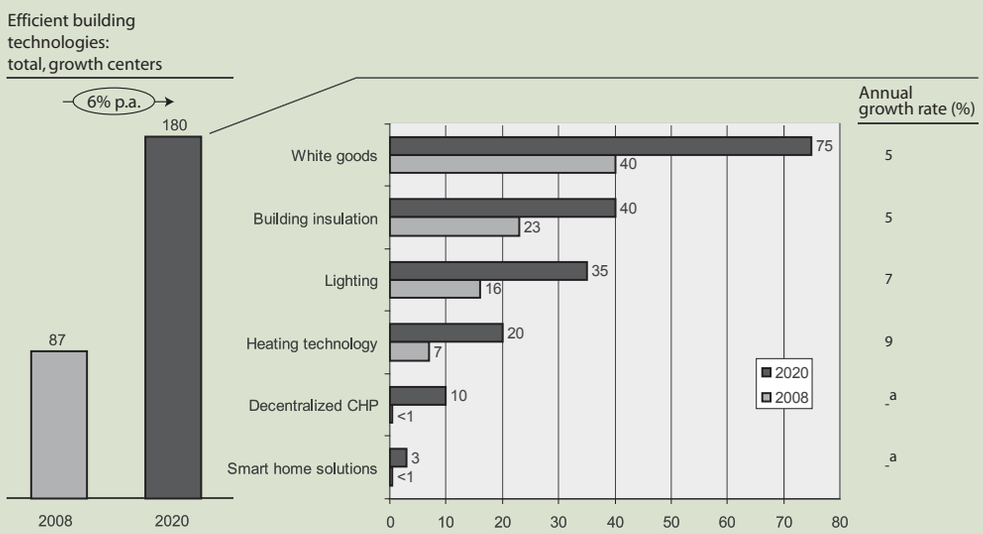


Source: The Climate Group, 2008: 19.

[a] Estimates.

[b] Under business-as-usual assumptions.

Figure 3. Efficient building technologies: estimated global market potential in some growth centres
(Billions of euros per annum and per cent)



Source: McKinsey Germany, 2009: 29.
Note: CHP - combined heat and power.
[a] Market currently too small to estimate the growth rate.

dropped from 25 to 18 per cent between 1995 and 2006, whereas material input costs soared from 37 to 43 per cent (Bleischwitz et al., 2009; Bleischwitz, 2009). With drastic reductions in material/energy input costs, there is much more room for manoeuvre to invest in R&D and staff training (both extremely important for strategic competitiveness) as well as to increase wages and employment opportunities. As Bleischwitz (2009: 4 and 9) correctly underscores, a resource-efficiency enhancing approach has the advantage of combining climate, energy and waste-policy aspects with the core economic interest in cost reduction and innovation. The resulting cost reductions will enhance the ability of companies to increase wages, make workers actively participate in (and profit from) efficiency efforts and free more resources for related staff training and R&D.

Against this background, the economic stimulus packages developed in response to the current crisis in developed and some developing countries[24] (table 1) are an ideal opportunity for shifting emphasis and directing funding to the strategic green growth areas identified above. Although this can only be the beginning of a much more profound restructuring and economic, social and environmental reorientation,[25]

Table 1. Economic stimulus packages of selected developing economies

Developing economies	Share of planned expenses in GDP
Argentina	6.4
Brazil	5.6
China	13.3
Chile	2.8
Hong Kong (China)	1.4
India	1.8
Indonesia	2.0
Malaysia	9.0
Mexico	4.7
Peru	3.2
Philippines	4.4
Republic of Korea	6.2
Saudi Arabia	11.3
Singapore	8.0
South Africa	7.4
Taiwan Province of China	4.8
Thailand	3.4
Viet Nam	0.9

Source: UNCTAD, 2009g, table 1.8; ILO, 2009, figure 8; and Yap, 2009.

these first steps would have considerable catalytic effects worldwide:

(a) Investment by one country in low-carbon and material-efficient technologies could reduce the cost of those technologies internationally (unless technologies protected by intellectual property rights (IPRs) become unaffordable to others).[26] Coordinating government-driven R&D and government-funded demonstration projects could maximize the energy, economic, social and environmental benefits of every public dollar spent.[27]

(b) Efficiency investments that reduce material/resource/energy demand in some countries (in particular the bigger ones) influence material/resource/energy prices around the world, and thus also the cost-benefit analysis used by national policymakers when evaluating domestic programmes (WRI, 2009).

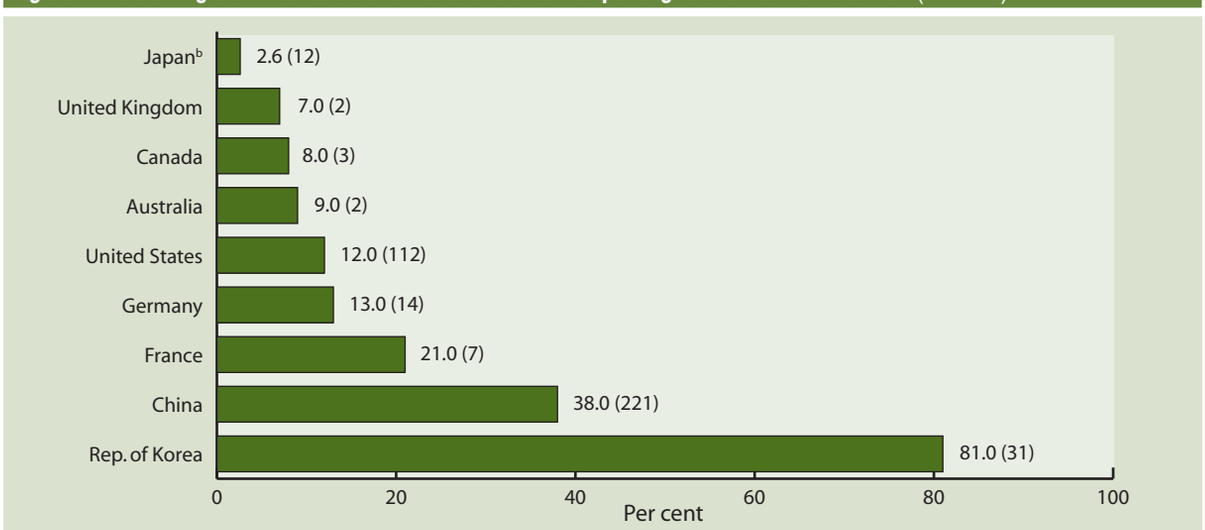
These two elements point to the importance of global cooperation and coordination. Indeed, the more international the action, the more efficient, cost-effective and climate-friendly it will be.

It is also important to note that the private sector tends to underinvest in public goods, as it can capture only a small share of social returns. Likewise, there is underinvestment in new technologies because of externalities and insufficient government support to related market creation. As elaborated on in the commentary by Ackerman in this Review, this implies that the State may need to become a more active agent in directing investment in the context of a proactive industrial policy. According to UN-DESA (2009b: XV), "the big policy challenge lies in ensuring that these investments trigger more virtuous growth circles, through which to crowd in private investment and initiate cumulative technological changes in dynamic growth sectors, thereby supporting economic diversification and creating employment opportunities."

However, according to a recent study by the bank, HSBC (cited in Vorholz, 2009), only about 16 per cent of the $2.8 trillion government stimulus packages analysed fall into the environmental and green efficiency areas. Only in the Republic of Korea, China and France do the shares of green investments exceed 20 per cent (figure 4).[28]

Apart from creating a large number of "green jobs",[29] an important justification from a macro- and microeconomic point of view is that such investments pay off very quickly; some may even have negative costs.[30] For instance, according to calculations by the World Resources Institute (WRI) concerning the United States Government's economic stimulus package, on

Figure 4. Share of green investments in economic stimulus packages of selected countries (Per cent)[a]



Source: Vorholz, 2009.

[a] The figures should be considered as estimates only, because in a number of cases they are based on proposals rather than approved spending. Figures in parenthesis signify green investments (in $ billion).

[b] In early April, Japan launched the legislative process for a second stimulus package of 15 trillion yen (about $154 billion), which is equivalent to another 3 per cent of GDP. It includes fiscal incentives for green cars and energy-efficient appliances.

average, for every billion dollars invested in the green recovery scenarios the country's economy saves $450 million a year (in terms of direct savings and indirect benefits through lower energy prices) (WRI, 2009). A study by the Kathy Beys Foundation (2005) on Germany found that investment in material, energy and resource efficiency would lower production costs by 20 per cent over the next 10 years, increase GDP by 10 per cent and create some 700,000 additional jobs (i.e. the equivalent of about 2 per cent of the current economically active population in Germany).

Experience of developed countries shows that investment in energy efficiency and renewable energy will need strong regulations and incentives. In the case of energy efficiency, regulation may often be enough to harness potential gains, but investment in renewable energy will generally not take off without some financial incentives or support (unless energy prices become very high indeed). The key question is whether developing countries can introduce the necessary regulations and provide a critical level of financial incentives and support. International support will be required in this regard. There is also the need for technological cooperation and capacity-building to support "nationally appropriate mitigation actions" by developing countries (Bali Plan of Action) and the concept of Sustainable Development Policies and Measures (SD-PAM).[31]

The value of investments in environmental protection and clean energy cannot be viewed in isolation. Investments in basic industries may be more labour-intensive and cost-effective in terms of immediate job creation and income generation. Investments in basic infrastructure, education and health are often more effective stimuli than certain environmental initiatives. The integration of environmental considerations into core economic planning, including responses to current economic recovery plans, is an extremely positive policy development, but it requires much more thorough analysis and debate.[32]

E. Creating low-carbon and other poles of clean growth in developing countries

When analysing the interplay between economic recovery, climate change and sustainable development, it is worth recalling that economic and climatic predictions build on the assumption that there is a direct causal relationship between an increase in economic activity and greater GHG emissions. This is the logic that underlies the emissions scenarios developed by the IEA and IPCC.

However this relationship is not automatic; it can be altered (or even reversed) by a number of factors such as structural change, technological progress, better utilization of resources and materials, and changes in consumption habits. These factors interrelate with the scale effect of economic growth and are at the heart of a "decoupling" of GHG emissions from economic growth – a major challenge (and opportunity) currently confronting governments. This Review argues that such a "decoupling" is technologically, economically and socially feasible, if based on cost-saving and income-generating activities. From a policy-making viewpoint, this entails mainstreaming climate change in economic development policies; that is, identifying and pursuing mutually supportive mitigation, adaptation and growth strategies.

Climate change can undermine development (possibly altering competitive advantages) and development can undermine climate sustainability (if it is not carbon conscious). But the opposite is also true: climate policies can strengthen development policies. For example, more efficient utilization of energy and materials also means greater economic competitiveness and energy security, and this in turn can fuel sustainable income-generation activities and job creation.[33]

Early action on climate change (pre-emptive adaptation and mitigation) is more cost-effective than delayed action (responsive adaptation and mitigation). Therefore, the corollary for developing countries whose production and technological patterns have not yet been locked in is: early movers will benefit from a competitive edge. Indeed, Stern (2007) termed mitigation costs as "investment" decisions.

Two of the three clean growth poles in this Review (i.e. the promotion of sustainable agricultural practices, and harnessing of renewable energy for sustainable rural development) were selected to illustrate how the current systemic crisis can be turned into an opportunity by the vast majority of some 140 developing countries that are not major carbon emitters. They are estimated to have a combined share of only 10 per cent of energy-related CO_2 emissions generated by all developing countries.[34] The Review gives special attention to the agricultural sector because of its significant contribution to GHG emissions, its importance for adaptation to climate change and for poverty alleviation, and the pivotal role that enhanced rural en-

ergy supply can play for adding value to agricultural products.

The Review singles out three areas of sustainable, "green" growth that are of particular importance to global objectives, especially for developing countries. These offer a truly universal development perspective through interconnections and pulling effects with the rest of the economy in terms of:

- Enhancing energy efficiency;[35]
- Mainstreaming sustainable agriculture, including organic agriculture as its most sophisticated form;[36] and
- Harnessing the use of renewable energy for sustainable rural development.

These potential poles of clean growth reconcile the development and global climate change mitigation imperatives, create opportunities for more and better jobs, lucrative markets, added value, and multiple social and environmental benefits, assure energy security, and foster local technological and institutional capacity-building.

In order to set the context for the subsequent chapters, we focus here on some key general concerns and queries frequently raised as factors that might complicate or pose insurmountable hurdles for developing countries in their transition to a more sustainable development path.

Part of the challenge in developing and exploiting poles of clean growth involves concerns about affordability and the significant up-front costs. Overall, the areas proposed here offer, on the one hand, significant cost-cutting potential (in some cases to the extent of negative costs); on the other hand they offer an income-generation potential that makes the investment either virtually self-financing, thereafter resulting in self-dynamic growth, or so lucrative that attracting appropriate funding – including from private sources – should pose few problems. However, there are significant market barriers and counterproductive or inadequate policies in place that prevent the flow of capital into these profitable, socially attractive and environmentally sustainable investments.

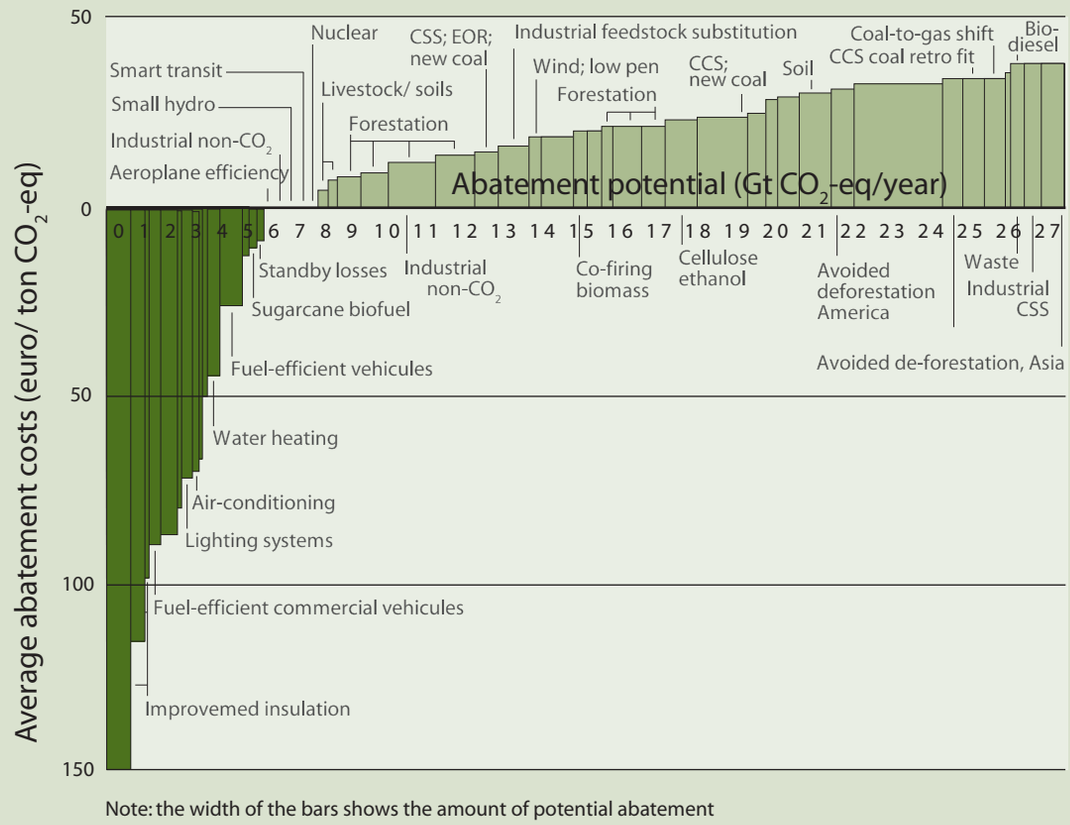
1. Energy efficiency – not just for industrialized economies

Large improvements, for instance in the area of energy efficiency (EE), can be achieved, in particular in developing countries, at negative net costs. The long-term benefits of EE investments outweigh the costs, as there are many leapfrogging opportunities for countries that are using either non-existent or old-fashioned energy-based equipment. Although most of the EE opportunities are in the rapidly industrializing countries, it is estimated that almost 30 per cent of the EE potential can be exploited in other developing countries (McKinsey Global Institute, 2008: 22).

Demand-side EE measures may be particularly cost-effective. Yet there are many well-documented obstacles to EE improvements. Some of these obstacles are greater in developing countries, such as lack of awareness of and information on benefits of EE, lack of capital, proliferation of inefficient equipment (including through imports of used and/or inefficient equipment), the desire to minimize initial costs and energy-supply constraints (e.g. limited availability of commercial fuels in rural areas, which often impedes switching to more energy-efficient equipment). In some developing countries, subsidized energy prices reduce the incentive to introduce EE measures. The large number of small and dispersed end users and inefficient small and medium-sized enterprises (SMEs) also represent a particularly difficult barrier to EE improvements in many developing countries. Furthermore, a large number of developing countries lack an effective EE policy at the national level. Realizing untapped EE opportunities requires appropriate private and public sector strategies and policies to remove obstacles and stimulate EE investments (as discussed in more detail in the chapter on energy efficiency in this Review).

As can be seen from figure 5, a number methods for EE improvement already carry negative economic costs, even without internalizing multiple benefits or avoided costs (such as health and environmental benefits, as well as lower energy prices). EE is generally the most cost-effective investment for GHG reduction. For approximately 7 Gt CO_2-eq, there are net gains from EE improvements, and for about 20 Gt CO_2-eq, abatement is possible at a cost of less than 40 euro per ton. In other words, EE alone could offer 27 Gt CO_2-eq of reduction at a relatively low cost. This emission volume would represent almost two thirds of the 42 Gt CO_2-eq reduction required globally by 2030 (figure 2). According to McKinsey Global Institute (2008: 22), capturing these EE opportunities could create energy savings that would translate into an estimated 17 per cent annual rate of return in the period to 2020 (assuming an average oil price of $50 per barrel during the period – higher oil prices would mean

Figure 5. Carbon abatement opportunities and their estimated costs, 2030



Source: McKinsey Global Institute, 2008:15.
Note: CCS - carbon capture and storage; EOR - enhanced oil recovery.

higher returns). This is, by any standard, a very lucrative rate of return for a productive economy.

Such EE measures demonstrate that good environmental management goes hand in hand with efficient economic management. Moreover, the policy road map for EE is well known: it draws on existing technologies and proven policy options.[37] According to McKinsey Global Institute, the cost curve in figure 5 counters a number of myths about carbon abatement, for example that there are only limited low-cost abatement opportunities, or that higher abatement can be achieved only with new technologies. Indeed, 70 per cent of the total abatement potential until the year 2030, as shown in figure 5, is not dependent on new technologies.

As further elaborated in the chapter on energy efficiency, in the current economic crisis the focus of investment in EE may shift from long-term technological innovations to short-term EE gains resulting in quick cost reductions. This may also help the companies involved to position themselves for the future, when energy prices rebound and climate mitigation measures become an increasingly significant factor of competitiveness.

2. Mainstreaming sustainable agricultural practices

Apart from the material/resource/energy-savings' potential, another important element of the green growth-pole approach advocated here is the creation of employment and income opportunities through new production methods. These generate a more than sufficient income stream to pay back initial investment and fuel self-sustained development in the medium term (and this even in the absence of internalization of multiple benefits or avoided costs). The wider use of sustainable agriculture[38] and the harnessing of renewable energy for sustainable rural development are two cases in point. In this regard it is worth emphasizing that more than any other sector agriculture is closely associated with poverty reduction and the

generation of environmental public goods. In least developed countries (LDCs), about 70 per cent of the labour force derives its income from agriculture. Some of the public goods generated by agriculture include carbon sequestration,[39] conservation of soil and biodiversity, landscape maintenance and watershed protection. It is important to note that land use and land-use changes account for around 31 per cent of total human-induced GHG emissions into the atmosphere (Worldwatch Institute, 2009: 31), three quarters of which occur in developing countries.

As discussed below, to optimize the trade-offs between food security, climate change and ecosystem degradation, a transition towards productive and ecologically sustainable agriculture is crucial. In that context, organic agriculture represents a multi-targeted and multifunctional strategy (FAO, 2009: 16).

As regards profitability, UNCTAD research (UNCTAD, 2008b) has shown that farms that engage in certified organic production in East Africa were significantly more profitable than comparable groups of farms engaged in conventional production.[40] It is also important to bear in mind that, in contrast to the experience in developed countries, organic conversion in many African countries is associated with increases, rather than reductions, in yield. This is due mainly to the low-input characteristics and generally low productivity of conventional farming on that continent.[41]

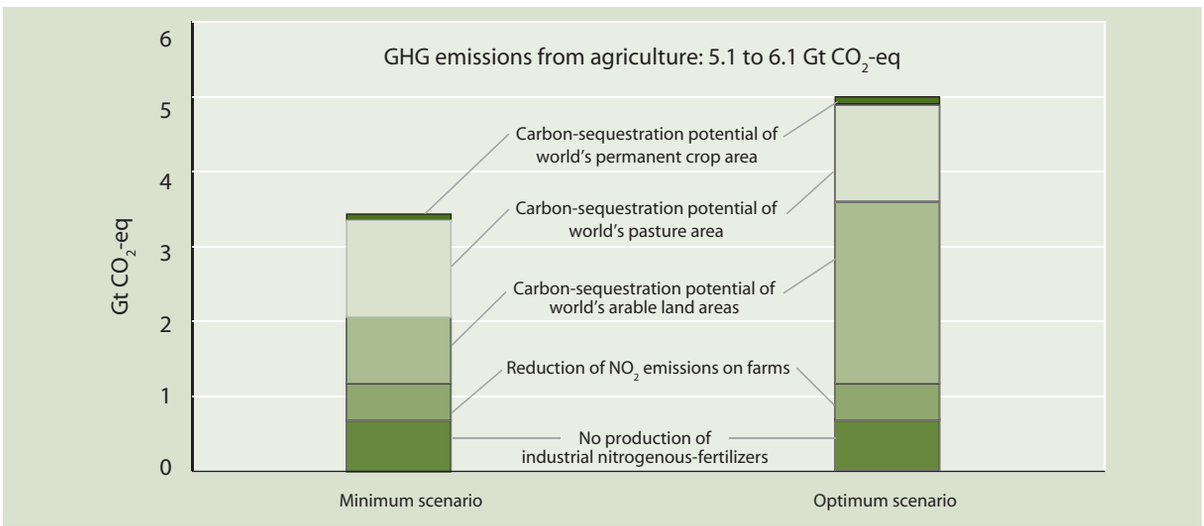
Sustainable forms of agriculture in general not only bring multiple benefits to producers in terms of soil fertility, productivity, energy efficiency, occupational safety and market access opportunities, but also certified organic produce often yields price premiums. The potential to export to consumers willing to pay more for such produce generates significant additional income opportunities for organic farmers in developing countries. Global markets for such produce have been growing at rates of over 15 per cent per annum over the past two decades. Between 2002 and 2007, global certified organic sales doubled to reach $46 billion (Sahota, 2009), and are expected to increase further to $67 billion by 2012. Even in the current economic crisis, where demand for most products is dropping fast, demand for organic products is continuing to grow. While sales are concentrated in North America and Europe, production is global, with developing countries producing and exporting large and ever increasing shares. Africa, for instance, is home to some 20–24 per cent of the world's certified organic farms. Exports of organic products from Uganda rose fivefold in five years – from $4.6 million in 2002/03 to $22.8 million in 2007/08. Price premiums for farmers range from 30 to 200 per cent (UNCTAD, 2009a).[42]

Organic production is also particularly well suited to smallholder farmers, who comprise the majority of the poor in developing countries. Resource-poor organic farmers are less dependent on external resources and benefit from higher and more stable yields and incomes, thus enhancing food security (UNCTAD-UNEP, 2008).

Surveys by the Soil Association in the United Kingdom (UK) and Rodale Institute in the United States found that organic farms in the UK provide roughly one third more jobs per farm than equivalent non-organic farms, in addition to being 25 to 50 per cent less energy-intensive (Soil Association, 2006; LaSalle and Hepperly, 2008: 3; FAO, 2009:16). Furthermore, there are significant savings from non-use of agrochemicals (in terms of economic costs, occupational safety and carbon emission savings in the production of agrochemicals).[43] Developing countries in Africa, for instance, import 90 per cent of their agrochemicals, which most small-scale farmers cannot afford. Instead of relying on imported agrochemicals and seeds of plant varieties that are protected by IPRs, African countries should build on their strengths – land, local resources, indigenous plant varieties, indigenous knowledge, biologically diverse smallholder farms and limited use (to date) of agrochemicals. It is time for them to mainstream sustainable agricultural practices that increase agricultural productivity, build soil fertility, minimize harm to the environment and create sufficient incomes through diversified production (UNCTAD, 2009a).

From an economic point of view, apart from cost savings, higher revenues and enhanced food security, a move towards more widespread use of sustainable agricultural practices has other advantages: it reduces the exposure or vulnerability of developing-country agriculture to some major distortions in international agricultural markets, such as subsidies[44] and excessive market dominance by a few seed and agricultural input companies. Furthermore, there are lucrative and unexploited domestic and regional markets for sustainably produced food in developing countries, where market domination of globally active retailers is low or non-existent. Some international labelling schemes for sustainably produced products, such as those of Utz and the Rainforest Alliance, usually lead to price premiums for producers in international markets, fol-

Figure 6. GHG mitigation potential from conversion to organic agriculture[a]



Source: FAO, 2009:13.

[a] GHG emissions from agriculture amount to 5.1–6.1 Gt CO_2-eq. With improved farm and crop management, most of these emissions could be reduced or compensated by sequestration. A conversion to organic agriculture would reduce industrial nitrogen-fertilizer use that emits 6.7 kg of CO_2-eq per kg of nitrogen on manufacture and another 1.6 per cent of the applied nitrogen as soil-based N_2O emissions. It could also considerably enhance the soil sequestration of CO_2. For the minimum scenario, the FAO experts took a sequestration rate of 200 kg of carbon/ha per year for arable and permanent crops and 100 kg of carbon/ha per year for pastures. The optimum scenario combines organic farming with reduced tillage on arable land (with a sequestration rate of 500 kg of carbon/ha per year).

lowing the example of organic produce mentioned above (Liu, Byers and Giovannucci, 2008).

The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), an intergovernmental process co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the Global Environment Facility (GEF), the United Nations Development Programme (UNDP), UNEP, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Bank and the World Health Organization (WHO) and supported by over 400 experts, released its summary report in April 2008. It stated strongly that "the way the world grows its food will have to change radically to better serve the poor and hungry if the world is to cope with growing population and climate change while avoiding social breakdown and environmental collapse." The report found that progress in agriculture had reaped very unequal benefits and had come at high social and environmental costs. It called for more attention to small-scale farmers, and recommended the utilization of sustainable agricultural practices, including organic farming (IAASTD, 2008).[45]

As far as the impact of organic agriculture on climate change is concerned, its main potential lies in its considerable capacity to sequester CO_2 in soils, its low nitrous oxide emissions, its low energy intensity, and its synergies between mitigation and adaptation (see commentary by Niggli in this Review).[46] According to a recent FAO study (2009:11), global GHG emissions from agriculture amount to 5.1–6.1 Gt CO_2-eq. Considering that arable and permanent cropping systems of the world have the potential to sequester an estimated 200 kg of carbon/ha per year and pasture systems 100 kg of carbon/ha per year, together they could contribute to a total of 2.4 Gt CO_2-eq per annum of the world's carbon sequestration. A minimum scenario of conversion to organic farming would mitigate no less than 40 per cent of the world's agricultural GHG emissions. When combining organic farming with reduced tillage techniques, the sequestration rates on arable land could easily be increased to 500 kg of carbon/ha per year. This optimum organic scenario would mitigate 4 Gt CO_2-eq per year or 65 per cent of agricultural GHGs. Another approximately 20 per cent of agricultural GHGs could be reduced by abandoning the use of industrially produced nitrogen fertilizers, as is practiced by organic farms. This is an encouraging figure, which shows that low-GHG agriculture might be possible and farming could become climate neutral (figure 6).[47]

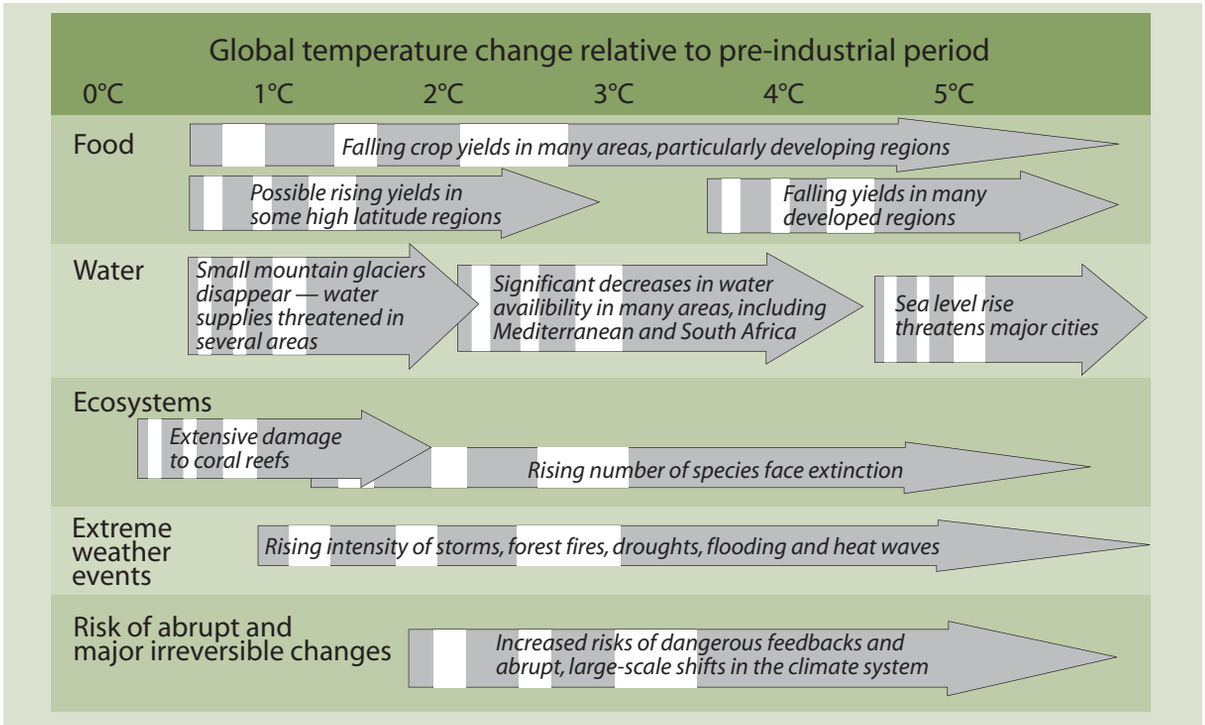
More stable and enhanced productivity of sustainable agriculture is also very important in the context of adaptation to the potential adverse consequences of climate change for agriculture (figure 7), in particular significant yield losses (estimated to reach as high as 20–50 per cent for sub-Saharan African countries, for instance) and water-constrained production (Stevens, 2009). According to a recent FAO study (2009: 15): "the diversity of landscapes, farming activities, fields and agro-biodiversity is greatly enhanced in organic agriculture, which makes these farms more resilient to unpredictable weather patterns that result from climate change. Organic agriculture systems build on a foundation of conserving and improving diversity by using diverse crops, rotations and mixed farm strategies. Enhanced biodiversity reduces pest outbreaks. Similarly, diversified agro-ecosystems reduce the severity of plant and animal diseases, while improving utilization of soil nutrients and water." All these are very important factors for adaptation to climate change.

3. Renewable energy for sustainable rural development

Renewable energy is another area that offers great potential for self-sustaining income generation and sustainable rural development. Some 1.6 billion people (i.e. one quarter of the world's population), mostly in South Asia and sub-Saharan Africa, have no access to electricity.[48] Some 2.4 billion people rely on traditional biomass (i.e. wood, agricultural residues or dung) for cooking and heating. The required collection of the biomass contributes to deforestation. Biomass-based heating and cooking, with the resulting indoor air pollution, is a leading cause of respiratory disease and death in many rural areas. As cooking fuel, biomass is also a major source of black carbon (soot), which scientists have identified as the second greatest cause of global warming after CO_2, and which also causes severe local pollution effects. Lack of electricity exacerbates poverty and contributes to its perpetuation, as it precludes processing of agricultural products and industrial activities and the jobs they create, not to mention the associated poor quality of life (IEA, 2002).

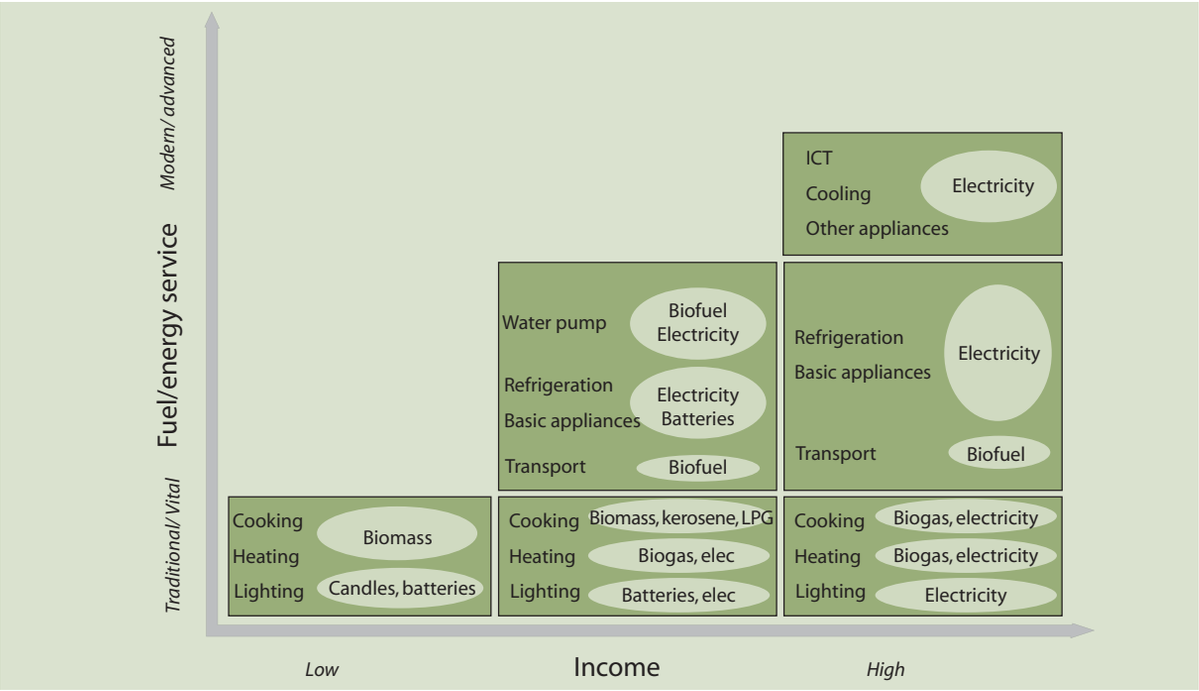
Bringing a menu of integrated, decentralized renewable energy solutions to the countryside could provide a sufficient mix of thermal, mechanical and electric power that would create a completely new and wide range of opportunities for handling, storing, processing and transport of agricultural products, in particu-

Figure 7. Critical future challenges of climate change for agriculture, related resources and ecosystems



Source: Stern, 2007: 330

Figure 8. Fuel mix and its impact on local household activity in rural areas



Source: IEA, 2002: 370.

lar food items (figure 8). This could result in multiple added value and employment opportunities in the agricultural sector, including processing, in industrial activities closely related to or required for agriculture (such as repair of agricultural machinery and vehicles) and the maintenance of the renewable energy equipment. Agricultural productivity is likely to increase significantly with improved irrigation on the one hand, and lower production, storage and processing losses on the other.[49]

An illustrative example of the tremendous opportunities offered in this regard is the initiative of Grameen Shakti, a sub-program of Grameen Bank in Bangladesh, to provide rural people access to green energy and income (box 3). Another example is DESI Power's Employment and Power (EmPower) Partnership Programme in India (as described in the commentary by Sharan in this Review), which illustrates how self-sustained growth can be triggered through rural electrification linked to village microenterprises for local value addition and employment generation. The power generated using local renewable energy resources provides reliable and affordable electricity supply to make the microenterprises profitable and thus attractive to private entrepreneurs. There are so many welfare benefits of utilising renewable energy technologies in rural areas that governments should integrate their use into development policy packages, and not deal with them as a stand-alone element of investment in infrastructure.

Although the initial procurement and installation costs of renewable energy equipment are high (depending on the level of sophistication of the solution – whether a single-focused or hybrid approach), the running costs are very low, as there are no fuel costs.[50] For example, in the DESI EmPower programme, power from local renewable energy sources is about 30 per cent cheaper than grid-provided electricity. In other words, the major share of the annual costs is related to amortization payments for the renewable energy equipment.[51] Thus such systems contribute to enhanced energy security and shield the economy from escalating energy prices of conventional fuels and their price volatility.

To sum up, the promotion of poles of clean growth as outlined above combines sound economic and ecological management. Cost-wise, in the medium term, it entails very low or even negative costs and creates its own self-sustained sources of income. This is the case even under conditions of no or imperfect internalization of many key externalities, in particular health and environmental costs. However, the greater the strategic focus, policy coherence and gradual inter-

Box 3. Off-grid renewable energy solutions in Bangladesh

Grameen Shakti (GS) was initiated in 1996 by the developers of Grameen Bank in order to overcome energy poverty in rural areas that hampered their social and economic development. The mission of GS is to provide rural people with access to environment-friendly and pollution-free energy at affordable costs. GS aims at creating synergy between renewable energy technology and microcredit in order to enable rural people to improve their quality of life and also take part in income-generating activities.

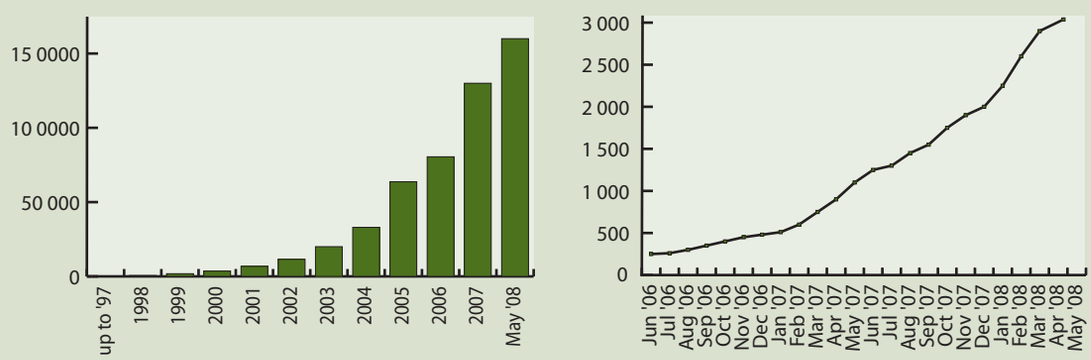
It has embarked on an ambitious programme to provide a range of affordable renewable energy technologies to rural households. Already, over 205,000 homes across Bangladesh have installed photovoltaic (PV) solar systems capable of powering lights and small-scale electronic appliances (so called solar home systems – SHS). Over 8,000 PV solar systems are being installed per month, and demand for the systems is increasing exponentially. The goal is to install 2 million such systems in homes by 2011 and 7.5 million by 2015, which would serve half of the total rural population of Bangladesh.

In addition, GS has installed 6,000 biogas facilities, which convert animal dung and organic residues into pollution-free biogas and slurry. The biogas can be used to cook food, for lighting and to produce electricity. The slurry is used as organic fertilizer and as fish feed. The goal is to build 500,000 biogas units by 2015. GS has also distributed over 20,000 improved cooking stoves and aims to provide one million stoves by 2010, covering 35,000 villages.

The employment and other economic opportunities of the programme are far-reaching: at least 20,000 jobs have already been created with the current adoption of these three renewable energy technologies across Bangladesh. The goal is to create at least 100,000 direct jobs by 2015, mainly for women. This example illustrates a non-grid solution to clean energy for the poor, especially powerful because: (i) it is a commercial and microfinance-driven initiative, and (ii) it substitutes kerosene (the usual lighting fuel, held responsible for respiratory diseases) with PV- and biogas-generated electricity.

Number of solar home installations ***Number of biogas facilities***

(cumulative)



Results at a glance:

Number of villages covered	40 000 villages
Total beneficiaries	more than 2 million people
Total employees	5 000 (mostly engineers)
Total installation of solar home systems (SHS)	220 000
Total number of improved cooking stove (ICS)	35 000
Installation of biogas facilities	7 000
Installed power capacity	11.0 MW
Daily power generation capacity	44 MW-hours
Installation of micro utility systems	over 10 000 systems
Number of trained technicians	2 575
Number of trained customers	97 996 users
Fully paid customer (ownership)	55 494 customers
Users under maintenance agreement (after 3 years)	4 975 customers
Number of LEDs (light-emitting diodes) installed	15 885 lamps
Future plan: installation of SHS by 2012	1 million
Future plan: biogas facility construction by 2012	500 000
Future plan: improve cooking stove construction by 2012	10 million
Green jobs created by 2015	100 000

Source: Barau, Dipal C (2008); and www.gshakti.org/glance.html

nalization of externalities (starting with the removal of perverse incentives and subsidies), the more effective will be the approach and the stronger the pull and spillover effects from the growth poles.

F. Why has the "greening" of economies not yet happened?

Given the high economic returns (even discounting the social and environmental gains or avoided costs) and the low risk associated with investments in the clean growth poles described above, it is legitimate to ask why the existing opportunities have not already been captured, despite a major surge in energy, mineral and metal prices in recent years.

The straightforward answer is that it would be naive to assume that the required changes for making the green growth poles a reality will occur spontaneously or effortlessly. A number of challenges abound. One challenge is the "perverse" pressure of shareholder-value-driven management approaches and unrealistic profit expectations caused by the financialization of non-financial entities. Another is the need for the necessary awareness, skills, capabilities and vision in the private sector and government, and the ability to mobilize society as a whole, which the growth-pole approach requires.

Analytical work on cost curves related to energy demand and efficiency shows that macroeconomic costs are not the greatest barrier to lowering GHG-intensive growth.[52] Rather, it is the lack of appropriate policies, regulations and institutional structures to support the shift towards poles of clean growth. Some of the key challenges in this regard include:

- Institutional factors (i.e. lack of vision, awareness and policy coherence).
- Lack of awareness about financing opportunities, and low investment and absorptive capacity in the poorest developing countries.
- High consumer discount rates for energy-efficient investment (e.g. surveys show that less than one third of consumers are willing to consider energy-efficient investments with payback periods greater than two years) (McKinsey Global Institute, 2008:23).
- Existing patterns of perverse subsidies, notably related to agriculture and fossil fuel use (UNEP, 2008b).
- The current low level of energy prices and the high volatility of carbon offset prices discourage investment in energy efficiency and undermine predictability in long-term investment decisions.
- Up-front finance requirements for some initiatives (in particular renewable energy equipment and some EE investments).
- Reliance on carbon price increases alone would be both ineffective and inequitable. For certain end uses with small price elasticity, such as residential electricity and especially transportation, a higher fuel price leads primarily to a less equal distribution of resources – not to a reduction in carbon emissions. Other policies are needed to offset the equity impacts of higher fuel costs and to launch the new, low-carbon energy technologies of the future. Because technology choice is path-dependent, with strong learning-curve effects, public sector initiatives are essential to ensure that the global economy follows a climate-friendly path.[53]
- The power wielded by strong lobby groups that favour the "brown" economy and related ill-conceived incentives and disincentives.
- There are some systemic constraints that developing countries face in terms of acquiring, learning from, innovating and developing technology, which may arise as a result of pre-existing economic policies and relationships among countries. Examples of such constraints include IPRs, licensing prohibitions, domestic technology absorptive capacity constraints, and trade-driven economic distortions, such as prioritization of export-oriented production in a few goods over diversified production for the domestic or regional market.
- Lack of global cooperation and solidarity on some issues (e.g. lack of coordination of economic stimulus packages or of funding by developed countries of sustainable, "green" growth pole initiatives in developing countries).
- There is also the need to change the focus of the intergovernmental process on climate change. Its evolution so far has been governed largely by considerations of environmental protection. Issues that affect development (i.e. climate change as a development challenge), related investment and R&D have been left to other forums and institutions although the UNFCCC process has sufficient mandates in this regard (UN-DESA, 2009b).

The policies advocated here clearly contribute to the fulfilment of the MDGs, notably MDG 1 (end poverty and hunger), 2 (gender), 3 (children's health), 7 (environmental sustainability) and 8 (global partnerships). It is important to emphasize the multiple gains that can accrue from the suggested approach, including

decarbonization of economic development, related restructuring, and changes in production and consumption methods. Furthermore, the green growth poles are self-dynamic in nature, with catalytic and spillover effects, notably in terms of income generation, enhanced technological and skills capacity, as well as lower pressure on material/resource depletion and related resource pricing.

Given the lucrative nature of investment in these growth poles (e.g. double-digit annual rates of return in the area of energy efficiency, as noted earlier), it is reasonable to assume that in developing countries they would attract public and private investment (e.g. Grameen Shakti in Bangladesh). However, in some areas (e.g. EE in end-use sectors and renewable energy equipment), additional investments will have to be made by a large number of small investors, for which viable financing arrangements/facilities should be made available.[54] Furthermore, mobilization of private investment in poor developing countries will not be straightforward, and will likely require significant additional official development assistance and other foreign assistance, as well as foreign direct investment. Several international schemes could be tapped for this purpose, including the following:

- A large number of plurilateral, regional and bilateral agreements between developed and developing countries, which include the provision of concessional funding for climate mitigation projects.
- Many projects in the green growth pole areas qualify for funding through the Clean Development Mechanism (e.g. those involving energy efficiency, renewable energy and fuel switching). Recent discussions and decisions on expanding programmatic forms of CDM could facilitate this further, in particular in LDCs and other developing countries.[55] However, the CDM does not yet provide funding opportunities for conversion to sustainable agriculture, with the exception of afforestation and reforestation.[56]
- The World Bank is stepping up its support to agriculture, with an emphasis on a smallholder-driven approach to agricultural growth that reconciles the economic, social and environmental functions of agriculture (World Bank, 2008b).
- The European Parliament's Environment Committee has recently proposed that half of the proceeds obtained through the auctioning of EU emission rights should be earmarked for an international fund to assist developing countries in GHG mitigation projects.[57]
- Japan, the United Kingdom and the United States jointly launched what is planned to become a $30 billion "Marshall Plan" to pay for clean technologies in developing countries. Similarly, a group of companies, including Sony and Nokia, have created an "eco-patent commons" with initial donations of 31 EE-related patents.
- The recently created Climate Investment Funds of the World Bank offer a new source of concessional funding support for mitigation projects, and for the transfer and effective use of mitigation technologies.[58]
- New funding opportunities may also arise from the G-20 Summit decision in London on 2 April 2009 on a "substantial increase in lending of at least $100 billion by the Multilateral Development Banks (MDBs), including to low income countries, and ensure that all MDBs have the appropriate capital" (G-20, 2009).
- Government-sponsored green bonds are another option for attracting private resources and channelling them to much-needed investments in the clean growth pole areas in developing countries outlined above.
- For several export-dependent developed and developing countries that are major producers of energy-efficient and renewable energy equipment, such as China, Denmark, Germany, India, the Republic of Korea, Spain and the United States, to name but a few, it would make good economic sense to finance private and public energy-efficient and renewable energy projects in developing countries to expand their export markets.
- For discouraging financial speculation, the introduction of a financial transaction tax (FTT) on stock market, currency and commodity trading transactions has recently been proposed by several policy makers and analysts (e.g. see Schulmeister, 2009). At the same time, a FTT would yield substantial revenues, part of which could be used to support and stimulate investment in the clean growth poles in developing countries. According to Schulmeister, for Europe, revenues would amount to 1.6 per cent of GDP at a tax rate of merely 0.05 percent (transaction volume is assumed to decline by roughly 65 per cent at this rate). In the United Kingdom, tax receipts would be highest, yielding 3.6 per cent of GDP. In Germany, FTT receipts would amount to 0.9 percent of GDP. If a FTT were introduced in these two countries at the same time, neither country would need to fear a significant "emigration" of trading. This can be presumed because roughly 97 percent of all transactions on exchanges in the EU are carried out in these two countries.

II. Sustainability and Global Economic Recovery

Mark Halle
Executive Director, IISD-Europe

» The current global economic and financial crises need to be understood as the final failure of the current economic paradigm. While the Washington Consensus produced rapid accumulation of wealth, it was socially and environmentally unsustainable.

» As a response, most of the calls for a re-launched economy stress the need for greater social justice, more attention to the environment and a greater role for government. In a new paradigm, the power of markets is harnessed to do good.

» A new economic growth can only emerge if inspired leadership is manifest among a critical mass of countries. Policy measures that undermine change must be reformed or eliminated, such as subsidies (e.g. to agriculture or energy), domestic energy policy (energy pricing), as well as national investment policies.

President Barack Obama's chief of staff, Rahm Emanuel, once said that we should "never let a good crisis go to waste". The current global economic predicament certainly qualifies as a good crisis. While some will blame excessive deregulation of the financial sector, lack of diligence by the financial regulators or sheer greed, this crisis cannot be explained away so superficially. It represents, instead, the final failure of the economic paradigm that has dominated the world for over two decades. Since it was introduced by Ronald Reagan and Margaret Thatcher, the Washington Consensus gained near-religious status among its supporters. It was the economic policy for "The End of History", the policy which, when adopted by all countries, would allow the world to emerge onto a sunny plateau of peace, prosperity and opportunity.

Now that the Consensus has unravelled and landed us in the worst economic crisis since the Great Depression, it is too easy to say that its flaws were evident from the start, that it contained good ideas but was pushed too far or that its success required good governance to be in place before its benefits could truly be felt. And yet, in many ways, the economic paradigm failed because it ignored realities that could be shoved aside momentarily, blocked out knowingly, but that nevertheless stubbornly refused to go away.

There can be no doubt, for example, that the Washington Consensus produced rapid accumulation of wealth and a swelling of the global economic pie. Nor can there be any doubt that it replaced some very sorry economic policies in many countries, allowing the market to work its magic to some extent. The disciplines called for by the Washington Consensus are not all bad – only, in isolation they had no chance of working. What was missing?

The answer to that question is of course fundamental as we scramble to define a new economic paradigm and wonder how the broken shards of the old one might fit in a new model. The answer must be sought in the notion of *sustainability* – a concept that emerged in parallel with the Washington Consensus but that has had a far less distinguished career.

The trouble with the Washington Consensus is that it was unsustainable. It pursued the economic pillar of sustainability at the expense of the social and environmental pillars, assuming that the wealth generated through applying its precepts would give governments the capacity to deal with the social and environmental destruction left in its wake. Even if this might have been possible, a central plank in the economic policy was radically restricting the capacity of the public sector to do just that. As a result, large parts of the world enjoyed spectacular economic growth while real wages stagnated, while jobs were trimmed and while the wanton destruction of the earth's natural resources and ecosystems accelerated. Even if the economic pillar had not collapsed under the weight of its own contradictions, the wave of social discontent or the mounting consequences of environmental deterioration would soon have overwhelmed it.

It is not surprising, then, that most of the calls for a re-launched economy stress the need for greater social justice, more attention to the environment and a

greater role for government. This is a natural backlash against a paradigm that has done so much harm. The International Labour Organization calls for a Decent Work Agenda, a form of economic reconstruction predicated on employment, decent wages, health care and pensions. It is an agenda that recognizes that true economic development does not come from making the top one per cent of the income pyramid even richer, but from drawing ever more people into the middle class, investing in social capital and ensuring that the fruits of economic productivity are shared across society. Indeed, it is hard to deny that genuine development and the sort of social marginalization brought about by the Washington Consensus are incompatible.

The United Nations Environment Programme (UNEP) calls for a Green Economy or – better still – a Global Green New Deal. Its vision is of an economy dedicated to repairing the damage done to the world, one that prospers through creating a myriad of new business opportunities in the environmental field – in renewable energy, in low-carbon goods, in organic agriculture, in sustainably managed fisheries and forests, and in the power of innovation and invention. In this world, the power of the market is not sent back to its corner by the power of the lion-tamer's chair and whip; instead, it is harnessed to do good.

These two visions are part of one and the same approach. They both call for our economy, as it is reconstructed, to contribute to moving towards sustainability. One focuses on the social dimensions of economic development, the other on the environmental underpinnings. But in truth, both are needed. Whatever paradigm emerges to take the place of the disgraced Washington Consensus, it must be an economy that reverses the trends of the past decades and places us, finally and resolutely, on the path to sustainability.

Nobody thinks this will be easy. Many of us believe that it will come about only if inspired leadership is manifest among a critical mass of our leaders – leadership sufficient to overcome the tired politics of narrowly defined national interest, to unblock the Doha Round and to reach a robust and enforceable climate deal in Copenhagen or soon after. But it will take more than leadership. Or, rather, it will take more than the capacity to take and enforce the right decisions. It will require a vast job of dismantling a series of truly rotten decisions taken in the past and that continue to plague us.

We tend to think that repairing the world requires doing more of the good things, or even introducing dramatically new good things. Too often, we ignore the many bad things that undermine our determination to change. Subsidies are a good example. The world's nations annually contribute over $1 trillion to subsidies for agriculture, energy, water and transport. This is 12 times the amount needed to bring official development assistance up to the 0.7 per cent target set in 1966; it is 15 times the amount that was estimated to be necessary if the Millennium Development Goals were to be fully implemented; and it is even 8 times the massive amount that the architects of the Earth Summit calculated would be needed to implement the ambitious Agenda 21.

Not all subsidies are bad, but it is an unfortunate fact that the great majority of them undermine the search for sustainable forms of development. Subsidies to irrigation, for example, lead to massive wastage of scarce water resources; subsidies to coal production and consumption invalidate efforts to move towards cleaner energy; subsidies to fishing fleets lead to the devastation of fish stocks; and subsidies to transport fuel lead to wasteful use of energy in transport. The list is long and, cumulatively, it has a devastating effect. We all know that subsidies are the "currency" of politics, the means of exchange used by politicians to reward constituents and interest groups for their support. We know also that subsidies are relatively easy to introduce but notoriously difficult to remove. Often, they are a response to a real and urgent need, but they quickly become entitlements, and interest groups organize furiously in their defense. We know that subsidies are deemed a sensitive domestic issue, and that there is strong resistance even to discuss subsidy policy at the multilateral level. And yet if ILO's or UNEP's dreams are to be realized, we cannot go on pretending that the scandal of public subsidies does not exist, or is a secondary matter. Subsidy reform must become a central pillar of the new economic paradigm. It will be complicated, but unless we deal with it, we will fail in our endeavour to craft a decent, sustainable economy.

Subsidies are just one of the anomalies undermining sustainable development. There are many others. Although seldom spoken about, it is highly probable that domestic energy policy – for example, energy pricing policy – is as great if not a greater obstacle to the move towards clean energy than intellectual property rights or other obstacles to the transfer of clean energy technology. Yet while the latter is a fitting subject for multilateral discussion and deal-making, the former is

rigorously off the agenda. However, even if domestic energy policy is the sovereign right of nations, climate change is a global issue and it is inconceivable that the problem can be solved without a serious effort to reform domestic energy policy.

Investment is another example. The world's leaders call for massive investment in the developing world, and UNEP insists that this investment be in green development. The International Energy Agency estimates that some $44 trillion – over and above the business-as-usual scenario – will be needed by 2050 to meet even the lowest of the IPCC's *estimates* for stabilizing global climate, most of it in the developing world. And yet the agreements that frame these investments – whether multilateral, bilateral or governing single projects – are silent on the kind of investment needed and on the need for investment to support sustainable forms of development. Indeed, the agreements and contracts signed contain clauses that make a sustainable approach to development well-nigh impossible. We call for one thing in our political declarations, but do a very different thing in reality.

Getting the economic paradigm right is now the overriding priority for humanity, and it will not be right unless it is sustainable. That means that the results of our economic organization must advance social equity and justice and repair the damage done to the earth's natural resources and ecosystems. We know how to do it and are waiting for our leaders to lead us to the Promised Land. But we will not get there if we continue to ignore the herd of elephants in the room.

III. Carbon Markets Are Not Enough

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- Setting a price for carbon emissions is only the beginning of climate policy – not the end.
- While carbon prices will change energy costs, energy consumption and carbon emissions, relying on this mechanism alone would be both ineffective and inequitable. For example, in residential and transportation end-use, higher fuel prices would lead to a less equal distribution of resources – not a reduction in carbon emissions.
- Other policies are needed to offset the equity impacts of higher fuel costs and to launch the development of new, low-carbon energy technologies of the future.
- Because technology choice is path-dependent, with strong learning-curve effects, public sector initiatives, such as investment in promising new energy technologies, are essential to ensure that the global economy follows a climate-friendly path.
- As with many of the new energy technologies that will be needed around the world, decades of public investment may be required before developing-country technologies are successful in the marketplace.

The good news is that all major voices in the climate policy debate are now taking the problem seriously. Scepticism about the science is no longer an option: the world's scientists have never been so unanimous, and so ominous, in their projections of future perils. The bad news is that too many participants in the debate consider a climate policy as consisting primarily of manipulating markets and prices. If the only tool available were market liberalization, then the solution to every problem would seem to be a matter of getting the prices right. But setting a price for carbon emissions is only the beginning of climate policy – not the end. To address the threat of climate change, it is not only necessary to charge a price for carbon emissions; governments have to do much more, through actions to support innovation and diffusion of new, low-carbon technologies.

A. The state of the debate

For market-oriented institutions, the path is clear. The IMF simply assumes that climate policy consists of adjusting the price of carbon, when it states: "An effective mitigation policy must be based on setting a price path for the greenhouse gas (GHG) emissions that drive climate change" (IMF, 2008, 4: 2). Although it gives an occasional nod to the importance of developments such as hybrid vehicles, energy efficiency and new infrastructure spending, the IMF's approach to climate policy focuses almost entirely on market instruments. Moreover, it apparently does not consider the problem as being so serious. In the IMF's view, the world can afford to move at a comfortably slow pace: "Carbon-pricing policies … must establish a time horizon for steadily rising carbon prices that people and businesses consider believable. Increases in world carbon prices need not be large – say a $0.01 initial increase in the price of a gallon of gasoline that rises by $0.02 every three years" (IMF, 2008, 4: 42).

However, changes in carbon prices of this magnitude have been dwarfed by recent swings in the price of oil. While it may be possible to achieve climate stabilization at a moderate total cost, considerable ingenuity and new policy directions will be required; by themselves, price changes of a few cents per gallon of gasoline are not enough to achieve anything of importance.

Other voices in the international debate have recognized the greater urgency of the problem, and have been willing to consider a broader range of policy instruments. In its *Human Development Report,* the

United Nations Development Programme (UNDP, 2007: 21) states: "Carbon markets are a necessary condition for the transition to a low-carbon economy. They are not a sufficient condition. Governments have a critical role to play in setting regulatory standards and in supporting low-carbon research, development and deployment." The Report calls for carbon markets to be accompanied by government incentives for renewable energy production, tightened standards for vehicle fuel efficiency, expanded research on carbon capture and storage technology, and increased technology transfer to developing countries.

One of the most detailed recent proposals is Nicholas Stern's "global deal on climate change" (Stern, 2008). Stern argues that climate stabilization requires cutting global emissions to half of their 1990 level by 2050, with continuing declines thereafter. Stern calls for binding national reduction targets to be adopted soon by developed countries and by the fastest growing middle-income countries, and by all other countries by 2020. He envisions a carbon market in the form of a global cap-and-trade system that would allow developing countries to sell emission rights, combined with arrangements for technology transfer and large-scale government support for the development of new technologies. He states: "The world should aim for a liquid international carbon market in order to allow for the most effective, efficient and equitable emissions reductions. In addition, non-price interventions are required to expand the global market for low-carbon technologies, support common standards and promote cost-effective reduced deforestation" (Stern, 2008: 3).

In short, all major proposals for climate policy include a substantial role for carbon markets and prices, either in the form of taxes or cap-and-trade systems. While some give greater emphasis to the manipulation of prices and financing in carbon markets, others see carbon markets as only one part of a complex ensemble of policies.

B. What would carbon prices accomplish?

Carbon prices will change energy costs, energy consumption and carbon emissions. They will also change the distribution of income available for non-energy purchases. If carbon prices were increased by a tax or trading system, what would be the extent of the (intended) effect on emissions and the (unintended) effect on income distribution?

Increased energy costs to consumers fall disproportionately on low-income groups, since the poor spend a higher proportion of their income on energy. As incomes rise, total spending on energy usually rises, but more slowly; thus the fraction of income spent on energy decreases.[60] As a result, policies that raise the price of fossil fuels either reduce the use of those fuels (thereby reducing GHG emissions), or increase the economic burden on low-income consumers – or both. Thus, there is a trade-off between the effects of fuel prices on the environment and on the distribution of income. The relative importance of the two effects depends on the price elasticity of demand for energy.[61] A larger elasticity means that a price increase has a greater effect on emissions and a lower effect on income distribution; a smaller elasticity means that the same price increase does less to reduce emissions but more to increase inequality.[62] Since price elasticities are small for energy in general, and extraordinarily small for petroleum products in the short run, price incentives are a blunt and painful instrument for achieving lower emissions.

Consider the effects of a 20 per cent increase in the price of energy. At an elasticity of -1, the 20 per cent increase in price causes a 20 per cent drop in demand. Consumers purchase 80 per cent as much energy as before at 120 per cent of the former price per unit, so that the total cost to consumers amounts to 96 per cent of the former total. At this elasticity, most of the effect is seen in the change in the quantity of energy used (and therefore emissions), while total consumer spending is little affected. In contrast, at an elasticity of -0.05, a 20 per cent price increase causes only a 1 per cent change in quantity. Consumers buy 99 per cent as much energy as before at 120 per cent of the former price per unit for a total expenditure of 119 per cent of the earlier cost. At this elasticity, there is almost no effect on the quantity of energy used, or on emissions, but a large effect on the total cost to consumers. Therefore, judged as a strategy to reduce energy consumption and emissions with minimal burdens on consumers, energy price increases seem quite effective at an elasticity of -1, but decidedly inferior at an elasticity of -0.05. Intermediate values naturally have results falling between these two extremes.

What elasticity values are applicable in reality? The largest elasticities are found in industry. Studies of 15 countries by three research groups found the price elasticity for industrial energy demand to be between -0.77 and -0.88. Estimated elasticities for Brazil and

India were not significantly different from those for developed countries (Roy et al., 2006). Industrial energy use, in other words, provides fertile ground for the application of price incentives for emission reductions. Indeed, industry lowered its energy use much farther and faster than any other sector in response to the oil price shocks of the 1970s.

Household demand for electricity, on the other hand, is much less elastic than industrial energy use. Recent estimates for the United States found a short-run price elasticity of -0.20, and a long-run price elasticity of -0.32, broadly consistent with earlier research (Bernstein and Griffin, 2006).[63] This finding of a small elasticity for electricity does not appear to be unique to the United States; for instance, the estimated long-run elasticity for Taiwan Province of China was estimated to be -0.16 (Holtedahl and Joutz, 2004).

In both industrial energy use and electricity generation, there are alternative fuels that yield the same result with differing carbon emissions. An increased carbon price would cause a noticeable reduction in industrial energy demand (but less so in household electricity demand), and also a shift towards the use of lower carbon fuels, such as replacing coal with natural gas.

The picture is different in the transportation sector – the principal market for oil – where there is essentially no widely available alternative to the use of petroleum fuels. On a global basis, the available supply of biofuels is too small to make a noticeable dent in the demand for petroleum. In the wake of the oil crises of the 1970s, most countries and industries cut back on oil use wherever possible. Oil-fired electricity generation, for example, has become much less common, except among members of the Organization of the Petroleum Exporting Countries (OPEC). Today the largest proportion of crude oil is used for transportation, and a portion of the remainder is dedicated to non-fuel uses, such as petrochemicals for which there are no close substitutes. The connection between petroleum and transportation is projected to grow even tighter: an estimated two-thirds of the growth in oil demand through 2030 will be for transportation.[64] Thus the oil/transport market is almost disconnected from the market for other fuels and end uses.

The lack of alternatives to oil means that in the short run, price elasticity is close to zero for many consumers. Households in automobile-dependent environments – including the great majority in the United States, a large proportion in many OECD countries, and increasing numbers in fast-growing, middle-income countries – have little control over the amount of driving required to go to work, school, stores and other essential services. Thus, in the short run, purchases of gasoline will be quite insensitive to price, and higher prices will simply be a burden on consumers. However, in the long run, as old cars require to be replaced, high oil prices will stimulate purchases of smaller, more fuel-efficient vehicles, as was the case in 2007-2008. Over time this will affect oil consumption, as the fleet of cars on the road slowly becomes more fuel-efficient, implying that the price elasticity is greater in the long run than in the short run.

A comparative international analysis estimated oil price elasticities for many countries for the period 1979–2000 (Cooper, 2003). For the United States, it found a short-run elasticity of -0.06 and a long-run elasticity of -0.46,[65] and for the G-7 group of industrialized countries, it found a short-run elasticity ranging from -0.024 to -0.071, and a long-run elasticity from -0.18 to -0.57.

Short-run price elasticities for gasoline and other transport fuels are close to zero, which is why the 2007–2008 surge in the price of oil did not cause an immediate collapse in demand. Many months later, a global economic downturn depressed incomes and fuel use. As highlighted in this Chapter, that downturn was not solely, or even primarily, caused by the high price of oil. Any feasible carbon policy would, in the near term, raise fossil fuel prices by less than the oil price increases of 2007–2008. While such a policy could cause a noticeable change in industrial energy use, it would have less effect on transportation than the recent surge in oil prices. Something more needs to be done, therefore to reduce emissions on the necessary scale and timetable.

C. Where do new technologies come from?

Price signals lead to efficient choices among existing alternatives. This is the great success of the market economy. However, while it is an important step in climate change mitigation efforts, it is not enough. New technologies are necessary to solve the climate crisis, and will not be created by high carbon prices alone. Where will the new technologies come from?

Conventional economic models have often finessed this question with the ad hoc assumption of a predictable rate of technical change, unrelated to investment choices or policy decisions. That assumption creates

a bias towards passively waiting for new technologies to emerge: abatement, so the argument goes, will always be cheaper if it is done later, after better technologies have made their appearance. However, in reality, important innovations do not fall from the sky. New technologies are created by conscious effort. They typically start out expensive and become cheaper over time, a process that is often described in terms of "learning curves" or "experience curves". As a result, early investment in start-up costs can determine which technologies will become cost-effective in the future. Technological change is path-dependent: the current set of available choices depends on past policies and actions, just as the available technological options in the future will depend on our policies and actions today.

The learning-curve phenomenon is particularly important when there is a benefit from standardization. In such cases, an early market leader can become "locked in", whether or not it represents the ideal technology, as occurred with the Windows operating system for computers, for example.[66] The current style of industrialization has been described as "carbon lock-in", meaning that carbon-intensive technologies gained an early lead at a time when fossil fuels were cheap and concern about global warming was not yet on the horizon (Unruh and Carrillo-Hermosilla, 2006). Today, the economic benefits of standardization and the low costs of imitating and replicating existing technologies keep the world locked into that same undesirable path.

New energy technologies often display strong learning-curve effects. Research on wind power, for example, has found reductions in unit costs as great as 20 per cent from a doubling of production (Junginger, Faaij and Turkenburg, 2005), which made it competitive in the marketplace under many conditions. This success was made possible by decades of European and United States governments' investments in R&D. Brazilian ethanol production, another alternative energy industry launched by government policy, experienced a 29 per cent reduction in costs when production doubled (Goldemberg et al., 2004).

With technological progress at these rates, often private enterprises only find it profitable to buy a new product after others have been buying it for a number of years, thereby bringing down the price. Hence the need for public sector involvement: governments can and must choose to support the new technologies, especially when – as with climate policy – there is a clear need for change. A plausible model of energy development projects, solar photovoltaics, which are at present one of the most expensive ways to generate electricity, could become one of the cheapest options by 2100 as a result of learning-curve effects (Rao, Keppo and Riahi et al., 2006).

This is not a unique characteristic of new energy technologies; rather, it is the norm in technological change. Microelectronics, a major success story of the private sector today, was the outcome of United States Government spending during the Cold War years. According to Morton (1999), "The U.S. military initially purchased nearly the total production of transistors in the early 1950's, using them to make the new generation of communications, radar and improved avionics systems, command and control systems, as well as for missiles and jet fighters … The U.S. government acted as the major market for integrated circuits in the early years … In 1962 … the U.S. government, with extensive research interests in space, defense, and other areas, purchased virtually 100 per cent of all integrated circuits manufactured in the United States." As with wind power, a few decades of generous public support were sufficient to launch the microelectronics industry as a success in the marketplace. If the world had waited for automatic technical change, or relied on getting the prices right, microelectronics might never have happened.

D. Carbon markets and developing countries

It has become commonplace to insist on the need for a globally harmonized price of carbon. Price harmonization is thought to ensure efficiency in worldwide abatement efforts: with appropriate market institutions, investment in emissions reductions will flow to the countries where the marginal abatement costs are lowest. Fears about the effects of unharmonized carbon charges have slowed climate policy initiatives in some high-income countries, and prompted an unproductive and potentially protectionist discussion of border tariff adjustments. This notion is mistaken, both in fact and theory. Empirically, only a handful of industries are so carbon-intensive that a difference in carbon charges could lead them to move from one country to another – and large segments of these industries have already moved to middle- and low-income countries.

In theory, remarkably enough, marginal abatement costs do *not* have to be equal in every country in order to achieve economic efficiency. Theorists who conclude that equal marginal costs are needed generally rely on the unexamined assumption that world income distribution is equitable, or, equivalently, that increases in per capita consumption are equally urgent everywhere (Sheeran, 2006; Chichilnisky and Heal, 1994). In the absence of that assumption, it is more efficient to carry out abatement efforts in richer countries, even though that might entail higher costs. That is, in an inequitable world, efficiency can be improved by imposing higher carbon prices in richer countries. This is not to suggest that the problem of climate change can be solved in high-income countries alone. Rather, it means that it is equitable for richer countries to invest in more costly measures, higher up on their marginal abatement curves.

It seems unlikely, however, that the movement towards a uniform worldwide carbon price will be blocked for long. Eventually, developing countries are likely to face a global carbon price, while their local prices for labour, land and other inputs remain far below the levels of higher income countries. The dissonance between expensive carbon and cheaper local inputs will create both an obstacle and an opportunity. The obstacle is that development may be distorted in the direction of activities of little or no value, simply because they yield marketable carbon reductions. Safeguards will be needed to prevent "carbon-allowance-seeking" investments. That is, in any global carbon market it will be essential to verify that emissions are not newly created in order to profit by reducing them. Unfortunately, the temptation to seek bogus allowances is a natural consequence of a global carbon price in a low-cost local economy.

The positive side of the same effect is that much deeper reductions in carbon emissions will be economical in developing countries. In the simplest terms, the fixed price of saving a ton of carbon in those countries is "worth" more hours of labour at a lower wage rate. Thus there will be a category of carbon-saving investments and technologies that are profitable only in developing countries, where the trade-off between carbon and other inputs is more favourable to emissions reductions. With appropriate public initiatives and financing for these technologies, developing countries could "leapfrog" beyond the patterns of energy use in higher income countries, thereby establishing a new frontier for carbon reduction. The potential for leapfrogging beyond the current technology frontier has been much discussed, but is difficult to achieve. The classic example is in telephones, where developing countries have been able to skip the expensive development of universal land lines and go directly to the use of cell phones. This, however, became possible only after cell phones were invented and commercialized in developed countries (Unruh and Carillo-Hermosilla, 2006).

To realize the opportunity created by a global carbon price in low-cost economies, there will be a need for R&D in appropriate, cutting-edge technologies for carbon reduction. As with many of the new energy technologies that will be needed around the world, decades of public investment may be required before the developing-country technologies are successful in the marketplace. This is one more reason why carbon prices are necessary, but not sufficient, for an equitable solution to the climate crisis.

E. Conclusion

Setting a price for carbon emissions is a valuable beginning, but not the end, of climate policy. Much more needs to be done to complement the new markets in carbon emissions, and to ensure an effective policy response to the threat of climate change.

Reliance on carbon price increases alone would be both ineffective and inequitable. For end uses with small price elasticities, such as residential electricity and, above all, transportation, a higher fuel price leads primarily to a less equal distribution of resources – not to a reduction in carbon emissions. Other policies are needed to offset the equity impacts of higher fuel costs, and to launch the development of new, low-carbon energy technologies of the future. Because technology choice is path-dependent, with strong learning-curve effects, public sector initiatives, such as investment in promising new energy technologies, are essential to ensure that the global economy follows a climate-friendly path.

Developing countries must play a leading role in key aspects of climate policy. If international agreements move towards a globally harmonized carbon price, it will become profitable for those countries to "leapfrog" beyond the technologies which are cost-effective in higher income countries.

IV. Making the Transfer of Clean-energy Technology Effective: From Concept to Action

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» The UNFCCC's Bali Action Plan calls for developing countries to undertake mitigation action and technology transfer, and for developed-country financing to support both objectives. Properly harnessing the power of investment can help to satisfy all three objectives.

» Government support for technology transfer has proved particularly difficult, but it is critical in the case of climate change, where the need for new mitigation and adaptation technologies on a massive scale is urgent and massive.

» The most useful role for public finance in technology deployment and diffusion is to operate as a *catalyst* for the vast flows of private investment that will have to materialize, particularly in R&D and demonstration, to avoid dangerous levels of atmospheric GHG concentrations.

» Governments must, therefore, focus on the enabling environment for technology transfer in order to remove barriers specific to investment in climate-related areas.

» Most of the support that is needed will be development assistance and capacity-building, helping domestic governments in developing countries achieve goals that are often already part of nationally enunciated development priorities, such as energy security, reduced local air pollution, increased industrial efficiency, and more foreign direct investment and domestic investment.

» The key question is whether sufficient levels of financial support will be forthcoming.

Among other things, the UNFCCC's Bali Action Plan calls for developing countries to undertake mitigation action and technology transfer, and for developed-country financing to support both.[67] Properly harnessing the power of investment can help to satisfy all three mandates.

Technology transfer long ago ceased to be viewed as a simple transfer of machinery; to be successful it also encompasses elements such as operating practices, management expertise and other associated knowledge that makes a given technology effective in its setting (IPCC 2000). To be successful, technology transfer also requires some degree of innovative capacity in the host environment, to manage the inevitable adaptation to local circumstances. As such, technology transfer covers a broad process of cooperation and development.

In that process, the challenge of government support for technology transfer has proved stubbornly difficult. In numerous international agreements, spanning multilateral environmental agreements, free trade deals and cooperation agreements, countries have pledged to foster technology transfer, but in the end there has been very little to show for those promises.[68] One of the problems is that patents and technological know-how are privately held, and there is limited potential or appetite for governments to "transfer" that which is not theirs against the owner's will.[69] Thus, while there are substantial amounts of global private investment in R&D, deployment and diffusion of technologies, resulting in large-scale, meaningful technology transfer, governments for their part have struggled to fulfil their technology transfer obligations.

The challenge is particularly critical in the case of climate change, where the need for new mitigation and adaptation technologies on a massive scale is urgent. Yet that very scale again begs the question of exactly what role governments should play in supporting tech-

nology transfer, as the levels of investment involved are enormous. The International Energy Agency (IEA, 2008b) estimates that halving global CO_2 emissions by 2050 relative to 2005 levels (its BLUE Map scenario, which roughly corresponding to a 2–3 degree Celsius global average temperature increase) would require a total of $27 trillion in *incremental* investment in cleaner energy-related technologies and goods in non-OECD countries between 2010 and 2030.[70] This is the amount of required spending on new capital goods over and above the IEA's projected baseline levels of investment. These investments – including in transport equipment, electricity generating capacity, and technologies for increased industrial and residential efficiency – if they materialized would be the result of firms, project proponents and consumers investing in and purchasing new technologies at levels that dwarf anything the public sector could muster. To put it in context, the average annual incremental investment needs projected by the BLUE Map scenario amount to almost 150 times the combined total of all energy-related ODA, all mitigation-related funding by the Global Environment Facility (GEF), and the expected average annual disbursement of the World Bank's Clean Technology Fund (CTF).[71]

In light of these facts it is obvious that the most useful role for public finance in technology deployment and diffusion is as a *catalyst* for the vast flows of private investment that will have to materialize if we are to avoid dangerous levels of atmospheric GHG concentrations. More direct public support is possible and appropriate in the areas of R&D and demonstration – the earlier stages in the so-called innovation chain – an example being the substantial public support for research and demonstration on carbon capture and storage.

There is also, however, rich experience on which to draw in catalysing flows of private investment. Institutions such as UNCTAD, along with multilateral development banks, other intergovernmental organizations, bilateral aid agencies and governments worldwide have worked for decades on just this challenge, aiming to improve host countries' "investment climates". Recently there have been efforts and studies on the more specific challenge of fostering "climate-friendly" investment, which have gone beyond the general barriers to investment (e.g. macroeconomic stability and rule of law) to focus on barriers specific to investment in such areas as clean energy infrastructure.[72] A typical study, on wind energy in Egypt, found that despite ideal wind regimes, nearby growing urban demand for electricity and various publicly funded demonstration projects, there had been no significant private investment (El Sobki et al., 2009).[73] The main reason seemed to be because of subsidized domestic natural gas, which was provided to consumers and power producers at levels as low as one fifth of world prices, and which made it impossible for alternative energy producers to compete. Other common barriers include:

- Lack of a strong energy policy with long-term goals (thus, failure to provide investors with long-term investment support, fiscal incentives and price signals);
- A regulatory structure that penalizes new technologies (for example, by failing to allow new energy technologies to feed into a monopoly structured grid);
- An unclear legal status for new technologies (e.g. no legal ownership of captured landfill gas by landfill concession operators; unclear liability law);
- Lack of incentives (such as preferential feed-in tariffs for renewable energy suppliers); and
- Poor enforcement of climate-related environmental regulations where they exist (i.e. failure to create a market for cleaner alternatives).

To address such barriers it is necessary to focus on the enabling environment for technology transfer. To ignore them is to doom any efforts at technology transfer to be marginally successful at best. Even where technologies are commercial, finance is available and demand exists, private investors will not sink their money into countries that have these sorts of barriers, all of which work to make a long-term return on capital uncertain or minimal.

For the most part, the kind of support that is needed has the character of development assistance and capacity-building, helping domestic governments in developing countries achieve goals that are often already part of nationally enunciated development priorities, such as energy security, reduced local air pollution, increased industrial efficiency, and more foreign direct investment and domestic investment. The good news is that there are decades of experience with such efforts.

But will they happen on the scale needed? One sign of hope is the negotiations on a climate change regime to succeed the Kyoto Protocol which expires in 2012, and to increase the effectiveness of the Protocol's parent treaty – the UNFCCC. In the talks, there seems

to be agreement building that developing-country mitigation commitments might take the form of nationally appropriate mitigation actions (NAMAs), which would be financially supported by developed countries.[74] While the final shape of those talks will only be clear after UNFCCC's COP-15, it is possible that we will eventually see a support mechanism for developing-country pledges to pursue their nationally enunciated development goals in ways that simultaneously achieve climate change mitigation. The key question seems to be what levels of support will be forthcoming. Will there be finance for actual reform efforts, or simply for analysis of what reforms are needed? Will it apply to all developing countries or just to LDCs? From a technology transfer perspective, the ideal outcome would be in the form of broad support for actions themselves, for policy reforms that address the barriers to investment in new mitigation and adaptation technologies. This might constitute the most effective manner possible for developed countries to fulfil their Bali pledges to finance technology transfer.

Notes

1 Other promising areas include sustainable transport, energy-efficient construction and building management, material/resource efficiency, waste avoidance and enhanced material re-use and recycling.

2 For more information, see: www.millenniumassessment.org/en/index.aspx. Following this study, the United Nations Environment Programme (UNEP) launched The Economics of Ecosystems and Biodiversity (TEEB) initiative to draw attention to the global economic benefits of biodiversity, to highlight the growing costs of biodiversity loss and ecosystem degradation, and to draw together expertise from the fields of science, economics and policy to enable practical actions for moving forward. For more information on TEEB, see: www.teebweb.info.

3 UNEP has been promoting the concept of a Global Green New Deal to describe the start of this type of paradigm shift towards a green economy. On the concept, areas and policy measures of the Global Green New Deal, see UNEP, 2009a and 2009b; and Green New Deal Group, 2008.

4 In 1979, 34.2 per cent of all capital gains in the United States went to the top 1 per cent of recipients; by 2005 the figure was 65.3 per cent (*The Economist*, 2009a).

5 For more information, see *The Economist*, 2009a.

6 For more information, see: ILO, 2009: 42–43.

7 Brazil and Malaysia are two examples of developing countries where inequality decreased in the period 1990 to 2006 (ILO, 2008: 144–147).

8 According to OECD, "income poverty among the elderly has fallen, while poverty among young adults and families with children has increased" (OECD, 2008: 17).

9 The "brown economy" denotes an economic growth model which is based on extensive use of materials, energy and resources, including the use of hazardous and other problematic substances that have a negative impact on the environment and on human beings. The environmental and health costs (or costs of avoided damage) are not taken into account in the brown economy. The latter also has a very short-term focus on maximizing private profit, often unsustainable and at a high cost to the general public.

10 As further elaborated on in the chapter on energy efficiency in this Review, global energy-efficiency improvements, for instance, slowed down from 2 per cent per year in the period 1973–1990 to only 0.9 per cent per year in 1990–2005.

11 For more detail, see section D below.

12 It goes without saying that the recent commodity price boom had a beneficial developmental effect on many commodity-dependent developing countries. Between 2004 and 2007, income gains from changes in the terms of trade were high for oil- and mineral-exporting countries, amounting to 7.5 and 3.9 per cent, respectively, of GDP, while, on average, exporters of other commodities experienced losses (UNCTAD, 2009e: 22). In more than 90 developing countries (47 of them being non-fuel commodity exporters), commodities account for at least 50 per cent of their export earnings, and in many other developing countries, they account for between 20 and 50 per cent of their export earnings (UNCTAD, 2008a: 11).

13 The total investment in speculative capital (including derivates) was estimated by the Bank for International Settlements at almost $600 trillion at the end of 2007. This is 10–11 times the equivalent of global GDP (estimated at between $55 and 65 trillion for 2007), which itself is inflated by figures that reflect value generation in the financial services sector.

14 Normally, one would expect that under conditions of low real interest rates that have been prevailing in recent years, and thus low rates of return on financial investments, capital would be invested in the real economy. However, exactly the opposite happened.

15 Hedge funds have shown spectacular growth in recent years (thereby diverting investment from productive capital). Their assets increased from $39 billion at the end of the 1990s to $1.9 trillion at the end of 2007 (*The Economist*, 2008). Many hedge funds aimed at extremely high rates of return (often in the order of 30 per cent and above), which could not be sustained by even very high rates of returns of companies (of about 15–20 per cent) in the real, material economy.

16 For a more elaborate analysis in this regard, see UNCTAD, 2009f.

17 The very high levels of public debt might well oblige governments to scale back public spending and/or increase taxes in the not too distant future, as is already happening in the Baltic Republics, Greece, Hungary and Ukraine.

[18] As aptly described by the Green New Deal Group: "In essence, finance will have to return to its role as servant, not master, of the global economy" (Green New Deal Group, 2008: 23). The protective financial umbrella currently being erected by many developed-country governments gives them critical leverage to institute reform of the banking and international financial system.

[19] As the European Commissioner for the Environment, Stavros Dimas, suggested: "We need the equivalent of an environmental war effort" (Dimas, 2007).

[20] The five previous Kondratieff waves focused on: (i) the steam engine; (ii) railway and steam shipping; (iii) basic innovations in chemistry and electricity use; (iv) vehicles; and (v) information and communication technology.

[21] It is often overlooked that, based on current projections, the major fuel reserves will be exhausted by the turn of 2100. However, many of the strategically important metals will already be exhausted in some 20–25 years (Bleischwitz et al., 2009).

[22] UNCTAD's *Trade and Development Report 2009* correctly emphasizes that "climate change mitigation is best understood as a process of structural change" (UNCTAD, 2009g).

[23] The effects of GHG abatement, for instance, will not only be felt globally in terms of better climatic conditions that are more conducive to economic and social progress, but also at the local level in countries, regions or cities in the form of improved air, water and soil quality, with resulting benefits for health and eco-balance (UNCTAD, 2009g).

[24] According to a recent ILO study, which examined economic stimulus packages in 32 countries, including all members of the G-20, the stimulus packages represent on average the equivalent of 1.3 per cent of GDP in the covered developed countries, whereas they account for 2.7 per cent of GDP in the examined developing countries (ILO, 2009: 48).

[25] It is estimated that in the United States Government's current stimulus package, the $100 billion directed towards energy and environmental programmes will cut carbon emissions in that country by no more than 1 per cent (WRI, 2009).

[26] However, several recent studies seem to suggest that IPRs present fewer risks for the transfer of low-carbon technologies to developing countries than expected. A paper commissioned by the International Centre for Trade and Sustainable Development (ICTSD) on IPR issues related to access to renewable energy equipment for solar photovoltaics, biofuel and wind concluded that there were insignificant IP barriers (Barton, 2007). Another ICTSD study concluded that IPRs present fewer risks for technology transfer to developing countries in the context of climate change than for public health (Abbott, 2009). A new study for the European Commission by Copenhagen Economics (2009) found that patents are not a major barrier to the transfer of climate change technology; rather, there are other important factors such as the technological capacity, the market size and purchasing power of the recipient developing countries. A World Bank study (2008a) on technology diffusion in developing countries found that effective diffusion very much depends on institutional structures, availability of infrastructure, property rights, education and human capital. For a contextualization of technology transfer issues and the creation of an enabling environment, see the commentary by Cosbey in this Review. Furthermore, the commentary of Dong Wu provides examples for access to and effective use of technology for windmill production in China.

[27] From the perspective of developing countries – especially in the context of the negotiations under the aegis of the United Nations Framework Convention on Climate Change (UNFCCC), for example –coordinating R&D and implementing demonstration projects is important. However, equally important is to ensure that the transfer of the needed technologies from developed to developing countries, especially when developed with public support, takes place under the most advantageous conditions, in accordance with UNFCCC Art. 4.5 and the provisions of the Bali Action Plan on enhanced action on technology development and transfer.

[28] It is difficult to develop clear criteria for distinguishing "green" from other stimulus measures, as illustrated by the example of car scrapping allowances.

[29] There are a number of studies on the effectiveness of creating "green" jobs (*The Economist*, 2009b).

[30] Critics may argue that "green" investments may pay off quickly until a certain point (i.e. as long as there is low-hanging fruit, in particular related to enhancing energy efficiency), after which investments in clean energy might require increasingly costly measures. While this is true in principle, it applies particularly to the major GHG emitters among developing countries. And the large majority of developing countries are likely to have plenty of low-cost opportunities to exploit.

[31] According to UNEP (2008a), the share of developing countries in worldwide investments in energy efficiency and use of renewable energy has already risen from 13 per cent in 2004 to 23 per cent in 2007.

[32] For an in-depth discussion, see Halle and Wooders, forthcoming.

[33] On the general relationship between economic growth, sustainable development and climate change, see UNCTAD, 2009c, sections 2.3 to 2.5; and UNCTAD, 2009g, chapter V – Climate change mitigation and development.

[34] Developing countries accounted for 41 per cent of all energy-related CO_2 emissions in 2006. However, only 10 countries (China, Brazil, India, Indonesia, the Islamic Republic of Iran, Mexico, Saudi Arabia, South Africa, Thailand and Turkey) accounted for 90 per cent of those emissions (IEA, 2008a).

[35] Although this Review singles out energy efficiency as one of the clean growth poles, as will be seen below and in the chapter on energy efficiency, it is often closely interlinked to material and resource efficiency.

[36] The contributions relating to sustainable agriculture in this Review elaborate on the challenge of reducing the agri-food sector's GHG emissions in the context of growing demand due to higher incomes and population growth.

[37] The IEA, for instance, proposed to the G-8 a list of 12 simple EE measures to be taken globally (see: www.iea.org/G8/docs/final_recommendations_heiligendamm.pdf).

[38] Sustainable agriculture integrates three main goals: environmental health, economic profitability, and social equity. Sustainable production practices involve a variety of approaches. Specific strategies must take into account topography, soil characteristics, climate, pests, local availability of inputs and the individual grower's goals. Despite the site-specific and individual nature of sustainable agriculture, several general principles can be applied to help growers select appropriate management practices: (i) selection of species and varieties that are well suited to the site and to conditions on the farm; (ii) diversification of crops (including livestock) and cultural practices to enhance the biological and economic stability of the farm; (iii) management of the soil to enhance and protect soil quality; (iv) efficient and humane use of inputs; and (v) consideration of farmers' goals and lifestyle choices. Examples of some of the key specific strategies of sustainable agriculture are: organic farming, low external input sustainable agriculture, integrated pest management, integrated production and conservation tillage.

[39] It has been estimated that carbon sequestration in agricultural soils has a mitigation potential of 1 to 4 Gt CO_2 per year in the period to 2030, representing between 11 and 17 per cent of total estimated GHG mitigation potential, of which 70 per cent lies in developing regions (Martino, 2009).

[40] For example, under the Environmental Action Team project in Kenya, maize yields increased by 71 per cent and bean yields by 158 per cent. Moreover, increased diversity of food crops available to farmers resulted in more varied diets, and thus improved nutrition. For 20,000 farmers in Tigray, previously one of the most degraded regions of Ethiopia, crop yields of major cereals and pulses have almost doubled through the use of ecological agricultural practices such as composting, water and soil conservation activities, agroforestry and crop diversification (UNCTAD, 2009a).

[41] The low level of agricultural productivity in low-income developing countries is a major source of concern and is one of the main causes of the recent food price and food security crisis. Today, LDCs have lower productivity in agriculture than half a century ago: between 1983 and 2003 agricultural productivity declined in two thirds of the LDCs for which data were available (UNCTAD, 2006).

[42] For example, in Uganda the farm gate price for organic pineapples is 80 per cent higher than for conventional pineapples, for ginger it is 185 per cent higher and for cotton it is 33 per cent higher (communication from the National Organic Agriculture Association of Uganda).

[43] In the United Kingdom, a 100-hectare stockless arable farm is estimated to consume on average 17,000 litres of fossil fuel annually through fertilizer inputs alone (Cormback, 2000). Globally, chemically fertilized soils release more than 2 Gt CO_2-eq per annum, or more than 4 per cent of total GHG emissions (Worldwatch Institute, 2009: 35).

[44] This is because supply of organic products from developing countries usually does not directly compete with developed-country supply patterns, as it is either supplementary (e.g. tropical fruit and beverages) or off-season (e.g. vegetables).

[45] The report highlights the following specific areas of importance: (i) improved resource conservation technologies; (ii) better techniques for organic and low-input systems; (iii) better breeding techniques for temperature and pest tolerance; (iv) research on the relationship of agricultural ecosystem services and

human well-being; (v) economic and non-economic valuations of ecosystem services; (vi) increasing water-use efficiency and reducing water pollution; (vii) enhancing bio-controls of current and emerging pests and pathogens; (viii) developing biological substitutes for agrochemicals; and (ix) reducing the dependence of the agricultural sector on fossil fuels (Herren, 2008).

[46] For more information, see Rodale Institute and FiBL, 2009; and FAO, 2009.

[47] According to the Rodale Institute, in 2006 United States CO_2 emissions from fossil fuel combustion were estimated to be nearly 6.5 Gt. If all 434 million acres of cropland in the United States had been converted to organic production methods, nearly 1.6 billion tons of CO_2 would have been sequestered per year, mitigating close to one quarter of the United States' total fossil fuel emissions (LaSalle and Hepperly, 2008: 5).

[48] In sub-Saharan Africa, more than 92 per cent of the rural population has no access to electricity.

[49] The local availability of renewable energy sources would also help overcome the serious health effects of indoor air pollution from biomass use for cooking and heating, which cause the premature death of an estimated 1.5 million women and young children in developing countries every year (a figure twice as high as the death toll from open-air pollution and respiratory diseases) (WHO, 2006).

[50] With the exception of diesel for diesel generators, if required as power back-up.

[51] A survey of the World Bank's Energy Sector Management Assistance Program of six renewable energies for electricity generation found that renewable energy is more economic than conventional generation for off-grid applications of less than 5 kW (World Bank, 2007). It should also be pointed out that decentralized renewable energy systems prevent, or drastically reduce, transmission losses (often as high as 20–40 per cent in developing countries) of conventional grid-connected systems.

[52] For more information, see McKinsey Global Institute, 2008: 20. UNCTAD's *Trade and Development Report 2009* draws the same conclusion (UNCTAD, 2009g).
Macroeconomic costs of overcoming specific environmental problems have tended to be grossly overestimated in the past, thus discouraging early and decisive action. In the case of the Montreal Protocol, for instance, the phasing out costs of ozone-depleting substances in the United States were estimated to be almost eight times higher than they actually were, while those related to a cap-and-trade programme for abating sulphur dioxide emissions that cause acid rain were overestimated by18 times the actual costs (McKinsey Global Institute, 2008: 19).

[53] For more detail, see the commentary by Ackerman in this Review.

[54] Estimates of the required mitigation and adaptation-related investment in developing countries vary widely from $85 to $800 billion per annum in the period 2015 to 2030, compared to $21 billion currently available from bilateral and multilateral sources (UN-DESA, 2009b). However, these estimates might be exaggerated; they could be lower if economies of scale and technology-induced cost reductions – and thus related leapfrogging opportunities – are factored into the calculations.

[55] CDM allows the development of many smaller projects as part of a larger CDM programme under a coordinating mechanism. The programmatic approach can be of special interest to LDCs and other poor developing nations, since these countries often have potential for smaller scattered projects such as for renewable energy. For an overview of programmatic CDM projects as at February 2009, see UNCTAD, 2009b, annex 5 and section 3.3.

[56] For further details and an elaborate discussion on future prospects, see UNFCCC, 2008 and http://unfccc.meta-fusion.com/kongresse/090329_AWG_Bonn/templ/ply_page.php?id_ kongresssession=1635&player_mode=isdn_real.

[57] Germany has already announced that it will provide one third of the income obtained from auctioning of emission allowances under the EU ETS to support the transfer and effective use of carbon efficient technologies to developing countries.

[58] For more information, see: http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTCC/0,,contentMDK:21713769~menuPK:4860081~pagePK:210058~piPK:210062~theSitePK:407864,00.html.

[59] This article is based on the author's G-24 Discussion Paper, Carbon markets and beyond: The limited role of prices and taxes in climate and development policy (2008); see: www.unctad.org/en/docs/gdsmdpg2420084_en.pdf.

[60] A major exception to this pattern occurs in countries where some of the poorest people cannot afford fossil fuels, and instead rely on traditional biomass fuels.

[61] Price elasticity is the percentage change in demand that results from a 1 per cent change in price.

[62] Price elasticities are, strictly speaking, negative numbers. This discussion follows the common convention of referring to values farther from zero as "larger" elasticities: an elasticity of -1 is "larger" than an elasticity of -0.5.

[63] See also Reiss and White (2005), who estimate a long-run price elasticity for California households of -0.39, and point out that previous high-quality studies have generally yielded estimates of between -0.15 and -0.35.

[64] The EIA (2007) notes that transportation will account for two thirds of the growth in world oil use through 2030; OPEC data (2007) imply that transport will absorb 62 per cent of the growth in oil use.

[65] Another study in the United States similarly found that the short-run price elasticity in 2001–2006 was between -0.034 and -0.077 (Hughes, Knittel and Sperling, 2006).

[66] The classic references on technological lock-in include those by David (1985) and Arthur (1994).

[67] UNFCCC Decision 1/CP.13: Bali Action Plan, para. 1 (b), as well as these three priorities, the fourth "pillar" in the Bali Action Plan is adaptation.

[68] The Montreal Protocol on Substances that Deplete the Ozone Layer is often cited as an example of successful government support for technology transfer. Its Multilateral Fund supports the investments needed for new ozone-free technologies. While this is encouraging, showing that such success is indeed possible, it is the only obvious example of its kind.

[69] There is, however, a strong argument to be made for the public availability of research that is publicly funded, as much of it is.

[70] Note that these figures are not an approximation of the investment needed for technology transfer alone; they include, for example, consumer spending on such new goods as efficient automobiles. And there is an imperfect correspondence between "non-OECD" countries and developing countries in need of technology transfer. The figures are cited here simply to give an idea of the scale of incremental spending needed.

[71] Based on annual World Bank CTF disbursement of $2 billion, GEF 2007–2008 funding of $198 million and average annual energy-related ODA over the period 1997–2005 of $7 billion.

[72] See, for example, two summaries of case studies, by Neuhoff, 2008; and Cosbey et al., 2008.

[73] Since the study was completed, the government of Egypt has issued a request for proposals in the Wind sector – a significant first.

[74] See the note by the UNFCCC Secretariat reflecting the state of negotiations on long-term cooperative action as at June 2009, FCCC/AWGLCA/2009/INF.1, 22 June 2009: 84–109.

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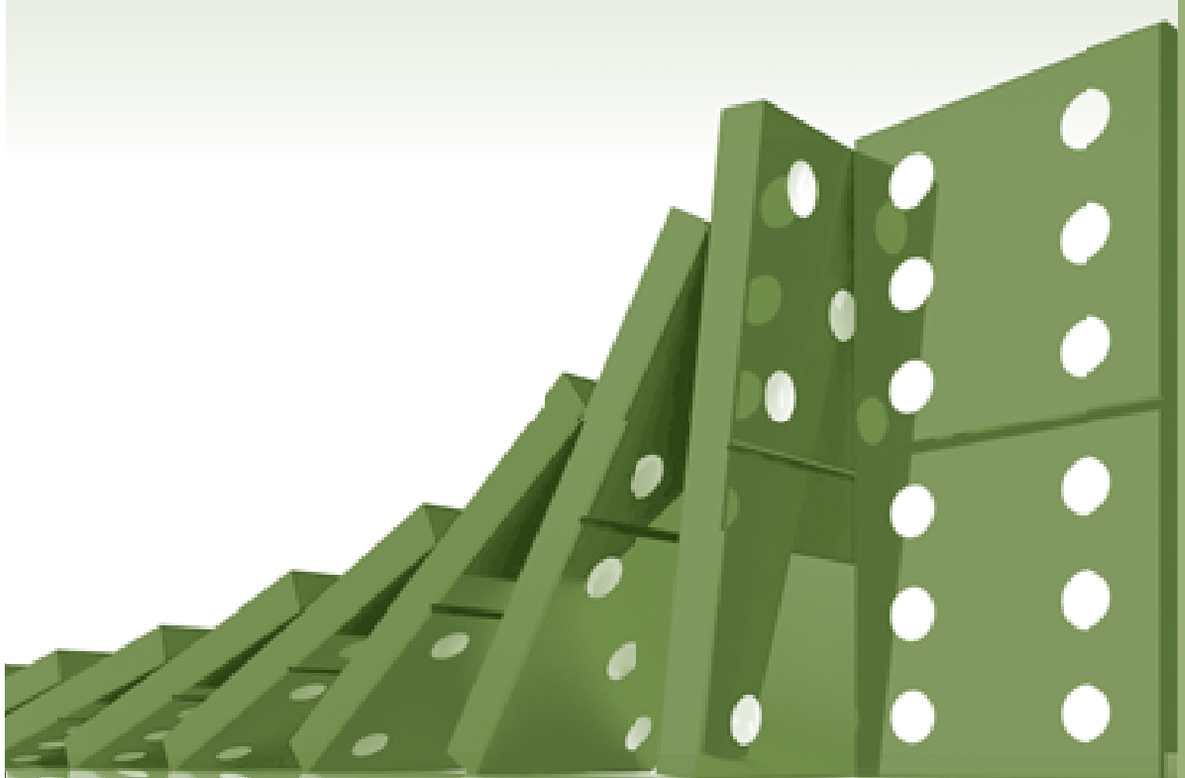
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CHAPTER 2

GROWTH POLE: ENERGY EFFICIENCY



I. Energy Efficiency: Turning Challenges Into Opportunities for Developing Countries

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» Major improvements are needed in the quality and quantity of energy services to sustain the growth and development of developing countries. Given the GHG intensity of current energy generation, improving energy efficiency (EE) is often the cheapest, fastest and most environmentally friendly way to meet energy needs and help address climate change.

» In addition, the benefits of improvements in EE go beyond climate change: they include lower fossil fuel imports, reduced air pollution, increased access to energy that requires less investment in new energy infrastructure, and overall enhanced competitiveness. EE also offers opportunities for low-carbon green growth and employment, becoming strategic in the current economic downturn. EE is a particularly strategic goal for developing countries.

» However, because of the existence of important obstacles to EE improvements, which are generally greater in developing countries, there remains a large untapped potential for cost-effective EE policies. Most of these obstacles are well documented, which provides a good starting point to formulate policy responses to help unlock the large potential for EE gains.

» EE policies and measures, as illustrated in this Chapter, in particular in major end-use sectors (i.e. manufacturing, households, services and transport), provide cost-effective tools that can bring significant sustainable development gains.

» In addition, international trade can make a positive contribution to market transformation and the diffusion of EE technologies, particularly if there is appropriate international coordination and cooperation, including with regard to standards and conformity assessment.

A. Introduction

Energy use is more efficient when the same level of a given output or service is produced with a lower total amount of energy inputs. Alternatively, energy use becomes more efficient when more goods or services are produced with the same amount of energy inputs. Efficiency gains in end-use technologies reduce the demand for energy to provide specific energy services, such as heating and powering a range of industrial processes, conditioning (cooling/heating), lighting residential and commercial buildings and transporting people and freight (Edmonds et al., 2007). "Energy efficiency" (EE) can thus be defined as an energy input-output ratio. (Enhanced supply-side efficiency reduces the amount of energy that is lost when the power generation and refining sectors transform energy from one form to another.) EE improvements result in a reduction of the energy used for a given service or level of activity. Such reduction is usually associated with technological changes, but can also result from better organization and management or improved economic conditions, as well as behavioural changes (non-technical factors).

Growing concerns about energy security and climate change have reinvigorated the search for renewable sources of energy and for measures to use energy more efficiently. In the context of the current economic recession, interest in EE and investments in renewable sources of energy have gained momentum due to their potential to create significant market opportunities and to contribute to the promotion of low-carbon green growth.[1] Such growth is seen as playing a significant role in simultaneously addressing several major challenges confronting the world today, in particular poverty and climate change.

There is indeed broad consensus that EE is the fastest, cheapest and most sustainable way of providing

energy for sustainable development and of addressing climate change. Large improvements in EE have already been made, resulting in net economic benefits to consumers and firms. Further savings in world energy use are still possible, and would result in major reductions in energy-related carbon dioxide (CO_2) emissions. For example, the International Energy Agency (IEA) estimates that accelerated EE improvements would enable three quarters of the savings in energy-related CO_2 emissions to be achieved by 2030 if governments were to implement all the policies to address energy security and climate change that they were considering up to mid-2007 (IEA, 2007a). Improved EE would also make the largest contribution to projected savings in energy-related CO_2 emissions in more recent scenarios prepared by the IEA (2008a and 2008b).

In addition to their important role in gearing economies towards a lower carbon future aimed at climate change mitigation, EE policies can bring other benefits as well. They can reduce air pollution and dependence on fossil fuel imports, enable developing countries to provide their populations with greater access to energy while reducing the need for new investments in energy infrastructure, and contribute to enhanced competitiveness and savings in consumer spending on energy. In addition, EE programmes targeted at poor households can make an important contribution to alleviating energy poverty (UNCTAD, 2009a). In the context of the current economic crisis, the cost-savings potential of EE is particularly relevant. Investment in EE may provide opportunities for employment and exports. Even though developing countries are not subject to mandatory reductions in greenhouse gas (GHG) emissions, investing in EE will help those countries to position themselves in the future, when low-carbon growth becomes an increasingly important factor of competitiveness and sustainable development.

Yet a large proportion of the potential for cost-effective EE improvement remains untapped. The reasons for this "efficiency gap" can be explained by a range of known barriers and market failures, such as hidden and transaction costs, lack of information about available options, capital constraints, misaligned incentives, as well as behavioural and organizational factors affecting economic rationality in decision-making (Stern, 2007). A range of policy interventions, including information, regulations, financing and multilateral cooperation, can be designed to overcome these barriers.

Improvements in EE can be made both in the supply (e.g. electricity generation) and end use of energy; both reduce the amount of energy that needs to be generated to meet final energy demand. For instance, enhanced supply-side efficiency reduces the amount of energy that is lost when the power generation and refining sectors transform energy from one form to another.[2] On the other hand, it is often more cost-effective to invest in end-use EE improvements than to increase energy supply to satisfy demand for energy services (IPCC, 2007). Demand-side policies contribute to reductions in direct CO_2 emissions in end-use sectors, and, indirectly, to reductions in CO_2 emissions in the power sector (depending on the energy mix).

This chapter focuses on demand-side EE policies and measures aimed at addressing barriers to EE investment. It first makes the case for EE investments and reviews recent trends in final energy consumption and EE (section B). Section C reviews some key EE issues in each of the major end-use sectors. Although this chapter does not address supply-side EE issues, section C also reviews policies and measures aimed at enhancing the contribution that power generation and supply sector (particularly electricity suppliers) can make to EE gains in end-use sectors. Section D reviews key EE policies and measures that target both domestically produced and internationally traded products, focusing on EE standards and labelling requirements. Section E highlights the trade dimension by examining key factors that may influence trade, such as market penetration of energy-efficient products, compliance costs and trade structures. It argues that harmonization of testing procedures, coordination in standard-setting and transparency, including the proactive involvement of key developing-country suppliers of energy-using products (EuPs), can strengthen the contribution of international trade to the wider diffusion of energy-efficient products. Section F recommends national strategies for improving EE and frameworks for the financing of end-use EE projects, and section G concludes with further recommendations.

B. Benefits deriving from improvements in energy efficiency

Investments in EE can bring multiple benefits, the most important of which relate to improvements in the quality and quantity of energy services in developing countries,[3] climate change mitigation and employment generation. Despite these benefits, recent trends in EE show that investments need to be scaled up if EE is

to fully contribute to improved energy services and climate change mitigation. The removal of certain policy and investment barriers would further contribute to the effective deployment of EE measures.

1. Energy use and climate change

The combustion of fossil fuels (coal, oil and gas) for energy purposes is by far the most important source of carbon dioxide (CO_2) emissions: energy-related emissions account for 61% of all GHG emissions. The power sector alone emitted 41 per cent of total CO_2 emissions in 2006 (IEA, 2008a), largely through the combustion of fossil fuels to generate electricity. Emissions from electricity generation are often allocated to end-use sectors (e.g. on the basis of each sector's share of aggregate electricity consumption). The major end-use sectors contributing directly and indirectly to CO_2 emissions are industry, households, services and transport (table 1).

Table 1. Shares of end-use activities in global final energy consumption and CO_2 emissions, 2005 (per cent)

	Final energy consumption	Direct and indirect CO_2 emissions
Industry	33	38
Households	29	21
Services	9	12
Transport	26	25
Other*	3	4
Total	100	100

Source: IEA, 2007b, figure 2.1.
* Includes construction and agriculture/fisheries

The IEA reference scenario projects that by 2030 global CO_2 emissions will increase by 45 per cent, or 1.6 per cent per year on average (table 2). Almost 90 per cent of this increase will be in developing countries and almost three quarters in China, India and West Asia.

EE policies and measures can reduce CO_2 emissions by reducing direct energy use in end-use sectors, and by reducing fossil fuel combustion in the power industry to generate electricity for consumption in end-use sectors. Most models show that EE improvements will play a more important role in lowering CO_2 emissions than carbon-intensity reductions (comprising the aggregate effect of replacing fossil fuels by low-carbon energy sources and carbon capture and storage (CCS)) in the period until 2030. However, improvements in EE alone will not be able to yield the type of reductions in GHG emissions required to achieve more ambitious curbs on the accumulation of CO_2 in the atmosphere; the widespread deployment of low-carbon energy sources and CCS will also be needed.[4]

2. Energy efficiency, market opportunities and job creation

The drive towards improved EE in many countries, reinforced by incentives and regulations to improve EE in end-use products, buildings and industrial processes should create significant demand for energy efficient products, technologies and services. A study by the American Council for an Energy-Efficient Economy estimates that in the United States $300 billion was invested in EE technologies and infrastructure in 2004 (nearly 60 per cent of which was in buildings alone), and that the country's annual EE market will increase to $700 billion in 2030 (Ehrhardt-Martinez and Laitner, 2008). According to the IEA, limiting the increase in the global average temperature to only 3°C (i.e. a maximum concentration of 550 parts per million (ppm) of CO_2-equivalent) would require additional investments in EE, above the reference scenario,[5] of $3 trillion over the period 2010–2030. Limiting the increase to only 2°C (450 ppm of CO_2-equivalent) would require additional investments of $5.7 trillion (IEA, 2008a).

A study by Merrill Lynch found that companies in capital goods, semiconductors, automotives and building insulation, may be particularly well placed to benefit from the drive to improve EE (Merrill Lynch, 2007).[6] For example, EE in the transport sector creates market opportunities for components that improve fuel efficiency, including through the use of electronics, hybrid battery technologies and fuel-efficient tyres. Semiconductor companies benefit from growing demand for chips to improve EE (e.g. for reducing standby power, lowering heat loss, the introduction of variable speed drives in motors and smart energy meters). The drive to improving EE may also provide market opportunities for companies in developing countries (e.g. producers of chips and electrical motors and, more generally, energy-efficient building materials).

A number of recent studies and policy statements emphasize the job creation potential of investments in a clean energy economy, including in EE. For example, EE investments in residential and commercial buildings and in recycling may offer promising opportunities (see UNEP/ILO/IOE/ITUC, 2008, in particular table III.2-1). Positive impacts on employment arise directly from new business activities in EE improvements, and

indirectly through the economic multiplier effects of spending the money saved on energy costs (Ürge-Vorsatz and Metz, 2009).

3. Energy efficiency in the economic downturn

Rapidly rising oil prices until mid-2008 made investments in EE increasingly attractive. However, lower oil prices, the financial crisis and the economic downturn may exert downward pressure on investments in sustainable energy. Lower or negative rates of growth in such investments and consumption may slow down the rates at which capital, equipment and appliances are replaced by new and more energy-efficient alternatives. However, since EE investments in general have negative costs, due to lower spending on energy, they remain very attractive. Some observers have noted that the focus of investments in sustainable energy may shift from long-term technology innovations to short-term EE gains. As elaborated in chapter I of this Review, companies seeking to introduce cost-savings may implement new EE measures. This may also help these companies to position themselves for the future, when energy prices rebound and climate mitigation measures become an increasingly significant factor of competitiveness.

An assessment by the Grantham Research Institute on Climate Change of how a range of climate change proposals would perform against specific criteria (including with regard to timeliness and effectiveness) for an effective "green" stimulus found that EE measures scored particularly well. These include measures for residential EE (driven by utilities or local authorities) and public buildings, boiler replacement programmes, lights and appliances (e.g. utility-driven), and a switch to cleaner cars (fleet renewal) (Bowen et al., 2009).

Several countries provide (or are considering) support for the construction of new energy infrastructure, especially renewable sources of energy, and incentives for EE improvements as part of their fiscal stimulus programmes. For example:

- In the United States, the American Recovery and Reinvestment Act of 2009 (involving about $789 billion) has allocated around $30 billion to smart grid technologies, advanced batteries and the implementation of EE measures. The latter include tax credits for the purchase of energy-efficient furnaces, windows and insulation, $5 billion for EE improvements in over one million lower income homes and $6.3 billion for improving energy efficiency in public housing.
- The Government of the Republic of Korea plans to invest $38 billion over the next four years in "green growth plans", including specific EE measures such as the conversion of 20 per cent of public lighting to light-emitting diode (LED) lamps (UNEP, 2008).
- Japan's second economic stimulus plan announced in April 2009 (amounting to about $154 billion) includes fiscal incentives for green cars and energy-efficient appliances, including a focus on saving energy in residential and office buildings (unlike plans of some other governments that focus more on grids and other infrastructure) (New York Times, 9 April 2009).
- A European Economic Recovery Plan presented in November 2008 (Commission of the European Communities, 2008b) calls on member States and European institutions to take urgent measures to improve EE in buildings and to stimulate demand for products that offer high potential for energy savings. In 2009, the European Commission decided to allocate €3.98 billion to clean energy projects, gas and electricity infrastructure, offshore wind energy and CCS (but not to EE projects) (European Parliament, 2009). Some non-governmental organizations (NGOs) and members of the European Parliament had called for the inclusion of EE projects and more funds for renewable energy (smart cities), arguing that this would have a larger and quicker impact on economic recovery and the creation of green jobs than CCS projects. Funds not committed to the above-mentioned clean energy projects before 1 September 2010 may be redirected to EE improvement projects.
- Part of the $586 billion stimulus package announced by the Government of China in November 2008 will be directed towards improved energy efficiency (The Guardian, 2008).
- Several countries of the European Union (EU) are providing tax incentives as part of their national stimulus packages (in addition to existing incentives for green cars in some of these countries) for scrapping old cars and replacing them with new cars that meet specified CO_2 emission standards.[7] In the United States, the Car Allowance Rebate System (CARS), also known as the "cash for clunkers" programme, provided similar incentives. The programme was signed into law on 24 June 2009 and ended on 24 August 2009.[8]

4. Trends in energy use and EE

World primary energy consumption increased by 34 per cent between 1990 and 2006, and is projected to

Table 2. Energy demand by region and end-use activity in the IEA reference scenario: 2006–2030

	Energy demand (Mtoe)[a]			Growth rate (%)		Percentage growth per annum 2006-2030
	1990	2006	2030	1990–2006	2006–2030	
Total primary energy demand (Mtoe)						
World	8 757	11 730	17 014	34	45	1.6
OECD	4 519	5 536	6 180	23	12	0.5
Developing countries	2 566	4 893	9 150	91	87	2.6
Eastern Europe and Eurasia[b]	1 559	1 118	1 454	-28	30	1.1
Final energy consumption (Mtoe)						
World	6 285	8 086	11 405	29	41	1.4
Industry	1 810	2 181	3 322	20	52	1.8
Transport	1 575	2 227	3 171	41	42	1.5
Other sectors	2 429	2 937	3 918	21	33	1.2
Non-energy use	472	740	994	57	34	1.2
Developing countries	1 950	3 356	5 981	72	78	2.4
Industry	587	1094	2 108	86	93	2.8
Transport	299	600	1 352	101	125	3.4
Other sectors	942	1374	1 975	46	44	1.5
Non-energy use	122	288	547	136	90	2.7

Source: UNCTAD secretariat, compiled from IEA, 2008a, various tables.
[a] Mtoe = million tons of oil equivalent.
[b] Eurasia comprises: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan and Turkmenistan

continue growing (table 2). It increased by 47 per cent in developing countries and by 23 per cent in OECD countries. Total final energy consumption increased by 29 per cent, with the fastest growth in transport, followed by household/services and industry.

The IEA found that at the end of the 1990s it took one-third less energy to produce one unit of gross domestic product (GDP) in its member States than in 1973 (IEA, 2004). This was the combined result of structural changes, higher energy prices, EE policies and other factors. A decline in energy services relative to GDP accounted for one fifth of the reduction in energy use per unit of GDP, with the rest resulting from declining end-use energy intensities (used as a proxy for EE improvements). The IEA projects that, under current circumstances, global final energy intensity will continue to fall at a rate similar to that of the last 30 years (1.6 per cent per year). This would mean that by 2050 the amount of energy used to produce one unit of GDP will be half that of today. However, lower CO_2 emission scenarios require a larger reduction in final energy intensity (of 2.2–2.5 per cent per year), driven by rates of EE improvement of 1.4–1.7 per cent per year (IEA, 2008b).

Impressive as past EE gains may be, EE improvements must be accelerated to limit the atmospheric concentration of CO_2 to safer levels. Yet the rate of EE improvements slowed down from an average of 2 per cent per annum in the period 1973–1990 to an average of only 0.9 per cent between 1990 and 2005. Observing that intensities fell fastest in the 1973–1990 period, the IEA noted, "These findings provide an important policy conclusion: that the changes caused by the oil price shocks in the 1970s and the resulting energy policies did considerably more to control growth in energy demand and reduce CO_2 emissions than the EE and climate policies implemented since the 1990s" (IEA, 2008c).

Available end-use technologies are becoming steadily more energy efficient. The rate at which available technologies are actually taken up by end users varies, mainly as a function of how quickly the current and future stock of energy-using equipment is retired and new equipment added. In most cases, capital stock is replaced only gradually. Rapid economic development in large developing countries such as Brazil, China and India offers an opportunity to penetrate a large segment of the market with high-efficiency equipment, products and services. Indeed, EE opportunities tend to be interesting, as an additional injection of capital creates an opportunity for deploying the most efficient technologies commercially available. In China, India and other developing countries, payback

periods based on economically efficient energy pricing would generally be shorter than in the countries of the Organisation for Economic Cooperation and Development (OECD), because there is more potential for replacing inefficient equipment (IEA, 2007a).

5. Barriers to energy efficiency improvements

A number of cost-effective EE improvements are possible with existing, commercially available and "near-commercial" technologies. Large EE improvement and reductions in CO_2 emissions can be achieved through the widespread application of best available technologies worldwide (table 3).[9] An important challenge therefore is to remove obstacles to the widespread deployment of such technologies.

The most common barriers to the more effective deployment of EE technologies are well documented, and include the following:[10]

- Lack of awareness and comparable product information.
- Hidden costs and benefits. Hidden or transaction costs are difficult to measure. In general, they could have the greatest impact on small- and medium-level energy users such as households, non-energy-intensive firms, particularly small firms, as well as the public sector (Stern, 2007).
- Limited product availability.
- Perceived risks (such as difficulties in integrating unfamiliar technologies into existing production processes, or, from the perspective of lending institutions, creditworthiness of small end users).
- Business interruption and sunk costs associated with retrofits.
- Failure of industry to manage energy at the strategic level (e.g. different parties purchasing equipment and paying operating costs).
- Energy price distortions.
- Limited access to capital. Lack of available capital may prevent investment in more energy-efficient processes which typically entail higher up-front costs, but which are cheaper overall when evaluated over a longer period. Restricted access to capital is especially common among poor households and small firms, particularly in developing countries (Stern, 2007).
- The split incentive: those who make investments in energy efficiency are often not the final users who pay the energy bill (e.g. the "landlord-tenant" problem in the buildings sector).
- Difficulty in reaching small end users.

Obstacles to EE improvements are sometimes greater in developing countries, such as lack of awareness of the benefits of EE, lack of capital, proliferation of inefficient equipment (including through imports of used and/or inefficient equipment), the desire to minimize initial costs and energy supply constraints (e.g. limited availability of commercial fuels in rural areas often impedes switching to more energy-efficient stoves). In some developing countries, subsidized energy prices can reduce the economic attractiveness of EE measures. The large number of small and dispersed end users[11] also represents a particularly strong barrier in many developing countries. Moreover, many developing countries lack an effective EE policy at the national level (Jochem, 2002). These barriers are well understood and several policy measures are available to help overcome them. The most cost-effective

Table 3. Examples of mitigation technologies

Sector	Key mitigation technologies and practices currently available commercially	Key mitigation technologies and practices projected to be commercialized before 2030
Transport	More fuel-efficient vehicles, hybrid vehicles, cleaner diesel vehicles.	Higher efficiency aircraft; advanced electric and hybrid vehicles.
Buildings	Efficient lighting, more efficient electrical appliances and heating and cooling devices, improved cooking stoves, better insulation, passive and active solar design for heating and cooling, alternative refrigeration fluids, recovery and recycling of fluorinated gases.	Integrated design of commercial buildings, including technologies such as intelligent meters that provide feedback and control, and solar photovoltaic panels incorporated into buildings.
Industry	More efficient end-use electrical equipment, heat and power recovery, material recycling and substitution, control of non-CO_2 gas emissions, a wide array of process-specific technologies	Advanced energy efficiency, CCS for cement, ammonia and iron manufacture, and inert electrodes for aluminium manufacture.

Source: Adapted from IPCC, 2007.

approach to accelerating EE is likely to include market-based instruments that place an explicit financial value on CO_2 emissions. In addition, non-price measures are necessary to help create the necessary conditions to speed up the development and deployment of energy-efficient equipment. Such policy responses include: regulation, information and financing (Stern, 2007). These measures are described and assessed in section C below, while section D enumerates additional policy instruments that could be used to promote EE in specific end-use industries.

C. Selected EE policies and measures

Market-based instruments, including fuel and/or energy taxes, which place an explicit financial value on CO_2 emissions, have considerable potential to enhance EE. In addition, non-price measures are necessary to help create the necessary conditions to speed up the development and deployment of energy-efficient equipment. Such policy responses include: regulation, information and financing (Stern, 2007).

(i) *Regulatory measures* are less efficient and flexible than market mechanisms in the context of perfect markets, but they can be an efficient response to overcome a number of the above-mentioned barriers to EE. Regulatory measures include, for example: building codes, minimum energy performance standards (MEPS) for energy-using equipment, energy consumption reporting (requiring designated or large energy users to report their energy consumption, either to the government or in their annual reports), nomination of energy managers in companies above a certain size, energy saving plans, mandatory maintenance of energy-using equipment (to maintain the initial efficiency for as long as possible), and an obligation imposed on utilities to save energy (World Energy Council, 2008).

(ii) In addition, *reliable information* is important for making consumers and firms aware of the full lifetime costs and benefits of an economic decision, and hence for supporting good decision-making. Information policies include: labelling and certification, billing and metering, and the dissemination of best practices. Information-based instruments, such as energy labelling, may increase the competitiveness of energy-efficient equipment.

(iii) Finally, *financial incentives* may be appropriate to address certain capital constraints (for example, it may be harder for poorer households and firms in developing countries to acquire more energy-efficient equipment) and technology-related market failures, or for the delivery of wider policy objectives. For example, financial support could help create opportunities to achieve wider climate-related or social policy objectives (see Stern, 2007, chapter 17, for an analysis of these issues).

A range of measures can thus be implemented, often in conjunction, to improve the energy performance of energy-using products, such as MEPS, energy labels, consumer information and incentives to promote innovation. These may be complemented by policies to create demand for energy-efficient products, such as public procurement policies and financial incentives offered to consumers.[12] This section reviews policies and measures that target internationally traded products, particularly MEPS and EE labelling.

1. Energy efficiency policies and measures targeting energy-using products

In general, MEPS and mandatory labelling are used to increase the efficiency of individual technologies. They can also be used to phase out inefficient products (such as incandescent lamps) and replace them with more efficient alternatives. Basically, MEPS promote the gradual removal from the market of the least energy efficient appliances.[13] Labelling stimulates technological innovation and the introduction of new, more efficient products. Together, MEPS and labelling facilitate market growth and reduce financing risks by helping to ensure that new EE technologies have a rapid market impact (UNEP, 2008b).

a) Minimum energy performance standards (MEPS)

MEPS define an EE performance threshold that energy-consuming equipment should meet. Mandatory and voluntary MEPS can coexist in the same market. For example, mandatory standards can be set for one efficiency level (to remove inefficient products from the market) and voluntary specifications set for a more stringent level (to promote the most efficient products). MEPS threshold levels are usually reviewed periodically to keep pace with technological progress. Some 60 countries already have MEPS programmes, and more programmes are under development.[14] Developing countries that have mandatory MEPS include the Bolivarian Republic of Venezuela, Brazil (see box 1), China, Costa Rica, Egypt, the Islamic Republic of Iran, Jamaica, Mexico, the Philippines, the Republic of

Box 1. MEPS and energy labels in Brazil

In Brazil, energy labelling started in 1984 as a voluntary programme initiated by INMETRO. Today Brazil has a comprehensive programme known as the PBE (Brazilian Labelling Programme), which is being implemented in partnership with PROCEL (National Electricity Conservation Program) and CONPET (National Program for the Rationalization of the Use of Oil and Natural Gas Derivatives). By mid-2008, labelling requirements had been developed for 22 product groups (largely domestic appliances) and were envisaged for another 20, including for consumer electronics, to be developed over the next few years (www.inmetro.gov.br/consumidor/pbe.asp). Starting in mid-2008, all televisions sold in Brazil must use the standby efficiency label (the objective is to reduce television standby per set to ≤ 1 W). Electrical household appliances with an A rating may also be granted the PROCEL EE seal.

Korea, Singapore, Thailand and Tunisia. Programmes vary in terms of product coverage and characteristics (UNCTAD, 2006). While MEPS programmes initially focused on large appliances such as refrigerators and washing machines, they increasingly also cover commercial and industrial equipment. For example, countries such as Australia, Brazil, Canada, China, Mexico, New Zealand and the United States have MEPS for motors (such as 3-phase motors used in manufacturing).

The coverage and stringency of MEPS vary from country to country. Australia, Canada, Japan and the United States,[15] for example, have stringent MEPS for a broad range of EuPs. In Australia, the Greenhouse Gas Office has a general policy to adopt the highest MEPS prevailing worldwide. In the United States, the Energy Policy and Conservation Act and the Energy Policy Act of 2005 require the Department of Energy to set appliance efficiency standards at levels that achieve the maximum improvement in EE that is technologically feasible and economically justified. In EU member countries, MEPS programmes have so far been less ambitious than those of some other developed countries in terms of the number of standards set and performance levels demanded. However, the EuP Directive represents a new approach by setting eco-design requirements for a larger range of EuPs. In December 2008, the EU member States approved a regulation (formally adopted by the European Commission (EC) in March 2009) for the progressive phasing out of incandescent bulbs by 2012. This regulation is one of the eco-design measures expected to be adopted by the EC, targeting many more products such as tertiary sector lighting equipment (covering both public street lighting and office lighting), standby and off-mode electricity losses, external power supplies and simple set-top boxes for digital reception of television signals.[16]

In Japan, the Top Runner programme has the advantage of making the definition of new targets easier. As the most efficient appliances on the market at a given time are used to set future standards, there is no need for extensive market or techno-economic analysis to set the minimum energy efficiency standards. With this type of approach, the preparatory work can be shortened and the negotiations between manufacturers and public authorities facilitated, as the targets correspond to existing appliances that are already available on the market. Presently, the Top Runner programme covers 18 energy-intensive products, including the main household appliances and passenger cars.

Existing and already planned MEPS in IEA countries cover 50 to 70 per cent of household electricity consumption. Amongst the major developing countries, China covers nearly 70 per cent of its electricity consumption. As mentioned in section B.4 above, the impact of improved EE in appliances already covered by MEPS and energy labels on household energy consumption has been offset by the growing demand for new appliances. The trend towards introducing mandatory measures to tackle standby power reflects increasing concern about the growth of electricity consumption due to the greater use of small household appliances, often grouped as "miscellaneous" end uses (Ellis, 2007).

Given the large size of its domestic market and its importance as a producer and exporter of EuPs, the development of MEPS in China is particularly important. Since 1989, China has had MEPS for about 20 product groups, including refrigerators, air conditioners, washing machines and fluorescent lamps (IEA, 2007b).[17] The recent sharp rise in appliance ownership and usage has prompted the Government to adopt a new approach to setting standards, which, according to the IEA, "involves the development of two tiers of standards: one for initial implementation and a more stringent second tier, or reach, standard for implementation three to five years later. The lag between the adoption and implementation of the reach

standards gives manufacturers time to redesign their products and to retool their production facilities, making it easier for them to comply."

b) Energy labelling

Energy labels provide information to consumers on the energy performance of products. There are two main categories: comparative and endorsement labels. Comparative labels rate the EE of different models of an appliance in terms of a set of EE classes, usually ranging from A (most energy efficient) to G (least energy efficient). Endorsement labels identify only the best performing products in the marketplace.

Labelling programmes introduced in developing countries are based on the experiences of OECD countries and use models that have already been proven: the European label has been used as a model in Brazil, China, the Islamic Republic of Iran and Tunisia, while labels introduced in Thailand and the Republic of Korea are based on the Australian model.[18]

c) Voluntary agreements

Voluntary agreements can be an effective alternative to regulatory EE requirements. Since they have the support of manufacturers, they can be implemented more rapidly than regulations. In the EU, agreements covering standby power losses from televisions and videocassette recorders, domestic washing machines, and refrigerators and freezers are said to have been implemented successfully by industry as unilateral commitments.[19] In general, however, their effectiveness depends on the precise requirements of and efforts by industry. Success factors include: clear targets, a baseline scenario, third-party involvement in design and review, formal provisions for monitoring, and close cooperation between government and industry. In some countries, MEPS have replaced unsuccessful voluntary agreements.

d) Complementary and alternative measures

Apart from policies and measures aimed at increasing technical energy performance, there is considerable potential for lowering energy consumption by reducing demand for energy services through complementary measures. For example, fuel efficiency standards for cars are often complemented by improvements in public transport and the promotion of fuel-efficient tyres. In some areas (e.g. electrical heating of spaces) there are hardly any MEPS, because there is little room for technical improvements. However, in these cases, there is potential for reducing energy through the adoption of alternative approaches. Examples include switching to heat pumps, and reducing the demand for space heating through improved building fabric and design, as well as insulation (Ellis, 2007).

2. International EE initiatives

The emergence of a number of international initiatives involving governments, industry and other stakeholders in major developed and developing countries shows the increasing recognition of the importance of international coordination and cooperation for promoting market diffusion of energy-efficient equipment worldwide through transparent and cost-effective policies and measures. Such cooperation may be further developed, including, where possible, in the areas of technology-sharing and finance. Examples of such initiatives include:

- The Standards for Energy Efficiency of Electric Motor Systems (SEEMS) Initiative[20] and, more recently, the Electric Motor Systems Annex (EMSA) of the IEA Implementing Agreement for a Co-operating Programme on Efficient Electrical End-Use Equipment (4E). EMSA bundles best practices and policy know-how in order to stimulate market transformation towards EE in electric motor systems and their applications in industry, infrastructure and large buildings.
- The Efficient Lighting Initiative (ELI) supported by the International Finance Corporation and the Global Environment Facility.
- The World Business Council for Sustainable Development (WBCSD) Energy Efficiency in Buildings project.
- The IEA 1-watt Plan.[21]
- The International Task Force for Sustainable Products (ITFSP), which is led by the United Kingdom with participants from 13 countries, the IEA and the United Nations, seeks to encourage larger market shares for more environmentally sustainable, energy-efficient products, among others, through cooperation on product standards and labelling.
- The Asian Development Bank's Energy Efficiency Initiative.[22]

In June 2008, the G-8 countries, along with China, India, the Republic of Korea and the European Community, established the International Partnership for Energy Efficiency Cooperation (IPEEC).[23] The partnership offers a forum for high-level policy discussion, regular strategic cooperation and exchanges that focus exclusively on EE.

3. Impacts of MEPS and energy labelling

In order to replicate successful efforts as widely as possible, it is useful to analyse the impacts of MEPS, energy labels and other product measures, including their effectiveness in enhancing EE performance of equipment, impacts on market transformation, and prices and compliance costs.

A number of studies suggest that MEPS and mandatory energy labels have already contributed significantly to energy savings. Ellis (2007) reports that the efficiency of a range of household appliances in Australia, Europe, Japan and the United States increased by 10 to 60 per cent over the periods when data were collected. At the same time, all products also experienced a decline in real prices of between 10 and 45 per cent. Evidence suggests that the majority of efficiency gains have been driven by the introduction of regulatory policies.[24] These gains have been made without sacrificing levels of service. As shown by various studies, the greater use of more efficient appliances did not result in a price increase for consumers, as producers were able to adapt and benefit from increased sales ("learning effect"). Programmes oriented toward motor energy efficiency appear to have produced significant and cost-effective results when of sufficient size and having enough resources to attract participation (IEA, 2006). However, none of the programmes introduced were able to reverse or stop the increase in electricity consumption in the domestic appliance sector.

With regard to market transformation, the European and Australian programmes are considered to have been generally successful (World Energy Council, 2007). In the EU, for instance, there was a rapid increase in the market share of the most energy-efficient appliances. Sales of Class A refrigerators increased from less than 5 per cent of total sales in 1995 to 23 per cent in 2000 and 61 per cent in 2005; in addition, 19 per cent of refrigerators sold in 2005 were in the two new, more efficient classes (A+ and A++). For washing machines, progress was even more rapid: with an increase in sales of 1 per cent in 1996, 38 per cent in 2000 and 90 per cent in 2005. Labelling has resulted in market transformation that can be attributed both to the increased interest of consumers in EE and to changes in the models made available by manufacturers, as well as to other accompanying measures (such as rebates and information campaigns).

With regard to electric motors, in countries that have implemented MEPS at relatively high efficiency levels, such as Canada and the United States, high-efficiency motors have market shares of over 70 per cent. It has been argued that Australia's MEPS for electric motors have helped to protect its market from a flood of lower efficiency motor imports from Asian suppliers (IEA, 2006). However, in countries that do not have MEPS, such as European countries it would appear that the market share of premium efficiency motors has not risen above 15 to 20 per cent, despite significant policy efforts, such as the European Motor Challenge Programme (SEEEM, 2006).

Experience shows that EE regulations in general have not resulted in sustained increases in real prices of regulated appliances. In a few instances, the introduction of MEPS or similar programmes has coincided with temporary price rises, but this may be due to other factors, and in all cases the long-term downward trend has been rapidly restored (Ellis, 2007). The costs of meeting energy performance requirements have fallen due to several factors, including:

- Sufficient advanced notice, which has made it possible to meet the requirements through normal redesigning processes;
- Manufacturers have been innovative in improving energy performance; and
- Some components (for example, electronic time clocks and controls) have become more easily available and cheaper.

From the above, it follows that EE performance is likely to become an increasingly important requirement in the marketplace. It also confirms that public policy instruments have an important role to play in stimulating EE investments; it is doubtful that private firms would move in the direction of ever more efficient end-use products in the absence of such instruments. It also follows that in the menu of possible policy instruments, there are sectoral particularities that require specific mixes (i.e. implementation of different measures in tandem). The following section discusses EE in the context of selected end-use activities.

D. Energy efficiency in end-use sectors

Potential for EE gains with net economic benefit exists in all activities (table 4) and in all regions. EE options in new and existing buildings may be particularly relevant (and also offer significant co-benefits) in all developing countries. In many developing countries, EE

Table 4. End-use energy savings in 2050 under different technology scenarios

Scenario*	Demand (Mtoe/year)		Annual percentage change per year			Change compared to baseline	
	2005	Baseline 2050	baseline	ACT	BLUE	ACT	BLUE
Industry	2 564	5 415	1.7	1.5	1.3	-8.8	-16.9
Transport	2 141	4 729	1.8	1.0	0.5	-30.8	-43.8
Buildings	2 913	5 234	1.3	0.4	0.2	-32.0	-39.8
Non-energy use	129	306	1.9	1.9	1.4	0.0	-20.2
Total end use	7 748	15 683	1.6	1.0	0.7	-23.0	-32.9

Source: IEA, 2008b, table 2.3.
* The ACT (Accelerated Technology) scenario analyses how global CO_2 emissions can be brought back to 2005 levels by 2050, whereas the "BLUE" scenario targets a 50 per cent reduction in CO_2 emissions by 2050 compared to 2005 (see annex).

improvements in industry and transport also account for a significant share of low-cost mitigation opportunities. This section presents a very brief and general analysis of some drivers of energy use and technological development, based on recent reports. Further analysis based on developing-country case studies would be very relevant from a policy perspective.

1. Industry

The industrial sector represents about one third of the world's end-use energy consumption and slightly more of global (direct and indirect) energy-related CO_2 emissions (IEA, 2007b; UNIDO, 2007). Energy-intensive industries (e.g. iron and steel, chemicals, petroleum refining, cement, aluminium, and pulp and paper) account for more than two thirds of energy consumption and CO_2 emissions. With growing industrial activity and the need to construct basic infrastructure, energy-intensive industries account for a relatively large share of manufacturing output in a number of developing countries.

Growth of demand for industrial energy is concentrated in large developing countries. China alone accounts for about 80 per cent of that growth in the past 25 years. On average, industrial EE in developing countries is lower than in developed countries. However, rapid expansion also allows developing countries to leapfrog technology. Since new plants tend to be more efficient than older ones, in some cases the most efficient industries can be found in developing countries. For example, the most efficient aluminium smelters are in Africa, and Brazil is among the most efficient cement producers. Similarly, some of the most efficient steel plants can be found in China (IEA press release 25 June 2007). In addition, the dissemination of best practices may assist developing countries in making rapid gains in industrial EE.

Industries, including in developing countries, can derive important gains from EE improvements in terms of competitiveness. A UNIDO study (2007), for example, notes that industry is motivated to take actions that improve EE efficiency for a variety of reasons, such as:

- Cost reduction;
- Improved operational reliability and control;
- Improved product quality;
- Reduced waste stream;
- Ability to increase production without requiring additional, and possibly constrained, energy supply;
- Avoidance of capital expenditures through greater utilization of existing equipment;
- Seeking recognition as a "green company"; and
- Access to investor capital through demonstration of effective management practices.

IEA estimates that the manufacturing sector can improve its EE by 18 to 26 per cent, while reducing CO_2 emissions by 19 to 32 per cent, based on proven technologies (IEA, 2007b and 2008b). These EE improvements are the combined results of: (a) systems/life-cycle improvements (in particular motors and motor systems, combined heat and power (CHP), steam systems, process integration, increased recycling and energy recovery); and (b) sector-specific improvements, in particular in energy-intensive sectors.

All countries can benefit from potential savings through "systems/life cycle improvements", in part because options apply to all industries. For example, a number of countries have implemented policies and measures to promote the use of more efficient motors, such as MEPS and motor classification (i.e. rating) schemes.[25]

The IEA estimates that a 30 per cent market penetration of existing heat pump technology would lead to a 6 per cent reduction in global CO_2 emissions. Options for EE improvements may be identified in energy audits.

Specific EE improvements are particularly important in energy-intensive industries. The chemical and petrochemical industry accounts for 29 per cent of global industrial energy use and 16 per cent of direct CO_2 emissions (IEA, 2008b). However, more than half of energy resources are used as chemical feedstock, rather than being consumed as energy, and therefore EE policies cannot have any effect on them (IEA, 2007b).[26] Other energy-intensive industries with a large share in global industrial energy use are: iron and steel (20 per cent), non-metallic minerals[27] (10 per cent), pulp and paper (6 per cent) and non-ferrous metals[28] (3 per cent) (IEA, 2008b).

2. Buildings and appliances/equipment

In 2005, buildings accounted for almost 38 per cent of global final energy use, around 46 per cent of which was consumed in developing countries. The households and services sectors consumed almost 90 per cent of this. Electricity represents about 25 per cent of energy used, making buildings the largest electricity consuming sector (IEA, 2008b). The WBCSD estimates that buildings are responsible for at least 40 per cent of energy use in most countries (WBCSD, 2008). Moreover, energy use is growing rapidly in many developing countries with booming construction sectors.

Knowledge and technology are already available to reduce the increase in energy use through EE improvements of the building envelope, space heating and cooling systems, water heating systems, lighting, household appliances and business equipment. Policies and measures aimed at improving the effectiveness of the building envelope can be particularly efficient, especially with regard to new buildings, but also in the case of existing buildings, because significant EE improvements can be made through retrofitting.[29] Public policy should seek to encourage designers, developers and construction companies to implement energy efficiency measures, for example through mandatory EE codes for buildings.[30] Indeed, a number of developing countries, such as China, India and Thailand, have implemented such codes.[31]

a) The household sector

Household energy use accounted for 29 per cent of global final energy consumption in 2005 (table 1). The type and amount of energy used by households vary from country to country, depending on income levels, natural resources, climate and available energy infrastructure.[32] Households in OECD countries use far more energy than those in other countries, in part because their higher income levels allow them to purchase more energy-using equipment. Consequently, household energy use in the OECD countries accounts for about 60 per cent of the world's residential delivered energy use, although these countries account for only 18 per cent of the world's population (Energy Information Administration, 2007). By contrast, as much as 77 per cent of people in sub-Saharan Africa and 59 per cent in South Asia do not have access to electricity (www.undp.org/energy/).

In all regions, energy consumption per capita is increasing (World Energy Council, 2008). In developed regions, growth has been slowing for some time as a result of near saturation in ownership of appliances and the effect of policies aimed at improving EE in electrical appliances. In Europe and North America, however, there has been a slight increase in the rate of electricity consumption by households since 2000. This may be due to the growing numbers of new appliances being used, such as air conditioners in Europe, and information technology (IT) devices linked to the development of the Internet and new telecommunications equipment. Increased electricity consumption by appliances in "active" mode (i.e. they are turned on, even though they may be in standby mode) is an issue of concern. This is because of increased consumption of televisions in active mode, as larger screen sizes have come to dominate the market, and, in particular greater use of set-top boxes and home networked products, which seldom have an effective standby mode (Ellis, 2007).

In low-income developing countries, household energy consumption tends to shift from traditional to commercial fuels when disposable income increases. This trend has several implications. On the one hand, since cooking appliances using commercial fuels are more energy efficient than those using biomass, energy consumption per household tends to fall. On the other hand, since traditional energy is often not included when energy/GDP ratios are calculated, the substitution of commercial for traditional fuels raises those ratios. In addition, electrification in rural areas and increasing income and mobility in urbanizing areas increase energy use (Jochem, 2002).

b) The services sector

The services sector involves different types of buildings, in particular commercial buildings and buildings for public services (e.g. schools, hospitals and government agencies). Energy consumed for services not associated with buildings, such as for traffic lights, may also be included in this sector.

Economic and population growth trends drive commercial sector activity and the resulting energy use (EIA, 2007). Electricity is a major source of energy used in the services sector. As that sector has grown in developing countries, so also has the consumption of electricity due to increased use of air conditioning, higher lighting levels, increased office automation and other developments (World Energy Council, 2007; United Nations, 2000).

There is large potential for EE improvements in the services sector, in particular in the areas of lighting, space heating and cooling. Apart from the policies and measures discussed in other parts of this chapter, certain mitigation options are of particular importance to this sector, for example in supermarket refrigeration systems. Integrated design of buildings, including the use of technologies such as intelligent meters that provide feedback and control, can contribute significantly to reducing energy use, in particular in commercial buildings. The services sector also includes public administration, and therefore public procurement policies are important.

3. Transport

Between 1990 and 2006, final energy use in transport (personal and freight) worldwide increased by 41 per cent. World demand for liquid fuels in the transport sector is expected to increase more rapidly than in any other end-use sector between 2006 and 2030, with the strongest growth expected in developing countries. Cars contribute the most to energy use and CO_2 emissions. In OECD countries, overall energy intensity of passenger transport fell by 5 per cent between 1990 and 2005 (IEA, 2007). However, improvements in the efficiency of engine technologies were partially offset by the increased weight of larger cars.

Several policies and measures have been implemented or are being considered to increase the fuel efficiency of cars and reduce CO_2 emissions. Examples include the European Commission's strategy aimed at reducing CO_2 emissions from new cars, new Corporate Average Fuel Economy (CAFE) standards in the United States and Japan's Top Runner programme. In Europe, in 1995 the European Commission set a target to reduce CO_2 emissions from new cars to 120 grams per kilometre (g/km). It was expected that this target would be achieved through a voluntary industry agreement. The 1998 voluntary agreement of the European Automobile Manufacturers Association included a commitment by carmakers to achieve a target of 140g/km by 2008. However, they achieved only limited progress, with average emissions falling from 186 g/km in 1995 to 163 g/km in 2004. In late 2007, the Commission adopted a new strategy, later followed up by legislative proposals setting a binding target for new cars of 120g/km by 2012.[33] Under the reformed CAFE standards, the fuel economy target for light trucks was increased from 22.2 miles per gallon (mpg) in 2007 to 24 mpg in 2011. In California, standards implemented by the California Air Resources Board (CARB) aim to reduce CO_2 emissions from passenger cars by 2016 by 33 per cent compared with 2002. CARB standards have been implemented in several other States. On 19 May 2009, President Obama announced an average fuel-economy standard target of 35.5 miles per gallon by 2016 for United States automakers, four years sooner than previously planned (thereby applying nationwide the standard proposed by California). In Japan, the Top Runner programme sets efficiency standards for cars (and trucks) according to that achieved by the most efficient vehicle in each category.

Several developing countries are also implementing fuel efficiency standards. China, soon to become the largest car market in the world, has been applying stringent fuel economy standards since 2005, and a new car-tax regime which penalizes large cars since 2006. In India, the absence of mandatory vehicle fuel efficiency standards suggests that the fuel efficiency of vehicles may lag behind that of other countries[34] (IEA, 2007b). The Bureau of Energy Efficiency (BEE) has introduced a voluntary energy labelling scheme as a first step to enforcing mandatory fuel economy standards for cars, two-wheelers and heavy commercial vehicles. According to press reports, the BEE recently came under pressure from car users in major cities as well as NGOs to accelerate the introduction of a mandatory fuel efficiency standard for car manufacturers.[35]

In its alternative policy scenario (APS), the IEA assumes that, as a result of prolonged and tighter fuel efficiency standards, in 2030 new light-duty vehicles (LDV) will be 40 per cent more efficient, on average, than 2005 models. In 2030, a new car in China would

be around 10 per cent more efficient than a new EU model in 2012. These efficiency gains result from improvements in the efficiency of internal combustion engines and the introduction of advanced vehicle technologies, including a higher penetration rate of mild and full hybrid technologies. The APS also takes into account complementary measures such as scrapping of old cars, faster development of public transport and larger use of alternative fuels (for details see IEA, 2007a, table 11.6).

Technology development plays an important role in reducing CO_2 emissions from cars. A wide range of technologies may be available to improve car efficiency, such as "clean" diesel vehicles, hybrid vehicles that combine an electric motor and related systems with a combustion engine (resulting in fuel economy which may be two and half times greater than a comparable gasoline engine vehicle), plug-in hybrid vehicles and fuel-cell vehicles (Edmonds et al., 2007).

4. Making energy supplying companies contribute to end-use energy efficiency

In addition to the use of policy instruments, governments may also seek the collaboration of energy suppliers to improve end-use EE. Sometimes, EE is pursued in combination with social objectives, such as providing low-income households with affordable access to electricity. Some types of collaboration include:

- *Cost reduction for consumers.* Some firms help their customers pay for the extra cost of EE measures through rebates or low-interest loans. In India, for example, the Bangalore Electricity Supply Company allows customers with no arrears on electricity bills to purchase Compact Fluorescent Light (CFL) bulbs from approved retailers, either via direct purchase at a discounted price or via payment in instalments over 9 months through electricity bills (Arquit Niederberger, 2008). In Mauritius, the Central Electricity Board provides CFLs at half price, supported by a government grant under the Maurice Isle Durable programme.
- *Decoupling* ensures that utilities retain their expected earnings even as their sales fall as a result of EE programmes. The importance of decoupling derives from the fact that where the profits of energy suppliers depend on energy sales there is a disincentive for utilities to engage in EE. Decoupling reverses that logic by providing an incentive for utilities to promote EE. California's long-standing decoupling policy (adopted in 1978 for the natural gas industry and in 1982 for the electric power sector) has contributed significantly to EE in that state (California Public Utilities Commission, undated).
- *Obligations on energy suppliers*. Some countries require their energy supplying companies to support EE improvements in end-use sectors. In the United Kingdom, the Energy Savings Trust (a government scheme) requires energy suppliers to encourage people to use energy more efficiently by helping with the supply and costs of installation of energy saving measures and providing advice on EE. Under the Energy Efficiency Commitment, now known as the Carbon Emissions Reduction Target, energy suppliers are required to achieve targets for the promotion of EE improvements in households. Suppliers are given flexibility to choose from a range of measures, typically insulation, low-energy lighting or high-efficiency appliances and heating systems, in order to meet their targets. In some countries, Energy Efficiency Portfolio Standards require energy suppliers to meet a specific proportion of their energy demand through EE (DEFRA, 2007).
- *Household energy generation*. Energy suppliers may also help reduce energy demand (and electricity bills) by encouraging households to generate their own electricity. Eventually, it may give customers the opportunity to sell power produced in the home back to the grid. In Mauritius, for example, the Government encourages innovation to enable households to produce electricity based on emerging technologies for renewable energy. In other countries, energy suppliers may also support the development of household-size CHP technologies to be used in homes. In the United Kingdom, micro-CHP units are expected to operate in the same manner as domestic central heating boilers, but will also deliver low-carbon electricity into the home and reduce the need to buy electricity. It is expected that competitive micro-CHP products may be on the United Kingdom market by around 2010.[36]

E. The trade dimension

1. Energy efficiency and trade

EE improvements can result in a number of benefits for a country's international trade and for the trade

competitiveness of its industries. First, countries that import fossil fuels will be able to reduce their import bill (and the effects of volatile prices of fossil fuels) compared to a business-as-usual scenario. Second, EE improvements will help to reduce energy-related production costs, which is particularly important for energy-intensive industries. Third, EE improvements may help to increase a firm's competitiveness, as they often go hand-in-hand with improved quality of products and processes, and thus may help it gain recognition as a "green" company. The international drive to greater EE may provide market opportunities for companies that are in a position to respond to growing demand for energy-efficient products, technologies and services.[37] Many of the EE measures analysed in the previous sections apply to both domestically produced and internationally traded products. International trade offers opportunities to enhance the effectiveness of MEPS and other product-related EE measures by increasing scale and facilitating market transformation. However, MEPS may also present some obstacles for producers in third countries that find it difficult to comply.

2. Trade implications of policies and measures targeting energy-using products

This section focuses on energy-using products (EuPs), as these products are the most exposed to EE policies and measures, and are a significant component of international trade.[38] With regard to product-related EE measures, the Agreement on Technical Barriers to Trade (TBT) of the World Trade Organization (WTO) helps prevent unnecessary adverse effects on trading partners. Several new EE standards and regulations have been notified under this Agreement, thus providing trading partners with information and an opportunity to comment. On a number of occasions, WTO members have used periodic meetings of the WTO TBT Committee (under "specific trade concerns") to seek clarification from trading partners on new EE standards that those members have been implementing, and corresponding conformity assessment procedures.[39]

In 1994, two panels of the General Agreement on Tariffs and Trade (GATT) were established at the request of the European Communities to consider United States EE regulations for automobiles. One panel found that the gas guzzler tax, which applied to the sale of automobiles that consumed less than 22.5 miles per gallon (mpg), was consistent with the GATT. Another panel found that the fleet-accounting mechanism used in the United States CAFE standards put foreign car manufacturers at a disadvantage vis-à-vis domestic producers and was not consistent with GATT article III on National Treatment.[40] However, the panel report was never adopted. The new version of CAFE (referred to above) is structured on a more equal treatment of domestic and foreign producers, and does not separate domestic and foreign fleet accounting.

a) Possible trade implications: imports into major developed-country markets

Any trade effects, positive or negative, of EE standards and energy labelling on developing- country exports are likely to be concentrated in a relatively small number of countries. An analysis of international trade for a sample of products covered by (or considered for inclusion in) MEPS and/or energy labelling in the major OECD markets, shows that the lion's share of imports into the EU (excluding intra-EU trade), the United States and Japan comes from a small number of developing countries, in particular China, Malaysia, the Republic of Korea and Thailand. In addition, a large proportion of imports into the United States come from Mexico and into the EU from Turkey. Brazil is a relatively important supplier of multiphase electric motors to the EU market. Possible trade implications, however, are likely to be relatively small for several reasons, such as the characteristics of trade in different categories of EuPs, and the fact that major developing countries are themselves implementing MEPS and other EE programmes. In addition, many producers in developing countries are subsidiaries of transnational corporations or large contract manufacturers for companies in importing countries.

Regional trade is important, particularly in larger household appliances. In some cases (e.g. refrigerators/freezers), product characteristics differ from region to region, resulting in little trade between regions (OECD, 1998). For example, more than half of United States imports (in value terms) of refrigerators/freezers and colour television sets come from Mexico. There has already been considerable regional cooperation and coordination between Canada, Mexico and the United States, for example, on EE standards and conformity assessment procedures to prevent obstacles to trade. A study for the North American Energy Working Group (NAEWG), established in 2001, identified 46 EuPs for which at least one of the three countries has EE regulations. Three products – refrigerators/freezers, room air conditioners and three-phase elec-

tric motors – had identical MEPS and test procedures in the three countries. Ten other products had different MEPS and test procedures, but there was potential for harmonization. The NAEWG Expert Group on Energy Efficiency has been working to identify mechanisms for mutual recognition of test results (Wiel and Van Wie McGrory, 2003). Similarly, under the Asia-Pacific Partnership on Clean Development and Climate, in particular its Buildings and Appliances Taskforce (BATF), a number of countries have been cooperating on EE for some time.[41]

In other products (e.g. office equipment), international trade, including interregional trade, is much larger. Since the market for these products is global, EE standards are likely to be similar in many countries. This should facilitate harmonization of EE standards and testing requirements and facilitate trade in energy-efficient products. Indeed, the United States "ENERGY STAR" label has already become a de facto international EE label for office equipment worldwide.[42]

Major exporters to developed-country markets have made considerable progress in designing and implementing MEPS and other EE programmes. An example is China, the leading foreign supplier to OECD markets. Chinese exporters have shown a keen interest in complying with EE requirements in import markets. In addition, China has developed its own MEPS programme, for which it received considerable international support, and, where feasible, it seeks to harmonize with MEPS in other markets (IEA, 2007a).

b) Possible trade implications: developing-country imports and South-South trade

Key developing-country exporters to OECD markets also supply EuPs to other developing countries. To the extent that these products meet similar energy performance standards as the models that are shipped to OECD markets (or sold in domestic markets of developing countries with stringent MEPS), there may be further progress in market transformation. For example, in its *World Energy Outlook 2007*, the IEA (2007a) observed that "China's efforts to improve the efficiency of vehicles and electrical appliances contribute to improved efficiency in the rest of the world, as the country is a net exporter of these products." However, there is also a risk that less efficient products that are no longer competitive in more demanding markets may be shipped to other developing countries, with no or less stringent EE requirements.

South-South trade accounts for a large proportion of developing countries' imports of EuPs. Much of this trade is intraregional (in particular trade amongst countries of the Association of Southeast Asian Nations (ASEAN)), with a significant share of imports from China. Apart from the small group of major exporters, which generally also have large domestic markets, large developing-country importers include India and South Africa, as well as oil producing countries such as the Bolivarian Republic of Venezuela and Saudi Arabia. For example:

- *Refrigerators and freezers:* Total developing-country imports amounted to $5.8 billion in 2006. The largest suppliers were ASEAN (30 per cent constituting intra-ASEAN trade), China, the EU-25 and the United States. ASEAN and Chinese imports come largely from ASEAN. Most imports into South and Central America are intraregional, but Mexico and the United States are also important suppliers.
- *Colour televisions:* China accounts for about 30 per cent of developing-country imports, and ASEAN for about 20 per cent (half of which is intra-ASEAN trade). A large share of imports into South and Central America come from Mexico (47 per cent), and another 20 per cent from China.
- *Air conditioners:* Around a third (in value) of developing-country imports come from China and 30 per cent from ASEAN.
- *Electro-mechanical domestic appliances:*[43] Around 80 per cent of developing-country imports come from China.
- *Electrical motors:* Developing-country imports come largely from the EU-25 (52 per cent), Japan and the United States. Only around 7 per cent (in value terms) come from China. China itself is a relatively important importer of electric motors, accounting for over 40 per cent of developing-country imports.

c) Implications

EE requirements aim to gradually remove inefficient products from the market and to increase market shares of energy-efficient products. Such measures can be effective only if they apply to both domestically produced and imported products. Standards, in particular international standards, can make an important contribution to market development of energy-efficient products and technologies (Waide and Gurundino, 2007), and international trade has considerable potential to disseminate them. However, national standards

may also fragment markets and entail high compliance and conformity assessment costs. In order to maximize positive and prevent negative impacts, the following are useful objectives:

- *Harmonization*. Whereas MEPS may differ across countries and regions to reflect local conditions, working towards harmonization brings benefits, such as the reduction of inspection and certification costs that producers incur for each different test protocol or standard. In practice, many countries have been aligning testing methods to ISO/IEC (International Electro-technical Commission) standards, but further progress would facilitate trade (Steenblik, Vaughan and Waide, 2006). Harmonization may also help to provide end users with comparable energy consumption information, which can then be taken into account in purchasing/investment decisions. It also helps eliminate outdated technology from global markets and thereby avoids the dumping of obsolete technology in developing countries.[44]
- *Coordination*. Regional cooperation on EE standards and conformity assessment procedures may be particularly effective for promoting the transformation of markets in favour of energy- efficient appliances. In addition, the importance of sharing expertise among countries, including on best practices in policy setting, and ensuring coordination of international initiatives aimed at implementing EE improvements in electrical equipment has been recognized for some time. In 2007, the IEA launched an Implementing Agreement for a Co-operative Programme on Efficient Electrical End-use Equipment (4E) to ensure such cooperation and coordination.[45] Similarly, the ultimate goal of the International CFL Harmonisation Initiative is to deliver higher-quality, low-cost CFL lighting products to consumers worldwide.[46]
- *Transparency*, including in standard-setting processes. Experience shows that sufficient advance notice and industry involvement in standard-setting processes have facilitated industry compliance with more stringent EE requirements. Since a small group of developing countries are the main suppliers of EuPs to world markets, it is important to facilitate their appropriate involvement in relevant stakeholder consultations (UNCTAD, 2006).[47] This may also facilitate the cost-effective introduction of higher EE standards in the domestic markets of these developing countries. Moreover, since these countries also supply other developing countries that largely depend on imports to satisfy the growing demand for various categories of electrical equipment and appliances, their involvement in relevant standard-setting consultations may bring EE benefits worldwide.

However, the extent to which international trade contributes to the wider dissemination of energy-efficient technologies and products worldwide also depends on factors such as the effective enforcement of standards and the market strategies of major companies in producing countries, as well as EE requirements and purchasing practices applied in major importing countries. For example, although China is moving towards more stringent EE standards, traditionally, the average energy efficiency of its appliances has generally been low. And smaller companies may still be producing less efficient products. Company marketing strategies may also play a role. It is often argued that manufacturers prefer to have a single production line for any single model. It is likely, therefore, that once a standard is established (e.g. in China), it will also be applied to models produced for export (IEA, 2007b).

F. Institutional issues

1. National and regional EE strategies

Developing countries should intensify their ongoing efforts to promote EE due to the projected increase in their energy demand, and also because EE policies can offer them competitive advantages. To this end, they could consider undertaking national efforts to remove obstacles to EE, while also taking advantage of the opportunities provided by new facilities, the dissemination of technologies (including through international trade) and the exchange of national experiences, including lessons learned. In addition, a large number of international initiatives have emerged.

Pursuing these objectives requires specific administrative capacity in developing-country institutions. The establishment of EE institutions, such as national EE agencies, may be useful for the design, coordination, implementation and evaluation of EE programmes and measures. Possible tasks of EE agencies include the following:

- Coordinate with a range of stakeholders, such as companies, local authorities, financial institutions and NGOs;
- Coordinate government initiatives in the field of EE; and

- Act as a promoter of EE vis-à-vis energy companies.

A number of developing countries have already set up national EE agencies, but most of them do not yet have well-defined EE strategies. The following are some of the elements that could be considered at the early stages of designing national EE strategies:[48]

- Make some projections of energy consumption in key end-use activities and identify areas where EE improvements could have the greatest impact;
- Develop building codes, standards and guidelines for appliances and materials used in buildings, including lighting and insulation;
- Establish standards for energy audits and certification of energy managers and auditors;
- Identify opportunities for EE improvements in small and medium-sized enterprises (SMEs);
- Provide consumer information and standards for household electrical appliances that are likely to become more popular as incomes increase;
- Establish MEPS and energy labels for industrial equipment, such as electric motors;
- Monitor improvements on the basis of indictors of energy performance, learning from experiences and regularly evaluating policies. National or regional EE programmes or action plans often set some quantitative targets and also include monitoring requirements.[49]

In some cases, efforts to identify possibilities for EE improvements and implement EE measures may be complemented by the activities of energy service companies.[50]

2. Supporting EE strategies in developing countries

Initiatives to support EE and renewable energy in developing countries are not new. For example, several initiatives were launched at the 2002 World Summit for Sustainable Development (WSSD), such as the EU Energy Initiative for Poverty Eradication and Sustainable Development and the Renewable Energy and Energy Efficiency Partnership. Another example is the Global Energy Efficiency and Renewable Energy Fund, a global risk capital fund that mobilizes private investment in EE and renewable energy projects in developing countries and in countries with economies in transition.

Challenges and opportunities for worldwide EE improvements (along with other climate mitigation measures) are also being considered in the context of a new global climate change policy regime beyond 2012, which is to be negotiated in Copenhagen at the 15th Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC). For example, certain EE improvements in developing countries may be considered as part of "nationally appropriate mitigation actions" by developing-country parties to the Convention in the context of sustainable development, which, according to the Bali Plan of Action, may be "supported and enabled by technology, financing and capacity-building."

A particularly interesting proposal is the Sustainable Development Policies and Measures (SD-PAM) concept. The World Resources Institute defines SD-PAM broadly as policies and measures taken by a country in pursuit of its domestic policy objectives (e.g. energy security or provision of electricity), but which are shaped so as to take a lower emissions path to achieving those objectives (World Resources Institute, 2005). Unlike projects of the Clean Development Mechanism (CDM), developing countries will not need to demonstrate that an SD-PAM was undertaken for climate mitigation objectives. Also, the fact that an SD-PAM is not exclusively an "additional" emission reduction measure opens up a wider range of sources for support. In the energy sector, policies and measures that developing countries are likely to pledge as SD-PAM include those aimed at increasing EE and the use of domestic renewable energy sources.

3. Financing EE in end-use activities

Improvements in EE generally require additional investment. Even where long-term savings outweigh initial investments, end users may fail to choose energy-efficient options because of financial constraints. Projects and programmes aimed at facilitating financial support therefore play a key role in removing barriers to EE investment, in particular in developing countries.[51] Energy savings resulting from EE investment by end users reduce the need for new investment in energy supply capacity. Whereas most supply-side investments would be made by a small group of actors, mainly large energy producers and distributors, the additional investment in end-use sectors will have to be made by a large number of small investors. The IEA therefore emphasizes that shifting investment from the supply side to the end user requires viable financing frameworks (IEA, 2006).

One option could be to reform the operation of the CDM to facilitate EE improvements in dispersed end-

use sectors (see, for example, Hinostroza et al., 2007; Figueres and Phillips, 2007).[52] It has been argued that EE is underrepresented in the CDM portfolio (accounting for just 1 per cent of projects). One reason is that emission reduction activities in end-use sectors are often dispersed, have high transaction costs and relatively low individual credit flows (Figueres and Phillips, 2007). Providing a new possibility of structuring end-use EE projects as programmes could significantly increase the participation of these projects in the CDM market.

The decision of the Conference of the Parties to the Climate Change Convention and the Meeting of the Parties to the Kyoto Protocol (COP/MOP) in December 2005 to include programmes of activities (PoAs)[53] in the CDM opens the door for scaling up implementation of dispersed end-use EE activities, because programmes are able to reach a large number of individual households and smaller industrial firms. For example, PoAs may be suitable for tapping EE potential in dispersed small building units, household appliances and SMEs in developing countries. Hinostroza et al. (2007) highlight that a "programmatic CDM" offers a promising framework to maximize development benefits by including "long tail" EE activites[54] in developing countries as eligible beneficiaries of CDM programmes.

G. Conclusions and recommendations

Improvements in EE, together with the greater use of alternative sources of energy, help developing countries meet their energy needs in a sustainable manner and contribute to climate change mitigation. Through EE improvements developing countries can reduce their dependence on fossil fuel imports, reduce environmental impacts, enhance competitiveness and provide their populations with increased access to energy while reducing the need for new investment in energy infrastructure. EE improvements make the largest and least costly contribution to lowering GHG emissions. However, the average annual rate of EE improvements will have to accelerate significantly compared with recent trends. Many observers have argued that the economic downturn provides an opportunity for governments to help create a basis for low-carbon future growth. Indeed, some countries have included the energy sector, including investments in renewable energy and EE, as a part of their stimulus packages. Developing-country governments and entrepreneurs should think strategically about the future and position themselves so as to exploit the upturn when it comes. They should also be prepared for a rebound in oil prices. Low-carbon growth should therefore become an increasingly important pillar of competitiveness and sustainable development.

Significant EE improvements can be achieved, particularly in developing countries, at negative net costs (i.e. whereby the long-term benefits of EE investments by far outweigh the costs). Demand-side EE measures may be particularly cost-effective. However, there are many, well-documented obstacles to EE improvements, which may be greater in developing countries. They include lack of awareness, limited access to capital, and difficulty in reaching small and disperse end users. Realizing untapped EE opportunities requires appropriate strategies and policies to remove obstacles to EE investments.

A number of developing countries have already set up national EE agencies and are developing and implementing national EE strategies, but most developing countries lack them. Certain elements could be considered at early stages of designing national EE strategies, such as establishing buildings codes, encouraging systemic EE gains in industry, dissemination of consumer information, application of standards for household electrical appliances that are likely to become more popular as incomes increase, and setting fuel-efficiency standards for cars. In some countries, energy suppliers are encouraged to support end-use EE and to contribute to the achievement of social objectives in the provision of energy.

Scaling up the implementation of EE policies worldwide requires international cooperation and support aimed at removing obstacles to EE improvements, including through capacity-building, access to technology and finance. The climate change negotiations in December 2009 could play a catalytic role in encouraging multilateral bodies, the public and private sectors and civil society to provide such support. This includes support for SD-PAM (i.e. policies and measures taken by a country in pursuit of its domestic policy objectives such as energy security or provision of electricity, but which are designed to take a lower emissions path to realizing those objectives).

International cooperation is also useful to ensure EE policies encourage the transfer of EE technologies, particularly through trade. However, product-specific measures, such as MEPS, which target both domestically produced and internationally traded products

Box 2. Key recommendations

Industry	• Promote use of energy-efficient electric motors and motor systems, in particular through: - The introduction and updating of MEPS; and - Optimization of EE in electric-motor-driven systems. • Provide effective assistance in the development of energy management capabilities through the development of energy management tools, training, certification and quality assurance. • Promote packages of policies and measures to support EE in SMEs, including: - Easily accessible energy audits for SMEs; - Provision of high-quality and relevant information on EE best practices. Provision of energy performance benchmarking information; • Encourage major energy users to implement comprehensive energy management procedures and practices, including the following: - A formal energy management policy. - Appointment of qualified energy managers. - Monitoring, evaluating and reporting industrial energy consumption and efficiency.
Buildings	• Establish EE requirements in building codes for new buildings. • Encourage the development of passive energy houses and zero energy buildings. • Promote EE improvements in existing buildings (e.g. through obligations on energy suppliers, financial incentives and support to vulnerable groups). • Promote better insulation (including MEPS, labelling and procurement policies).
Appliances	• Introduce MEPS and/or energy labels. • Require low-power modes for electronic equipment. • Adopt the IEA 1-watt initiative. • Promote international measurement and testing standards for traded products. • Support market transformation initiatives.
Lighting	• Phase out inefficient incandescent bulbs where commercially/economically viable. • Include energy performance requirements for lighting systems in building codes. • Create a portfolio of measures for energy-efficient lighting in non-residential buildings. • Substitute fuel-based lighting in off-grid communities with stand-alone high efficiency systems (which would help meet development objectives).
Transport	• Impose mandatory fuel efficiency standards for light-duty and heavy-duty vehicles. • Require fuel-efficient tyres and air conditioning. • Provide labelling and financial incentives based on vehicles' fuel efficiency. • Encourage progress in battery technologies. • Implement complementary measures (e.g. traffic management and enhanced use of bio-fuels).
Energy utilities	• Governments and utility regulators to implement mechanisms that strengthen the incentives for utilities to deliver cost-effective energy savings among end users, including: - Decoupling; and - EE obligations on energy utilities.
National strategies	• Create goals and action plans for improving EE in key sectors. • Establish EE policy agencies. • Set standards for energy audits and certification of energy managers and auditors. • Develop data and indicators on EE. • Ensure compliance monitoring, enforcement and evaluation. • Governments should facilitate private sector involvement in EE investments, by: - Identifying potential EE improvements and corresponding benefits; - Encouraging financial institutions to develop evaluation criteria and financial tools for energy EE projects; - Reviewing current subsidies and fiscal incentives; - Promoting risk mitigation instruments; - Promoting public-private partnerships to facilitate EE; and - Establishing institutional frameworks to ensure regular cooperation and exchanges on EE issues between the public sector and financial institutions.
International cooperation	• Mobilize finance and capacity-building. • Ensure international cooperation and coordination on EE product standards. • Facilitate CDM projects related to EE in end-use sectors. • Exchange experience on national EE strategies and related coherence

used in different end-use activities may adversely affect trade opportunities for producers that find it difficult to comply. As such measures are becoming more widespread and more stringent, transparency, including in standard-setting, harmonization of testing and certification requirements, as well as policy coordination will become all the more important to promote market transformation. This should be possible, as a large share of energy-using products imported in both developed and developing countries comes from a relatively small number of developing economies, in particular Brazil, China, Malaysia, Mexico, the Republic of Korea, Taiwan Province of China, Thailand, Turkey and Singapore.

Several reports have been published that provide comprehensive recommendations on how to promote EE through specific measures in end-use activities, national strategies and international cooperation. These include, for example, those by Stern (2007), the Expert Group on Energy Efficiency (2007), the World Energy Council (2008), and the IEA's report (2008d) in support of the work of the G-8, as well as a range of other publications cited in this chapter. Box 2 briefly lists some key recommendations.

II. Energy Efficiency in Brazil

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» The Brazilian government has enacted a good set of institutional arrangements to help achieve end-use energy efficiency (EE) goals. These arrangements proved to be very effective, as shown during the serious power supply crisis in 2001. Despite EE improvements, there is large scope for cost-effective EE improvements in Brazil.

» Transforming the large losses of energy biomass into useful renewable energy, for instance, can prove rewarding, particularly as it can foster the emergence of solutions for application throughout the tropical world, thus creating considerable South-South trade and investment opportunities.

» According to the Brazilian Institute for Energy Efficiency (INEE), the best way to integrate EE considerations into energy policy is to assess all possible paths to energy transformation and transport on a "well-to-wheel" basis, and work to identify the more efficient options.

» Unfortunately, while EE is normally perceived as politically correct, it is considered to be a solution for implementation only in emergencies. To reverse that situation, strong cultural changes among all stakeholders and new institutional guidelines are required, highlighting the role of the government and regulators in triggering change.

Even though Brazil's energy mix is one of the least CO_2-intensive in the world, improvements in energy efficiency (EE) could further reduce the environmental impacts of energy use, especially by transforming losses from biomass energy generation into useful renewable energy. This comment discusses the main incentives and obstacles to designing and implementing an EE policy in Brazil. Based on the experience of the Brazilian Institute for Energy Efficiency (INEE) in promoting EE in Brazil, it highlights the role that EE could play in the further decarbonization of the Brazilian economy.

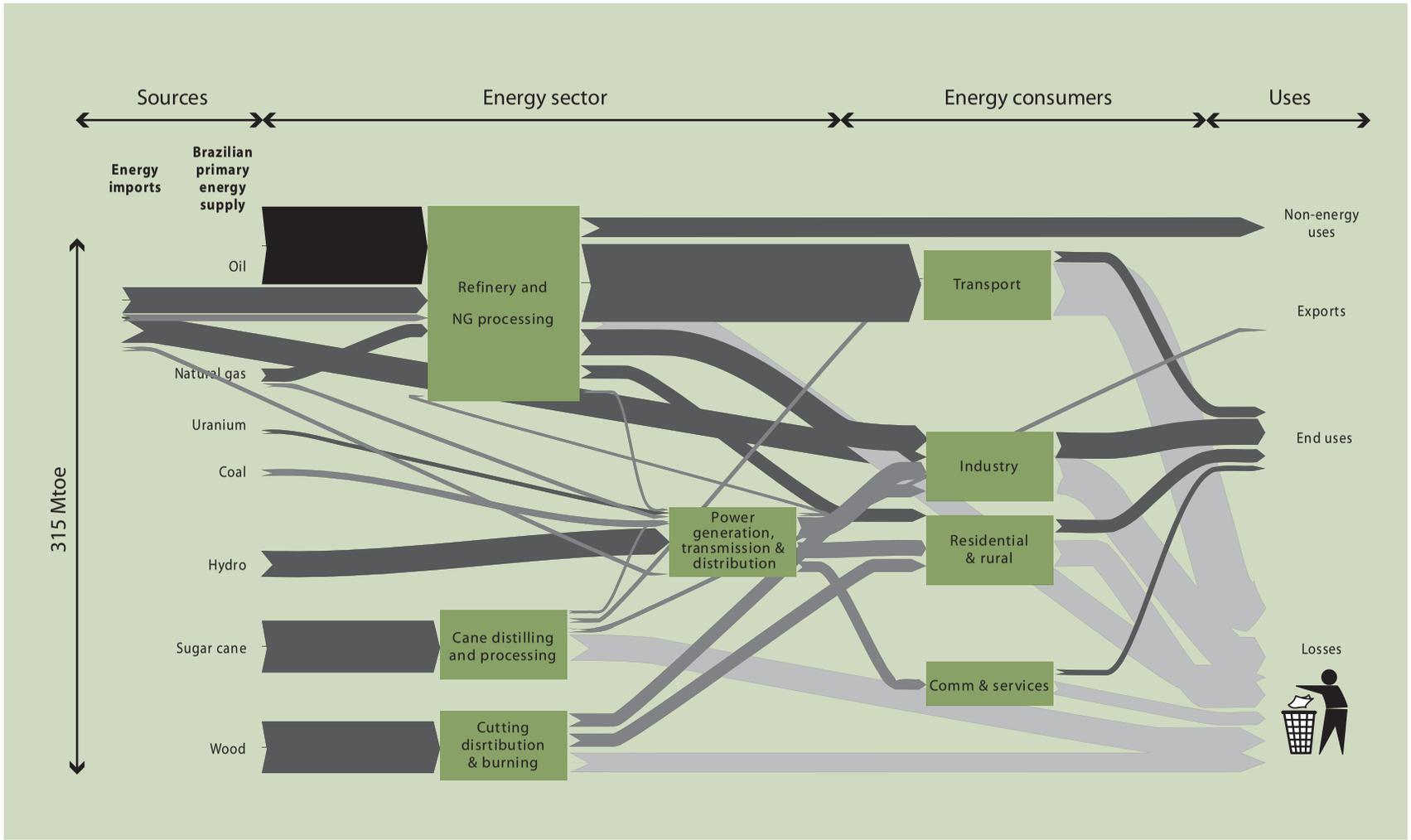
A. Energy efficiency in Brazil

Brazil's primary sources of energy are highly diversified (figure 1). A large proportion comprises renewable sources of energy, one third of which is hydropower and two thirds biomass. These renewable sources meet 45 per cent of the country's primary energy needs. The figure shows that useful energy in Brazil presently amounts to only about one third of the total primary energy inputs, while the remaining two thirds are lost. Energy losses (represented by a large garbage can in the figure) include transformation and distribution losses, as well as process energy consumption within the energy supply sector. In each transformation, the ratio of energy loss to input is a measure of inefficiency. There is considerable scope for avoiding or reducing such losses through EE improvements.

End-use energy needs can be met by increasing primary energy supplies and/or reducing energy losses, whichever is more cost-effective, taking into account environmental and social costs. A sound energy policy should strike a balance between the two, but, traditionally, emphasis has been placed on the generation of additional energy because externalities, among others, have been neglected. However, EE has gained greater visibility as energy sources have become scarcer and environmental concerns more pressing. The oil price increases of the 1970s, the high capital costs of increasing electricity supply and the need to cope with a serious power supply crisis in 2001 led the Brazilian Government to adopt several programmes and legislation which were designed to promote end-use efficiency. The following were the major milestones:

- CONSERVE, a Federal Government programme created in 1981 to reduce industrial energy needs and to develop local energy alternatives to oil imports. Managed by Brazil's Economic and Social Development Bank (BNDES), it was discontinued when international oil prices fell.
- National Labelling Programme, created under the Ministry of Industry and Commerce in 1981 to provide consumers with information regarding the

Figure 1. Energy flows in Brazil, 2007



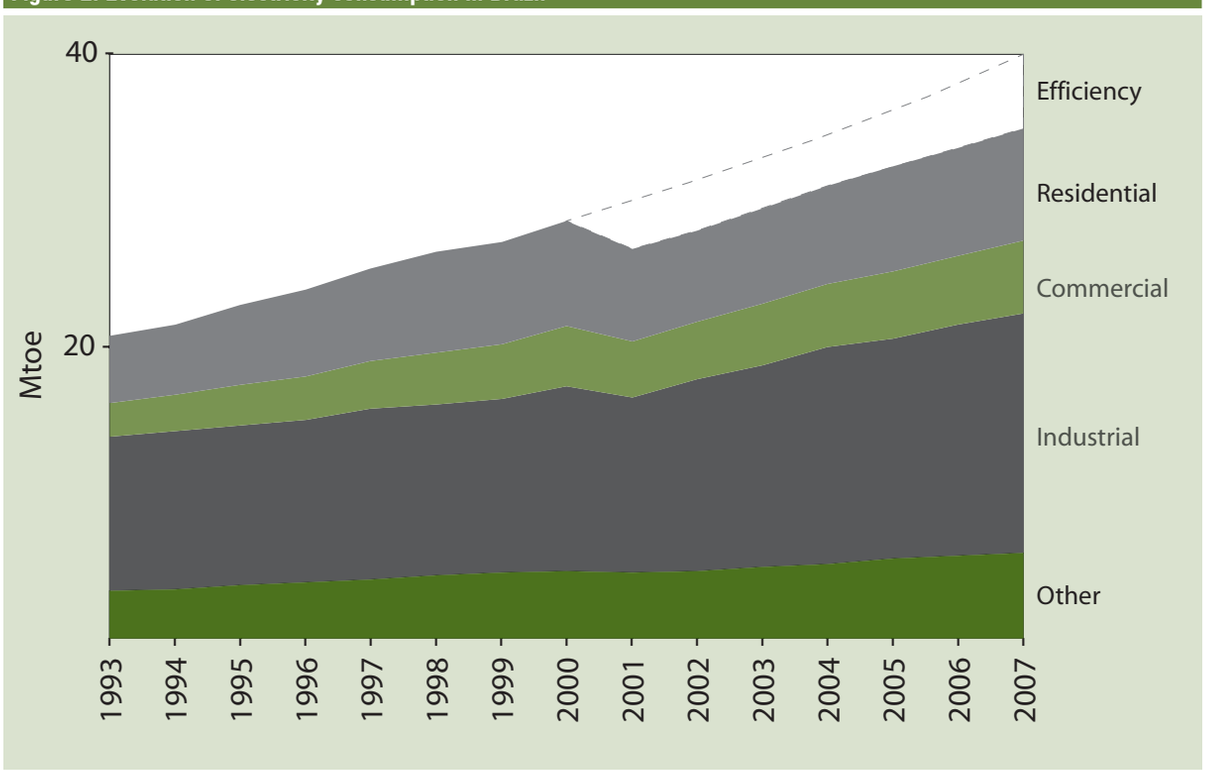
Sources: Ministério de Minas e Energia, 2007 and authors' calculations.

energy consumption of the most commonly used appliances. Under the programme 22 types of appliances are currently labelled.

- PROCEL, created in 1985 and managed by ELETROBRAS (a Federal Government holding company which has stakes in major power generation utilities), this programme aims at reducing the demand for electric power and investment needs of the capital-intensive hydroelectric programme at a time when funds were very scarce.
- CONPET (the national programme for rationalizing the utilization of oil derivates and natural gas), created in 1995, is managed by PETROBRAS, the Government-controlled oil and gas company. It addresses the end-use efficiency of oil derivates and natural gas, and focuses mainly on the conservation of diesel and natural gas.
- Law 9478 of 1997 defined the scope of Brazil's energy policy. Energy efficiency and environmental sustainability are explicitly mentioned as being among its priorities.
- Compulsory investments by utilities in energy efficiency: power utilities are legally obliged to invest 0.25 per cent of their net revenues in programmes aimed at increasing the end-use energy efficiency of their clients. The goal is to reduce energy requirements at a cost lower than that needed to supply it. These gains have to be evaluated by an independent agency, and utilities can be penalized by the power sector regulator (ANEEL) if they do not reach the goals set.
- PROESCO, a line of credit created in 2007 by the national development bank, BNDES, for energy service companies, accepts as a guarantee the expected cash-flow revenues from energy savings.
- Law 10295 of 2001 gives the Government the authority to establish minimum EE standards for manufacturing, trade and imports of energy-consuming equipment. The Government can also define minimum EE standards for buildings.

In 2001, a severe shortage of power supply, aggravated by a drought, led to power cuts throughout most of the country, including in the richer parts. As there was no short-term supply-side solution, and to prevent overall rate increases and supply interruptions, the Government decided to use EE as the main tool

Figure 2. Evolution of electricity consumption in Brazil



Source: Ministério de Minas e Energia, 2007

to adjust demand to availability. The President made a dramatic appeal to the nation to reduce energy use by 20 per cent. A carrot and stick programme was organized and speedily implemented in order to reduce consumption. The media was mobilized to disseminate ideas and information on how to save energy. A major contribution to reduced consumption was achieved by the substitution of fluorescent lamps for incandescent ones. People also modified their habits, turning off lights when not needed, discarding freezers that were barely used and reducing their use of air conditioning.

In one month demand dropped by 6,000 MW (figure 2). This market shrinkage had long-lasting effects, postponing the need for investment in new supply facilities. It was the largest experiment of its kind in the world and it showed conclusively that conservation measures can be very effective in meeting society's energy needs. The authors believe that the overall experience was positive and generally supported by the population, although it had a negative effect on many uninformed industries that refused to admit that they might reach their energy demand reduction goals by means of efficiency measures, instead choosing to shut down production lines and reducing their labour force in order to achieve their reduction targets. This experience helped the Government to push through Congress the bill that led to the energy efficiency law (Law 10295/01), a strong measure for breaking market barriers and anticipating improvements that might otherwise take a long time to be implemented.

As soon as the hydrological situation improved and the need to curb demand was over, the power authorities resumed their supply-side, business-as-usual attitude. Rates were increased to compensate for the market shrinkage and to pay the rent on 2000 MW of emergency diesel generator sets, based on the view that with the end of the power crisis consumers would resume their traditional habits of inefficient energy consumption. However, as shown in figure 2, this did not happen.

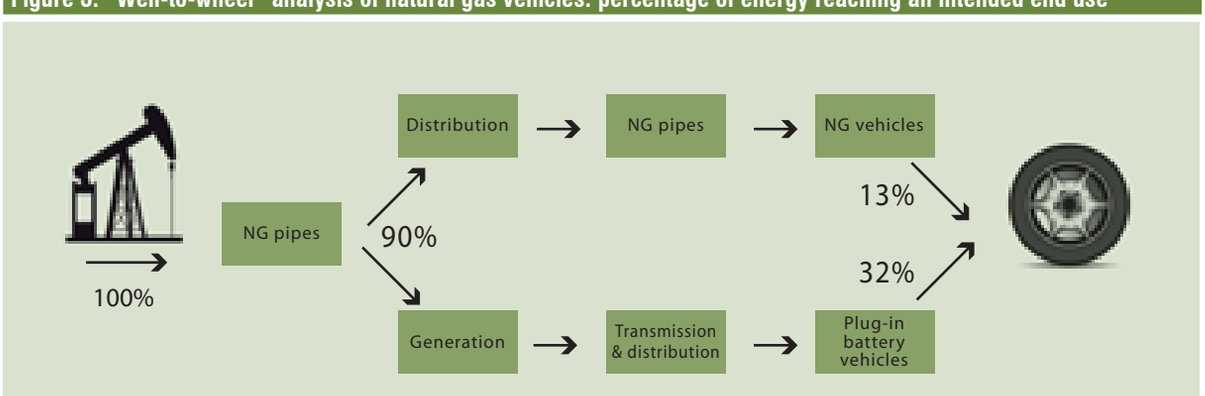
Once the risk of power shortage was over, investments in efficiency programmes dwindled to extremely low levels compared with supply-side investments. Although the quantum leap in efficiency was clearly a consequence of consumers' collaboration and their realization of the possibilities of rationalizing their electricity consumption, no major market study was conducted to analyse consumer behaviour and quantify the main contributions to the reduction in consumption that had been achieved. The most significant reductions were in the residential and commercial sectors (figure 3).

Summing up, Brazil has a good set of institutional arrangements to help achieve end-use EE goals, as shown in 2001. Unfortunately, while EE is normally perceived as politically correct, it is considered to be a solution for implementation only in an emergency. There is a need to inculcate a sense of urgency, whatever the supply conditions may be.

B. Barriers to energy efficiency

Some conditions that are at the root of energy inefficiencies tend to self-perpetuate and are hard to change, either because they benefit some agents (although not intentionally, but some agents may profit from market distortions they create) or because investment decisions may have been based on such conditions. For instance, power utilities used to give excessively high priority to becoming self-reliant: electricity prices were kept artificially low and capital costs

Figure 3. "Well-to-wheel" analysis of natural gas vehicles: percentage of energy reaching an intended end use



for eventual cogenerators were very high. Such factors, among others, led to the belief that only large power plants could deliver low-cost, reliable energy. This understanding has been considerably detrimental to the development of distributed power generation, including cogeneration.

Figure 3 is a "well-to-wheel" presentation that shows two paths of energy transformation. Both start with the same units of natural gas energy (100 per cent) and deliver the same amount of energy through transportation. However, in the upper path, which corresponds to the utilization of compressed natural gas (CNG) in passenger cars (highly promoted in Brazil until recently), only about 13 per cent of the energy reaches the wheels. The lower path, by contrast, in which gas is used to generate electricity to supply a plug-in electric vehicle, energy efficiency is almost three times greater. A similar analysis might be carried out to compare different procedures to obtain ethanol or to produce hydrogen for use in a fuel cell. Efficiencies of the different components of each energy chain are cumulative, so that the whole well-to-wheel effect is what determines the amount of primary energy that will be required to perform a given end-use service. A similar approach is used to compare overall emissions along different paths representative of different technologies.

In addition to enabling an overview of the energy chain, the well-to-wheel approach is also helpful for evaluating the ratio of fossil fuel energy that is required to obtain a certain amount of renewable energy. For instance, ethanol production in Brazil currently uses one unit of fossil energy to produce nine units of renewable energy. Ethanol therefore currently has a 10 per cent fossil fuel energy "content", most of which corresponds to the diesel used to transport the sugar cane from the fields to the mill. If ethanol was used as a transportation fuel, that fossil content would be virtually eliminated.

INEE has advocated many initiatives to promote end-use energy efficiency by focusing on issues that can increase overall energy efficiency through structural changes. To our knowledge, INEE is probably the only organization in Brazil using this approach. Possibilities for improving efficiency include:

i) Increasing energy prices;
ii) Increasing consumers' awareness of the desirability for EE, and of the social costs of energy consumption;
iii) Pushing for the substitution of inefficient equipment and systems by efficient ones, such as the use of LCD, instead of cathode ray, computer monitors and televisions. The latter need 10 times more energy as the former to perform the same service. This substitution was gradual over two decades until LCD prices dropped to a level where it was no longer profitable to sell the inefficient technology in Brazil. Energy consuming equipment has a natural tendency to increase in energy efficiency as technologies develop, and the traditionally inefficient systems are discarded in a Darwinian-like selection process; and
iv) Eliminating or reducing legal, regulatory and cultural barriers to energy efficiency and/or those that impede efficient energy uses. Examples of inefficient energy use in Brazil include the reduced role of cogeneration, the high proportion of incandescent bulbs (basically the same as designed by Edison 120 year ago) in use, and the widespread use of sport utility vehicles (SUVs). Inadequate rules which send wrong signals to the market also hinder EE improvements. For instance, the present rates structure leads to such a high average price of electricity during peak hours – quite above its supply cost – that many consumers are supplementing their energy consumption during peak hours with local diesel power generation.

In the late 1990s, when the unbundling of the power sector took place, INEE advocated the promotion of distributed generation and the creation of independent power producers (IPPs) -– new players that can produce power competitively due to proximity to users and to economies of scale. INEE also pushed for the development of highly efficient cogeneration facilities fuelled by natural gas and sugar cane residues – two fuels which have seen a considerable increase in consumption and which are still generally being used at low efficiency levels. In many, if not in most cases, cogeneration may compete favourably with conventional power plants partly because it tends to be located close to the consumers.

In 1995, Law 9074 set the main guidelines for the reorganization of the Brazilian power sector and its main agents, as well as criteria for authorizing their operation, including basic tariff rules. As a result of a fruitful collaboration between INEE and the Government, the text included the first explicit legal reference to cogeneration and district cooling/heating associated with cogeneration. INEE also contributed to the inclusion

of distributed generation (DG) in the text of the 2004 Law 10048, which defines the new power sector model. This law and its ensuing decrees allow distribution utilities to buy up to 10 per cent of their energy needs directly from cogenerators and other DG sources, instead of by means of public auction.

INEE also foresaw the importance of disseminating the concept of energy service companies as a means to achieving higher energy and economic efficiency levels. It organized seminars and workshops that showed their importance for the Brazilian economy and environment. Such efforts contributed to the decision of the national development bank (BNDES) to create PROESCO, a credit line designed to provide an incentive to energy service companies. PROESCO provides loans and mechanisms that reduce bank loan risks.

Concern about the low efficiency of cogeneration based on sugar cane bagasse, mainly due to the use of low pressure boilers, led INEE to organize several seminars to raise awareness about the technical possibilities as well as possible commercial and investment advantages of increasing that efficiency. Sugar cane biomass, which was generally disposed of by incineration, constituted a large potential source of electricity and revenue. BNDES supported the replacement of inefficient boilers and adapted its lending criteria to this industry's needs. It started to offer attractive financial conditions which enabled the installation of high pressure boilers for the production of considerable amounts of surplus power, ranging from about 50kWh to 100kWh per ton of processed sugar cane, using conventional technologies. If all plants had been equipped in this way, about 50 terawatthours (TWh) could have been added to the public network in 2008.

Brazil's main efforts should now focus on reducing or removing the main inefficiencies in overall energy supply and use. As shown in figure 1, these are concentrated in four areas: (i) transportation, (ii) natural gas utilization, (iii) sugar cane transportation and residual biomass utilization, and (iv) wood production and utilization for energy purposes. These areas are discussed separately below.

1. Electric vehicle drivetrain

The use of electric vehicles (EVs) – battery powered and hybrids – is expected to grow rapidly worldwide, and thereby enhance "well-to-wheel" energy efficiency and emissions reductions, contributing to decarbonization. This shift is expected to take place not only with respect to cars, but also light vehicles, such as scooters, motorcycles and bicycles, as well as buses and trucks. This is a market-driven trend that is being accelerated by recent events in the world economy (see, for instance, the significant resources allocated to spur the development of electric cars in the the United States)[55]. INEE strongly supports this shift, and has published several papers to publicize the subject in order to help reduce market barriers and promote the wider use of such vehicles in Brazil. However, INEE is concerned about a possible, though not new, strategy of car manufacturers to import into Brazil the traditional internal combustion motor technologies that are becoming obsolete in their home countries, thereby delaying the utilization of EVs in the country. By supporting the Brazilian Electric Vehicle Association (ABVE), INEE improves awareness about business opportunities for EVs and EV components. At present, ABVE has 72 associates, including power utilities, electric equipment manufacturers, manufacturers of electric cars, bicycles and scooters and related businesses, battery manufacturers, as well as private persons. This initiative is encouraging the emergence of new players to supply the new market needs.

2. Sugar cane

Brazil's sugar-cane-derived ethanol is the most successful effort in modern times to replace a fossil fuel by a renewable alternative. The 2008/2009 sugar-cane harvest[56] had an energy content of 96 Mtoe, equivalent to 1.7 million barrels of oil per day.[57] About 40 per cent of the total juice from the sugar cane harvested in that period was used to produce ethanol and 60 per cent to make sugar. The energy content of the ethanol output was approximately 15 Mtoe, but significant amounts of energy were lost in both production processes.

Table 5. Energy content per unit of sugar cane

1 ton	10^3 kcal	%
Juice (sugars)	608	35
Bagasse	598	35
Leaves and tops	512	30
Total	1 718[a]	100

Source: Onório Kitayama, 2007.
[a]= 1.2 barrels of oil

Table 5 presents the average energy content of sugar cane and its distribution. It should be noted that the juice contains only one third of the energy offered by the plant, whereas the other two thirds are stored in the biomass that is burnt in the field to enable manual harvesting.

The bagasse is used as fuel to supply a mill's heat and power needs. The only energy input from an external source to the sugar cane agro-industry is the diesel used to fuel trucks and harvesting machines (totalling about 1 Mtoe).

Sugar cane mills' energy needs are much lower than the energy content of bagasse and leaves. When the ethanol programme started in the late 1970s, the mills used low pressure boilers (mostly 22 bar) to supply their steam and power needs. These mills could not obtain a long-term price for the surplus power generated and therefore had no incentive to invest in more energy-efficient systems.

The sole objective of the sugar cane programme was the substitution of gasoline, both for security reasons and to reduce the financial burden of high prices of imported oil on the national balance of payments. At the same time, due to investment subsidies and high oil prices that pushed up the price of ethanol, the new ethanol industry did not need the revenue that the surplus electricity would have generated. Furthermore, selling power surpluses would have meant entering a whole new business in a very regulated and, at that time, mostly Government-controlled environment.

Table 6. Boiler pressure and surplus power of a sugar-cane plant

	kWh/tC	TWh	Power (GW)[a]
Counter pressure turbine 65 bar/480°C[b]	40-60	30	7,8
Counter pressure turbine 65 bar/480°C[b]	100-150	70	16
Gasification	200-300	140	32

Source: Macedo and Horta, 2005.
[a] Considering a 50 per cent load factor.
[b] For a full-year operation and using 50 per cent of the leaves and tops.

As table 6 indicates, a quantum leap in the overall efficiency of power plants that use ethanol and sugar can be obtained by increasing the pressure of boilers. Ethanol- and sugar-derived energy producers could generate up to 20 per cent[58] of the country's electric power needs by relying on available technologies. In addition, power generation based on gasification of biomass, a technology still being tested, could double this output. As most mills are located near major industrial sites, they do not need to install extensive transmission lines. And as the harvest coincides with the dry season, it avoids and/or delays the drawdown of reservoirs, thereby increasing the overall availability of hydroelectricity. These reasons strengthen the case for a strategy of promoting sugar-cane-derived power.

The good news is that on the one hand there are fewer obstacles to selling power to the national grid, and on the other hand more efficient energy systems are increasingly being utilized in the sugar-cane-based industry. New plants are using high pressure boilers (up to 92 bar) and their electricity surplus has grown considerably, in a very competitive setting. However, about 90 per cent of the mills still use 22-bar boilers and other sugar plant equipment produces less surplus power.

Finally, regarding sugar cane transportation, it is possible to use hybrid electric trucks because their generator prime engines may be fuelled with ethanol that is used more efficiently. Actually, such internal combustion motors, which can work on an Otto-cycle, may be of a smaller size than those of conventional trucks using diesel oil. Since the truck wheels are driven by very high torque electric motors, the smaller internal combustion motors have lower torque requirements than the present diesel motors. Hybrids are particularly appropriate for short-haul and stop-and-go transportation and, as battery technologies improve, hybrid trucks will also be able to work as plug-ins, using off-peak power generated at the sugar mill. This would improve energy efficiency and reduce, if not remove, the dependence of the sugar cane industry on diesel.

3. Natural gas cogeneration

Natural gas (NG) supply is relatively recent in Brazil, and is mainly associated with oil production in the south-eastern part of the country, close to the main industrial centres. This supply is now supplemented with imports from Bolivia through GASBOL, a 1,200 km pipeline with a capacity to transport 30 million m^3/day. Although the Government had set a market share target for NG of 12 per cent of the total primary energy supply, practically no preparations for the gas

distribution and consumption were made prior to its commissioning in 1998. Even though that pipeline crosses the highly industrialized State of São Paulo, it remained largely idle for several years.

As in other countries, NG supply had difficulty penetrating the Brazilian market since it had to compete with well-established markets for other fuels (i.e. an increase in NG consumption would have required the reduction or relocation of competing energies). Market development has gone through a trial-and-error approach that included a government decision in 2000 to build 49 power plants with a total capacity of 14,000 MW. This belated and unrealistic decision was taken when the risk of a power shortage had become acute. That plan was dissociated from the existing hydro system, and was eventually dropped, but not before a number of plants had been built, including several open-cycle inefficient plants. Other experiments involved tax incentives to develop the market for compressed natural gas (CNG), including retrofitting light vehicles and gasoline-run Otto-cycle motors, which become very inefficient when fuelled with NG since their compression rate is too low for its use. This use of NG, with a well-to-wheel efficiency of less than 15 per cent, contributed to reducing the country's overall energy efficiency. Of course, at the time the decision was taken on a $/kcal basis, and the energy from NG was cheaper than that of gasoline or ethanol. But the setting of these prices proved inappropriate because NG prices have since increased and it ignored the major externalities involved, as often still happens when renewable and non-renewable energies costs are compared.

New appropriate uses of NG by industry are developing, but its most efficient use, in cogeneration, is developing too slowly. Cogeneration, which enables up to 85 per cent of the energy input to be converted into useful energy (much more than combined cycle power generation, the efficiency of which is close to 50 per cent), is still much below its potential, because the legal framework hindered self-generation (i.e. typically by the users themselves, such as solar panels in households) and the rates applied to large consumers of high voltage that were often subsidized.

As mentioned, however, the new power sector model lifted obstacles to accessing the national grid, and the new regulatory agency (ANEEL) is gradually reducing distortions in power rates. At the same time, newly found and very important NG reserves are under development in Brazil, which will increase the possibilities of using it more efficiently in the future.

4. Wood

According to the 2007 National Energy Balance, published by the Ministry of Mines and Energy, wood as an energy source contributed almost 29 Mtoe (i.e. 12 per cent of Brazil's total primary energy supply). One third was used for domestic and rural activities in a fairly sustainable way, while the remainder was used for industrial purposes. While the overall chain of transformations and uses of wood in Brazil is poorly understood, it is clear that the overall efficiency of biomass is very low. Wood is still treated as a non-commercial source of energy and is not covered by any regulation. This is certainly related to the fact that wood is widely available for use with primitive technologies, not to be compared with the "noble" sources (e.g. oil, coal and hydro) that require sophisticated equipment in their chains of transformation and use.

However, some industries and segments of the rural population in Brazil are heavily dependent on wood. Charcoal is used instead of coke and NG for 34 per cent of the country's pig iron production of 34 million tons.[59] It is also widely used in the steel and alloy industries. Nevertheless, the country has no specific energy policy for this source. About 5 per cent of wood (1.3 Mtoe) is used as an energy source in the pulp and paper, bricks and tiles, and lime industries. Whereas the pulp and paper industry and some iron producers use biomass residues from planted trees, most of the other industries rely on wood collected from the wild, and use primitive technologies and inefficient furnaces.

About half of the charcoal is derived from wood from planted forests, while other charcoal producers use wood collected from the wild. The latter use primitive and inefficient kilns built with local materials. Their prices, given the informal nature of production, are lower than those of charcoal from planted trees, although the latter is generally produced in industrial, more efficient, facilities. Worse still, there are no incentives for the industries to exploit the gases from combustion, which can be used both for energy and non-energy production purposes. The rudimentary kilns used in the forests to carbonize native wood are unable to preserve the fluid by-products of charcoal production, but neither is this done even in the majority of the relatively modern facilities. With the exception of the pulp and paper industry, that uses state-of-the-art cogen-

eration technologies, there is no incentive for efficient use of energy in the wood chain.

An energy policy for wood, with explicit rules for production, distribution and sale of all wood-derived energy products would be crucial to organizing the wood market. It would involve regulating physical and chemical characteristics of all wood energy products in a similar way as is done for all other commercial energy production in Brazil. Standardization will be paramount to optimize furnaces for pyrolysis and gasification. Market mechanisms, if properly organized, would increase productivity, reduce prices of charcoal and prevent the use of native forests much more effectively than today's efforts at enforcing environmental and labour laws in remote, barely controlled areas. At the same time it would certainly increase the utilization of wood by-products, such as bio-oils and tars.

Regulation would also help to develop the use of pellets and brickets – wood substitutes produced by compressing biomass residues – which are available in large quantities throughout the country. Some fieldwork by INEE shows promising results in using short-duration crops of high-yield grass (e.g. elephant grass and *Pennisetum purpureum Schum*) in the wood energy chain. These can produce cheap wood substitutes and bio-oils and charcoal by fast pyrolysis. The charcoal powder, obtained from grass carbonization, can be used as a soil enhancer and at the same time as a very cheap carbon sink.

C. Conclusion

Brazil's energy use is one of the least carbon-intensive in the world, in terms of both per capita and GDP. Energy efficiency could further improve this position, especially because, as argued above, there is plenty of scope for transforming the large losses of energy biomass into useful renewable energy. Accumulated experience in this field can be very helpful in providing solutions for application throughout the tropical world, thus creating considerable South-South trade and investment opportunities.

Diversity of energy sources in Brazil is certainly a blessing, but it also poses difficult challenges to policymakers and stakeholders in energy supply and use. There is a tendency to ignore this diversity and to focus on specific energy sources and their related technologies. Energy policies often concentrate on particular transformations and products instead of focusing on the entire chain. The Brazilian sugar-cane-derived ethanol industry is often compared with those based on cassava (in Brazil), corn (in the United States) and sugar beet (in Europe). The basic reason for the superior competitiveness of sugar-cane-derived ethanol is that all other alternatives are strongly dependent on fossil fuels, as the plants they use do not provide the process energy required, mainly for grinding and distillation.

In INEE's view, the best way to integrate EE considerations into energy policy is to assess all possible paths to energy transformation and transport on a "well-to-wheel" basis, and work to identify the more efficient options. That is not an easy task, as demonstrated by the case of power generation in Brazil's sugar-cane mills. While power-generating opportunities from bagasse were known when Proalcool was in its infancy,[60] they were neglected both by the power sector and the sugar-cane industry. In order to reverse that situation, strong cultural changes among all stakeholders and new institutional guidelines were required, thereby highlighting the role of the government and regulators in triggering change. Once efficiency gains are triggered, a self-sustained cycle starts because inefficient technologies tend to be superseded by more efficient alternatives.

The complete picture in a complex economy will reveal a number of possibilities and business opportunities. Governments must play a fundamental role in this process, as many market imperfections exist that are a consequence of a lack of political will to develop efficiency as well as a lack of appropriate fiscal and rate structures.

Notes

1 EE provides significant opportunities to change development pathways towards lower emissions (Sathaye et al., 2009).

2 For example, the IEA (2007a) estimates that in China, one dollar invested in more efficient electrical appliances could save $3.50 on the supply side.

3 Commission on Climate Change and Development, 2009.

4 However, in the longer term, and with more ambitious climate stabilization targets, the mitigation response may be shifting from EE towards reduced carbon intensity. The main reason identified in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) is that the costs of further EE are expected to grow in the longer term, while those of low-carbon energy sources are projected to decrease (Urge-Vorsatz and Merz, 2009).

5 The reference scenario envisages the need for a cumulative investment in energy infrastructure of $26.3 trillion during the period 2007–2030.

6 In 2007, Merrill Lynch introduced an Energy Efficiency Index including the stock values of 40 companies in these sectors that derive a significant share of their revenues from supplying the EE market.

7 In France, the Government provides €1,000 to those who scrap a car over 10 years old and replace it with a car with emissions of less than 160g/km. In Italy, the incentive is €1,500 for a car over 10 years old that is replaced by a new car with emissions of less than 140g/km. Germany provides €2,500 if the purchaser deregisters a vehicle that is older than nine years, whereas Spain provides an interest-free loan. In the Netherlands, the Government introduced a scrap premium of between €750 and €1,750, with a total budget allocation of €85 million.

8 The programme provided a rebate of either $3,500 or $4,500 per car. Rebate applications worth $2.877 billion were submitted, slightly below the $3 billion provided by Congress to run the programme. Under the programme, nearly 700,000 "clunkers" were taken off the roads and replaced by more fuel-efficient vehicles. Cars purchased under the programme are, on average, 19 per cent above the average fuel economy of all new cars currently available, and 58 per cent above the average fuel economy of cars that were traded in (United States Department of Transportation, 2009).

9 See, for example, Edmonds et.al.,2007; and Blair and the Climate Group, 2008.

10 For sector-specific barriers, see, for example, UNIDO (2007) on motor systems and the WBCSD (2008) on constraints in the buildings sector.

11 In India, for example, much of the industrial output is derived from small-scale, often village-based, enterprises, fuelled by inefficient motors and equipment, and it has been difficult to implement efficiency improvements (IEA, 2007b).

12 The Energy Efficiency Policies and Measures database of the IEA provides information on policies and measures taken or planned in IEA member countries, the Russian Federation and major developing economies. The database provides a comprehensive annual update of the policy-making process in place since 2000 (www.iea.org/textbase/effi/index.asp). Information can also be found on the website of the Collaborative Labeling and Appliance Standards Program (CLASP), at: www.clasponline.org/worldwide.php.

13 They may also be needed where EE is not an important selection criterion of consumers (e.g. television sets).

14 Comprehensive information can be found on the website of the Collaborative Labeling and Appliance Standards Program (CLASP) cited above.

15 Although some states play a major role in establishing MEPS, a number of states' standards have now become Federal law, and Federal MEPS have been given pre-emption over state standards.

16 In 2009, the Commission also intends to submit implementing measures on televisions, domestic lighting, domestic refrigerators and freezers, washing machines, dishwashers, boilers and water heaters, computers, imaging equipment, commercial refrigerators, electric motors, pumps, fans, circulators and room air-conditioners (Commission of the European Communities, 2008a).

17 The *WEO 2007*, table 11.8 (IEA, 2007a) summarizes policies that have already been enacted and others that are still under discussion in China.

18 In some developing countries, second-hand appliances may account for a relatively large market share of the appliances sold, thus reducing the impact of labelling, which is normally restricted to new appliances.

19 See website of the European Commission, Directorate-General for Energy and Transport at: http://ec.europa.eu/energy/demand/vol_agreements/index_en.htm.

[20] The SEEEM Initiative was launched in 2006 as an independent, multi-stakeholder effort to promote the rapid market diffusion of high-efficiency motor component technologies and systems worldwide. The intention was to promote international agreement on testing procedures, efficiency classes and labelling schemes to enable product comparisons worldwide. Completed in November 2008, it was merged with the 4E Motor Systems Annex in early 2009.

[21] IEA, Standby power use and the IEA "1-watt Plan", Fact sheet. April 2007; available at: www.iea.org/textbase/papers/2007/standby_fact.pdf.

[22] See: www.adb.org/Documents/Reports/Energy-Efficiency-Initiative/default.asp.

[23] At a meeting of energy ministers hosted by Japan within the framework of the 2008 G-8 Summit in Aomori, Japan.

[24] Examples of energy savings under the Japanese Top Runner programme are: 68 per cent for air conditioners, 55 per cent for refrigerators and 26 per cent for televisions (World Energy Council, 2008).

[25] However, the full savings potential of high-efficiency models can be achieved by a combination of measures such as proper motor sizing and appropriate use of adjustable speed drives (IEA, 2006). Various approaches have been identified in energy audits to improve the average performance of electric motors.

[26] Similarly, cement production is an important source of CO_2 emissions, but these result from chemical reaction in cement clinker production, rather than energy use, and are not affected by EE measures.

[27] For the production of cement, bricks, glass, ceramics and other building materials.

[28] For the production of aluminium, copper and a number of other materials.

[29] In existing buildings, the most lucrative EE projects involve renovation of energy service systems (such as lighting, heating, ventilation and air conditioning (HVAC), and water pumping), in particular in commercial and public buildings. Similar system replacement projects exist in residential buildings, but are often more difficult to package attractively (Taylor et al., 2008).

[30] The key components for achieving EE in new buildings are: (i) building design and orientation, (ii) ventilation and lighting system design, (iii) thermal integrity, including insulation and energy-efficient windows and doors, (iv) proper construction methods, and (v) efficient heating, cooling and lighting equipment (Taylor et al., 2008).

[31] See, for example, presentations made at the Indi-IEA Joint Workshop on Energy Efficiency in Buildings & Building Codes, 4–5 October 2006, at: www.energymanagertraining.com/Presentations/IndiaIEA4_5Oct2006/list.htm.

[32] A useful website: www.bmu.de/english/energy_efficiency/household/doc/38272.php

[33] Carmakers will have to reduce their emissions to 130 g/km by 2012, with the remaining reduction of 10 grams to be achieved through complementary measures (such as fuel-efficient tyres and air conditioning, traffic management, enhanced use of biofuels and changes in driver behaviour). The Commission also proposed that CO_2 emissions be reduced to 95 g/km by 2020, to be achieved through increased research and development (R&D).

[34] On the other hand, the IEA also notes that the large number of partnerships in India between local and foreign vehicle manufactures does mean that more efficient vehicle technology is being introduced into the country. In addition, India has introduced mandatory standards for pollutant emissions comparable to those adopted in the EU, which has probably had the effect of accelerating the introduction of more fuel-efficient vehicles. Indian emission standards on two-wheelers are stricter than EU standards, but four-wheel vehicle standards lag behind those in Europe (IEA, 2007b).

[35] *The Times of India*, 8 June 2008, "Soon a fuel efficiency tag for cars"; and the *Hindustan Times*, 13 September 2008, "Demand for efficient cars up".

[36] See: http://uk.biz.yahoo.com/14012008/323/interview-chp-technology-set-enter-uk-households-says-chief-chpa.html.

[37] The Energy Efficiency Export Initiative of the German Ministry of Economics and Technology supports German companies in taking advantage of opportunities for exports of energy-efficient equipment and EE services in the buildings sector (see:www.efficiency-from-germany.info/EIE/Navigation/EN/Technologies/buildings,did=255402.html).

[38] However, EE policies and measures may also have implications for markets for non-electrical products and components. For example, EE regulations for buildings can create demand for efficient equipment and components and eliminate inefficient products from the market, as observed in the disappearance of single-glazed windows and non-condensing gas boilers from the markets of Denmark, Germany and the Netherlands (IEA, 2008e).

[39] This includes the following: Japan: Revision to Enforcement Regulation for the Law Concerning the Rational

Use of Energy and Ministerial Notification of the Ministry of Economy, Trade and Industry; United States: Energy Conservation Program for Consumer Products: Test Procedure for Residential Central Air Conditioners and Heat Pumps; Proposed Rule; and Energy Conservation Standards for Certain Consumer Products and Commercial and Industrial Equipment; Hong Kong, Special Administrative Region of China (SAR China): Energy Efficiency Labelling Scheme; Republic of Korea: Average Fuel Economy Standards for Passenger Cars; European Communities: The Eco-design for Energy-using Products Directive; China: Energy Efficiency and Energy Efficiency Grades for Copy Machines.

[40] Also, the method for calculating average fleet EE performance differentiated between imported and domestic cars on the basis of factors relating to control or ownership of producers or importers, rather than on the basis of factors directly related to those products.

[41] See: www.asiapacificpartnership.org/. The BATF has initially selected three project areas for cooperation: (i) harmonization of test procedures for energy-using appliances and equipment; (ii) standby power; and (iii) market transformation.

[42] The United States and the European Community ENERGY STAR labelling programmes use common specifications (for energy-efficiency and performance requirements, including testing methods) and the same logo for office equipment (under an agreement between the Government of the United States and the European Community which supersedes an earlier agreement reached in 2000). Programme participants (manufacturers, vendors or resale agents) that sell designated energy-efficient products that meet the specifications of the programme can register to use the ENERGY STAR. The right to use the logo is based on self-declaration (products can be tested in participants' own facilities or by an independent testing laboratory).

[43] There are few MEPS and labelling requirements in this group of products.

[44] In addition, the International Organization for Standardization (ISO) is developing an international standard on energy management. The standard will provide organizations and companies in various sectors (including utility, manufacturing, commercial building, commerce and transport) with a framework for integrating EE into their management practices. The standard is expected to offer a range of benefits, such as providing a logical and consistent methodology for identifying and implementing EE improvements across facilities, offering guidance on benchmarking, measuring, documenting and reporting energy intensity improvements and their projected impact on reductions in GHG emissions, and assisting facilities in evaluating and prioritizing the implementation of new energy-efficient technologies.

[45] The 4E will build on progress made in the Collaborative Labelling and Appliance Standards Program (www.clasponline.org/index.php), the International Task Force for Sustainable Products (www.itfsp.org/) and other relevant international cooperation efforts.

[46] The Initiative has three main objectives: (i) to create a uniform international testing method, covering the performance features of self-ballasted CFLs; (ii) to identify a number of performance specifications for self-ballasted CFLs to facilitate international comparisons of CFL performance requirements; and (iii) to propose and promote these initiatives to the wider international lighting community.

[47] Relevant discussions have taken place in the context of the UNCTAD Consultative Task Force on Environmental Requirements and Market Access for Developing Countries (CTF).

[48] See: www.gtz.de/en/themen/umwelt-infrastruktur/879.htm.

[49] Targets may be expressed, for example in terms of rate of EE improvement, volume of energy savings, and rate of decrease in energy intensity or rate of fall in energy consumption. For example, the EU Energy End-Use Efficiency and Energy Services Directive sets a 9 per cent energy saving target by 2016, and the United Kingdom's Energy Efficiency Action Plan 2007 expects a saving of 18 per cent (DEFRA, 2007).

[50] An energy service company is a natural or legal person that delivers energy services and/or other energy efficiency improvement measures in a user's facility or premises, and accepts some degree of financial risk in so doing. The payment for the services delivered is based, either wholly or in part, on the achievement of energy efficiency improvements and on the meeting of the other agreed performance criteria (an EU Directive definition).

[51] The United Nations Environment Programme (UNEP) estimates that global new investment in sustainable energy amounted to $148.4 billion in 2007, largely driven by new investments in renewable energy (especially in the wind sector). EE investment was $7.5 billion – less than 4 per cent of total investment. However, UNEP points out that these figures only include external financing. Since most EE investment is made internally by beneficiaries of the technology, the actual amount of investment in EE is likely to be much higher.

[52] Out of a total of 2,037 CDM projects in the pipeline as at June 2007, 116 projects were demand-side EE projects, of which 96 were in industry (69 of them in energy-intensive sectors), 4 in appliances in the household sector and 11 in the services sector. The demand-side EE projects included only very few CDM-like projects,

such as energy-efficient light bulbs (Hinostroza et al., 2007). More recent data show that 466 EE projects have been presented to the UNFCCC, almost all of which are for EE improvements in heavy industry and are on the supply side; less than 3 per cent are for residential or commercial EE improvements. About 47 of the EE projects are being undertaken in India alone (UNEP, 2008b).

[53] A PoA is a programme coordinated by a private or public entity that provides the organizational, financial and methodological framework for undertaking emission reductions. An entire set of activities (rather than individual GHG-reducing activities) constitutes a single CDM project under a PoA.

[54] Hinostroza et al. (2007) categorize energy end uses into three groups: (i) large centralized end-use units owned by single owners; (ii) conglomerated units which consist of small to medium – and sometimes large – units, owned by single or multiple owners; and (iii) a large number of small end-use units owned by and operated by individual owners. Due to the large quantity, dispersed end-use requirements and preferences of individual owners, the third category presents characteristics of long-tail energy use.

[55] See, for instance, "President Obama Announces $2.4 Billion in Grants to Accelerate the Manufacturing and Deployment of the Next Generation of U.S. Batteries and Electric Vehicles", Press release of the U.S. White house, August 2009; available at: www.whitehouse.gov/the_press_office/24-Billion-in-Grants-to-Accelerate-the-Manufacturing-and-Deployment-of-the-Next-Generation-of-US-Batteries-and-Electric-Vehicles/

[56] The harvest resulted in 560 million tons of juice and bagasse transported to the mills. The total primary energy was inferred considering that the leaves correspond to 25 per cent of the juice and bagasse content, because good plantation practices require that half of this biomass remain in the fields to be recycled.

[57] This was the same volume as Brazil´s present oil production today.

[58] Energy losses in sugar cane mills amounted to 36 Mtoe in 2007. If 24 Mtoe had been converted into electric power with 30 per cent efficiency, 8 Mtoe could have been exported to the grid which sold 34 Mtoe to end users. This is of particular significance, considering that sugar cane production has grown at a much faster pace then overall energy demand.

[59] Sindifer Statistics, at: www.reflore.com.br/palestras/alidadeDaMadeiraETecnologiasParaProducaoDeCarvaoVegetal.pdf (referring to 2006).

[60] Proalcool, launched in 1975, is a Federal Government scheme aimed at increasing domestic ethanol production as a substitute for oil consumption. Brazilian ethanol production soared to 12.3 billion litres in 1985-1986 from just 600 million litres in 1975-1976, and about 10 million vehicles were manufactured or adapted for ethanol use. The scheme was reformed to reflect variations in oil prices and other factors. It contributed to rapid technological advancement in the entire production and consumption chain of ethanol – from agricultural production to hybrid cars.

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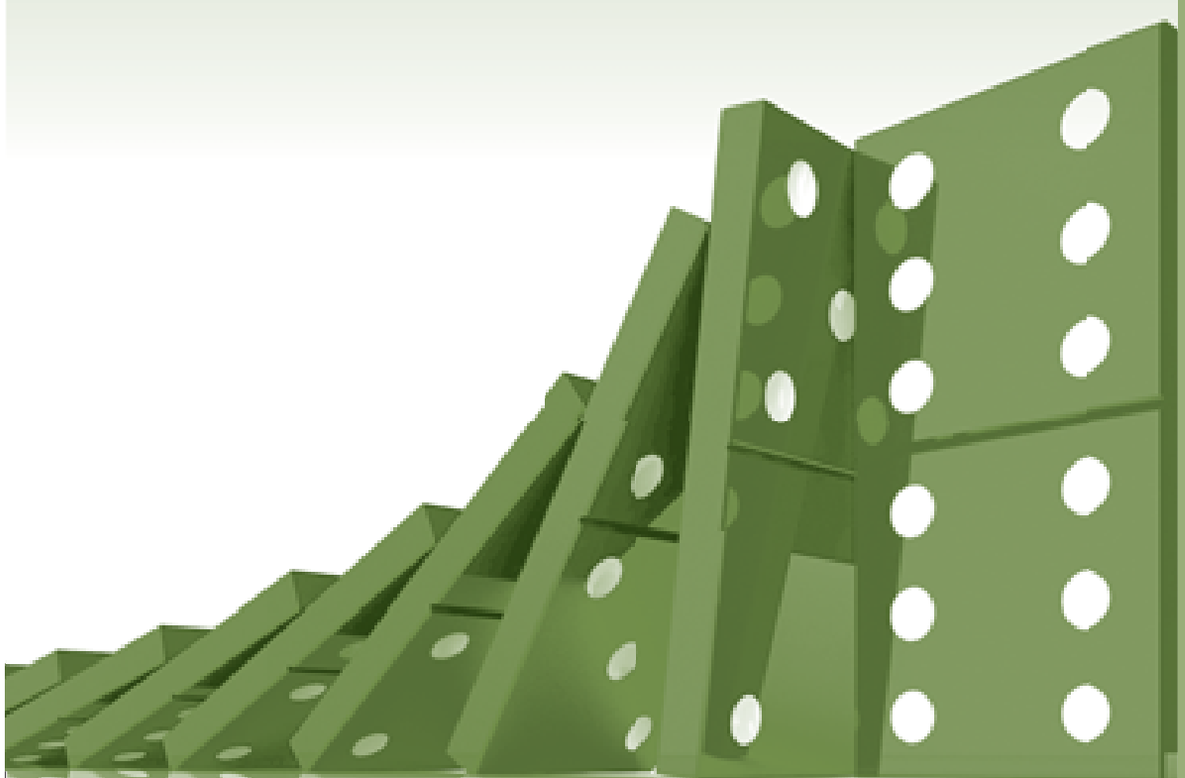
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CHAPTER 3

GROWTH POLE:
SUSTAINABLE AGRICULTURE



I. The Effectiveness, Efficiency and Equity of Market-based and Voluntary Measures to Mitigate Greenhouse Gas Emissions from the Agri-food Sector

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» Agriculture accounts for as much as a third of global GHG emissions if deforestation and trade in agri-products are attributed to this sector. The agricultural contribution to climate change is even larger if emissions from the production of chemical inputs are also included. Nonetheless, no reduction of emissions from agriculture was included in the Kyoto Protocol or the EU's Emissions Trading Scheme (ETS).

» Economic instruments offer a large potential to help reduce emissions in the agricultural sector and in the agri-food supply chain. Such market-based instruments include: carbon taxes, emissions trading schemes, payment for environmental services (PES) schemes, border tax adjustment measures, carbon food miles, accounting and labelling.

» Because of the importance of agriculture for exports and employment in developing countries, the environmental benefits from the application of these instruments must the weighted against their effectiveness, efficiency and equity.

» The main limitation found for the application of market-based instruments to mitigate agricultural GHG emissions relate to the difficulty in monitoring, reporting and verifying (MRV) schemes in agriculture.

» Despite these limitations, market-based mechanisms must be preferred as other alternatives, such as a regulatory or voluntary approach would be unnecessarily expensive and ineffective.

A. Introduction

Most scientists agree that human activity that releases carbon dioxide (CO_2) and other greenhouse gases (GHGs) into the atmosphere is the dominant cause of climate change. The current concentration of CO_2 in the atmosphere is around 380 parts per million (ppm), up from 280 ppm in pre-industrial times. The Intergovernmental Panel on Climate Change (IPCC) considers it will be necessary to stabilize global GHGs at a maximum level of 450 ppm CO_2 equivalent (CO_2 eq) to avoid a temperature rise of more than 2°C. This would require a reduction in global emissions of 80 per cent below 2000 levels by 2050 (IPCC, 2007). However, global emissions increased by 70 per cent between 1970 and 2004, and are still growing.

Some climate models predict that emissions growth without constraints could result in rises in temperature of between 4° and 5°C on average by 2060. This could mask far higher temperature rises (10°-15°C) in many areas, including in lower latitudes and the Arctic (Met Office, 2009). As pointed out by Stern (2008: 57), the human effects "could be catastrophic, but are currently very hard to capture with current models as temperatures would be so far outside human experience."

According to the IPCC (2007b), agriculture accounts for about 13 per cent of total GHG emissions. This figure rises to 30–40 per cent if deforestation through land clearance for agriculture and trade in agri-products are included. Agricultural emissions grew by 17 per cent during the period 1990–2005. The value of trade in agricultural products grew by 100 per cent over a similar period (1990–2007) (WTO, 2008). Production of and trade in food is projected to continue to increase in response to population growth and changing diets, in particular towards greater consumption of ruminant meats (i.e. beef, veal and lamb) (UNFCCC, 2008). Yet, despite their large contribution to climate change, emissions from agriculture are not included in reduction commitments under the Kyoto Protocol or the EU's Emissions Trading System (ETS). It is therefore important to examine the potential economic instruments that could help reduce emissions in the agricultural sector as well as in the rest of the agri-food supply chain.

Stern (2008) cites three criteria for the design of climate change policies: effectiveness (i.e. resulting in emission reductions), efficiency (i.e. policies that cost little to implement) and equity (i.e. policies that are not regressive, and do not distort trade or have an undue impact on competitiveness). This paper examines the effectiveness, efficiency and equity of market-based instruments (MBIs)[1] for a climate change mitigation in the agri-food sector. These instruments include carbon taxes, emissions trading schemes, payment for environmental services (PES) schemes, border tax adjustment measures, carbon food miles, accounting and labelling.

The scope of this paper does not include support for research and development (R&D) or subsidies for clean energy, although their importance in contributing to climate change mitigation in the agricultural and food retail sector is acknowledged. In addition, the paper does not examine adaptation measures.

B. Impact of the agri-food sector on climate change

1. Contribution to climate change

Agricultural emissions account for 13 per cent of total GHG emissions, or between 5 and 6 gigatons (Gts) of CO_2 equivalents (CO_2 eq),[2] and they are predicted to rise by almost 40 per cent by 2030 (Smith et al., 2007). This is largely due to increased demand from a growing population and to a greater demand for ruminant meats. Of these emissions, methane (CH_4) accounts for 3.3 Gts equivalent and nitrous oxide (N_2O) for 2.8 Gts equivalent annually. Net emissions of CO_2 are just 0.04 Gts of CO_2 eq per year.[3] Agriculture emits over half of the world's emissions of nitrous oxide and methane (figure 1). These are the most potent GHGs: N_2O traps 260 times more heat than CO_2, and CH_4 traps 21 times more heat.

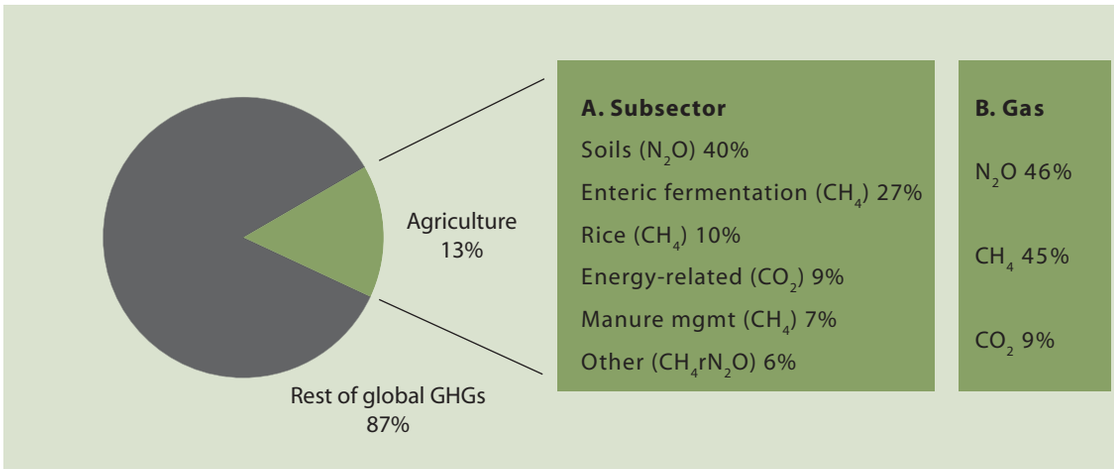
Nitrous oxide is emitted mainly from fertilizer and manure applications to soils, while methane is emitted mainly in livestock production (fermentation in digestion), rice production and manure handling. Emissions from these sources are also projected to rise.

Emissions from the agricultural sector rise further, to between a quarter and a third of total GHGs, if the estimated emissions from deforestation in developing countries (where agriculture is the leading cause of deforestation) are added. However, the IPCC does not attribute these emissions to the agricultural sector.

Transport, processing, retailing and household consumption of food adds further emissions associated with agriculture. Swaminathan and Sukalac (2004, cited in Bernstein et al., 2007) report, for example, that the fertilizer industry accounts for about 1.2 per cent of world energy consumption and is responsible for about the same share of global GHG emissions. In the United Kingdom, processing, transport, retail and households accounted for two thirds of total GHG emissions along the food supply chain in 2006, while agriculture accounted for most of the remainder (figure 2).

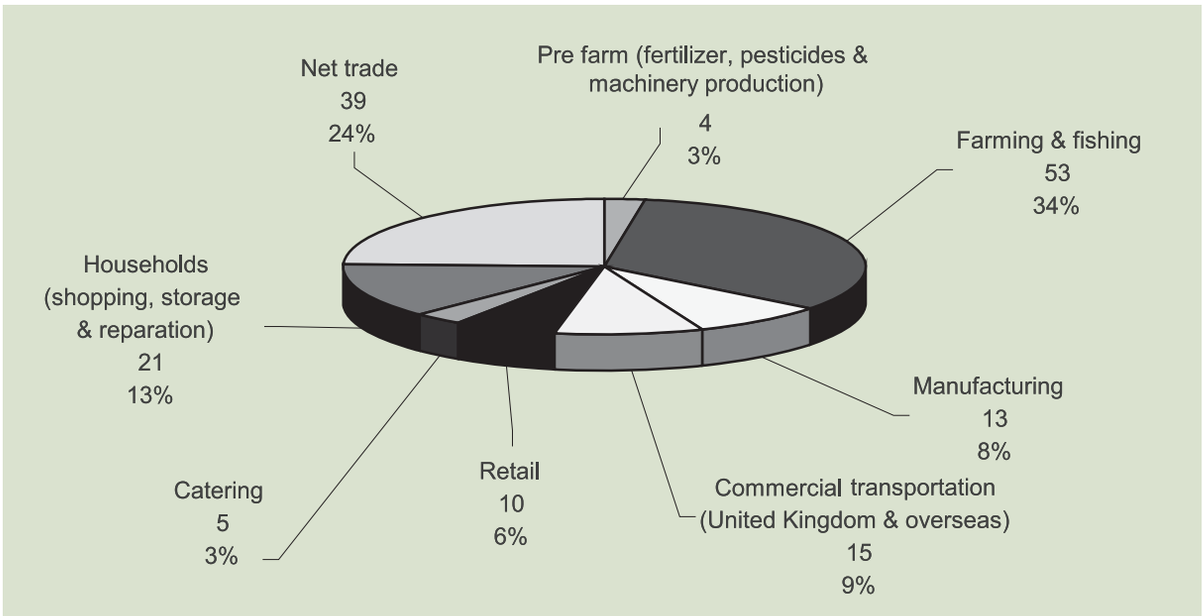
In agricultural production, food products vary in the intensity of their emissions. For example, around 50

Figure 1. Greenhouse gas emissions from agriculture



Source: Worldwatch Institute, 2009, citing EPA, 2004.

Figure 2. Greenhouse gas emissions from the food chain in the United Kingdom, 2006 (millions of tons and percentage)



Source: DEFRA, 2008.

per cent of GHG emissions in Dutch food come from dairy and meat production (Kramer et al., 1999, cited in Garnett, 2008), whereas these two categories of food contribute 8 per cent of the United Kingdom's total GHG emissions.

2. Mitigation potential of the agri-food sector

The agricultural sector has the potential to mitigate climate change mainly by increasing the carbon sequestration rate (i.e. rate at which carbon is stored in the soil), and to a lesser degree, through the reduction of some GHG emissions (principally N_2O and CH_4) (Smith et al., 2007). Across the rest of the agri-food supply chain, mitigation can be achieved through carbon emission reductions.

The technical mitigation potential of agriculture is around 6 Gt CO_2-eq per year by 2030. The economic mitigation potential (i.e. the amount of GHG mitigation that is cost-effective for a given carbon price) is considerably lower: between 1 and 4 Gt CO_2-eq per year. The level achievable depends on the level of the carbon price and the effectiveness of policy instruments: the higher the carbon price, the greater is the potential for mitigation. Barker et al. (2007) estimate that 89 per cent of the potential for GHG mitigation in the agricultural sector could be achieved through carbon sequestration. Most of this potential (70 per cent) lies in developing countries. Improved grazing and cropland management and agroforestry offer the highest potential for carbon sequestration (UNFCCC, 2008a; FAO, 2007), while the remaining 11 per cent of the mitigation potential is achievable through reductions in nitrous oxide and methane emissions.

Niggli et al. (2008a and 2009) see strong potential for climate change mitigation in organic agriculture, for instance, and highlight added benefits such as conserving agricultural biodiversity, reducing environmental degradation and integrating farmers into high value food chains.[4] Similarly, the UNFCCC (2008a) emphasizes that mitigation options offer "synergies for improved sustainability". However, the adoption of sustainable agricultural systems, such as organic farming, depends on supportive policies (Twarog, 2006) and the internalization of environmental costs across the agricultural sector in order to improve the economic incentives for farmers to adopt more sustainable practices.[5]

The UNFCCC (2009a: 8) cautions that, given the increasing population and the growing demand for ruminant meat and dairy products, the sector is severely constrained in its ability to achieve emissions savings. It concludes that "...it would (therefore) be reasonable to expect emissions reductions in terms of improvements in efficiency rather than absolute GHG emissions." The IPCC also makes recommendations for reducing GHG emissions in energy, transport, build-

Table 1. Selected mitigation options in agriculture and the agri-food sector

Sector	Part of agri-food supply chain	Selected mitigation options
Agriculture	Food production	Improved cropping and grazing land management to increase carbon storage Improved rice cultivation techniques and livestock to reduce methane emissions Improved nitrogen fertilizer application techniques to reduce nitrous oxide emissions
Energy	Energy for fertilizer production, food processing, tractors, consumer and retailers use, transport	Improved supply and distribution efficiency, fuel switching, nuclear and renewable energy, carbon capture and storage
Industry	Fertilizer production Food processing (e.g. corn wet milling)	Energy efficiency improvement and retrofit
Building	Lighting, cold storage in warehouses and retail outlets Consumer food preparation	Efficient lighting, more efficient electrical appliances and heating and cooling devices, improved cooking stoves
Transport	Food logistics Consumer travel to shops	More fuel-efficient vehicles More efficient aircraft

Source: Adapted from IPCC, 2007c and Bernstein et al., 2007.

ing and industry. Those relevant to reducing emissions across the whole agri-food supply chain are summarized in table 1.

3. Policy measures for emissions mitigation in the agri-food sector and carbon storage in agriculture

a) Types of measures

A number of policy instruments can be used to mitigate emissions by the *agri-food sector* and to store carbon in agriculture. These include: regulation, market-based instruments (cap and trade, taxes), agricultural cross-compliance programmes,[6] information provision and voluntary measures, subsidies, and support to R&D and technology transfer. Non-climate policies also have an impact on emissions from agricultural activities, including, for example, the European Union (EU) Common Agricultural Policy (CAP) and the EU Nitrates Directive (UNFCCC, 2009a).

b) Design criteria

The IMF (2008) and Stern (2008) have identified several criteria for designing successful policies to mitigate climate change. These include (italics added):

i) To be *effective*, policies must raise the prices of GHGs to reflect the environmental damage from emissions. Higher GHG prices would discourage the production and consumption of GHG-intensive products and services and encourage the development of new, low-emission technologies;
ii) To ensure policy objectives are achieved at the *lowest cost*, mitigation policies must be applied across all GHGs, firms, countries, sectors and time periods;
iii) Mitigation policies must address *distributional impacts* across firms, income groups and generations, for reasons of fairness and to ensure that policies are politically viable;
iv) Mitigation policies must be *flexible* enough to adapt to changing economic conditions and scientific information about climate change; and
v) Mitigation policies must be *enforceable* and remain in place in order to induce the needed behavioural change.

c) Issues for consideration

According to UNFCCC (2008a), the adoption of any policy or measure to reduce GHG emissions in the agricultural sector would need to take account of the following issues:

i) Increasing world population, which is forecast to reach 8 billion by 2030 and 9–9.5 billion in the second part of this century;
ii) The population growth will translate into higher demand for food, particularly for animal products. Developing countries are likely to account for a large proportion of this new demand, due to higher incomes which will induce changes in dietary habits;
iii) Three quarters of agricultural emissions are in developing regions;
iv) Continued pressure for land-use change, mainly in developing countries, resulting in the conversion

of forest lands to agricultural lands, would cause greater carbon losses due to deforestation;

v) Non-climate-related policies implemented by countries, which could affect the levels of GHG emissions from agriculture;

vi) Continued pressure on agricultural land for the production of biofuel crops;

vii) Mitigation efforts in agriculture, which could contribute to sustainable development; and

viii) Security and poverty alleviation efforts.

d) Market-based instruments and voluntary measures

Policymakers increasingly favour market-based instruments (price incentives) over compulsory measures, such as regulation, as a way to address market failures.

This paper examines market-based instruments and voluntary measures for reducing emissions in the agri-food sector according to the criteria of effectiveness, efficiency and equity.

The analysis covers the following:

1. Cap-and-trade schemes and carbon taxes;
2. Border tax adjustments (BTAs);
3. Payments for environmental services (carbon sequestration);
4. Carbon labelling ; and
5. Food miles campaigns.

C. Emissions trading schemes and carbon taxes

1. Background

Emissions trading schemes and carbon taxes are the two main market-based instruments for pricing GHGs, in particular CO_2.

Under the Kyoto Protocol, a group of developed countries, known as Annex 1 countries, agreed to reduce emissions during the period 2008–2012 to 5 per cent below 1990 levels. Annex 1 countries can meet their emission reduction commitments by using the "flexible mechanisms" in the Protocol. These mechanisms include: Emissions trading, the Clean Development Mechanism (CDM) and Joint Implementation (JI).

A number of governments and municipal authorities have implemented emissions trading schemes, also referred to as cap-and-trade schemes. Under these schemes, governments set a limit (cap) on the amount of GHG emissions permitted by industry. Every large company is allocated a permit to release a set amount of GHGs, and companies can trade these permits. The most notable example of cap-and- trade schemes is the EU Emissions Trading System (ETS) and the scheme proposed by the Warxman Markey bill under review by the United States Senate.

Carbon taxes, an alternative instrument to cap and trade for reducing GHG emissions, have been introduced by a number of countries, including Costa Rica, Finland, France, the Netherlands, Norway and Sweden, and also by the Canadian province of British Columbia..

2. Effectiveness and efficiency

a) Carbon tax versus cap and trade

In theory, both cap and trade (with auctioned permits) and carbon taxes achieve a similar level of efficiency by reaching the abatement level target at a minimum cost (*Environmental Economics*, 2008; Viard, 2009). However, the two instruments differ in design. A cap-and trade-scheme sets a limit (cap) on emission levels and allows the price of the emissions (in this case CO_2) to vary. A carbon tax, on the other hand, puts a price on emissions, but allows the emission levels to change. A carbon tax can be increased if the emission levels are still too high, whereas permits are allocated for the duration of a cap-and-trade scheme.

The IMF (2008) cites three main advantages that carbon taxes have over cap-and-trade schemes: greater price stability, greater flexibility as economic conditions change, and a larger stream of revenue that can be used to enhance efficiency and equity (see also WTO/UNEP, 2009; and Blandford and Josling, 2009 for further discussion).

b) Inclusion of agriculture in cap and trade

Agriculture is not part of the ETS or the United States Cap and Trade Climate Bill.[7] The main obstacle to including the agricultural sector in a future cap-and-trade scheme is establishing a cost-effective system of what the UNFCCC (2008a) terms "monitoring, reporting and verification" (MRV).

Establishing reporting procedures for emission reductions under a national GHG inventory framework requires a reliable data set based on different parameters. However, such data may be subject to discrepancies or they may be unavailable (UNFCCC, 2008a). It is particularly difficult to estimate emission reductions and carbon sequestration from agriculture

because of the high degree of spatial (soils and environments) and temporal (climatic) variability. Moreover, full accounting is costly and complex (Paustian et al., 2004).

DEFRA (2009) highlights the high transaction costs that smaller farmers would face in trading emission permits. Unless farmers can group together to share these costs, it is unlikely that individual farmers will find it economical to trade.

c) Need for upstream pricing instruments

An important consideration in designing a carbon reduction policy is the issue of obligation (i.e. where a tax or quantitative restriction is imposed). A downstream trading programme like the EU-ETS, for example, currently covers electricity and large industrial emitters, and accounts for only 50 per cent of total CO_2 emissions. It therefore precludes other potentially low-cost abatement opportunities.

Upstream programmes, on the other hand, which price the externality at the source of energy production, capture a far higher proportion of emissions. If a tax or trading system was applied upstream in the fossil fuel supply chain (e.g. petroleum refineries and coal producers), the price of carbon would be passed on to the fossil fuel price, and ultimately to the price of electricity and other energy-intensive products. Such a system would also be easier to administer (IMF, 2008).

Notwithstanding the high non-CO_2 GHG emissions from agriculture, a global carbon price applied upstream would obviate the need for MRV, as all *carbon-related* environmental costs would be immediately "internalized" in the supply chain. The MRV issue thus underlines the importance of applying a carbon pricing instrument as far upstream as possible.

d) Production-based accounting

Global upstream pricing instruments also help resolve the problem of countries' GHG emissions being measured by production rather than consumption. Accounting for GHGs based on location of production creates a "misleading and partial basis" to inform policy (Helm et al., 2007). A country could have a very low production of GHGs but at the same time have a high consumption level; it could produce low GHG-intensive goods, but import and consume high GHG-intensive goods. The shift in production from Europe and the United States to Asia, and the consequent increase in emissions in Asia, suggests that this effect might be considerable. Thus, emerging Asian economies might argue that although they produce high emissions, these are on behalf of consumers in developed countries, and that therefore the consumers should pay for the relevant reductions. In this way, the consumer, not the producer, is the polluter (Helm, Smale and Philips, 2007). An upstream carbon price would feed through to the consumer to internalize pollution costs.

With respect to the agricultural sector, carbon pricing upstream would help raise the price of both fuel and chemical inputs, resulting in reduced tillage and improved residue management. These are both important outcomes in reducing nitrous oxide emissions and sequestering carbon. Transport, retail and consumer use of fuel in the agri-food supply chain would also automatically internalize the environmental costs of CO_2 emissions. This would provide an incentive for emission-reducing behaviour throughout the supply chain and the wider economy.

e) Pricing non-carbon GHGs

It is desirable to incorporate all sources of GHGs into any mitigation programme. Nitrous oxide and methane, about 45 per cent of which are produced by agriculture, account for about one third of total GHGs. The costs of MRV could be a considerable obstacle to the adoption of a cap-and-trade system for agriculture (Breen, Donnellan and Hanrahan, 2009; DEFRA, 2009).

The IMF (2008) suggests that some sources of these gases (e.g. landfills, manure and soil management) be incorporated into an emissions offset programme. The onus would then be on the agency responsible for offsetting to demonstrate a credible system of MRV for crediting. As discussed in section E below, an emissions offsetting programme in agriculture would face high transaction costs due mainly to the need to profile heterogeneous land types and farmers and to contract and monitor many different farmers.

f) Need for global implementation

Pricing carbon, be it through a tax or cap-and-trade scheme, is most efficient if it is implemented globally. Countries that do not have commitments, or at least do not implement emission reduction policies, are likely to have a competitive advantage over those that do. Production will therefore "leak" or relocate to countries that do not make GHG-reduction commitments. Estimates of leakage are uncertain, but may

range from 5 to 20 per cent (IPCC, 2007c: 12) of the reduction in emissions of the mitigating countries.

The extent to which exporting countries without commitments will have a competitive advantage in agricultural products over those countries with commitments depends on three factors:

i) The severity of the emission reduction commitments in developed countries;
ii) The ability to substitute alternative fuels in industries where emission reduction policies are implemented; and
iii) The GHG intensity of production in each country, which depends largely on the energy use and mix of industries in each country.

g) Consumption tax

A national tax on consumption could be used to raise the price of GHG-intensive products like beef and dairy products. However, consumers in export markets would continue to demand these products in the same quantities. The incentives (i.e. prices) for domestic farmers would thus not change very much, and consequently the impact of a domestic consumption tax would be minimal (Breen, Donnellan and Hanrahan, 2009).

Furthermore, to the extent that it might discourage production, a uniform tax would be a blunt instrument if it did not take into account differences in emissions per unit of output at the farm level, and therefore failed to encourage innovation at that level.

3. Equity

a) Distributional impacts

Pricing carbon through cap and trade and taxation would increase the prices of goods and services according to their carbon "intensity". This could have negative impacts on lower income groups that spend a large proportion of their total income on fuel products and services, like heating and transport.[8] However, proponents of carbon taxes argue that equity issues can be addressed by reducing other taxes paid by low-income groups, for example on employment and income, or by setting up dividend funds for consumers (Hansen, 2009).

b) The carbon intensity of agriculture

In almost all countries, agriculture as a sector produces more value per unit of carbon input than the manufacturing and services sectors. This means that agriculture is less carbon-intensive per unit value of output than manufactured goods and services. The services sector, which includes transport, tends to be the most carbon-intensive.

Within the agricultural sector, GHG emissions per unit of output vary greatly across countries (see table 2). The variation reflects the composition of products. For example, production of flowers and vegetables under heated greenhouses is energy-intensive, whereas cereal production is not, at least relative to heated greenhouse production. In low-income countries, where wages are low, labour is used instead of fuel-driven equipment, fertilizers and pesticides. In many poor countries draft animals are used instead of tractors to cultivate fields. Thus the carbon intensity of such operations is low.

Several developing and transition economies such as China, the Russian Federation and Turkey, have output well below the global average of $8,000 per ton of CO_2 emissions, but many more have output-to-emissions ratios well above the average. This implies that the former countries have low carbon-intensive agriculture, and may have a competitive advantage should global measures to reduce GHG emissions be implemented.

c) Impacts on developing-country agricultural exports

The effects of a carbon tax or similar mitigation policies in Annex 1 countries on developing-country agricultural production and exports are likely to be relatively small. The potential impacts can be estimated using a suitable general equilibrium model, such as GTAP, in which the sectors are linked according to national input-output tables and countries are linked through international trade.[9]

GTAP is designed to show the potential impacts on production, consumption and trade in a range of sectors in response to changes in various taxes. In this application, a tax on the production of petroleum and coal products according to the carbon content is simulated to assess the likely impact. The additional tax works its way downstream through the economy to the final consumer. This leads to a fall in consumption, especially of domestically produced carbon-intensive goods. However, consumers would be expected to demand more imported goods from countries which do not impose a similar tax. On the other hand, a simulation of a $30 per ton carbon tax (the approximate price in the EU-ETS prior to the global financial crisis)

Table 2. Carbon intensity of selected countries, by sector: value of output per ton of CO_2 ($ thousand)

	Agriculture	Manufacturing	Services
Developed economies			
European Union	8.4	7.5	2.1
United States	7.0	5.5	3.1
Japan	24.8	13.6	6.5
Canada	9.5	3.5	2.3
Australia	7.9	2.6	1.5
New Zealand	21.9	4.5	2.8
Korea, Republic of	6.6	6.7	1.9
Developing and transition economies			
Russian Federation	2.4	1.2	0.3
Turkey	3.4	3.0	1.2
China	4.1	2.1	0.5
Zimbabwe	4.7	2.9	0.8
Thailand	4.9	2.4	0.9
Tunisia	5.0	3.7	1.4
Brazil	5.1	3.4	3.7
Argentina	6.1	2.7	4.4
South Africa	6.4	1.5	0.5
Malaysia	6.4	4.0	1.0
Colombia	8.4	1.6	3.1
Viet Nam	10.8	1.7	1.0
Indonesia	11.0	1.3	0.8
Chile	13.1	2.0	2.5
Taiwan Prov. of China	15.0	6.3	1.9
Bangladesh	15.5	2.4	2.8
Uruguay	16.7	6.9	8.9
Philippines	19.3	5.0	1.2
Venezuela, Bolivarian Rep. of	24.9	1.0	2.2
Peru	29.8	4.5	3.7
Mexico	30.7	7.3	0.8
India	35.1	1.7	0.6
Morocco	41.7	6.3	1.6
Zambia	69.3	3.4	4.3
Sri Lanka	69.3	8.9	1.1
Mozambique	94.3	8.9	4.2
Botswana	97.3	31.6	2.4
Uganda	195.4	6.0	1.8
Malawi	231.2	14.0	1.7
Tanzania, United Rep. of	239.2	8.2	3.7
Madagascar	354.6	28.7	1.5
World[a]	8.2	4.2	2.4

Source: Derived from Global Trade Analysis Project (GTAP) database, Center for Global Trade Analysis, Purdue University; and Lee, 2002.
[a]World includes countries in addition to those listed in this table.

on EU GHG emissions leads to no significant change in developing countries' agricultural exports. This is because land previously used for cereal and oilseed production in the EU is switched to the production of other crops and livestock, displacing some of the imports from developing countries.[10]

Table 3 shows the estimated change in agricultural exports from developing countries by sector as a result of a hypothetical carbon tax on EU emissions. This simulation excludes taxes on methane emissions, and also ignores agriculture's potential for bio-sequestration.

Agriculture is not sufficiently energy-intensive for a carbon tax to make much of a difference to production and exports. The estimated fall in developing-country agricultural exports is $220 million, mainly in crops other than cereals and processed crops.

There are winners and losers among exporters, depending on the composition of their exports. Changes in the terms of trade, especially in manufacturing and textiles, from the imposition of a carbon tax in the EU lead to welfare losses for developing countries estimated at $3.7 billion. This includes a welfare loss of $138 million per annum for selected LDCs specifically, indicating that a carbon tax in the EU may impose a burden on some of the poorest countries, even though there are no border taxes imposed on embedded carbon. Global welfare losses are estimated at $17 billion per annum, borne mainly by the region imposing the tax. However, it is important to emphasize that the values of the damages avoided (i.e. the benefits of the policy) should be subtracted from these costs to derive the overall cost/benefit of the policy.

Table 3. Percentage changes in value of developing-country agricultural exports following a hypothetical $30/t carbon tax on EU emissions ($ thousand)

	Rice	Wheat	Other cereals	Oilseeds and fats	Other crops	Livestock	Meat	Other processed agriculture	Total, including non-agriculture
Selected LDCs[a]	0.30	0.51	0.30	0.36	0.23	0.21	0.23	-0.19	-0.03
China	-0.11	0.32	0.18	-0.04	-0.07	0.07	0.12	-0.06	0.03
India	-0.35	-0.27	-0.03	-0.06	-0.30	-0.24	-0.62	-0.31	0.09
Brazil	-0.35	0.10	0.20	-0.23	-0.11	-0.02	-0.42	-0.21	0.04
South-East Asia	-0.33	-0.12	0.12	0.03	-0.13	0.02	-0.25	-0.08	0.08
West Asia	-0.06	0.15	0.05	0.20	-0.22	-0.18	-0.04	-0.17	-0.03
Central and Eastern Europe	-0.54	-0.17	0.10	-0.55	-0.55	-0.46	-1.36	-0.57	0.96
Central America	-0.21	-0.12	0.12	-0.13	-0.15	-0.02	-0.23	-0.15	0.05
Mercosur	-0.24	0.09	0.12	-0.07	-0.19	-0.12	-0.63	-0.28	0.06
Andean Community	0.06	0.18	0.27	0.03	-0.20	0.05	-0.19	-0.21	0.08
North Africa	0.23	1.62	0.51	0.24	0.01	0.10	0.31	-0.24	-0.06
West Africa	1.18	2.92	0.49	1.04	1.14	0.18	2.07	0.27	-0.03
Central and East Africa	0.13	0.59	0.24	0.09	-0.14	-0.28	-0.31	-0.43	0.00
Southern Africa	-0.33	0.29	0.06	-0.10	-0.36	-0.05	-0.76	-0.38	0.04
Rest of the World[b]	0.06	0.81	0.24	0.09	0.08	0.25	-0.03	-0.08	0.02

Source: GTAP simulation.

[a] The selected least developed countries (LDCs) are: Afghanistan, Angola, Bangladesh, Bhutan, Cambodia, Democratic Republic of the Congo, Madagascar, Malawi, Maldives, Mozambique, Nepal, Senegal, Uganda, United Republic of Tanzania and Zambia. Some LDCs are aggregated into other regions. Derived from Global Trade Analysis Project (GTAP) database, Center for Global Trade Analysis, Purdue University; and Lee, 2002.

[b] Rest of the World includes countries in addition to those listed in this table.

Some commentators believe that as the emission targets become more restrictive, a much larger carbon tax will be necessary. A simulation of a hypothetical tax of $100 per ton leads to estimated losses in developing-country agricultural exports of $1,414 million, well up from the $220 million resulting from a $30 per ton tax, but still only 0.04 per cent of annual exports. Once again, gains and losses would vary from country to country. A tax on carbon-intensive fuel in developed countries would reduce demand for that fuel and reduce its relative price in developing countries. This should lower transportation costs in favour of those remote from the major markets. However, a tax on shipping fuels would place the more distant suppliers at a disadvantage.

It is not clear to what extent agriculture would relocate in response to changes in the price of carbon. As noted, agriculture is not particularly energy-intensive, at least compared with industries such as aluminium, iron and steel and cement. As illustrated in table 3, developing countries with a large agricultural sector are therefore unlikely to gain much of a competitive advantage from a carbon tax in this respect. This is because their economies would not be much affected – directly or indirectly – by carbon reductions in developed countries. The carbon tax would mainly affect carbon-intensive industries rather than agriculture.

d) Non-carbon greenhouse gas emissions

Methane has received relatively little attention to date, with no applicable emissions trading scheme similar to that for carbon, but this may change. Any future methane taxes on beef and sheep meat in developed countries may give some developing countries (e.g. Argentina, Brazil and Uruguay) a competitive advantage. Proposals by the Governments of Denmark, Ireland and New Zealand for a methane tax[11] met with a strong negative reaction from their domestic farm industries (*Times,* 10 March 2009) because of concerns over the potential loss of competitiveness. There is currently limited scope to reduce methane in production economically.[12] Thus the likely response to a methane tax would be for consumers to substitute their consumption of beef and sheep meat with pig and poultry meat as well as with game such as venison. Australians see a potential market in kangaroo meat (Garnaut, 2008: 540). However, the substitution effects are estimated to be slight.

Garnaut (2008, table 22.3) reports that a $40 per ton tax covering carbon and methane would add perhaps $1 per kg, or 6 per cent, to the retail price of beef and veal. However, Jiang, Hanslow and Pearce (2009), using farm-level data to assess the potential impact at the farm level of an ETS that incorporates methane and nitrous oxide as well as carbon, conclude that an emissions tax (in Australian dollars) of A$ 25/t CO_2-e would raise the costs to beef producers by 18 per cent and to sheep producers by 10 per cent. This would result in a 60 per cent fall in farm cash income for the average beef producer. Moreover, a tax of A$ 50/t would lead to a fall in income of an estimated 125 per cent, resulting in a net loss for these farms.

The implications for beef- and sheep-producing developing countries are obvious: countries without methane reduction commitments would gain. This raises the issue of how to respond to a loss in competitiveness.

D. Border tax adjustments

1. Background

Under the Kyoto Protocol, producers in Annex 1 countries are committed to emissions reductions, while producers of energy-intensive products in non-Annex 1 countries do not make any such commitments. This policy has failed to curb emissions in fast-growing developing countries. It has also led to concerns about loss of competitiveness for countries not constrained by emissions reduction commitments.[13] Some developed countries have therefore considered responding to measures that increase the cost of carbon pollution by imposing border taxes on imports from countries that do not implement similar emissions reduction policies.

There have been suggestions that the EU should impose carbon taxes on imports from the United States and that the United States should levy similar taxes on imports from China. These policies are likely supported by domestic industries as well as environmentalists. To date, such calls have focused on energy-intensive products, particularly those that embody carbon, such as cars that contain aluminium, a light but energy-intensive metal. It is a logical extension to include methane emissions in border measures, in which case ruminant meat imports could receive more attention as well.

One approach for addressing the loss of competitiveness as an exporting country is to reduce taxes or grant, for free, a proportion of carbon credits to trade-exposed industries. These concessions need not involve full compensation, but should be limited

to reflect the loss of competitiveness because of the absence of a tax in competing countries. A difficulty with this approach is that it would encourage intensive lobbying, with each industry claiming to be a special case deserving of special treatment.

2. Effectiveness and efficiency

Border tax adjustments are difficult to design because of the high costs of establishing the levels of carbon embedded in imported products. Regulators will also be exposed to domestic lobbying when setting tariffs or allocating permits to trade-exposed industries. BTAs may also lead to retaliation, particularly following the global financial crisis which has increased protectionist pressure by domestic producers. BTAs effectively shift the tax from the producer to the consumer. Moreover, they may fall foul of international trade agreements. In these respects, they are an imperfect solution to a market failure, namely the oversupply of GHGs.

3. Equity

Border tax adjustments would have a negative impact on developing countries, such as China, that export carbon-intensive products not currently subject to a carbon price. A border tax would discourage exports of such products. However, developing-country importers of carbon-intensive products would benefit from the lower prices in the world market.

A BTA would have a small efficiency effect, but the main effect would be distributional, as with any tax. In this case, the burden would fall on developing countries, while the beneficiaries would be the governments that impose the taxes. However, there would also be distributional effects within the importing country, with consumers bearing the additional burden. While it is possible to identify the distributional effects, whether these would be equitable would depend on the starting point. For example, it could be argued that an equitable outcome would require all consumers to contribute equally to reducing emissions, and that a border tax would move towards this. Given the various alternative criteria for assessing an equitable outcome, such discussions are difficult to resolve.

E. Payment for environmental services

1. Description

The primary output of agriculture is food and fibre, but there is also potential for it to deliver environmental services. These "joint outputs" of commodity production include biodiversity, carbon sequestration, landscape and soil conservation and watershed protection. The extent to which agriculture can provide these public goods depends to a large extent on the crops grown or livestock raised, and on the economic incentives available. To date, these incentives favour the production of conventional food and fibre in response to consumer demand and as a result of agricultural support policies. Since there are few, if any, incentives for farmers to supply environmental goods and services, these are undersupplied or not supplied at all. The aim of payment for environmental services (PES) programmes is to get the incentives right, so as to encourage farmers and other natural-resource managers to increase the provision of environmental public goods from land use (FAO, 2007).

PES programmes were initiated in the 1980s when the EU and the United States introduced agri-environmental schemes as a response to public concern over environmental degradation in agriculture. In the 1990s, PES programmes were introduced in developing countries, the most notable being payments for forest-based environmental services in Costa Rica and Mexico. Hundreds of PES schemes are now implemented in both developing and developed countries, mainly for forest-based services, primarily carbon sequestration, biodiversity conservation, watershed protection and landscape conservation. To date, relatively few of the programmes have targeted farmers in developing countries, particularly for carbon sequestration (FAO, 2007).

The demand for environmental services from agriculture is mainly channelled through governments and international agencies. However, the private sector's role is growing in importance through conservation contracts and organic certification schemes.

There are two main sources of payment for carbon sequestration from agriculture: the Clean Development Mechanism (CDM) and "voluntary" carbon markets (see table 4). The world's largest carbon market, the EUETS, does not sell or trade credits generated by carbon sequestration. This is due to uncertainty in the EU concerning the measurement and maintenance of carbon stocks sequestered in agricultural soils (Young et al., 2007).

The Clean Development Mechanism (CDM) allows developed countries the option of buying carbon "credits" (or "certified emission reductions (CERs)) from developing countries in place of making their

Table 4. Summary of carbon market and eligibility for carbon sequestration and emissions reductions in agriculture

Type of carbon market	Value, 2007 ($ million)	Volume, 2007 ($MtCO_2$-eq)	Carbon sequestration	Agriculture-related emissions reductions
Allowances EU ETS	50 000	2 100	None	None
Voluntary carbon market (Chicago Climate Exchange)	91	265	No till agriculture ($34 m in 2006)	None
Project-based transactions CDM and JI	13 600	874	Forestry (1% limit) $52 m max.	Methane capture (3% of market)

Source: Adapted from FAO, 2008; Capoor and Ambrosi, 2008.

own emission reductions. In 2006, developing countries sold $5.2 billion worth of carbon offsets to Annex 1 countries under the CDM (Hamilton et al., 2007). However, CDM rules restrict the type and amount of carbon emission reduction credits that can be obtained from carbon sequestration. Only afforestation and reforestation are allowed, and these are limited to 1 per cent of the total base-year emissions. Emission reductions from land use, land-use change and forestry (LULUCF) account for only 1 per cent of the volume of CO_2 traded so far. Agriculture benefits from methane capture projects, amounting to 3 per cent of the $30 billion total carbon trade (FAO, 2008).[14]

The "voluntary" carbon offset market is very small compared with the regulated market, but it is more accessible to agricultural projects. The market was worth $90 million in 2006, of which carbon sequestration from agriculture accounted for $34 million. The voluntary market for agriculture-based carbon credits is thus worth around 0.1 per cent of the value of the total world carbon market. While there is potential for the voluntary market to grow, the market risks being undermined by concerns over the validity of the offsets, such as lack of additionality (discussed below) and its performance in curbing emissions growth.

International and national agencies support carbon sequestration through specialized funds like the World Bank's Biocarbon Fund and the National Carbon Fund of Italy and the Netherlands. A leading voluntary carbon offset market, the Chicago Climate Exchange (CCX), reports that 40 per cent of its projects fund agricultural schemes under the category Agricultural Methane Offset and Soil Carbon Offset (CCX, 2007). The CCX funds carbon-offset projects for grass tillage and conservation no-till agriculture in the United States. These are farming systems in which the farmer plants crops and controls weeds without turning the soil, thus reducing GHG emissions from the soil and tractor use. The United States also encourages the use of soil carbon sequestration on a modest scale through its agricultural policy and research (Young et al., 2007).

The demand for organically produced food further encourages carbon sequestration and other environmental goods and services from agriculture. In 2007, the global market for organic products was worth $46 billion, having tripled in value over eight years (Sahota, 2009). Whilst the majority of consumers buy organic products for their perceived health benefits, environmental protection is also cited as a reason.

2. Effectiveness and efficiency

a) Farmers' opportunity costs

The ability of PES schemes to deliver environmental goods and services from agriculture depends to a large degree on the decision-making of farmers. Farmers' management of their natural resources is driven by the market returns for these activities and the broader agricultural policy environment (FAO, 2007). In most property rights regimes, farmers do not have sufficient incentive to adopt environmentally friendly farm practices because these would reduce their net benefits. Depending on the degree to which the polluter-pays principle applies, payments would be needed to compensate farmers for the costs (i.e. forgone income) of the new practices. Other barriers to the adoption of environmentally friendly practices include limited access to information, appropriate technologies and finance, as well as insecure property rights and legal constraints. These constraints are often compounded by poorly functioning markets and infrastructure, risk and difficulties in the collective management of commonly held resources like pasturelands (FAO, 2007).

b) Farmers' transaction costs

Farmers face transaction costs in PES schemes in terms of time and effort spent (and sometimes fi-

nancial costs) in finding and processing information about those schemes. Transaction costs are higher as a proportion of total costs for small farm enterprises and smallholders than for larger ones. Such costs will thus be considerably higher in developing countries where farm size is much smaller and levels of human capital, farmers' organization and access to markets are much weaker. Luttrell, Schreckenberg and Peskett (2006) identify transaction costs as a major obstacle to the participation of the rural poor in forest-based carbon markets. Specifically, regulated carbon markets (i.e. the CDM) are unfavourable to participation by small farmers for several reasons (FAO, 2007):

- The CDM excludes the two forms of carbon storage that farmers can deliver easily: reduced emissions from deforestation in developing countries (REDD) and soil carbon sequestration. The process of certifying projects to be eligible under the CDM is complex and costly, as is the process of delivering credits to the market.
- The CDM allows simplified procedures for establishing small projects, but sets a cap on the size of these projects. These are too small to make the projects financially viable at the current low level of carbon prices.

The small voluntary carbon market is more accessible to agriculture and does not face either the restrictions on the size of projects or carbon sequestration through agriculture. However, Pannell (2008) questions the financial benefits to farmers of carbon sequestration services on the following grounds:

- Soil sequestration is a one-off process: once farmers change their management to increase soil carbon, it increases up to a new equilibrium level and then stops. After that, there are no net additions of carbon to the soil each year, meaning that farmers would receive only a one-off payment;
- It is difficult to measure the amount of carbon stored in soils. To do so in a convincing way would involve regular and ongoing costs, which would eat away at the modest one-off benefits; and
- It is difficult to increase the amount of carbon stored in most cropped soils, for example in Australia, even with zero till and when large amounts of stubble are retained (Chan, Heenan and So, 2003).

c) Administration costs

Publically funded schemes operate with limited budgets, and therefore have to demonstrate cost effectiveness. A key element of this is ensuring a minimal level of service provision while minimizing the level of administration costs (FAO, 2007). Such costs (or demand-side transaction costs) are potentially high in PES schemes. A survey of 37 case studies of EU agri-environmental schemes revealed administration costs as a proportion of total payments to landholders varied from 6 to 87 per cent (Garnaut, 2008).

Administration costs for sequestration of carbon in agricultural land typically include the following: mapping out the land, estimating its carbon sequestration potential, the costs of sequestration for different farm types, drawing up negotiating contracts and monitoring schemes to ensure agreed environmental actions are taken by farmers. The level of administration costs will depend on the following three factors:

i) Measurement of the carbon sequestration potential of the land. Measurement costs are higher because of the diverse emissions profiles of individual farmers, and sampling is expensive. Moreover, estimation of emissions and sequestration is difficult because of seasonal, annual and spatial variations. FAO (2008) outlines in more detail the challenges to measuring soil carbon stocks at field scales and larger. Some of the main challenges are that soil carbon contents are often highly variable within an individual field, and multiple factors (e.g. soil type, climate and previous land use) influence soil responses at a specific location.

ii) Information hidden by the farmer (adverse selection). Farmers can hide information about their costs of compliance with schemes (adverse selection) when negotiating contracts. They have better information than the regulator about the opportunity costs of supplying environmental services and can thus secure higher payments by claiming their costs are higher than they actually are. In other words, farmers may attempt to extract informational rents from the regulator in the form of a higher than necessary payment to induce them to participate in the PES programme (Ferraro, 2005).[15]

iii) Action hidden by the farmer (moral hazard). In contrast to hidden information, hidden action (moral hazard) arises after a contract has been negotiated. Farmers may find monitoring contract compliance costly and thus be unwilling to verify compliance with certainty. Therefore they may avoid fulfilling their contractual responsibilities. This is another instance where the farmers attempt to extract informational rents from the regulator. In this case, the rents arise from payments for actions never taken (Ferraro, 2005).

Reducing information asymmetry by the regulator involves costs, as a higher level of monitoring is needed to uncover hidden action (moral hazard). Uncovering hidden information, for example about the cost of storing carbon requires measuring individual soil profiles and marginal storage costs. Both sets of action require expenditures.

Transaction costs will increase under conditions where property rights are uncertain (e.g. over contract enforcement and land tenure), the number of contracting parties are higher and the concept of PES is unknown. These are common conditions in developing countries, where the potential for carbon sequestration is the highest. Transaction costs can be reduced by simplifying scheme design and contracting larger farmers. There is thus a trade-off between administration (transaction) costs and scheme effectiveness.

d) Lack of permanence

Environmental benefits in agriculture take a long time to accrue (e.g., building biodiversity values). However, when contracts expire, farmers are under no obligation to continue maintaining the newly formed environmental assets (e.g. soil structure that has a greater capacity to hold carbon). Farmers may then have new incentives (for instance from high commodity prices) to return to more intensive forms of agriculture at the expense of the environmental benefits created. This could apply equally to carbon sequestration contracts, whereby farmers revert to carbon depleting farm practices such as intensified tilling. The degree to which farmers are subsequently rewarded for keeping carbon stored in the soil will depend on the prevailing property rights regimes. If these favour farmers, regulators may be inclined to offer payments to stop farmers tilling land intensively so as to avoid releasing carbon.

e) Lack of additionality

Additionality means that people should be paid for doing things that they were not going to do. This is important if budgets, and therefore resources, are limited. Lack of additionality will reduce the benefits of a programme (Pannell, 2009). Forest-based carbon sequestration schemes have been criticized for not offering additionality. The largest agri-based carbon sequestration market, the CCX, has also been criticized for the lack of additionality in its no-till agricultural projects. There have been several cases where farmers have received carbon offset revenues for practising no-till agriculture despite the fact that they had been practising no-till for many years already (Kollmuss, Zink and Polycarb, 2008).

Whilst conceptually simple, it is difficult to apply the concept of additionality in practice. It is not easy to tell what farmers would have done without the payment, considering that people's behaviour and business management is always in a degree of flux. One strategy is to use an auction or tender-based process whereby participants in a bid reveal what they are willing to do for a certain price, and the regulator can choose those bids that offer best value for money (Pannell, 2009). This system has been applied in developed countries, but is unproven in the weaker regulatory environments of developing countries.

f) Limited practice of organic agriculture

Organic agriculture generates environmental benefits such as carbon sequestration (Niggli et al., 2008a; 2009), but its growth is constrained by unfavourable government policies and limited willingness on the part of consumers to pay higher food prices. Furthermore, the lack of a price for the environmental benefits of sustainable agriculture is a major constraint. There are also implicit subsidies for conventional agriculture in terms of water pollution clean-up costs, particularly in developing countries. Furthermore, the economic costs of biodiversity loss and human health problems from agrochemical use are not reflected in the costs of conventional agricultural production.

Currently 0.8 per cent of the world's agricultural land is under certified organic production (Willer, Rohwedder and Wynen, 2009). The scope for growth in organic production depends not only on increasing consumer demand, but also on government agricultural policies that support the sector's development, for example, through R&D in organic agriculture (Twarog, 2006).

The constraints on carbon sequestration through PES schemes are summarized in table 5.

3. Equity

PES schemes run the risk of favouring larger farmers who face proportionately lower transaction costs for participation. The transaction costs for farmers can be reduced by simplifying the design of schemes. However, the trade-off is that schemes will have to be less targeted and so risk delivering weaker environmental benefits.

If farmers are offered contracts to reduce methane emissions, they may reallocate their resources away

Table 5. Constraints on sequestration of carbon through PES schemes

Type of constraint	Cost impact	Result	Examples of constraints
Competing market incentive	Farmer	Low participation by farmers	High commodity prices /low carbon prices make environmental practices unprofitable
Size limits to scheme	Farmer	Reduced participation by small farmers	Limit to size of simplified CDM schemes
Time and effort collecting and processing scheme information	Farmer	Reduced participation by small farmers	Rural poor highly constrained in forest-based carbon trade
Lack of knowledge about environmental practices	Farmer	Reduced participation by farmers	Lack of knowledge about organic agriculture techniques
Lack of information on land's carbon storage potential	Regulator	High cost of scheme design. Incentive to reduce scheme targeting.	Multiple, for example for Australia, Garnaut Review, 2008; and for developing countries, FAO, 2007.
Hidden action (moral hazard)	Regulator	Non-compliance with scheme due to imperfect monitoring	EU agri-environmental schemes, United States conservation payment schemes
Hidden information (adverse selection)	Regulator	Overcompensation of farmers	EU agri-environmental schemes, United States conservation payment schemes
Lack of permanence	Regulator	Loss of carbon sequestration after scheme	EU agri-environmental schemes. Farmers might feasibly resort to carbon depleting practices at the end of carbon sequestration contracts.
Lack of additionality	Regulator	Financial reward for farmer to do what he/she already intended to do.	CCX contracting no-till cultivation where the farmer was already practising no-till methods.

from emission-intensive ruminant livestock rearing to forestry, for example. Cattle and sheep producers are likely to be the first to switch to farming carbon. If this occurs only in Annex 1 countries, beef producers such as those in Argentina and Brazil will benefit from rising prices of their exports.

F. Carbon labelling

1. Background

In 2007, carbon labelling came to prominence in the retail sector with a raft of new labelling schemes that conveyed information about the amount of carbon emitted in the production and processing of products (for reviews of the different schemes, see Bolwig and Gibbon, 2009; Brenton, Edwards-Jones and Jensen, 2008; and the Øresund Food Network, 2008).

There is no universally accepted methodology for measuring the carbon footprint of a product. In principle, it should be based on the measurement of emissions during a product's life – from the production of inputs and their use, to their final consumption and disposal. This process is known as Life Cycle Analysis (LCA).

Carbon labelling has been driven mainly by food retail companies so far, though organic labelling and standard setters are also driving carbon initiatives. Governments provide incentives for the private sector to develop carbon labelling through their legislation and target setting. The reasons why retailers, and to some extent organic standard setters promote carbon labelling are: to demonstrate their corporate commitment to reducing sector GHG emissions (i.e. corporate social responsibility (CSR) commitment), to differentiate their products according to "green" consumer preferences (i.e. marketing purposes), and to identify carbon "hotspots" within the supply chain and take measures to reduce them (i.e. cost-saving puposes).

In the agri-food sector, Walmart, Tesco and Casino have been the most prominent retailers in developing carbon labels across a range of mainly food products. Tesco, for example, launched a trial of 20 products in 2007. In 2007, the United Kingdom's Carbon Trust tested its standard with 20 companies, mainly in the agri-food sector, including Tesco. In France, Casino launched a label that provides information on the amount of CO_2 emitted in three stages of the supply

chain: packaging, waste and transport. In the apparel sector, Patagonia and Timberland are both displaying carbon information on a limited range of their products. However, not all in the retail sector are involved in carbon labelling. For example, in 2008, Unilever, ASDA (the United Kingdom retailer and subsidiary of Walmart) and Carrefour were seeking to reduce their supply chain emissions through initiatives other than carbon labelling. These included, for example, installing energy-efficient technologies, switching to renewable energy sources and offsetting travel emissions through support for renewable energy initiatives in developing countries (Øresund Food Network, 2008).

Several organizations involved in organic certification and standard setting are developing standards that incorporate carbon accounting. For example, the Swiss organic labelling organization, Bio Suisse, does not give certification to air-freighted products (see box 1). In 2009, the main Swedish organic certifier, KRAV, was considering climate provisions in its new draft standards (Gibbon, 2009).

In Australia, the Carbon Reduction Institute (CRI) certifies organizations, including retailers, based on their GHG emissions. It markets a "NoCO_2" certificate, which signifies that a business is carbon-neutral and has accounted for, reduced and offset all GHG emissions from its operations as well as the GHG emissions embodied in the products it sells and uses. The CRI awards certificates of carbon credits to energy efficiency, renewable energy and tree planting projects. The agri-food sector in Australia has shown a strong interest in this certification scheme (Øresund Food Network, 2008).

At EU and member State level, government legislative requirements and target setting are driving the development of carbon labelling. The EU has a target to reduce GHG emissions by 20 per cent by 2020. The European Commission has proposed new regulations to specify mandatory requirements for measuring the carbon footprint of biofuels. The EU ETS may include agricultural and small food processing companies in the future, thus creating an incentive for them to cut their GHG emissions (Øresund Food Network, 2008). The International Organization for Standardization (ISO, 2006) has developed its own meta standard, which specifies principles and requirements that organizations can use for quantification and reporting of GHG emissions.

At the government level, France has set sustainability objectives for its retail sector, including proposed mandatory carbon accounting. The Government of the United Kingdom has set up the Carbon Trust, which has developed a pilot methodology to measure the carbon footprint of products as well as a label to display information about the products' carbon footprint. The Carbon Trust is working with public agencies to produce a standardized methodology for carbon accounting (known as the PAS 2050), which may serve as the basis for a future standard in that country (Brenton, Edwards-Jones and Jensen, 2008). Australia has established a National Carbon Accounting System (NCAS) that accounts for GHG emissions from land (Department of Climate Change, 2009).

Box 1: Swiss organic markets and import restrictions: the case of Bio Suisse

The Swiss organic labelling organization Bio Suisse has incorporated food miles measures into its standards. Some of the criteria for awarding its label include:

- Products imported into Switzerland by land or sea (but not by air transport);
- Priority to organic imports from nearby countries; and
- Products for which all the processing is carried out abroad.

Fresh products (fresh fruit, vegetables, herbs), fruit juices and frozen products from overseas (except the Mediterranean) cannot be labelled with the Bio Suisse organic label (BioBud). Products which are "detrimental" to the image of the Bio Suisse label may be refused a licence contract. The following criteria may apply: "Ecology, transport distances, packaging, consumer expectations". Examples of products which have been refused contracts in recent years due to this restriction are: wine from overseas, tinned tomatoes from overseas, caviar and instant ice tea.

The preference for Swiss products appears to be based on meeting the wishes of consumers. Jacqueline Forster-Zigerly of Bio Suisse said in 2008: "In a time of globalisation, it becomes more clear how important it to have a strong national or regional profile. We notice that the consumers are becoming more interested in locally-produced products, sometimes even more interested than in the organic products"
(The Organic Standard, 87: 3).

2. Effectiveness and efficiency

Carbon labelling potentially provides the consumer with information about the levels of GHG emissions associated with the life cycle of a product. According to retailers, this information will drive demand for low-carbon technologies and help reduce the sector's GHG emissions. The use of carbon accounting methods by companies can also help them identify climate "hotspots" in their supply and take mitigating actions.

All attempts to regulate GHG emissions need to address issues of measurement. However, there are additional problems with carbon labelling, discussed below.

a) Measurement methodology

Brenton, Edwards-Jones and Jensen (2008) identify four key elements for measuring GHG emissions that can have a critical impact on determining the quality and reliability of measurement:

- *The use of primary versus secondary (standardized) data*: it is preferable to use primary data (i.e. process-specific data collection from the supply chain) as opposed to to secondary data (i.e. non-process-specific data obtained from other sources, rather than direct measurement of the supply chain being investigated). Primary data collection is very expensive, and is rarely done in developing countries. Many companies therefore prefer to use a standardized approach relying on secondary data. However, this will not capture low-carbon technologies being used in developing countries or the varying levels of emissions from different farms producing the same crops. Without this capacity to measure farm level efficiencies, the carbon label is rendered ineffective as a tool to induce low-carbon technologies. In addition, secondary data collection cannot capture annual variations in GHG emissions and thus the label would convey an inaccurate measurement.
- *Emission factors:* the amount of carbon emitted during a particular part of the manufacturing process and/or use of products are called emission factors. However, these are location-specific. For example, a country that generates a large proportion of its electricity from nuclear power or hydro power will have lower emission factors than a country that relies more on coal-powered electricity. The carbon foot-printing methodology cannot capture these differences.
- *System boundaries*: these define the extent of processes included in the measurement. System boundaries may be defined so that they include only certain elements of the supply chain. For example, in agriculture, the boundary may extend to the use of heat and electricity in a farm building and machinery but not the energy used in their construction. Similarly, farm workers in developing countries tend to walk or cycle to work, while those in developed countries use more private transport. The definition of the system boundaries in methodologies can therefore favour capital-intensive production techniques over labour-intensive techniques, and thus disadvantage developing countries.
- *Land-use changes:* when food demand brings about changes in land use (for example organic farm conversion or ploughing of pasture for arable production) there is a change in the carbon composition of the soil. For example, clearing forests for agriculture is the main cause of deforestation in developing countries. However, it is difficult to measure changes in GHG emissions. Furthermore the labelling scheme has to determine over how many years the one-off increase or decrease in emissions should be spread.

Since measurement is also very expensive, it is undertaken only by a limited number of retailers. Moreover, consumers are likely to be confused when different methodologies are used by different retailers.

Øresund Food Network (2008) has identified other major limitations to carbon labelling:

- *Exclusion of other environmental impacts:* by measuring only carbon emissions, the process ignores other impacts, such as the use of pesticides, biodiversity impacts, water usage and other GHGs (particularly methane and nitrous oxide). A similar criticism has been levelled against food miles.
- *Consumer confusion*: another label may well confuse consumers. It is not clear that consumers will understand the meaning, for example of "75g CO_2" for Walkers crisps. While labels may develop in a way that addresses this problem, for example by providing supplementary information, the consumer will simply have more and more information to process and understand. On the introduction of carbon labels by Tesco in April 2008, the National Consumer Council of the United Kingdom observed that it would be hard for consumers to understand what a gram of carbon was and to make

a properly informed green decision on this basis. It noted: "Including this on a consumer facing label at this early stage of development could cause more harm than good" (NCC, 2008). Consumer confidence in labelling is also undermined by the different ways in which labels convey information. Companies currently present carbon labels in three different ways: according to the products' CO_2 equivalent per kg, use of a number and colour coded system, and a "climate friendly" or "carbon neutral" label without quantified information.

- *Criticism of climate neutrality:* companies are claiming "climate neutrality" for their businesses, products and services. Tree planting or energy efficiency offsetting projects are criticized for being ineffective in reducing emissions or for having negative impacts on local communities and their access to and use of land. Furthermore, there is no industry-wide standard on what constitutes climate neutrality. For example, for air travel, different companies offer to offset GHG emissions based on different GHG emission rates per km and different prices per ton of carbon.
- *Usefulness of a carbon label:* a carbon label does not capture the energy used by the retailer in storing the goods, nor by the consumer in travelling to the supermarket and preparing the food. Yet these parts of the supply chain constitute up to 60 per cent of total GHG emissions. It therefore does not give the complete picture of GHG emissions from "farm to fork". The label may even have perverse outcomes, as consumers may feel they are making a contribution to mitigation of climate change by buying low-carbon goods yet travelling to the supermarket and preparing the food in energy-intensive ways.

The interests of developing countries in the development of carbon standards will depend on the extent of their participation in the standard setting process. According to Brenton, Edwards-Jones and Jensen (2008), most carbon labelling standards are currently developed in a way that is not inclusive in this respect.

Life cycle analysis (LCA) studies illustrate that distance is not necessarily an important indicator of the environmental impact of a food product (see section G.2). However several climate-related standards have been developed by organic standard setting organizations in which the developers of the standard have concentrated exclusively on transport. In one case, no scientific work was referred to at all, while in a second case scientific findings and methods were referred to only selectively. In the third case, where LCA analysis was adopted to help measure GHG emissions, provisional results were combined with maximum limit levels that were justified on non-scientific grounds (Gibbon, 2009).

These standards have thus been heavily criticized and the transport components dropped, except in the case of Bio Suisse (box 1). In the end, the demands of the retailers to maximize supply and demand leave proponents of climate standards exposed when attacked from other sources (e.g. producer groups and development organizations) (Gibbon, 2009).

3. Equity

The impact of carbon labels on developing-country exports depends on several factors, including:

- The compliance costs exporters face compared to the higher prices they might receive;
- The relative carbon intensity of production and transport compared with European products; and
- The likelihood that technologies can improve their "carbon competitiveness", for example by reducing emissions in refrigeration and shipping.

Data in table 2 suggest that developing countries tend to have lower carbon intensity in agricultural production, reflecting the greater use of labour as opposed to fuel-consuming equipment, fertilizers and pesticides. Comparisons between countries are difficult because of differences in the composition of exports, but the generalization appears to hold for lower levels of aggregation (i.e. what holds for agriculture as a whole also holds for crops, livestock and so on). However, the premium and costs of compliance associated with the carbon label will determine its profitability.

Edwards-Jones et al. (2009) highlight the different levels of vulnerability of countries to embedded carbon import requirements. Countries "highly vulnerable" to the introduction of carbon labels to the supply chain include those that rely on:

- Crops that are air-freighted (and possibly substitutable (e.g. green beans from Kenya));
- Crops with a favourable carbon footprint for only a few months in the year (e.g. apples imported into Europe from Argentina or New Zealand); and
- Crops with a higher carbon footprint than EU production and which are vulnerable to technological

advances in the EU agricultural sector (e.g. onions from New Zealand).

Traditional tropical commodity crops such as coffee, cocoa, tea and bananas are not vulnerable because although they are produced far from the market their local substitution is not possible.

Carbon labelling, and the food miles initiatives discussed in the next section have the likely outcome of setting new requirements that would entail increased costs for exporting countries. There is limited evidence to date of how consumer behaviour and retailer demands will affect suppliers in developing countries. The impact will depend on the following:

- Degree of product substitution;
- Consumer reaction to embedded carbon approaches;
- Retailers' demands in the supply chain; and
- Integration of embedded carbon approaches in standard setting.

Each of these is discussed below.

a) Degree of product substitution

The degree to which an imported product can be substituted by a domestic product is important in determining vulnerability from mitigation measures like carbon labelling. Food exports of developing countries are still primarily commodity crops. Some of these crops such as tea, coffee and bananas cannot be readily substituted by European or United States production, whereas other commodities like vegetable oils, sugar, rice, tobacco and cotton are all substitutable. Higher value non-traditional exports, which have grown rapidly in recent years, are vulnerable to substitution. For example, Kenyan beans can feasibly be substituted in the northern hemisphere's summer period.

Edwards-Jones et al. (2009), however, point out that it is unclear when consumers are actually presented with a genuine choice between substitutable products. Fresh produce supply chains to major retailers in the United Kingdom, for example, are generally very well differentiated by season and products. Thus, consumers are unlikely to be presented with the choice of purchasing new potatoes from Israel and the United Kingdom on the same day. Therefore the degree of partial or total substitution across product lines tends to vary.

b) Consumer reaction

It is uncertain how consumers will respond to carbon labelling. A large proportion of "ethical" consumers are aware of carbon labels (Bourke, 2008[16]). However, it is unclear how consumers will prioritize these over other more established environmental and social attributes (no pesticides, food safety, child labour issues, fair trade and biodiversity). Furthermore, whilst some environmental food labels command a premium price (e.g. organic), it remains to be seen to what extent consumers will pay a premium for low-carbon products.

c) Retailer demands

Even if consumers do not show a strong preference for low-carbon products, retailers may require suppliers to provide information relating to carbon accounting. This could include such aspects as energy costs, types of technology employed, transport distances and carbon action plans in production and processing. This represents an additional barrier confronting exporters.

d) Integration of embedded carbon approaches in organic standard setting and labels

Carbon labelling is a voluntary initiative. Retailers have promoted local products, but so far have not actively excluded imported products. However, in the organic niche market, more serious obstacles have arisen. One of the most visible examples of integration of embedded carbon into food standards to date has been the decision of the leading Swiss organic label Bio Suisse to refuse to provide its organic label for air-freighted products. The Soil Association also considered such a move, but after broad consultations dropped the idea because of the apparently large detrimental development impact this would have.

G. Food miles

1. Background

Food miles refer to the distance travelled by food from the farm gate to the consumer. In other words, they count the miles between where the food is produced and where it is consumed. Since the transport of food consumes energy and is therefore responsible for GHG emissions, it follows that the further a product travels to market from the production site, the greater its environmental damage and contribution to global warming. To reduce this environmental impact, environmental groups encourage consumers to buy locally. Major retailers and farm lobbies have joined this campaign, which also promotes local economies and regional and local food sourcing. In Europe, air-

Figure 3. Comparative CO_2 emissions per ton of dairy and lamb produced in New Zealand and the United Kingdom

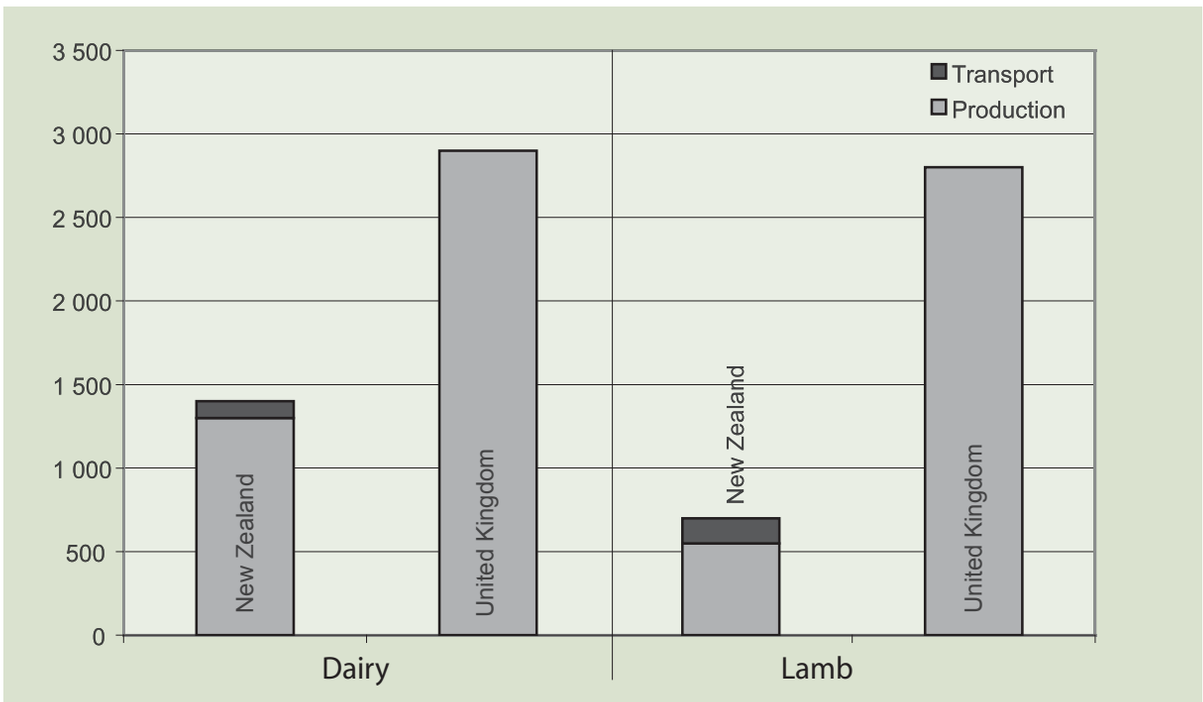
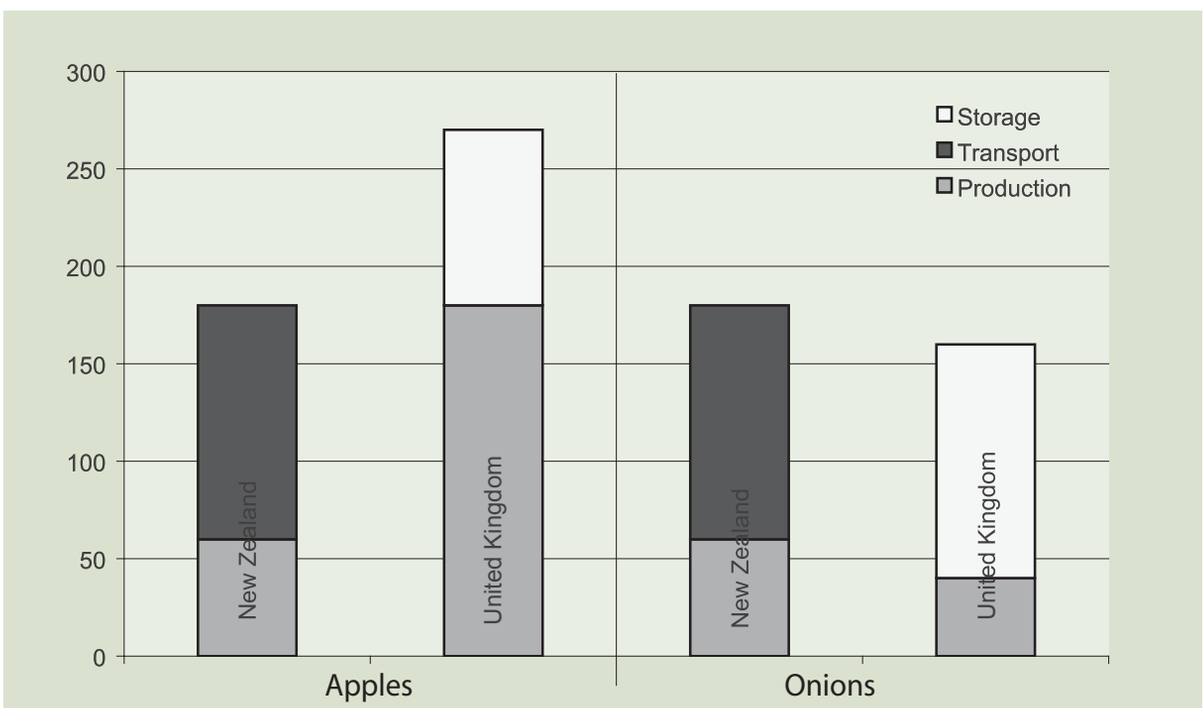


Figure 4. Comparative CO_2 emissions per ton of apples and onions produced in New Zealand and the United Kingdom



freighted products receive particular attention, especially from organic standard setters.

Labelling is the most common way retailers convey messages, such as about local sourcing, to consumers. With food miles, a common way of indicating that a product has been imported by air is to show the sign of a plane on the label.

2. Effectiveness and efficiency

The food miles approach is criticized as an oversimplified way to address the environmental problem of GHG emissions (see, for example, Edwards-Jones, 2006; McKie, 2007; ITC/UNCTAD/UNEP, 2007; Wynen and Vanzetti, 2008). The main points of criticism are:

- Its lack of a life cycle approach;
- Omission of sustainability impacts; and
- Omission of political economy variables.

a) Lack of a life cycle approach

The food miles focus on distance is a crude indicator of environmental damage as it ignores the difference in GHG emissions between different forms of transport and energy costs in other stages of the supply chain. It also ignores non-carbon GHGs. As illustrated earlier in figure 2, the use of energy in production systems and cold storage as well as by consumers in shopping and food preparation is also significant. Efficiencies in these areas can offset emissions from transport over great distances (as illustrated in figures 3 and 4).

Life cycle analyses (LCAs) illustrate where energy costs fall in each stage of the supply chain from "farm to fork". Such analyses have demonstrated that areas other than transport can be an important contributor to the carbon footprint of food products. LCAs have provided a number of insights, discussed below.

b) Production systems can compensate for energy costs from transport and storage

Certain production systems and locations are more energy-intensive than others. Tomatoes grown in greenhouses in Sweden, for example, were found to be 10 times more energy-intensive than those grown in open fields (Carlsson-Kanyama, Ekstrom and Shanahan, 2002).

Saunders, Barber and Taylor (2006) compared energy use and emission levels in the production and transport (from a New Zealand to a United Kingdom port) of several commodities (see figure 3 for dairy products and lamb, and Figure 4 for apples and onions, which include storage). They concluded that with 3 of the 4 products, emissions were lower when produced in New Zealand and transported by sea to the United Kingdom than when produced in the United Kingdom. The length of time that food is stored prior to retail can add substantially to GHG emissions. Saunders Barber and Taylor (2006) showed that the cold storage used to allow consumption of out-of-season apples can account for over 40 per cent of a product's energy inputs. Sim et al. (2007) found that the impact on global warming of locally grown United Kingdom produce placed in storage for 10 months was twice as high as that of South American apples sea-freighted to the United Kingdom.

Each of these case studies is based on sea-freighted transport. Air freight is very energy-intensive and normally does not compensate for lower energy costs associated with production in warmer climates like Kenya. Several studies have shown that fruit and vegetables grown in Kenya and air freighted to Europe involve substantially higher GHG emissions – around 10 times greater (Jones, 2006; van Hauwermeiren et al., 2007). Williams, Audsley and Sandars (2006) found that the carbon footprint of flowers grown in open fields with geothermal power in Kenya and air freighted to Europe was lower than that of flowers grown in greenhouses (and heated by fossil fuels) in the Netherlands.

c) Transport mode and efficiency

The climate impact of emissions from transport depends on the mode of transport and its efficiency: air freight has high emissions, while sea freight emissions are lowest followed by rail and road.[17] Road haulage accounts for the most noise and air pollution costs, while shopping for food by car accounts for the most accidents and congestion impacts (AEA Technology, 2006). There is a trade-off between transport distance, vehicle size and transport efficiency. The food distribution system of large vehicles when travelling large distances between regional distribution centres involves efficient loading of vehicles and thus reduces the impacts per ton of food. Local markets have shorter distances but less efficient loading through greater use of smaller vehicles (AEA Technology, 2005.

d) Consumer travel and food preparation

Consumer travel to the supermarket, storage and food preparation account for 13 per cent of total food chain energy costs. Although the choice of transport that consumers use to get to and from the supermarket does not depend on whether the prod-

uct is imported or not, it can make a large difference in terms of energy and CO_2 emissions associated with food. Van Hauwermeiren et al. (2007) found that a 5 km trip to purchase 25 kg of food (when combined with other activities), will incur an impact of 100g CO_2/kg of food. This compares with no emissions from shopping using a bicycle or on foot. The authors examined the relative impact of specific (i.e. solely to purchase food) shopping trips greater than 10 km. A consumer driving more than 10 km to purchase one kg of fresh produce will generate more GHG emissions than air freighting 1 kg of produce from Kenya.

Food preparation methods also vary in their energy intensiveness, which is not necessarily known by consumers. Baking potatoes, for example, requires over five times more energy than boiling them (Carlsson-Kanyama, Ekstrom and Shanahan, 2002). Similarly, preparing dried chickpeas (boiling over several hours) is considerably less efficient than buying ready-cooked tinned chickpeas. This is because cooking them at home on a stove is much less efficient than the large-scale industrial kitchens used when cooking for canning. The level of carbon intensity also depends on whether the consumer is using renewable energy, nuclear or coal-fired sources, all of which have very different carbon emission levels (McKie, 2007).

e) Omission of other sustainability impacts

If imports were to be excluded on the basis of international transport alone, this would omit consideration of the environmental benefits from traditional or organic farming systems associated with imports. For example, the exclusion of air-freighted organic products from certification in European countries may result in producers reverting to farm production using agrochemicals (Gibbon and Bolwig, 2007). In developing countries, where enforcement of environmental regulations is weak, there are well-documented cases of water pollution from agrochemicals and hazards for farm workers who handle pesticides. A return to chemical-based agriculture would lead to the loss of environmental benefits associated with organic agriculture, such as its effects on biodiversity and its carbon sequestration functions. Improved incomes from the premium prices for organically produced foods would also be at risk from the loss of organic export markets (Bolwig, 2007; Twarog, 2006; Bolwig and Gibbon, 2007).

f) Omission of political economy variables

Arguments that support the consideration of food miles cannot capture important policy variables such as subsidies for farm fuel use in some countries (e.g. Australia and the United Kingdom). These subsidies are disguised by effectively imposing a much lower duty on farmers than on non-agricultural users. Insofar as taxes on fuel cover activities on the road, such as building of the roads and costs associated with accidents, the imposition of lower taxes on fuel used in farm machinery but not that used off the farm has some merit. However, when taxes are raised to curb polluting emissions, there is less reason to exempt one group and not another. The ITC (2008) has argued that it is discriminatory to exclude imported products on the basis of transport – and fuel use – yet accept local products farmed with energy subsidies, thereby presumably stimulating the use of fuel.

3. Equity

The impacts of food miles campaigns and labelling schemes are likely to be similar to those of carbon labelling. These are summarized in section F.3, and therefore not repeated here. An additional factor is that developing countries tend to be more distant from the major markets, which would result in their being effectively discriminated against in any food miles scheme. This approach therefore has less merit than carbon labelling, which is a more sophisticated approach to measuring embodied carbon.

H. Summary and discussion

1. Addressing population and demand for meat

The agricultural sector, including products that are traded internationally, accounts for a high share of total GHG emissions. These emissions are increasing, driven both by a growing population and growing demand for ruminant meat. Upstream emissions (processing, transport, retail and consumption) are also growing.

This paper has identified market-based mechanisms as the most effective, efficient and fair way to reduce emissions from traded agricultural products. However, even market instruments are limited in their effectiveness because of the difficulty of implementing monitoring, reporting and verifying schemes in agriculture. Nevertheless, it is important that market-based mechanisms prevail. A regulatory or voluntary approach

would be unnecessarily expensive or ineffective, and would render the task of achieving the necessary GHG emission reductions far more difficult.

Pricing externalities effectively in transport, processing, retail and consumption is feasible, but it has only limited political support. The prospects for reducing emissions in the agricultural sector and its trade are therefore extremely dim, given the following key factors:

- The technical and political challenges in pricing externalities across the sector;
- The growing population; and
- The growing demand for ruminant meat.

Table 5 summarizes the effectiveness, efficiency and equity of market-based instruments and measures. A number of further key points are summarized below.

2. Pricing negative externalities: the most effective and efficient and fair policy

The benefits of adopting global mitigation policies are obvious. The most effective, efficient and fair policy for climate change mitigation across the agri-food supply chain is through carbon pricing. Pricing carbon internalizes the environmental cost of production and removes an implicit subsidy for carbon use.

Ending fossil fuel subsidies would also remove an explicit subsidy for carbon use, and represents "low hanging fruit" in terms of climate change mitigation.

Pricing carbon upstream would automatically internalize the costs of damage from GHG emissions across the agri-food supply chain, which would provide an incentive for emissions reducing behaviour and for the development of low-carbon technologies throughout the supply chain.

The economic impact of a carbon tax on developing countries' agriculture would be slight because of the low carbon intensity of the sector.

Carbon pricing is limited in its effectiveness if it is not applied globally. Without global pricing, there is the risk of "leakage" (i.e. relocation of industry and an undue impact on competitiveness, particularly in carbon-intensive sectors). Industry is likely to respond to these competitive pressures by either seeking border adjustments or lobbying against stringent mitigation measures. However, global and upstream carbon pricing is currently politically unfeasible. Global fossil fuel producers seem unlikely to accept such a policy. Carbon pricing also runs counter to the concept of "common but differentiated responsibility" as it restricts carbon-intensive fast growth paths.

Carbon pricing is also proving difficult to introduce in 1 developed country due to opposition from the public and industry lobbies. Recent experiences in Australia, the EU and the United States point to difficulties in implementing a cap-and-trade scheme in the face of opposition from those industries adversely effected.

3. The benefits of mitigation policies: need for further exploration

Policymakers and climate negotiators have to weigh the short-term costs to economic development of carbon reduction commitments against the longer term economic costs that unconstrained growth will cause through climate change. Stern (2007) calculates that "the benefits of strong, early action considerably outweigh the costs…the earlier effective action is taken, the less costly it will be." Further research is needed to help countries compute and communicate this trade-off between sacrificing some growth now for avoiding larger economic costs through inaction on mitigation later.

Making a commitment to carbon reductions has economic benefits as well as costs, for example in the "green economy". Research and development in sustainable agriculture and climate mitigation technologies, including in developing countries, would benefit greatly from countries signing up to carbon reduction commitments. Further knowledge and dissemination about these benefits is needed.

4. Difficulties in mitigating emissions in the agricultural sector

The unique emissions profile of agriculture and the large number of emitters (i.e. farmers) make it difficult to design emissions reduction strategies for the agricultural sector. Most of the GHG emissions from agriculture (90 per cent) consist of methane and nitrous oxide. These emissions cannot be easily incorporated into a GHG emissions reduction scheme. Establishing an MRV system is technically difficult and costly. Furthermore, unlike industry and services, emitters in agriculture (individual farmers) are small, numerous and diverse. Partly for this reason, current cap-and-trade schemes do not include agriculture. In this regard, an important market incentive for increasing the sustainability of agriculture (i.e. pricing GHG emissions) is missing. Until such MRV issues are resolved, market-

based instruments are limited in their ability to reduce methane and nitrous oxide emissions.

5. Carbon dioxide emissions are still a significant part of total agri-food supply emissions

Emissions from agricultural production only make up around a third of total GHG emissions in the agri-food supply chain. The rest are carbon-intensive processes, including input production (fertilizers, pesticides), processing, transport, retail, consumer travel and food preparation. Therefore pricing instruments for reducing carbon use are still very important means for reducing overall supply chain emissions.

6. Carbon taxes are preferable to cap and trade

Carbon taxes have some advantages over cap-and-trade schemes in terms of stability of prices, flexibility and revenue potential. Regressive impacts resulting from carbon pricing can be reduced through compensation and by lowering taxes on employment and income. Trading schemes must auction permits to function effectively and to create an income stream to use as compensation. Carbon taxes by definition raise this income.

7. Payment for carbon sequestration is a relatively ineffective and inefficient policy

Payment for environmental services schemes, including offsets for reducing methane emissions and storing carbon, appear to be limited in their effectiveness as a mitigation measure for agriculture. Unless the price of carbon is raised sufficiently high, such schemes are likely to be of limited economic interest to farmers. Designing effective schemes also incurs high transaction costs due mainly to the need to profile heterogeneous land types and farmers and to contract and monitor many different farmers. Lack of demonstrated "additionality" raises concerns about the credibility of the offset market. The use of offsets threatens the functioning of a carbon market, because the link between polluters and the appropriate tax is broken.

Table 6. Summary evaluation of market-based instruments and voluntary measures aimed at mitigating GHG emissions in the agri-food sector

Instrument	Effectiveness	Efficiency	Equity (distributional)	Equity (agricultural export impact)
Carbon tax	High, if applied globally[a] and upstream	High, if globally applied	Potentially regressive, although can be made revenue neutral	Insignificant[b]
Cap-and-trade scheme	High, if globally, upstream and with auction of permits[c]	High, if globally applied.	Potentially regressive, but depends on capacity to compensate losers	Insignificant
Border tax adjustment	Low[d]	Low[e]	Ambiguous, depends on sector	May disadvantage some developing countries but favour others
Payment for environmental services (PES)	Low with high opportunity costs for farmers	Low with high transaction costs	Disadvantageous for small farmers	Minimal
Carbon labelling	Low	Low	Favours larger exporters	Negative impact on countries using air freight or shipping over long distances[f]
Food miles initiatives	Low, perverse effects possible	Low Marketing costs	Favours local producers	Negative impact on countries using air freight or shipping over long distances

Notes:

[a] Limited impact on non-carbon GHG emissions, for example methane and nitrous oxide from ruminants.

[b] Insignificant impact on developing-country agri-exports due to low carbon intensity of agricultural trade. Tax revenue could fund adjustment to sector losses and to adaptation.

[c] Concern over price volatility and MRV constraints in agriculture. Limited impact on non-carbon GHG emissions.

[d] More effective for carbon-intensive items.

[e] Need to measure embedded carbon in imports.

[f] Inaccuracy in the data is especially likely for developing countries. Potentially high compliance costs for exporters.

8. Carbon labelling schemes and food miles campaigns are costly, ineffective and potentially unfair to developing-country exporters

Carbon accounting or LCA is a useful tool for identifying carbon "hotspots" in the agri-food supply chain. It enables companies to identify the most cost-effective areas for energy saving investments. However, carbon product labelling (which uses carbon accounting) is costly and is therefore unlikely to be widely adopted in a meaningful form. There is no commonly adopted methodology across different retailers, which makes it difficult for consumers to compare and comprehend the different labelling schemes. Their effectiveness in curbing emissions is further undermined by their voluntary nature, which allows free- riding by less "conscientious" consumers. In addition, there remain concerns about the potentially inequitable impact on developing-country exporters.

Food miles initiatives are a blunt and ineffective tool for measuring the environmental impact of food production and trade, and they may have perverse impacts, for example where imported produce is more energy efficient than local products despite the distance travelled. Neither carbon labelling nor food miles initiatives take into account consumer energy use in shopping and food preparation. Moreover, they could have a negative impact on vulnerable exporting countries, like high-value fruit and vegetable exporters in sub-Saharan Africa. There is strong evidence of a lack of a scientific basis in decision-making and insufficient transparency in the climate standard setting process. This should be of concern to exporters, particularly in developing countries.

II. Organic Agriculture: A Productive Means of Low-carbon and High Biodiversity Food Production

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» Innovative management options, such as organic farming, offer promising opportunities to reconcile the objectives of feeding a rapidly growing human population with minimal adverse impacts on the environment.

» Because of the multiple benefits of organic farming, including the soil sequestration of carbon, the current international efforts to mitigate and adapt to climate change and its consequences provide governments with an ideal platform for fostering a shift towards more sustainable agricultural production.

» Among the policy tools to promote more sustainable agricultural practices, this text highlights the importance of publicly funded research and extension work.

A. Introduction

At present, agriculture faces unprecedented challenges and exciting opportunities globally. The challenges result from the need to secure food supply for a rapidly growing human population, while at the same time having to minimize adverse impacts of agricultural production on the environment. Exciting opportunities relate to new management options, opened up by alternative production targets, technological developments and changing consumer preferences.

A shift towards sustainable agricultural production entails the adoption of comprehensive, more system-oriented strategies. Such strategies include farm-derived inputs and productivity based on ecological processes and functions. Furthermore, it involves the traditional knowledge and entrepreneurial skills of farmers (IAASTD, 2008). Currently, system-oriented sustainable practices include organic farming, low external input sustainable agriculture (LEISA), integrated pest management, integrated production (IP) and conservation tillage. The most consistent approach of these is organic farming. Because of bans or restrictions on the use of many direct control techniques such as pesticides, herbicides, fast acting fertilizers or veterinary medicines, organic farmers rely heavily on preventive and system-oriented practices.

The current international efforts to combat climate change and its consequences provide governments with an ideal platform for fostering a shift towards more sustainable agricultural production. Organic farming generates significant environmental and developmental benefits, including better resource management and more remunerative incomes. In addition, sustainable production of agro-energy and carbon sequestration in soils potentially offers alternative sources of income to farmers. As pointed out in the introductory chapter of this Review, this means that an increase in organic farming at the global level would not only contribute very significantly to general developmental and environmental improvements, but could also make a significant contribution to climate change mitigation and adaptation.

B. Characteristics of organic food and farming systems

Modern organic farm management aims at maximizing the stability and homeostasis of agro-ecosystems. It builds on improving soil fertility through the incorporation of legumes and compost and by strengthening the local recycling of nutrients and organic matter. It uses many preventive measures copied from nature in order to regulate pests and diseases in crops and livestock. Moreover, since it is free from synthetic pesticides and undergoes only gentle and careful processing, using few additives, organic agriculture offers consumers high-quality and healthy food.

The organic concept of how to farm, produce and process foods is globally regulated by a range of very similar standards. Trade is enabled by third-party certification from accredited bodies. In addition, and in order to meet the needs of smallholder farmers and local, low-income consumers, tens of thousands of

farms in developing countries are engaged in participatory guarantee systems (PGS). Furthermore, a fast growing number of farmers in developing countries are considered non-certified organic. They deliberately use organic technologies that optimize nutrient flows, and use local resources such as native seeds and traditional knowledge, instead of synthetic chemical pesticides or fertilizers.

Organically farmed and third-party-certified land (including in-conversion areas) amounts to 32.2 million hectares or 0.64 per cent of total global agricultural land area. It is most advanced and widely practiced in European countries (e.g. the Alpine region), Scandinavia and in some Mediterranean countries (where it constitutes 5–15 per cent of the agricultural land area). In developing countries, permanent crops such as coffee, tea, cocoa, coco nuts and olives are increasingly produced according to organic standards in order to satisfy fast-changing consumer habits. The global market for certified organic products has grown to 33.7 billion euros (Willer and Kilcher, 2009).

C. Multifunctional characteristics of organic farming

The unsustainable production of food, feed, fibre and fuel has strongly degraded global ecosystems and the services those systems provide for human survival (Millennium Ecosystem Assessment, 2005). Such ecosystem services include, for example:

- Provision of pure water,
- Recycling of organic matter and nutrients,
- Regulation of climate and weather events by fertile soils,
- Regulation of crop pests and diseases through biodiversity and natural enemies, and
- Pollination of crops by wild animals.

The pace of this degradation has not yet been halted or reversed, although sustainability has become the axiom of agricultural policy. The global loss of fertile soils, for example, is continuing at an annual rate of 10 million hectares (Pimentel et al., 1995). Consequently, an area close to the size of that under arable crop cultivation in Germany disappears by wind and water erosion every year, and is therefore lost for food production, due to unsustainable farming techniques.

No other form of agriculture and food production can claim to offer so many benefits to consumers and to provide such a bounty of public goods as organic farming and food systems. These claims are substantiated by scientific evidence (for a comprehensive review of the literature, see Niggli et al., 2008b; UNCTAD, 2006; Scialabba El Hage and Hattam, 2002; and Stolze et al., 2000). The most notable environmental advantages are summarized below.

1. Biodiversity

Biodiversity is an important driver for the stability of agro-ecosystems (Altieri and Nicholls, 2006), and hence for a continuously stable supply of food. In organic agriculture, biodiversity is both a means and an end. As organic farmers cannot use synthetic substances (e.g. fertilizers, pesticides and chemicals), they depend on carefully restoring the natural ecological balance. At farm level, diversity is practised through various farm activities (e.g. by adding value through processing and direct marketing, or by combining farming with farm schools, visits and adult courses). In the fields, diversity is achieved by multiple crop rotations or agroforestry. Ultimately, organic farms cannot be operated in the long run simply by cultivation that focuses only on economically attractive crops.

The diversity of species on organic farms is predominantly the result of the very specific organic techniques of farmers, including banning the use of pesticides, herbicides and fast-release fertilizers. An organic farm becomes more successful in a diversified landscape where there are sufficient semi-natural landscape elements like hedgerows, fallow ruderal habitats and wildflower strips, which serve as natural means of controlling pests (Zehnder et al., 2007). Soil quality management (e.g. enrichment with compost), tillage practices (e.g. conservation tillage), crop rotation and intercropping are important additional measures, aimed at lowering the risk of pest and disease outbreaks. It is therefore in the economic interest of organic farmers to enhance diversity at all levels, because organic weed, pest and disease management would fail without high diversity.

Comparative biodiversity assessments on organic and conventional farms reveal a 30 per cent higher species diversity and a 50 per cent greater abundance of beneficial animals in organic fields (Bengtsson, Ahnstrom and Weibull, 2005; Hole et al., 2005). The higher biodiversity applies to many different taxonomic groups, including micro-organisms, earthworms, insects and birds (Hole et al., 2005). In regions where the number of organic farms has increased, the diversity and abundance of bees has grown considerably, which contributes to the pollination of crops and wild plants over larger areas (Rundlöf, Nilsson and Smith, 2008).

2. Lower negative environmental impacts

The high dependence of traditional farming on chemical fertilizers, herbicides and pesticides has caused considerable environmental damage. Due to the ban of chemical fertilizers on organic farms, 35 to 65 per cent less nitrogen leaches from arable fields into soil zones where it could degrade ground and drinking water quality (Drinkwater, Wagoner and Sarrantonio, 1998; Stolze et al, 2000). Other nutrient elements like potassium and phosphorous are not found in excessive quantities in organic soils, which increases their efficient use (Mäder et al., 2002). Since synthetic herbicides and pesticides are not applied in organic farms, they cannot be found in their soils, surface and groundwater.

3. Stable soils – less prone to erosion

Fertile soils with stable physical properties have become the top priority of sustainable agriculture. Essential conditions for fertile soils are vast populations of bacteria, fungi, insects and earthworms, which build up stable soil aggregates. There is abundant evidence from European, United States, Australian and African studies that organic farms and organic soil management enhance soil fertility. Compared to conventionally managed soils, organically managed ones show higher organic matter contents, higher biomass, higher enzyme activities of microorganisms, better aggregate stability, improved water infiltration and retention capacities, and less water and wind erosion (Edwards, 2007; Fliessbach et al., 2007; Marriott and Wander, 2006; Pimentel et al, 2005; Reganold, Elliot and Unger, 1987; Reganold et al, 1993; Siegrist et al., 1998). The fact that organic farmers use a plough periodically in order to bury weed roots and seeds does not render their soils more prone to erosion (Teasdale et al., 2007; Müller et al., 2007).

4. Carbon sequestration

Organic farmers use different techniques for building up soil fertility. The most effective ones are fertilization by animal manure, by composted harvest residues and by leguminous plants as (soil) cover and (nitrogen) catch crops. Introducing grass and clover leys into the rotations as feedstuff for ruminants and diversifying the crop sequences, as well as reducing ploughing depth and frequency, also augment soil fertility. All these techniques also increase carbon sequestration rates in organic fields. Long-running field experiments in the United States and Europe reveal significant carbon gains in organically managed plots, whereas in the conventional or integrated plots soil organic matter is exposed to losses by mineralization (table 7). The average difference in the annual sequestration rate between the best organic and the worst conventional management in four field trials in Germany, Switzerland and the United States amounted to 590 kg of carbon (or 2.2 tons of CO_2) per hectare of arable land. A further increase of carbon capture in organically managed fields can be measured by reducing the frequency of soil tillage. In the Frick experiment in Switzerland (table 7) the annual sequestration rate was jacked up to 3.2 tons of CO_2/hectare per year by not turning the soil with a plough, but by preparing the seedbed by loosening the soil with a chisel plough instead.

5. More efficient use of nitrogen, less greenhouse gas emissions on organic farms

In agro-ecosystems, mineral nitrogen in soils boosts crop productivity. Crop productivity has increased substantially through the use of heavy inputs of soluble fertilizers – mainly nitrogen – and synthetic pesticides. However, only 17 per cent of the 100 Mt of industrial nitrogen produced in 2005 was taken up by crops. The remainder was lost to the environment (Erisman et al., 2008). Between 1960 and 2000, the efficiency of nitrogen use for cereal production decreased from 80 per cent to 30 per cent. High levels of reactive nitrogen (NH_4, NO_3) in soils may contribute to the emission of nitrous oxides, and are a major source of agricultural emissions. The efficiency of fertilizer use decreases with increasing fertilization, because a large part of the fertilizer is not taken up by the plant but instead emitted into water bodies and the atmosphere.

In organic agriculture, the ban on industrially produced nitrogen and the reduced livestock density per hectare considerably decrease the concentration of easily available mineral nitrogen in soils, and thus, N_2O emissions. Furthermore, diversifying crop rotations with green manure improves soil structure and diminishes N_2O emissions. Soils managed organically are more aerated and have significantly lower mobile nitrogen concentrations, which further reduces N_2O emissions. As a result, the limited availability of nitrogen in organic systems requires careful, efficient management (Kramer et al., 2006). In a long-running field trial in Switzerland, lasting 32 years, the total nitrogen input into an organic arable crop rotation over 28 years was 64 per cent of the integrated/conventional rotation; the

Table 7. Comparison of soil carbon gains/losses in different farming systems in field experiments

Field trial	Components compared	Carbon gains (+) or losses (-) (kg. of carbon/ ha per year)	Relative yields of respective crop rotations (%)
DOK[a] Experiment, Research Institute FiBL and Federal Research Institute Agroscope (Switzerland) (Mäder et al., 2002; Fliessbach et al., 2007) Running since 1977	Organic, with composted farmyard manure	+ 42	83
	Organic, with fresh farm-yard manure	- 123	84
	Integrated production, with fresh farmyard manure and mineral fertilizer	- 84	100
	Integrated production, stockless, with mineral fertilizer	- 207	99
SADP,[b] USDA-ARS, Beltsville, Maryland (United States) (Teasdale et al., 2007) Running 1994 to 2002	Organic, reduced tillage	+810 to + 1 738	83
	Conventional, no tillage	0	100
Rodale FST, Rodale Institute, Kurtztown, Pennsylvania (United States) (Hepperly et al., 2006; Pimentel et al., 2005) Running since 1981	Organic, with farmyard manure	+ 1 218	97
	Organic, with legume-based green manure	+ 857	92
	Conventional	+ 217	100
Frick[c] Reduced Tillage Trial, Research Institute FiBL, (Switzerland) (Berner et al., 2008) Running since 2002	Organic, with ploughing	0	100
	Organic, with reduced tillage	+ 879	112
Scheyern[d] Experimental Farm, University of Munich, Germany (Rühling et al., 2005), Running since 1990	Organic	+ 180	57
	Conventional	- 120	100

Note: Data given as C; for conversion into CO_2 multiply by 3.67.

[a] In the DOK trial, all plots started with exactly the same soil organic matter (SOM) content. In the organic treatment where the farmyard manure was applied as compost, the SOM slightly increased, whereas in the organic and integrated systems with fresh manure, the SOM slightly decreased. The integrated treatment with mineral fertilizers (stockless) showed a significant annual carbon loss. The difference between the best organic practice and the stockless integrated production was 249 kg of carbon/ha per year. DOK = bio**D**ynamic, **O**rganic and **C**onventional farming systems.

[b] SADP = Sustainable Agriculture Demonstration Project of the United States Department of Agriculture.

[c] In the Frick trial, only organic treatments are compared (ploughing versus reduced tillage). No conventional treatment is part of the comparison.

[d] In Scheyern, the experimental farm is separated into two parts: a conventional and an organic one. The organic rotation is situated on poorer soils, which explains the bigger differences in yields.

total organic yields over the same period were 83 per cent of the conventional ones. This demonstrated that organic farms use nitrogen in a more efficient and less polluting way (Mäder et al., 2002).

In a simplified scenario, a conversion of global agriculture to organic farming would reduce the greenhouse gas (GHG) emissions of the agricultural sector considerably and make agriculture almost GHG neutral (Niggli et al., 2009). GHG emissions in CO_2 equivalents, stemming from the production and application of nitrogen fertilizers from fossil fuel, are estimated to be 1,000 million tons (2 per cent of total global GHG emissions). These emissions would not occur using an organic approach, so that the GHG emissions of agriculture would be reduced by roughly 20 per cent. Another 40 per cent of the GHG emissions of agriculture could be mitigated by sequestering carbon into soils. For the assumption we calculate a modestly increased sequestration rate of 100 kg of carbon/ha per year for pasture land and 200 kg of carbon/ha per year for arable crops (see table 6). By combining organic farming with reduced tillage, the sequestration rate can be increased to 500 kg of carbon/ha per year in arable crops as compared to ploughed conventional cropping systems. This would reduce GHG emissions by another 20 per cent.

The scenario described above would mitigate total global GHG emissions by 6 to 9 per cent (from 2008

levels). In an in-depth study for Austria, a conversion to organic farming was modelled to reduce the Austrian GHG emissions by 3 per cent (Freyer and Dorninger, 2008). With the much higher sequestration rates as measured in the Rodale experiment in Pennsylvania (table 7), LaSalle and Hepperly (2008) estimated the potential for mitigation from organic agriculture to be 25 per cent of the total GHG emissions of the United States. This spread of the mitigation potential of different scenarios demonstrates that organic farming is an important option in a multifunctional approach to climate change.

D. Organic farms are well adapted to climate change

As a result of climate change, agricultural production is expected to face less predictable weather conditions than experienced during the last century. South Asia and Southern Africa, in particular, are expected to be the worst affected by negative impacts on important crops, with possibly severe humanitarian, environmental and security repercussions (Lobell et al., 2008).

Thus the adaptive capacity of farmers, farms and production methods will become especially important to cope with climate change. As unpredictability in weather events will increase, robust and resilient farm production will become more competitive and farmers' local experiences will be invaluable for permanent adaptation. Organic agriculture stresses the need to use farmer and farmer-community knowledge, particularly about such aspects as farm organization, crop design, manipulation of natural and semi-natural habitats on the farm, use or even selection of locally appropriate seeds and breeds, on-farm preparation of fertilizers, natural plant strengtheners and traditional drugs and curing techniques for livestock, as well as innovative and low-budget technologies. Tengo and Belfrages (2004) describe such knowledge as a "reservoir of adaptations".

Techniques for enhancing soil fertility help to maintain crop productivity in case of drought, irregular rainfall events with floods and rising temperatures. Soils under organic management retain significantly more rainwater thanks to the "sponge properties" of organic matter. Water infiltration capacity was 20 to 40 per cent higher in organically managed *loess* soils in the temperate climate of Switzerland when compared to conventional farming (Mäder et al., 2002). Pimentel et al. (2005) estimated the amount of water held in the upper 15 cm of soil in the organic plots of the Rodale experiment at 816,000 litres/ha. This water reservoir was most likely the reason for higher yields of corn and soybean in dry years. During torrential rains, the rate of water capture in the organic plots was approximately 100 per cent higher than in the conventional ones (Lotter, Seidel and Liebhardt, 2003). This significantly reduced the risk of floods, an effect that could be very important if organic agriculture were practiced over much larger areas. Similar findings, that organic farming improves the physical properties of soils and therefore the drought tolerance of crops, were made in on-farm experiments in Ethiopia, India and the Netherlands (Pulleman, et al., 2003; Eyhorn, Ramakrishnan and Mäder, 2007; Edwards, 2007).

The capacity of farms to adapt to climate change depends not only on soil qualities, but also on their diversity of species and diversification of farm activities. The parallel farming of many crop and livestock species greatly reduces weather-induced risks. Landscapes rich in natural elements and habitats buffer climate instability effectively. New pests, weeds and diseases – the results of global warming – are likely to be less invasive in natural, semi-natural and agricultural habitats that contain a high number and abundance of species (Zehnder et al., 2007; Altieri, Ponti and Nicholls, 2005; Pfiffner, Merkelbach, and Luka, 2003).

E. Can organic farming feed the world?

The fast growing human population gives rise to the crucial question as to whether organic farming could feed the world. The indisputable advantages of organic farming in delivering public goods and services shrink if too much land is needed to produce food. The question of the productivity of organic systems was addressed by a group of scientists led by Professor Ivette Perfecto at Michigan University. Analysing the yields of hundreds of plot and farm experiments, and comparing organic and conventional farming, they concluded that organic agriculture could feed considerably more people than the current world's population of 6.7 billion (Badgley et al., 2007). According to other review papers, yields of organic crops may be reduced by 30 to 40 per cent in intensively farmed regions under best geo-climatic conditions. In less favourable crop growing regions, organic yields tend to match conventional ones. In the context of subsistence agriculture, and in regions with periodic

disruptions of water supply (droughts, floods), organic agriculture is competitive vis-à-vis conventional agriculture, and often superior with respect to yields. The Capacity Building Task Force (CBTF) on Trade, Environment and Development of UNEP and UNCTAD recently published the results of numerous case studies showing that, in comparison to traditional subsistence farming, yields were more than double (with a mean of 116 per cent) by applying organic farming practices, especially through more diverse crop rotations, integration of legumes and through closing the cycles of plant nutrients and organic matter on farms or in regions. (For data on the competitiveness and performance of organic agriculture see, for example, Badgley et al., 2007; Halberg et al., 2006; UNEP-UNCTAD, 2008b.)

The picture painted by many critics of organic farming, that it is unproductive and technophobic, is misleading. In many cases, organic farming is very productive. In addition, organic farming systems use many modern technologies like bio-pesticides, natural fertilizers and parasitic or predatory insects or microorganisms in a smart way. Even in the case of highly controversial technologies like genetic engineering, organic farming uses selectively some tools (e.g. molecular markers in breeding or in the diagnosis of pest and disease incidence in crops and livestock). Actually, there is no contradiction between organic rules and cutting-edge technologies. Technologies are banned in cases where risks are increased, where precaution is necessary and prevention offers better solutions. The ban of synthetic nitrogen showcases this strategy: organic farmers manage nitrogen derived from organic matter, soils and legumes more carefully and with fewer losses, as nitrogen is scarce. As a result, organically managed soils are more fertile and resilient to diseases and drought. This also makes organic farmers independent of rising oil prices and imported synthetic inputs, and reduces the environmental impact of farming considerably (Granstedt, 2006; Crews and Peoples, 2004).

The overall concept of organic agriculture offers ample scope to increase the productivity of farms on the basis of eco-functional intensification. In conventional farming, "intensification is understood primarily as using a higher input of nutrient elements and of pesticides per land unit. It also means more energy (direct for machinery and indirect for inputs). Finally, it focuses on better exploiting the genetic variability of plants and animals; to do so, all available breeding techniques, including genetic engineering, are used" (Niggli et al., 2008b). Eco-functional intensification on the other hand "means, first and foremost, activating more knowledge and achieving a higher degree of organization per land unit. It intensifies the beneficial effects of ecosystem functions including biodiversity, soil fertility and homeostasis. It uses the self-regulating mechanisms of organisms and of biological or organizational systems in a highly intensive way. It closes material cycles in order to minimize losses (e.g. compost and manure). It searches for the best match between environmental variation and the genetic variability of plants and livestock" (Niggli et al., 2008b).

As in all food and farming systems, progress is the result of scientific research and educational activities. Technology and knowledge which is well adapted to organic food chains is not among the priorities of public and private funding. Thus it is completely underdeveloped in most parts of the world. Even in Europe, where organic farming research is the most advanced, annual spending for organic food and farming research is less than 80 million euros (Niggli et al., 2008b) – probably less than 1 per cent of private and public research and development (R&D) budgets.

F. Conclusions

Recently, the CBTF made 35 recommendations to developing-country governments on how they could promote their organic agricultural sector (UNEP-UNCTAD CBTF, 2008a). These recommendations are globally applicable, as comparable institutional, economic and political obstacles to organic farming are common in all countries. Many of them are low-cost measures which can be integrated into existing policies and implemented by existing organizations or units.

In the author's view, the most important actions concern the shift of publicly funded research and extension work towards a focus on sustainable ecosystem-based agriculture. This will create many novel solutions to bottlenecks that reduce the productivity of organic and near-organic sustainable food and farming systems. Organic food chains and organic production systems have to be analysed using cutting-edge scientific approaches, and their impact on landscapes, rural areas and society should be modelled. Governments should give incentives to scientists, teachers and advisers to value farmers' knowledge and sup-

port farmer-to-farmer exchanges. Recent studies show considerable financial and non-financial benefits where cooperation is high at all levels of food chains (Stolze et al., 2007).

Third-party certification is an important tool for accessing international markets and for creating trust in anonymous producer-consumer situations. In addition, governments should encourage/promote PGS for local markets, mainly for smallholder farmers and low-income consumers in developing countries. Such systems strengthen farmer-consumer cooperation, and instil a sense of responsibility and cooperation (and mutual control) among farmers (UNCTAD, 2008). The International Federation of Organic Agriculture Movements (IFOAM), as the pioneer in organic regulations and criteria-setting for certification, should promote PGS as it can underpin organic agriculture's role in addressing poverty in a sustainable way.

Many governments give false incentives to agriculture (e.g. by subsidizing agrochemicals, mineral fertilizers, fuels or specific crops like maize). This makes organic techniques (e.g. managing manure and waste in a proper way, growing legumes or diversifying crop rotations) economically less competitive. These ill-conceived incentives should be revised or abandoned, as they also have adverse environmental impacts. Specific social objectives or hardships could be better addressed through direct income support measures.

International organizations should increase their efforts at facilitating South-South cooperation and knowledge exchange at all levels of organic food chains. And finally, national and international organic farmers' organizations should become more actively involved in developing innovation. Much effort has gone into the consistent implementation of a pioneering idea through standardization, harmonization and market development over the last 15 years. At the same time, there is a certain backlog in organic agriculture. The combination of organic farming and reduced tillage, for instance, would offer huge carbon sequestration options and could become the basic requirement for GHG credit schemes.

Organic agriculture is more than a less polluting form of food production. It basically raises questions about the food habits of people in the developed and emerging regions of the world. As organic farms have lower livestock densities because of their environmental impact, and because they ban factory farms more land is available for vegetable production with a seven times higher calorie output for human nutrition. Consequently, organic agriculture inculcates an eating pattern involving less meat and dairy foods and a higher proportion of vegetables and fruits. Good for health thus becomes good for the environment and good for global food security!

III. Developing Low-carbon Agricultural Projects within Global Carbon Markets: Opportunities and Challenges

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- About 70 per cent of the economic potential for mitigation is in developing countries, where the agricultural sector is often a significant source of GHG emissions but also a primary source of employment.
- GHG mitigation activities in agriculture have co-benefits for and offer synergies with other policy objectives such as food and energy security, rural development and poverty alleviation goals.
- The extent to which developing countries will be able to scale up mitigation measures depend on their receiving the necessary assistance in the form of technology, financing and capacity-building support for implementing nationally-defined strategies. It requires, in addition, building capacity and awareness at the grassroots level (i.e. among farmers), improving the CDM/VCM for agricultural emissions and clarifying ambiguities in project-based carbon accounting in this sector.

One third of the world's population is engaged in agriculture and allied activities as a means of livelihood and subsistence. Agriculture accounted for estimated emissions of 5.1 to 6.1 Gt CO_2-eq/yr in 2005 (10-12 per cent of total global anthropogenic GHG emissions). Of these emissions, methane (CH_4) contributed 3.3 Gt CO_2-eq/yr and nitrous oxide (N_2O) another 2.8 Gt CO_2-eq/yr. Of global anthropogenic emissions in 2005, agriculture accounted for about 60 per cent of N_2O and for about 50 per cent of CH_4 (Smith P et al., 2007).

Globally, agricultural CH_4 and N_2O emissions increased by nearly 17 per cent from 1990 to 2005, representing an average annual increase of about 60 Mt CO_2-eq/yr (UNFCCC, 2009a). The growth in emissions from the agricultural sector is driven by the increase in population in developing countries, changes in food habits/patterns and an increase in energy-intensive agricultural practices. Hence, while emissions from agricultural activities in developing countries rose by 32 per cent during the period 1990–2005, they fell by 12 per cent in developed countries during the same period.[18] Agriculture is also a major driver of deforestation and forest degradation in developing countries, which result in the release of carbon previously stored in the forests. Although China and India are the major emitters of GHGs from agricultural practices,[19] their per capita emissions are less than 1 ton of CO_2-eq/yr, which is half the emission level of the United States and only about 20 per cent that of Australia.

Any action towards mitigating emissions in the agricultural sector in developing countries will have widespread social and economic effects. This is apparent from the fact that the workforce engaged in agriculture in China, India and Indonesia constitutes 66, 59 and 47 per cent, respectively, of their total workforce, and this sector accounts for 15, 23 and 17 per cent, respectively, of their GDP. GHG emissions from agriculture represent about 13 per cent of cumulative GHG emissions in China[20] and about 11 per cent of cumulative emissions in India.[21]

It has been estimated that carbon sequestration in agricultural soils has a mitigation potential of 1 to 4 billion tones of CO_2/yr. This represents between 11 and 17 per cent of the total estimated GHG mitigation potential. Of this, 70 per cent of the mitigation potential lies in developing regions (UNFCCC, 2009a). This potential was overlooked by the Kyoto Protocol, as it did not include stand-alone soil carbon sequestration as a GHG mitigation activity under the Clean Development Mechanism (CDM). This can be attributed to various policy reasons and issues relating to monitoring and verification of emission reductions. The process of monitoring of such projects is difficult and costly in most developing countries because farmers generally have small, scattered landholdings. Thus governments' efforts involving field testing and research, coupled with capacity-building, have been inadequate so far. This has been compounded by a very low level of awareness among small subsistence farmers and poor access to information regarding carbon emission mitigation options.

A. Challenges and future policies

About 70 per cent of the economic potential for mitigation is in developing countries, where the agricultural sector is often a significant source of GHG emissions but also a primary source of employment. Therefore, it was suggested at the 7th session of the Ad hoc Working Group on Long-Term Co-operative Actions on Climate Change that nationally appropriate mitigation actions (NAMAs) could be implemented in this sector in the context of national mitigation strategies and sustainable development. The extent to which developing countries will be able to scale up these activities will depend on their receiving the necessary assistance in the form of technology, financing and capacity-building support for implementing NAMAs.

There are technical, social, economic and environmental challenges in implementing practices and programmes for GHG emission mitigation measures in the agricultural sector.

- The major technical difficulties in implementing GHG emission reduction practices include collecting reliable data and monitoring emissions to validate emission reductions in scattered agricultural plots, and a lack of clarity regarding the effects of mitigation measures on the overall carbon and nitrogen cycles.
- The second barrier is the reluctance of farmers to adopt new technologies like reduced tillage and non-flooded intensive rice cultivation. Traditionally, farmers have been practicing flooded paddy (rice) cultivation and tilling for thousands of years, and hence are often reluctant to abandon such time-tested practices in favour of new technologies and practices.
- Adaptation of new technologies is costly and not affordable for most farmers in developing countries who eke out a living through subsistence farming.
- Although agriculture has been recognized as a major source of GHG emissions, there is as yet no fully comprehensive understanding of the functioning of nitrogen and carbon cycles, and therefore of the precise effects of agriculture-related GHG mitigation actions.
- One of the challenges to GHG mitigation in agriculture is the need for increased food production to support the growing global population.

The major barriers to the diffusion of GHG mitigation technologies in the agricultural sector thus include an incomplete understanding of the complex carbon and nitrogen cycles responsible for emission and sequestration of GHGs (as mentioned earlier), the high cost and non-availability of the appropriate technologies in developing countries, the risk of losing the carbon stored in the soil because of changes in soil carbon management, the failure of market mechanisms to reward farmers who adopt mitigation measures, lack of information and specific data at the regional and national levels to enable assessments of emissions in the agricultural sector, and the lack of development of reliable national baselines as well as complex methodologies[22] for carrying out proper assessments.

A variety of strategies have been envisaged for mitigation of GHG emissions in agriculture. The most important options are improved management of cropland and grazing land, restoration of organic soils that have been drained for crop production, replacement of chemical fertilizers with organic fertilizers, and intensive rice cultivation techniques. The mitigation measures generally involve the adoption of new technologies and improved agricultural practices, thereby shifting away from traditional, less efficient methods. Hence it is important that traditional wisdom, practices and culture, including the impact on indigenous and local communities, are taken into account when considering new technologies for the sector by incorporating appropriate modifications and adaptations.

In addition, a combination of existing and new sources of financing, including carbon market instruments and investments, technology transfer and deployment, and capacity-building, are needed for enhancing mitigation of GHG emissions in the sector. Dedicated funds for financing the adaptation of new technologies for low-carbon agriculture need to be established in developing countries. Preferential credits at lower interest rates and deferred repayment (possibly with the help of benefits accrued from carbon credits) may be options worth considering. To motivate national governments and help poor countries implement such schemes, a global funding pool could be established for financing such activities.

Technology transfer and capacity-building are also important for encouraging the adoption of low-carbon agricultural practices. Technology development and transfer is encouraged by both the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. Technology transfer not only helps in the rapid diffusion of knowledge; it also allows developing countries to access new technologies at much more affordable prices. Technology transfer should also involve the modification of exist-

ing techniques to suit the needs and socio-cultural practices of the relevant countries where they are adopted.

The identified strategies which need to be pursued for significant reductions in GHG emissions in the agricultural sector are: fertilizer switching (from chemical/synthetic to organic), system of rice intensification (SRI) involving reduced flooded irrigation, reduced tillage/residue management, agricultural waste management and reduced methane emissions through flaring of biogas and improved livestock waste management. While approved CDM methodologies exist for curtailing methane emissions from livestock waste and agricultural residue, relevant methodologies are still to be approved for SRI. Soil carbon management is still not qualified under CDM as a stand-alone GHG mitigation measure.

B. Synergy with other mitigation options

Agriculture-based climate change mitigation measures are often linked with sustainable development policies. Such measures may therefore influence social, economic and environmental aspects of sustainability. Thus GHG mitigation activities in agriculture could develop synergies with food and energy security, sustainable development goals and poverty alleviation in developing countries (UNFCCC, 2009b).

According to the World Bank (2008), if carbon-trading schemes were extended to provide financing for avoiding deforestation and for soil carbon sequestration, they could offer significant untapped potential to reduce emissions from land-use change in agriculture. Unsustainable agricultural practices like conversion of forest land for permanent commercial agriculture (e.g. palm oil plantations, soybean fields) and large-scale shifting cultivation (i.e. slash-and-burn, particularly short-cycle shifting cultivation), where forest is not allowed to regenerate due to subsequent clearing, are considered some of the major drivers of deforestation (ECOFYS and Max Planck Institute for Biogeochemistry, 2008). A successful mechanism for reducing emissions from deforestation and forest degradation in developing countries (REDD) will require adaptation measures to improve agricultural productivity, especially of small landholders who face economic and cultural barriers to access such measures. REDD strategies intended to wean farmers away from destructive cyclical cultivation practices are also conducive to biodiversity conservation. Thus, optimizing REDD and carbon sequestration objectives with other environmental co-benefits will need to take into account inputs and outputs over the whole agricultural cycle (Angelsen, 2008).

It is estimated that 30 per cent of total deforestation of the Amazon rain forest between 2000 and 2005 was for small-scale subsistence agriculture and 60 per cent for cattle ranching (Sanz, 2007). The consequences of stagnating agricultural productivity in developing countries, not to mention the increasing population and its adverse effects on the environment, are reflected in the fact that a mere 1 per cent rise in crop yield will result in avoided emissions from forest degradation of about 170 million tons of CO_2 and save about 7,000 species from extinction (Gockowski, 2008).

Unsustainable agriculture practices can result in negative environmental impacts like underground water depletion, agrochemical pollution, soil exhaustion and global climate change. Thus, managing the linkages between agriculture, natural resource conservation and the environment has to be a fundamental element of agriculture with a view to sustainable development.

Recognizing the need for optimizing GHG mitigation measures in the agricultural sector, the Bonn Climate Change talks (UNFCCC 2009a) have suggested the following steps that should be taken as a priority:

- Undertaking coordinated actions between national and regional parties for pilot activities to validate methodologies for agricultural mitigation and capacity-building projects;
- Mobilizing resources and rewarding countries that adapt such measures, and developing the appropriate mechanisms (including investment and carbon market mechanisms and lowering tariff barriers) required for “greening” agricultural production;
- Ensuring delivery of expected emission reductions and promoting implementation of best practices;
- Promoting technology transfer, technology deployment and increased R&D; and
- Developing methodologies for measuring, reporting and verifying emissions from this sector.

As a major source of GHG emissions, agriculture inherently offers considerable scope for mitigation. The mitigation measures can be categorized as land-use related, energy related and waste-management related. Land-use-related measures, such as residue management, low tillage, fertilizer switching and SRI, have not yet been taken up aggressively in the inter-

Table 8. Mitigation measures and their eligibility under the current climate change mitigation regime

Mitigation strategies	Possible measures	GHG emission mitigation effects			Recognition of measure as a GHG mitigation activity		Approved CDM/VCM methodology available
		CO_2	CH_4	N_2O	CDM	VCS, 2007	Yes/no
Cropland management	Low tillage/ residue management	✓				✓	Available for reduced tillage – indicative only, with limited scope
	System of rice intensification (reduced flooded irrigation)		✓		✓	✓	No
	Use of organic fertilizers			✓	✓	✓	Yes, with limited scope
Management of organic soils	Avoiding drainage of organic soils	✓				✓	No
Manure management/ animal waste management	Anaerobic digestion		✓		✓	✓	Yes
	Flaring of biogas;		✓		✓	✓	Yes
	Biogas for domestic use		✓		✓	✓	Yes
Energy efficiency and fuel switching	Improving energy efficiency of irrigation systems (e.g. drip irrigation, pump-sets); use of low-emission fuels in farming	✓	✓		✓	✓	Yes, with limited scope
Renewable energy technologies	Wind, biomass, solar, biofuels	✓			✓	✓	Yes, with limited scope

VCM - voluntary carbon market
VCS - voluntary carbon standard

national carbon market. Although some of the important agricultural land-use-related measures, such as soil carbon sequestration, are being implemented in projects of the Chicago Climate Exchange, they are still unexplored in other regimes. Stand-alone soil carbon sequestration is not eligible in CDM as of now, though it may be explored for inclusion in the future. However, new CDM/VCM methodologies will need to be developed for these measures. Agri-waste management is a widely accepted and practiced measure in the carbon market. Methodologies relating to energy efficiency (e.g. drip irrigation systems) and to renewable energy in agricultural practices (e.g. windmill pumps) need to be developed. While the CDM methodology AMS II.F includes energy-efficiency and fuel-switching, reduced machinery use, conservation tillage and reduced irrigation as eligible measures, it does not provide detailed accounting methods for them. There is a need to develop dedicated methodologies for each of these measures/opportunities (see table 8).

There is significant scope for GHG emissions mitigation in the agricultural sector, and most of the carbon market segments recognize these measures. Some indicative methodologies are available but are not sufficient. Less than 5 per cent of approved CDM methodologies are linked to the agricultural sector. However, this share is as low as 1.5 per cent if agri-waste management methodologies are excluded. No new CDM baseline and monitoring methodologies were in the pipeline as on 31 March 2009. A major reason for the absence of new methodologies could be that agriculture in developing countries involves mostly small landholders who are usually less aware of more environmentally friendly practices and their benefits.

Thus the strategy should be to build capacity and awareness at the grassroots level (i.e. among farmers), develop new CDM/VCM methodologies for addressing all GHG emission mitigation measures pertaining to agriculture and clarify ambiguities in project-based carbon accounting in this sector. This would require resources and transaction costs that may be borne by the agencies that perceive low-carbon agriculture as a means to sustainable development. Access to easy financing is crucial for the diffusion of low-carbon agricultural technologies among small farmers in developing countries. Such technologies, which are prevalent in developed countries, would need to be

modified in keeping with the skills and knowledge of traditional farming practices prevailing in the developing world in order to make the technologies more acceptable. Agriculture is closely linked to deforestation and the socio-cultural environment. Unsustainable farming practices that are widespread in many developing countries, which also have a large share of the world's forest resources, should be especially targeted for encouraging low-carbon-intensive agriculture practices. Implementing agencies need to bear this in mind, and should promote local knowledge and indigenous expertise in developing low-carbon agricultural projects.

Since agriculture accounts for a significant share of global emissions, it should be addressed much more in carbon mitigation schemes within global carbon markets. The need for this involvement is recognized by most stakeholders, as is the need to develop new and more robust mechanisms for inclusion of this sector in carbon markets.

IV. Sustainable Agriculture: Considerations about Methane Emissions

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» Methane is a significant contributor to climate change, and the bulk of methane emissions, i.e. 52 per cent, are emitted by the agricultural sector.

» While methane emissions in the OECD countries as well as in the CIS have declined over the past decade, methane emissions have been increasing in many developing countries and regions, With continuing growth in the demand for livestock products, methane will continue to constitute a large proportion of future GHG emissions, particularly in developing countries.

» Given their contribution to global warming, there might be a need to reduce methane emissions, particularly in countries where agricultural emissions account for a large share of total national emissions. While a number of methane mitigation strategies exist, there has been limited experience to date in the implementation of such mitigation policies.

» Mitigation policies can entail increased costs for farmers, which makes difficult their adoption in developing countries where rural poverty and income inequality are concerns, and where agriculture remains a major sector in terms of production and employment.

» The challenge will then be to design policies for managing such emissions without compromising income and poverty-reduction objectives.

A. Introduction

Greenhouse gases (GHGs) from anthropogenic sources – other than CO_2 – have accounted for 30 per cent of the enhanced greenhouse effect since pre-industrial times (IPCC, 2001). In 2000, emissions of these GHGs constituted 23 per cent of total CO_2-eq emissions. Methane is a significant contributor to climate change, as it is 21 times more effective than CO_2 in trapping heat in the atmosphere. Methane emissions amounted to 6.0 Gt, or 15 per cent of the total GHG emissions in 2000, compared with 5.8 Gt CO_2-eq a decade earlier (table 9).

The agricultural, energy and waste sectors are responsible for almost all global methane emissions. Of these, agriculture emitted 52 per cent of total global methane emissions in 2000. Methane is produced when organic materials decompose in oxygen-deprived conditions. In agriculture these are primarily from enteric fermentative digestion by ruminant livestock, from stored manure and from rice produced under flooded conditions. Of these three, enteric fermentation is the predominant source, accounting for 58 per cent of agricultural methane emissions in 2000. Natural gas and oil production account for most of the methane emitted by the energy sector, while both land-filling of solid waste and wastewater are the major emitters in the waste sector.

Both developed and developing regions are important emitters of methane (table 8). The countries of the EU and other OECD members contributed 21 per

Table 9. Methane emissions by sectoral source (Gt CO_2-eq)

Sector	1990	1995	2000	2005[a]	2020[a]
Agriculture	2.86	2.92	3.12	3.29	3.85
Energy	1.74	1.66	1.65	1.81	2.57
Waste	1.21	1.25	1.25	1.31	1.48
Global total	5.82	5.85	6.02	6.41	7.90

Source: EPA, 2006a
Note: Columns may not add up to global totals due to omission of minor sectoral sources such as industry.
[a] Business-as-usual projections.

Table 10. Total methane emissions by region (Gt CO_2-eq)

Region	1990	2005[a]	Percentage change 1990–2005	2020[a]	Percentage change 2005–2020
Africa	0.56	0.85	51.8	1.11	30.6
Cambodia, China, Laos, Mongolia, North Korea, and Viet Nam	0.86	0.99	15.1	1.22	23.2
Latin America	0.75	1.00	33.3	1.34	34.0
West Asia	0.14	0.27	92.9	0.44	63.0
Commonwealth of Independent States (CIS)	0.93	0.64	-31.2	0.78	21.9
EU-27 and other OECD	1.55	1.36	-12.3	1.45	6.6
South and South-East Asia	0.99	1.25	26.3	1.55	24.0
Global	5.82	6.41	10.1	7.90	23.2

Source: EPA, 2006a

[a] Business-as-usual projections.

cent of methane emissions in 2005, compared with almost 27 per cent in 1990, and their emissions declined by 12.3 per cent between those two years. An important driver of this outcome was the agricultural reform policies, especially in the EU. Emissions also declined over this period in the non-EU members of the Commonwealth of Independent States (CIS), due in part to the impact of their economic reforms on agricultural output and production systems. On the other hand, methane emissions have been increasing in many developing countries and regions, such as China, Africa, Latin America, South-East Asia and West Asia. For instance, those emissions increased by 93 per cent in the countries of West Asia and by 15 per cent in China between 1990 and 2005. Moreover, while methane emissions are expected to increase by 23 per cent worldwide by 2020, they are projected to grow even faster in all developing regions (table 10).

B. Livestock farming and methane emissions

Livestock farming was responsible for over one third of global methane emissions in 2005 and for two thirds of total agricultural methane emissions. Such livestock emissions arise from enteric fermentation and manure management. The former is the process whereby microbes in an animal's digestive system ferment food with methane produced as a by-product. Ruminant animals such as cattle, buffalo, sheep and goats account for the majority of these emissions which are influenced by the quantity, quality and type of feedstuffs used. Generally, lower feed quality or higher feed intake lead to higher methane emissions. Methane is also produced during the anaerobic decomposition of livestock manure, the amount emitted being dependent on the type of manure treatment or storage facility, the ambient climate and the composition (animal type and feed regimes) of the manure.

In 2005, around a quarter of livestock methane emissions took place in the developed countries of the EU and the OECD, which meant that the major sources of these emissions were developing countries. Between 1990 and 2005, total emissions from livestock declined in the OECD and EU, partly as a result of policy changes and productivity growth, and also in the non-EU members of the CIS as they transitioned to market economies (table 10). Among the high-income countries, livestock methane emissions increased somewhat in those of North America and Australasia as animal numbers increased. The Environmental Protection Agency (EPA, 2006a) projects an increase in methane emissions from livestock farming in all regions between 2005 and 2020. China, Africa, Latin America and South and South-East Asia together will account for over 90 per cent of the projected global increase.

Rapid growth in the demand for livestock products in the developing world is the principal driver of the growth in methane emissions as the share of these products in developing-country food consumption increases. Urbanization of populations in many developing regions continues to increase at a rapid pace, along with growth in per capita incomes and, in some cases, population growth. Domestic production of meat and milk has increased rapidly along with animal numbers, in response to growing demand: total production of meat and milk in Asian developing countries, for example, rose by more than 12 times and 4 times respectively from 1961 to 2004 (IPCC, 2007a).

Table 11. Livestock methane emissions[a] (Mt CO_2-eq) and projected changes

	1990	2005	2020	2005–2020 change (Per cent of global change)
OECD and EU	579	533	543	2.2
of which: North America and Australasia	264	270	283	2.9
Africa	225	294	387	20.7
Cambodia, China, Laos, Mongolia, North Korea, Viet Nam	223	309	423	25.4
Latin America	411	477	588	24.7
West Asia	21	29	38	2.0
Non-EU members of the CIS	196	109	130	4.7
South-East Asia	331	404	499	21.2
Global total	1 995	2 164	2 613	100.0

Source: EPA, 2006a
[a] Enteric fermentation plus manure management.

C. Approaches to mitigation of livestock methane emissions

Given their contribution to global warming, there might be a need to reduce methane emissions, particularly in countries where agricultural emissions account for a large share of total national emissions. In that respect, while a number of methane mitigation strategies exist, there has been limited experience to date in the implementation of policies to encourage the adoption of such strategies. For instance, agriculture (including livestock and hence methane) is included in New Zealand's emissions trading scheme (box 2), but that scheme is currently under review; Australia has delayed the decision as to how and when to include agriculture in its ETS; and the EU ETS does not include agriculture, although some individual EU member countries have started tackling their relatively high agricultural emissions (e.g. 25 per cent of Ireland's GHG emissions come from agriculture).

Mitigation options for enteric methane fall into three general categories: improved feeding practices, use of feed additives and changes to animal management and breeding (EPA, 2006b; IPCC, 2007a). Feed conversion efficiency can be enhanced by increasing

Box 2. The New Zealand Emissions Trading Scheme

The New Zealand ETS came into force in September 2008, but with a change in government later that year the scheme is currently undergoing review.

The scheme introduced a price on GHGs to provide an incentive for New Zealanders to reduce emissions and enhance forest sinks, and to develop and apply carbon-friendly techniques and technologies. In time, carbon will be viewed as another cost of production. Emissions trading provides flexibility, enabling participants to decide how they wish to comply with their obligations with a view to a least-cost response. This market-based approach requires emitters to pay for emissions increases and to be rewarded for decreases. The scheme operates within the emissions cap established by the Kyoto Protocol during its first commitment period. When fully implemented in 2013, the ETS will cover all six GHGs covered by the Kyoto Protocol. The scheme has a wide sectoral coverage – agriculture, liquid fossil fuels, stationary energy, industrial processes, synthetic gases, waste and forestry. Participants are required to match their emissions by surrendering an equivalent number of emission units, while some forestry participants are able to earn emission units for CO_2 stored or removed from the atmosphere. Participants acquire emission units by purchasing from the Government, another participant or from overseas sources, and they may acquire a free allocation from the Government.

Agriculture, the largest single source of GHG emissions in New Zealand and a major source of exports, will be included in the ETS from January 2013. The Government agreed to bear the cost of agriculture's GHG emissions during the first Kyoto commitment period provided the sector contributes to GHG mitigation research to develop effective and cost-efficient strategies. This sector is required to begin monitoring its emissions prior to 2013 to ensure relevant reporting and monitoring systems are working properly. The points of obligation within agriculture have not yet been finalized, but will include processing companies and/or individual farmers. Compliance costs will be higher if farmers are the responsible participants, but incentives to reduce emissions will be greater than if that responsibility rested with processors. A free allocation of emission units will be made initially to help offset increased costs imposed by the scheme.

the energy content and digestibility of feedstuffs so that less feed is converted to methane and more is utilized as product output. Methane emissions can be reduced by substituting concentrates for forage in animal diets, by adding oils or oilseeds to the diet and by improving pasture quality. Natural or synthetic dietary additives (such as growth hormone bovine somatotropin (bST) and antibiotics) can assist animals to use more of the potential energy available in their feed and to suppress methanogenesis. However, some countries ban the use of some of these agents, and in some cases these approaches increase emissions per animal but decrease those per unit of product output. Therefore reductions in total emissions are dependent on a sufficient decrease in total animal numbers. Such a reduction may be an approach to methane mitigation if coupled with improved animal productivity so that milk and meat outputs may still increase to meet consumer demands. Increasing animal productivity through breeding and improved management can also reduce methane emitted per unit output. For example, if meat-producing animals reach slaughter weight at a younger age, lifetime methane emissions can be reduced.

Approaches to mitigating methane emissions from manure involve the capture and use of methane through anaerobic digesters. The captured methane may also be used as an energy source – such as in small-scale decentralized systems used in China and India – thereby potentially offsetting farm purchases of electricity. Methane emissions from manure stored in tanks or lagoons can also be reduced by cooling, by the use of solid covers or through the mechanical separation of solids from slurry. Emissions from manure might also be reduced through changes to feeding regimes.

Estimates of regional and global reductions in net GHG emissions (methane and nitrous oxide) from livestock have been made (EPA, 2006b). Because some mitigation options increase yields and emissions per animal, these estimates assume either constant animal numbers or constant production (with reduced animal numbers). It is concluded that total global mitigation of these GHGs in 2020, holding animal numbers constant, would be 3 per cent at negative or zero cost. Emissions could be reduced further by around 7 per cent at a cost of $60 for each ton of CO_2-eq reduced. If production is held constant, mitigation of global emissions at $60/t of CO_2-eq increases to over 10 per cent.[23]

D. Conclusions and policy challenges

Methane, which is produced largely by the agricultural sector, is a significant contributor to climate change. However, with continuing growth in the demand for livestock products and the resulting expansion in livestock production, methane will continue to constitute a large proportion of future GHG emissions, particularly in developing countries. Whether these countries will be able to curb their methane emissions is uncertain. They have good reasons to continue to increase their livestock production: animal husbandry is seen as a pathway out of poverty for many smallholder farm households, and livestock products can make significant contributions to the human health and nutrition objectives of the developing world. But rapid livestock development leads to other problems – in addition to GHG emissions – which could be of even greater concern. For example several human diseases arise from livestock production.

While a number of methane mitigation strategies have been identified, there has been limited experience to date in the implementation of policies that encourage adoption of such strategies. With slower growth in livestock demand domestically, far superior R&D capabilities, economically more resilient livestock farmers and much larger scale production and processing, developed countries are in a considerably better position to meaningfully address methane reduction from livestock. But even these countries have not made significant strides in implementing methane reduction policies.

A major policy challenge in the developing world is posed by the structure and scale of farming. In many developing countries, farm (and livestock) production takes place predominantly within large numbers of geographically scattered, small-scale household production systems. In some countries, such as China, economic reforms and growth are encouraging structural changes whereby some small, diversified rural households are leaving farming, while others are becoming specialized household farm producers and larger scale commercialized production units are emerging. Similar trends may be found in processing activities. However, household-based livestock slaughtering and processing still remain dominant in some countries and regions, which creates problems in implementing effective mitigation policies with low associated transaction costs. Continued efforts by developing countries to modernize their livestock industry and to create market opportunities through

the development of transport and other supply-chain infrastructure, along with new market institutions and reduced trade facilitation costs, should make methane mitigation a more feasible option in the future.

Mitigation policies may be based on prices (such as emissions trading schemes and carbon taxes) or on implementation of emissions standards. Both these options can entail increased costs for emitters. This poses another challenge for developing countries, where rural poverty and income inequality are concerns, and where agriculture remains a major sector in terms of production and employment. Policies to overcome rural poverty, improve rural household incomes and narrow urban-rural income gaps are being implemented in many developing countries. As they succeed in reaching their goals, their rural sectors will be in a stronger position to bear the economic costs of mitigation. A challenge will then be to design policies for managing such emissions without compromising income and poverty-reduction objectives.

Uncertainty still abounds concerning the effectiveness of different approaches to mitigation outside original case study locations, across a range of farm production systems, managerial competencies, countries and agro-ecological zones. New research efforts are required to identify which mitigation approaches are best suited for different regions and systems, and the nature of barriers to the adoption of mitigation options. Governments can intensify their efforts, in partnership with stakeholders, to reduce such uncertainties through new research, demonstration and extension programmes. National agricultural research efforts, including those of developing countries, should be strengthened through cooperation and coordination with foreign and international research agencies and networks. In addition, programmes are needed that will help farmers and others to develop skills, knowledge and management techniques to improve effectiveness in the eventual implementation of mitigation policies.

V. Impacts of Climate Policies on Air and Maritime Transport in Developing Countries

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» The costs of international maritime and air transport may increase as a result of international climate mitigation policies. At a tax level or carbon price of $30/ton of CO_2, the costs of international maritime and air transport may increase by some $25 and $12 billion per annum respectively. Developing countries will bear part of these costs through increased costs of agricultural and other imports or through reduced exports.

» To some extent, these costs will be more significant for countries that rely on exports and are vulnerable to transportation costs, such as small island developing states and landlocked countries.

» However, economic instruments to reduce the emissions of maritime and air transport may also generate resources to finance adaptation and mitigation measures.

» A global climate policy that includes international maritime and air transport should therefore balance challenges and opportunities for developing countries.

This chapter discusses the consequences of climate change for agriculture and trade in agriculture. In this comment, we seek to highlight the impacts of mitigation policies on air and maritime transport, in particular with regard to developing countries' opportunities for trade. We argue that the costs of international maritime and air transport may increase as a result of international climate mitigation policies, and that developing countries will bear part of these costs because of higher prices of agricultural and other imports or reduced exports. To some extent, these costs will be more significant for countries that rely on exports and are vulnerable to transportation costs, such as small island developing states and landlocked countries. However, economic instruments to reduce the emissions of maritime and air transport may also generate resources to finance adaptation and mitigation measures. Therefore, a global climate policy that includes international maritime and air transport could offer opportunities for developing countries.

A. The context

Emissions from air and maritime transport deserve special attention, not least because they are substantial and still rising rapidly. In 2007, global CO_2 emissions from fossil fuels due to international maritime transport were about 870 Mtons (Buhaug et al., 2009), which is the same order of magnitude as the national emissions of, say, Germany, and twice the national emissions of Mexico. Global emissions of international aviation were 416 Mtons of CO_2 in 2005 (IEA, 2008).

Although emissions from international air and maritime transport are substantial, they are not included in the Kyoto Protocol. This protocol to the United Nations Framework Convention on Climate Change (UNFCCC) establishes legally binding commitments for the reduction of greenhouse gases (GHGs) produced by industrialized (Annex I) countries. In the run-up to the Kyoto Protocol, different options were studied to allocate emissions to countries and thus include them in the national totals, but no agreement could be reached (CE Delft, MMU and MNP, 2006). Instead, Article 2.2 of the Kyoto Protocol calls on Annex I countries to "pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively."

To date, progress on developing a climate policy to address bunker fuel emissions at the international level has been limited. At the UNFCCC level, parties have not been able to agree on a methodology to assign responsibility for emissions to States, even though a recent workshop concluded that, technically, a number of allocation issues were feasible (IISD, 2007). In addition, neither the International Civil Aviation Orga-

nization (ICAO) nor the International Maritime Organization (IMO) have been able to agree on effective implementation of mitigation policies, other than best practices in terms of air traffic management operations, in the case of ICAO, and voluntary guidelines for efficiency standards of the IMO.

However, in the build-up to the 15th Conference of the Parties in Copenhagen in December 2009, there were increasing discussions about the possibilities of developing a climate policy for aviation and maritime transport. The IMO is presently considering GHG mitigation options and the ICAO is contemplating emissions trading (ICAO, 2008). The UNFCCC is engaging in several processes to define long-term cooperative actions to be taken by all parties and further commitments to be made by Annex I parties. Consequently, it is reasonable to expect that there could be a climate policy for air and maritime transport in the (near) future.

B. The options

In the development of a climate policy, so-called *market-based options* receive special attention because of their ability to achieve GHG emissions reductions at the lowest costs. However, there are many degrees of flexibility in the design of such market-based options. The choices will affect the efficiency, effectiveness and distribution of the burden (fairness) of a climate policy.

A first major choice is between taxes and a cap-and-trade system. The former can be relatively straightforward if implemented as a levy on bunker fuel sales, for example. In a cap-and-trade system, a central authority sets a cap on the amount of GHGs that can be emitted. Companies or other groups are allocated emission permits and are required to hold an equivalent number of allowances that give the right to emit a specific amount of GHGs. If the amount of allocated permits (the cap) is less than the participants to the system would have emitted in the absence of the cap, the rights obtain an economic value. Consequently, a system of tradable permits offers an economic incentive to reduce emissions in the same manner as taxation. In this sense, there is no fundamental difference between the economic working (efficiency) of taxation and systems of tradable emission permits. The choice is predominantly determined by the kind of certainty preferred: with taxes, the economic impacts are more predictable, while the environmental impacts are more uncertain, whereas with tradable permits it is the opposite (see, for example, Weitzman, 1974; and Pizer, 1998).

A second important choice concerns the scope of the instruments: global or regional. In 2005, for example, the EU introduced the Greenhouse Gas Emission Trading System (EU ETS), covering energy and industrial installations within the EU. From 2012, the climate impact of the aviation sector will be included in the EU ETS. The scheme will cover all flights arriving at or departing from airports in EU member countries.

The third choice concerns the appropriation (recycling) of eventual revenues. Such revenues arise naturally in the case of taxation, but also when tradable emission permits are auctioned. By differentiating between countries in the use of the revenues, the net impacts of the policy on non-Annex I countries could be smaller than the net impacts on Annex I countries, for example. In that case, the principle of common but differentiated responsibilities would be satisfied.

In the following two sections, we first explain the potential impacts of mitigation policies on air and maritime transport in developing countries' opportunities for trade, assuming that the scope is global, and ignoring any recycling of revenues. Second, we discuss possibilities for mitigating undesired economic impacts by either limiting the scope of the system or the use of revenues.

C. The potential impacts

What are the potential consequences of mitigation policies for air and maritime transport on developing countries' opportunities for agricultural trade? Market-based options – both a tax and a cap-and-trade scheme – impose an additional financial burden on transport, which may result in reduced agricultural imports and exports. If a climate policy results in an increase in the price of transport, ship and aircraft owners and operators could respond in a number of ways. First, they would have the option to lower costs by taking technical or operational measures to reduce emissions, for example by increasing fuel efficiency or the load factor. However, most options to reduce emissions are expensive, particularly in the aviation sector. Therefore, the costs of a climate policy will generally be passed on to customers, who then would have the choice to pay the higher costs or lower their demand. This may have several impacts on developing countries, ranging from direct impacts, such as higher costs of food imports, to indirect impacts such as changed incentives for fragmentation of production.

Table 12. Food imports relative to GDP in selected developing countries

Country	Share of food imports in GDP, 1999–2004 (%)	Increase in costs of food imports (% of food imports by value) at $30/ton of CO_2	Increase in costs of food imports (as a % of GDP)
Sao Tome and Principe	28.02	0.37-0.62	0.10-0.17
Cape Verde	15.94	0.18-0.30	0.03-0.05
Tonga	12.77	0.33-0.55	0.04-0.07
Dominica	11.52	0.11-0.18	0.01-0.02
Samoa	11.23	0.32-0.53	0.04-0.06
Saint Lucia	10.95	0.03-0.06	0.003-0.007

Source: FAO Statistical Yearbook 2005-2006, table C.13 and CE Delft, 2008.

1. Imports

Some countries, particularly small island developing States, are highly dependent on maritime transport for their food imports. Islands import most of their food by sea, with the possible exception of perishables which may be imported by air. Table 12 presents a selection of countries where food imports account for a large share of GDP. Furthermore, the table indicates the increase in the costs of food imports assuming a tax level or emissions trading price of $30/ton of CO_2 and that all CO_2 emissions will be covered by the scheme (this tax level corresponds to roughly $90 per ton of fuel). The table shows that as a share of GDP, increased costs of food imports range from 0.003–0.2 per cent for a carbon price of $30/ton of CO_2. It should be noted, though, that food imports account for only a fraction of total imports.

2. Exports

In some countries, export-oriented industries account for a larger share of GDP than in others. A considerable proportion of these exports are transported by sea, certainly if measured on the basis of weight. If a climate policy were to be implemented for aviation and maritime transport to and from developing countries, this would have to be part of a global scheme in order to provide a level playing field for all participants. This implies that costs incurred due to a climate policy could, and generally would, be passed on to the clients of transport, thereby leaving most of the profit *margin* of agricultural producers intact. In a level playing field, the profit mark-up would not have to absorb the additional costs incurred due to a climate policy. However, climate policies that increase the costs of transport may result in *lower demand* for exports from these countries, and thus in their lower *overall* profit.

To make some rough estimates of the possible impacts of an increase in costs of maritime transport, we assume that the price level is about $30/ton of CO_2. This is about the price level of emission rights under the EU ETS, although prices have dropped recently due to the financial crisis.[24] At a fuel price of around $450/ton (the price level of July 2008),[25] fuel costs typically constitute about 30 per cent of total transport costs (Resource Analysis and CE, 2008). A carbon price of $30/ton of CO_2 ($93 per ton of heavy fuel oil) would add 21 per cent to fuel costs and 6 per cent to total transport costs. At a fuel price of around $250/ton of CO_2 (the price level of February 2009), the same carbon price would add 37 per cent to fuel costs and some 7 per cent to total transport costs.

The impact of these cost increases of maritime transport on exports is hard to assess. In the short term, they are unlikely to have an impact on the exports of manufactured goods, as transport costs make up only a small fraction of the total costs, and even if these costs were passed through in the prices, it is unlikely that this would affect demand significantly. UNCTAD estimates total freight costs (for all modes of transport) to be 5.9 per cent of the value of imports, with the share being lower in developed countries (4.8 per cent) and higher in developing countries (at an average of 7.7 per cent, ranging from 4.4 per cent in America to 10 per cent in Africa) (UNCTAD, 2007). It is not known what the maritime freight costs would be relative to the value of imports. Higher transport costs may have a larger impact on exports of raw materials, as transport costs make up a larger proportion of their total costs. Nevertheless, there will only be an impact if alternatives are available or if demand is reduced. In the longer run, higher transport costs could influence decisions to relocate production to bring it closer to markets or to halt the current trend of fragmentation

of production. However, it has to be noted that many factors affect the choice of production locations, such as relative costs of inputs of labour and materials and access to markets. Based on the above estimates, an increase of transport costs of about 6 per cent and of the share in value of transport costs in the range of 4–10 per cent would result in an estimated increase in costs of imports of less than 1 per cent on average.

As there are many other means of reducing transport apart from lowering exports (and even more ways to reduce emissions), the maximum impact of climate policies on profits would result from the impact on demand of higher transport costs. This can be calculated by applying the price elasticity of demand to the cost increase. There is only scarce information on the price elasticity of maritime transport. Oum, Waters and Yong (1990) present elasticities ranging from 0 to -1.1, with low values (-0.06 to -0.25) typically attributable to dry bulk for which there are hardly any alternative modes of transport, and higher values (0 to -1.1) attributable to general cargo. Meyrick and Associates et al. (2007) estimate the elasticity of non-bulk maritime transport to and from Australia at -0.23. Assuming an elasticity of -0.25, the 6–7 per cent rise in transport costs could result in a reduction in maritime transport of a small per cent relative to a baseline, which is forecast to grow at over 3 per cent per year (Buhaug et al., 2009). Thus the cost increase would result in sacrificing about half a year's growth. As mentioned above, the reduction in exports is likely to be lower than the reduction in transport, because a share of the transport reduction will result from logistics improvements and other measures to reduce emissions, such as slow steaming.

D. Options to mitigate economic impacts on developing countries

There are two main options to reduce the undesired economic impacts of a climate mitigation policy on developing countries: (i) limiting the scope of that policy; and (ii) using the revenues from economic instruments.

1. Limiting the scope of a climate mitigation policy

There are various options available to limit the scope of a climate mitigation policy with regard to international aviation and maritime transport.[26] First, in principle, market-based options could be applied to carriers from Annex I countries or ships registered in Annex I countries only. This would follow the line of thought literally expressed in Principle 1, Article 3 of the UNFCCC: "The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof." Since Annex I and non-Annex I country carriers may compete on the same routes, this could lead to unequal competition. But it is important to point out that such unequal competition is not necessarily *unfair* competition. The Climate Convention asks developed countries to take the lead in combating climate change and the adverse effects thereof. It is doubtful, however, whether the international community would accept unequal competition within the aviation and maritime sectors. In particular, unequal competition could be considered unacceptable between carriers from developed countries, which are subject to emission reduction obligations under the Kyoto Protocol, and carriers from developing economies, such as Singapore and Hong Kong (Special Administrative Region of China), which are not, but have highly competitive airlines. Furthermore, particularly in maritime transport, simply specifying that ships having an Annex I country flag would have to reduce their emissions while other ships would not is widely agreed to be ineffectual, as ships can easily change flags.

Therefore, a more realistic possibility is to limit the scope of a climate policy for international aviation and maritime transport by limiting the *area* or *routes* in which the policy is applied, irrespective of the flag of the carrier. This holds for example in the case of the EU ETS, which will cover all flights arriving at or departing from airports of EU member countries, regardless of the nationality of the carrier. In the view of some countries,[27] extending such a trading scheme to all Annex I countries would meet the requirements of the UNFCCC. Another possibility would be to limit the policy to traffic within and between Annex I countries, instead of including traffic between Annex I and non-Annex I countries as well.

2. Use of revenues

Market-based options raise revenues, which either might lighten the burdens in the transport sector itself or finance adaptation or mitigation policies outside the transport sector. In fact, many parties have already suggested the inclusion of international aviation

and marine emissions in a climate mitigation policy as a deliberate mechanism for raising funds to finance adaptation and mitigation in developing countries (UNFCCC, 2007 and 2008b). It is estimated that an auction of allowances for international aviation and maritime emissions or an international air travel levy could raise $10 to $30 billion per year in 2020.

There is an infinite palette of possibilities to recycle such revenues. There are conceivable schemes in which the revenues of global market-based options for international transport could be recycled in such a way that the share of revenues received by the developing countries amply outweighs their burden. However, whether such outcomes would be negotiable is a political matter, although, as mentioned previously, the UNFCCC requires the parties to develop a climate policy "on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities."

Earmarking revenues from global market-based instruments would also bring them in line with the ICAO Council Resolution on Environmental Charges and Taxes adopted in December 1996 and endorsed by the 32nd ICAO Assembly. This resolution strongly recommends "that the funds collected should be applied in the first instance to mitigating the environmental impact of aircraft engine emissions."

E. Conclusions

At a tax level or carbon price of $30/ton of CO_2 the costs of international maritime and air transport may increase by some $25 and $12 billion per annum respectively. Developing countries will bear part of these costs through increased costs of agricultural and other imports or through reduced exports. However, economic instruments to reduce the emissions of maritime and air transport may also generate the above-mentioned amounts as resources to finance adaptation measures. Although a climate policy entails net (short-term) costs on a global scale, its costs and benefits may balance out for individual countries. Given the UNFCCC principle that parties to the Convention should develop a climate policy "on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities", such a policy for international maritime and air transport offers opportunities for developing countries.

Notes

1 In this paper, market-based instruments include carbon taxes and offsets, although, strictly speaking, these are fiscal instruments.

2 Carbon dioxide equivalent expresses the amount of global warming by GHGs normalized to the equivalent amount of CO_2 that would have the same global warming potential (GWP). The major examples of such GHGs are methane and nitrous oxide.

3 The net flux of CO_2 between agricultural land and the atmosphere (released from microbial decay and burning of plant litter and organic matter in the soil) is approximately balanced (0.04 Gt of CO_2/yr). However, the emissions from fuel and electricity used in agriculture are included in other sectors (transport and building) (Smith et al., 2007).

4 For more information on this, see the commentary by Niggli in this Review.

5 Several general principles can be applied to help growers select sustainable management practices: (i) selection of species and varieties that are well suited to the site and to conditions on the farm; (ii) diversification of crops (including livestock) and cultural practices to enhance the biological and economic stability of the farm; (iii) management of the soil to enhance and protect soil quality; (iv) efficient and humane use of inputs; and (v) consideration of farmers' goals and lifestyle choices. Examples of some of the key specific strategies of sustainable agriculture are: organic farming, low external input sustainable agriculture (LEISA), integrated pest management, integrated production (IP) and conservation tillage.

6 Under the 2003 EU CAP reform, farm support shifted from price support to direct payments to farmers. Payments are contingent, or "cross compliant", on farmers respecting environmental requirements set at EU and national levels.

7 Apart from agriculture, the other non-ETS emission sources include transport, households, services, smaller industrial installations and waste. Agriculture represents up to 40 per cent of emissions by the non-ETS sector (Breen, Donnellan and Hanrahan, 2009).

8 In this regard, see also the commentary by Ackerman in this Review.

9 For a description of the GTAP model, see Hertel, 1997.

10 Author's estimates using the GTAP version 7 database (Dimaranan, 2006). The estimates apply to a 2005 base period and assume no technological improvements.

11 For more information in this regard, see the commentary by Rae in this Review

12 Garnaut (2008) cites Beauchemin et al. (2008) as claiming a 20–40 per cent reduction in methane emissions through better nutrition, but these changes are not cost-effective.

13 For a full discussion of BTAs, "leakage" and competitiveness issues, see WTO-UNEP, 2009.

14 For information on registered projects and approved methodologies in agriculture, see: http://cdm.unfccc.int/Statistics/index.html.

15 For further background information on issues relating to the design of contracts for delivery of environmental services in agriculture, see Latacz-Lohmann and Schilizzi, 2006.

16 A survey of organic consumers in Ireland showed that 60 per cent of respondents were aware of carbon labels.

17 Although there are difficulties in measuring these costs, and hence data should be used with care, an OECD report suggests costs in Germany of around €25.8 per ton per 1,000 kilometres for road transport, €3.7 for rail and €1.8 for waterways (Quinet, 1999: 28).

18 See: http://unfccc.int/files/meetings/ad_hoc_working_groups/lca/application/pdf/2_ipcc_new.pdf.

19 World Resource Institute, at: http://pdf.wri.org/navigating_numbers_chapter15.pdf.

20 The People's Republic of China's Initial National Communication on Climate Change, 2004.

21 India's Initial National Communication to the UNFCCC, Ministry of Environment and Forests, New Delhi, 2004.

22 There are two types of methodologies in the CDM context - baseline methodologies and monitoring methodologies. As defined in the Glossary of CDM Terms (Version 03), a baseline methodology, is "an application of an approach as defined in paragraph 48 of the CDM modalities and procedures, to an individual project activity, reflecting aspects such as sector and region." A baseline CDM methodology is a means to estimate the emissions that would be generated in the most plausible alternative scenario, had the proposed project activity not been implemented (called the baseline scenario). A monitoring methodology "refers to the method used by project participants for the collection and archiving of all relevant data necessary for the implementation of the monitoring plan."

[23] Note that these estimates assume partial adoption of each of the available mitigation options in each region, but do not allow for lower cost options being used in preference to higher cost approaches. In addition, feasibility and implementation barriers to adoption are not considered in these estimates.

[24] See European Climate Exchange, at: www.ecx.eu.

[25] For quoted prices, see: www.bunkerworld.com for IFO380 in Rotterdam.

[26] Various options are discussed, for example in CE Delft, 2002 and 2008.

[27] See, for example, Directive 2008/101/EC of the European Parliament and of the Council amending Directive 2003/87/EC to include aviation activities in the scheme for GHG emission allowance trading within the Community.

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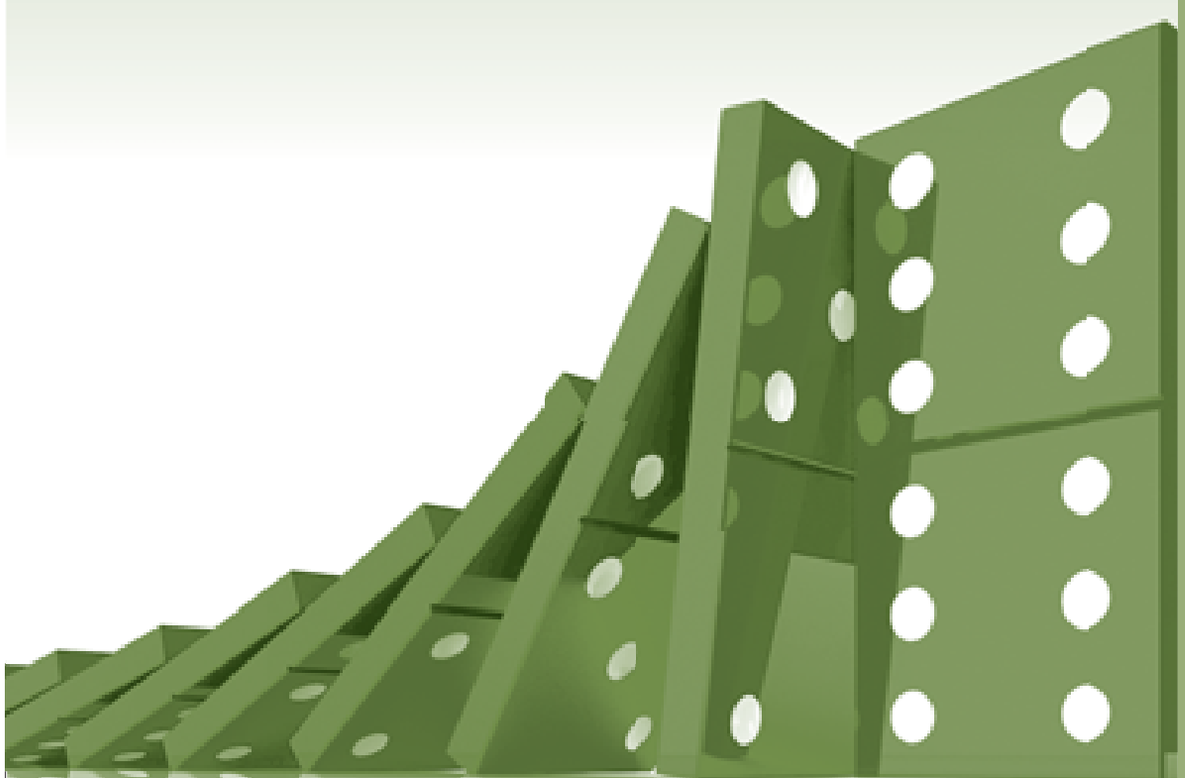
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CHAPTER 4

GROWTH POLE: RENEWABLE ENERGY TECHNOLOGIES



I. Harnessing the Potential of Renewables: the Case of Energy Access in Rural Areas

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» The widespread deployment of renewable sources of energy is not only an environmental and developmental imperative; it can also be strategic in multiple ways. As a matter of fact, in addition to constituting a tool for climate mitigation, renewable energy technologies (RETs) can also be combined with rural electrification strategies to offer leverage for trade and investment growth, innovation, and employment creation.

» The utilisation of RETs in policies to provide poor rural communities with access to modern energy is not new, but has been given renewed momentum with the current economic, environmental, and food crises. Fully seizing this momentum depends on government's ability to identify policy synergies between agriculture, energy, climate mitigation and adaptation, rural development, innovation and investment policies, to name but the most important. This requires strong institutional capacity and regulatory frameworks as well as financial support, which are often lacking in many developing countries.

» Awareness about the environmental and developmental potential of RETs is a first step to their deployment. A second is policy coordination and coherence.

A. Introduction

Access to electricity and modern energy sources is a basic requirement to achieve and sustain higher living standards. It is essential for lighting, heating and cooking, as well as for education, modern health treatment and productive activities. Yet 1.6 billion people lack such access, and more than half of all people living in developing countries rely on the combustion of traditional biomass (e.g. wood) to meet their basic energy needs for cooking and heating. Lack of access to modern energy sources is both the result and the cause of poverty, as it exacerbates and perpetuates poverty. The poorer the population, the more likely it is to lack access to electricity and modern energy supply, and the more difficult it might be to reverse that situation.

While lack of access to modern energy supply in developing countries affects poor people in general, it is a particularly defining feature of rural populations. First, because rural populations are geographically dispersed, often far away from main urban areas, and hence cannot be easily or economically connected to existing national grids. Second, because rural populations tend to have limited disposable income to finance the initial costs of connection to grids, in-house wiring and the monthly payments of energy bills. The combined result is that resource-constrained developing-country governments might find the costs of extending national grids prohibitive, and investments may be unattractive or entail too high a risk for the private sector. Therefore, the challenge faced by governments is to utilize their limited resources in the most strategic manner so as to achieve maximum welfare benefits while at the same time making rural electrification projects attractive for private sector investors and sustainable over the long run.

Renewable sources of energy such as solar, wind, biofuels and small hydro can very conveniently be developed to generate electricity in small stand-alone systems, not connected to national electric grids. They can constitute economical options to deliver energy to remote rural areas. The current global concern about climate change, with its imperative to decouple economic growth from an increase in carbon dioxide emissions, makes investing in renewable energy sources particularly timely and strategic. Renewables provide an exemplary win-win result for economic growth and environmental sustainability. This article focuses on some of the opportunities created by these synergies. First, it summarizes the nexus between poverty and

lack of access to energy, and then goes on to enumerate some of the main benefits of bringing clean, modern energy to rural areas. This is followed by a discussion of the most prominent renewable energy technology (RET) options that can be used in off-grid electrification projects, and considerations of how to scale up investments in such projects. Finally, it reviews typical tools that governments could employ to foster RET-based rural electrification projects and the possible sources of financing.

B. Energy Poverty and the "missing Millennium Development Goal"

Access to electricity and other modern sources of energy is a basic requirement for the achievement of economic growth and human development objectives. Of course, while such access alone is not sufficient to ensure human development, the achievement of higher standards of living in the absence of affordable and predictable energy supply is virtually impossible. Yet an estimated 1.6 billion people lack access to modern energy, and 2.5–3 billion people rely on traditional biomass for most of their energy needs (heating and cooking). The majority of electricity-deprived poor people live in sub-Saharan African and South Asia, and, at current rates of electrification, the number of people utilizing traditional biomass is expected to remain constant or could even increase to 2.7 billion by 2030 because of population growth (IEA, 2006).

Moreover, it is likely that the number of people who lack access to electricity could inflate over the coming months because of the employment and income effects of the global economic recession and the surge in food prices. The World Bank estimates that as a result of the food, financial and economic crises, an additional 89 million people will be living in extreme poverty (on less than $1.25 a day), by the end of 2010. This is compounded by significant fluctuations in the prices of fuels. At the same time, more constrained domestic budgets in developing countries and a consequent reduction of public spending for the expansion of national electrical infrastructure and capacity could delay or even reverse progress in rates of electrification (IEA, 2009).

Rural populations are hardest hit by the lack of access to electricity: 4 out of 5 people who lack access to electricity in the world live in rural areas. This is not surprising, as electricity consumption is closely correlated with wealth, and 75 per cent of the world's poor live in rural areas (World Bank, 2008a). Rural communities consume little electricity, and have little or no disposable income to pay for electricity services. Lack of access to electricity is also due to the difficulties in providing electricity to households scattered in large, isolated or remote geographical areas. Many governments have invested in the extension of national grids over the past three decades, in many cases reaching a large segment of urban populations. However, seizing these low-hanging fruit opportunities has exacerbated the urban-rural divide with respect to access to electricity. In all developing regions, electrification rates are significantly lower in rural areas. In sub-Saharan Africa, for instance, while 58.3 per cent of people living in cities have access to electricity, only 8 per cent of those living in rural areas have similar access (table 1).

Table 1. Access to electricity, by urban and rural areas (per cent)

Region	Total	Urban	Rural
Africa	37.8	67.9	19.0
North Africa	95.5	98.7	91.8
Sub-Saharan Africa	25.9	58.3	8.0
Developing Asia	72.8	86.4	65.1
China and East Asia	88.5	94.9	84.0
South Asia	51.8	69.7	44.7
Latin America	90.0	98.0	65.6
Middle East[a]	78.1	86.7	61.8
Developing countries	68.3	85.2	56.4
Transition economies[a] and OECD countries	99.5	100	98.1
World total	75.6	90.4	61.7

Source: IEA 2006, table B1.
[a] The regional designations follow those used by the IEA.

Income and geographical isolation, however, are not insurmountable stumbling blocks, as shown by several success stories. One of the most commonly cited successful electrification programmes is that of China, which has reached a rate of more than 98 per cent in less than two decades (1985–2000). Despite some shortcomings, this achievement is impressive, both because of its scope and because Chinese electricity consumers pay their bills, unlike consumers in many other developing countries (IEA, 2002: 374). Another good example is Morocco, which has reached 97 per cent coverage over a comparable time span.

Lack of access to modern energy has consequences for all aspects of social, economic and environmental conditions prevailing in rural areas. Access to modern energy strongly influences and determines living standards (e.g. availability of lighting), access to water and sanitation, agricultural productivity (i.e. through irrigation), health (refrigeration for medicines and vaccines, and power for equipment), gender and education. Its centrality in promoting higher living standards and enhancing productive opportunities means that none of the Millennium Development Goals (MDGs) can be met without major improvements in the quality and quantity of energy services in developing countries.

A concern related to energy poverty is that poor people overwhelmingly rely on the burning of traditional biomass to meet their most basic energy needs. Traditional biomass solid fuels are wood, charcoal, agricultural residues and animal dung. In some sub-Saharan African countries (e.g. Chad and Sudan), biomass provides 90 per cent of all energy consumed, and it is estimated to account for most of the household energy needs even in oil-rich sub-Saharan African countries such as Angola (95 per cent), Cameroon (78 per cent), Chad (97 per cent) and Nigeria (65 per cent) (IEA, 2008). Yet there are a number of major problems associated with the utilization of traditional biomass, including the following:

- First, there are health hazards because of pollutants emitted during its combustion (e.g. carbon monoxide, small particles and benzene). The indoor concentration of such pollutants is often several times higher than concentrations recommended by the World Health Organization (WHO), and result in a higher prevalence of respiratory diseases,[1] obstetrical problems, eye infections and blindness, among others (IEA, 2002). There is consistent evidence that indoor air pollution increases the risk of chronic obstructive pulmonary disease and of acute respiratory infections in childhood – the leading cause of death among children under five years of age in developing countries. Evidence also exists of an association with low birth weight, increased infant and perinatal mortality, pulmonary tuberculosis, nasopharyngeal and laryngeal cancer, cataract, and, specifically in respect of the use of coal, with lung cancer. Indoor air pollution could cause as much as 2 million deaths every year (WHO, 2000: 1086) – almost three times the death toll resulting from urban air pollution. Since women and children spend more time indoors, they are more exposed to such risks. WHO estimates that indoor air pollution ranks fourth in terms of the risk factors that contribute to disease and death in developing countries.
- Second, reliance on biomass by communities and households results in the wasteful utilization of resources, chiefly time spent gathering fuel (small wood or charcoal). The need to collect wood is thought to deprive girls (who usually collect the wood) from time spent in school. The IEA reports that women in Uganda walk up to 11 km daily to gather fuel wood (IEA, 2006: 430). It is estimated that in northern India, 2 to 7 hours are spent daily for the collection of biomass for fuel (IEA, 2002). Moreover, inefficient burning stoves unnecessarily increase cooking time.
- Another associated problem concerns the unsustainable use of forests through the collection of wood. There seems to be a strong correlation between deforestation and wood fuel for burning. Therefore the introduction of modern sources of energy can reduce this form of environmental degradation. It should be noted, however, that the effects on deforestation of biomass utilization by rural communities are very location-specific. While wood burning is not always a primary cause of tree cutting (as women carry mostly twigs), it can exacerbate other existing environmental problems. But in some instances (e.g. in Africa), fuel wood collection does constitute one of the causes of tropical deforestation (Modi et al., 2006:30).
- Society as a whole bears a heavy economic burden for these inefficiencies. For example, in India, the opportunity cost of time lost in gathering fuel, working days lost due to eye infections and respiratory diseases and the costs of medicines were estimated at 300 billion rupees, or close to 0.7 per cent of India's GDP in 2006 (Parikh et al., 2005).

While in absolute numbers it is mostly people in South Asia and to a lesser extent in countries in other subregions of Asia (China, Myanmar, the Philippines, Thailand and Viet Nam) that rely on traditional biomass, the highest proportion are those living in sub-Saharan Africa. Often, biomass is combined with other energy sources, such as candles, kerosene, diesel, gasoline or liquefied petroleum gas (LPG), to complement household energy needs.

C. Rural Electrification

Because of its centrality to the achievement of human development, access to energy has been defined as

the "missing Millennium Development Goal".[2] The implementation of electrification programmes over the past three decades has enabled the accumulation of enough empirical evidence to confirm the strong correlation between energy services, poverty reduction, and indeed the achievement of all the MDGs (Modi et al., 2006). This is why the Johannesburg Plan of Implementation, adopted at the World Summit on Sustainable Development in 2002, addresses energy in the context of sustainable development. It calls upon countries to improve access to reliable, affordable, economically viable, and socially acceptable and environmentally friendly energy services.[3] Conscious of this, several countries have started implementing electrification programmes with a clear poverty reduction goal.

1. Unlocking development potential

The full poverty reduction potential of energy access depends on the availability of three types of energy: energy for cooking (e.g. electricity, natural gas or LPG), electricity for lighting and to power household and commercial appliances, and mechanical energy to operate agricultural and food processing equipment (e.g. for grinding), to carry out supplementary irrigation (e.g. from water pumping), to support other productive uses, and to transport goods and people. The benefits of electrification are direct and indirect. Direct benefits include improvements in living conditions, such as illumination (and hence also the opportunity to study longer hours in the evening or to work longer hours in family businesses) and improved cooking methods (and hence the reduction of health hazards associated with biomass burning). Moreover, access to electricity can also reduce energy costs, especially for lighting and small uses, resulting in savings for poor households.

In addition, electrification may have more ample indirect benefits. These include improved school enrolment rates (particularly for girls, as the burden on girls of collecting fuel wood is reduced), access to information and communication technologies (telephony, Internet), and an increased ability of rural communities to retain doctors, teachers and other professionals as it improves living standards. Moreover, there are positive linkages between electrification and accelerated economic growth and employment generation, economic diversification and industrialization.

It is worth noting that there is an important difference between access to energy that improves living conditions (e.g. energy for lighting) and access to energy that enables productive activities (e.g. energy for water pumping and irrigation). While the first makes a direct contribution to better living standards and has several social dividends, only the second allows the fully-fledged economic and social transformations required to generate development spirals (figure 1).

In fact, where local community conditions are favourable, access to modern energy can stimulate the creation of new small and medium-sized enterprises (SMEs) and family businesses, or improve the competitiveness of existing firms (e.g. brick-making, silk production, textiles processing, sewing, joinery and handcrafts). It can also improve agricultural productivity (e.g. through irrigation), fisheries and fish farming, and enable the processing of agricultural and fish products (e.g. grinding, milling). Moreover, it may create new trading opportunities, for instance for perishable produce (by providing refrigeration). Evaluations of the impact of electrification show that the provision of lighting and power can unleash new productive activities or extend the length of the productive day. Many of these activities are undertaken by women, thereby increasing their chances for income generation and economic empowerment (Lallement, 2008).

In addition, investment in the provision of universal access to energy may generate numerous employment opportunities related to the manufacture, installation and maintenance of power generating units. There are several examples of projects based on RETs, for instance, that have fostered the creation of hundreds, sometimes thousands, of rural enterprises that supply electricity and ensure the maintenance of equipment. For example, in Cambodia, 600–1,000 rural SMEs supply electricity to some 60,000 households (World Bank, 2008b).

The experience gained in rural energy access projects is likely to generate knowledge, expertise and manufacturing capacity in renewable-energy-related industries, which will certainly be a fast-growing economic sector in global trade for years to come. The production and innovation capacity that has been built in China's solar and wind RETs industry illustrates the employment, technological and investment opportunities that RETs may offer (see WU in this Review). An important lesson for the design of rural projects is that efforts should be made to maximize local content and local knowledge in order to achieve the most positive results. For instance, biogas digesters utilize simple technology and can therefore be manufactured lo-

Figure 1. Renewable energy for people and the environment



Source: *UNDP Annual Report 2009: 27*, at: www.undp.org/publications/annualreport2009/report.shtml.

cally. In China, for example, it is estimated that 1 million biogas digesters are produced annually, and the market is set to continue growing, as the Government provides subsidies and has set targets to increase the number of digesters. Similar trends are also evident in India and Nepal (REN21, 2007: 33). Another illustration concerns the opportunities related to the manufacture of safer and more efficient cooking stoves for dissemination in the African continent. There is also a very interesting application of rural electrification (mainly mechanical power for productive industries using very simple technologies), which relates to the installation of multifunctional platforms in West Africa.[4] The developmental and environmental potential of these platforms is even more strategic if they are based on locally produced biofuels or on hydropower.

There are so many welfare benefits of utilising RETs to provide access to modern energy in rural areas that governments should approach this objective as a full component of an integrated development policy package, and not as a stand-alone element of investments in infrastructure. Seen in that light, investments in providing access to rural energy should be part of governments' public spending priorities, made all the more attractive since it can unleash the developmental potential of communities. By creating an enabling environment for the emergence of income-generating or income-improving activities, electrification projects can directly contribute to poverty eradication policies.

The gains in productivity in the agricultural and food sector, for instance, can be particularly rewarding from the social viewpoint. Benefits for agricultural production include irrigation (perhaps with the use of water pumps), increased utilization of motors, food processing, refrigeration and also better access to training through information and communication technologies (ICT). Successful electrification programmes linked to agriculture would not only result in more competitive farming and create employment opportunities, but would also improve trading opportunities and local food security, including through the reduction of post-harvest losses. The electrification of agriculture can yield several value addition opportunities, improving incomes and diversifying their sources, thereby improving the resilience of rural communities. Opportunities offered by policy synergies of this type highlight the importance of participatory approaches in the design of RET-based electrification policies, and call for policy coordination and coherence.

This highlights an essential aspect of rural electrification strategies, namely, that to deploy its full poverty developmental potential, electrification has to be well embedded in local or national poverty reduction strategies and considered within a broader development context. The mere installation of off-grid energy generating units is likely to fall short of triggering social and economic transformations commensurate with the full potential of RET-based electrification.

This translates into a developmental approach to energy problems. For instance, energy security is usually understood as a geo-strategic imperative, requiring the diversification of national energy mixes (to rely on more than one type of energy) and sources of supply (to rely on more than one country or region). That is certainly a worthwhile country-level guideline. However, what matters from a developmental viewpoint is that all individuals should have access to the bare minimum level of modern energy services. India's Expert Committee on Integrated Energy Policy defined energy security as the ability of the government to "supply lifeline energy to all our citizens irrespective of their ability to pay for it as well as meet their effective demand for safe and convenient energy to satisfy their various needs at competitive prices, at all times and with a prescribed confidence level considering shocks and disruptions that can be reasonably expected" (Government of India, 2006).

The investment policy challenge for governments is therefore to utilize limited resources in the most strategic manner, so as to maximize the social benefits of projects while ensuring the social and geographical equity of investments. The ultimate goal is for initial installation investments to create new income streams and trigger transformations that release the economic growth potential of rural communities.

2. Renewables: strategic in multiple ways

In addition to the general welfare improvements of rural electrification, additional benefits can accrue if electrification is based on RETs. In fact, not all electrification projects need (or indeed can) be based on an extension of national electricity grids. Mini-grids or off-grid electrification projects can be very well adapted to rural conditions. Typical RETs include solar energy (e.g. solar home systems (SHS)), wind, biomass and hydro power (see section D below for a description of the technologies). Renewable energy-based rural electrification is strategic in numerous ways.

First, RETs are very suitable for decentralized, standalone, small power-generating units. Their suitability depends on the availability of natural resources, the degree of maturity of a given technology and, ultimately, an assessment of cost-effectiveness. While grid extension may prove more cost-effective in some locations, off-grid RETs hold considerable promise for the electrification of communities that are not expected to be connected to national grids in the near future. Decentralized sustainable energy projects based on solar photovoltaic (PV) systems, wind-electric or micro-hydroelectric simple technologies are sufficient to provide lighting and electricity for basic appliances, and power for small-scale productive activities such as electric fencing, water pumping, irrigation and ice-making (see section D and table 2 below). This means that decentralized renewable energy units can provide a cost-effective solution to quickly improve social and employment opportunities in isolated poor rural areas (World Bank, 2008b).

A second, and related point is that off-grid renewable energy units do not entail an increase in overall national supply capacity managed through central grids. Since the units are not connected to the main national grid, there is no new demand on what is typically an already stretched national installed supply capacity. This can significantly shorten the time frame for implementation of rural electrification projects.

Third, the choice of renewable energies for rural electrification contributes to the diversification of national

energy mixes, thereby contributing to developing countries' energy security. While under certain circumstances projects utilizing diesel generators or diesel-RET hybrids may be more appropriate, the choice of renewables has the advantage of limiting an increase in fossil fuel imports. This is an important consideration in times of economic crisis, tighter national budgets and volatile oil prices. Finally, at the household level, access to electricity, particularly if based on RETs, can also improve the energy security of families, as they are no longer subject to oil price fluctuations[5] and to what can be high costs of transportation and delivery of fuel. This of course is only valid where RETs have a comparative advantage over fossil fuels in terms of resources and costs.

Fifth, while there are several business and regulatory models for the installation of off-grid renewable-based energy units and for the supply of power, it is possible to bundle together electrification projects with other public services such as water, financial services and telecommunications. Bundling several services together helps reduce the high transaction costs from servicing a myriad of dispersed end users (e.g. information and marketing, installation, fee-collection, maintenance, after-sales customer services and non-payment interventions). It also facilitates government regulation and oversight, and tremendously enhances the welfare and developmental impacts of projects. A study focusing on middle-income economies noted that the addition of a fourth service provides a marginal benefit about seven times greater than the addition of a second service (Reiche, Covarrubias and Martinot, 2000). However, fully exploiting the benefits of bundling rural services depends on government's ability to identify policy synergies (e.g. agriculture, energy, climate mitigation and adaptation, rural development, innovation and investment policies). This requires strong institutional capacity and regulatory frameworks, which are often lacking in many developing countries.

Finally, as already mentioned, renewable energy sources also offer several manufacturing opportunities. By adding local content to projects and by adapting RETs to local conditions, it is possible for developing-country first-mover manufacturers to benefit from domestic and international demand for RETs. Trade in RETs has in fact been brought into focus, for instance, as a possible contribution of the WTO to global climate mitigation efforts (see Vikhlyaev, Fliess, Zhang and Jha in this Review).

3. Opportunities for climate change mitigation and adaptation

Decentralized renewable energy production units have obvious benefits for the sustainability of developing countries' economic growth. Electrification projects should be designed in an integrated manner to also include capacity-building for improved land management, more sustainable agricultural practices and recycling. These are necessary to ensure the fullest sustainability of projects. For instance, certain renewable energy units utilize lead batteries, the disposal of which must be coordinated with local recycling policies.

The choice of renewables for rural electrification offers positive synergies with national, regional and global climate change mitigation policies. RETs deployment is a concrete mitigation action, since it avoids additional emissions from fossil fuel energy generation, and may even reduce current emissions if it results in fuel switching. Renewable fuels-based electrification programmes enable developing countries to contribute to global mitigation efforts in nationally appropriate ways. They are also an important adaptation measure, since access to this form of energy is likely to enhance the economic and social resilience of rural communities, whose livelihoods could be affected by climate change. By improving farmers' access to information and knowledge and by increasing farm productivity, rural electrification programmes can safeguard their livelihoods. The extent to which electrification policies are able to harness potential synergies with climate mitigation and adaptation objectives depends on how well electrification policies are integrated into national development and climate policies. This confirms and reinforces the case for policy coordination and policy coherence.

With respect to economic growth, renewable energy-based rural electrification projects offer significant benefits. First, they make a contribution towards decoupling economic growth from CO_2 emissions. Second, investments in renewable energies send a political signal about developing countries' commitment to climate change mitigation and a global climate change regime. Third, because the power supplied is likely to be utilized for agricultural production, access to renewable energy can, if coupled with capacity-building and training, trigger the progressive greening of agriculture and agro-processing, thereby creating new development and trade opportunities. However, the extent to which a real greening is possible would

require an assessment of the entire energy balance of agricultural systems (for instance, to reduce the reliance of farms on fossil fuels for tillage, harvesting, transportation and fertilizers).

D. Scaling up renewables: feasibility and prospects

Because of the multiple benefits of RETs-based electrification, scaling up projects is a developmental and environmental imperative. Many such projects and programmes are being implemented in a good number of countries, generally in collaboration with international development partners. However, the number and scope of such programmes will have to increase if the number of rural poor is to be significantly reduced to levels that allow the attainment of the MDGs by 2015. In this regard, major development partners[6] have recommended that energy services be explicitly addressed in planning for poverty reduction (Modi et al., 2006: 39) in particular that:

1. Half of the people who currently rely primarily on traditional biomass for cooking should switch to alternative fuels, such as LPG or electricity. In addition, support should be given to (a) the utilization of improved cooking stoves, (b) reducing the adverse health impacts from cooking with biomass, and (c) increasing sustainable biomass production.
2. Access to electricity should be provided to all in urban and peri-urban areas.
3. Modern energy services (in the form of mechanical power and electricity) should be made available at the community level for all rural communities.

These recommendations were considered not only necessary, but also achievable. In addition, part or perhaps even the bulk of that effort should be based on RETs. Several RETs have attained commercial maturity for the implementation of rural electrification projects, and there is also a wealth of past experience as well as new experimentation of business models that could ensure the long-term sustainability of such projects.

1. Technologies

An important lesson learnt from the design and implementation of rural electrification projects over the past three decades is that policymakers should not impose technology options, and that projects must be technology neutral (World Bank, 2008b). That would allow service providers to conduct cost-benefit comparisons of all options available and to choose the one that is the most economical, suitable to local resources and adapted to the expected demand. The analysis must also consider whether grid extension is a more appropriate electrification method for a given location. The analysis of all parameters should be conducted free from constraints regarding a predetermined technology choice (technology neutrality), and should strive to utilize as much local content as possible with the aim of maximizing trade, economic and investment benefits.

If a decision is made that grid extension is not an adequate option for a specific electrification project, it can be difficult to assess which off-grid technology is best suited to each circumstance (table 2). There are numerous off-grid RET and fossil-fuel-based options available (box 1), as well as combinations of technologies for use in hybrid units. While the availability of renewable energy resources varies depending on the site, many resources are abundantly available in developing countries, and some are well suited for off-grid, small rural electrification projects. This does not

Table 2. Decision-making steps in off-grid electrification technology options

⇨ *Grid extension vs. off-grid electrification*: choice depends on such factors as the distance of communities from the grid, the geographical dispersion of settlements, the type of load and the size of demand.

⇨ *If an off-grid solution is retained*: a preliminary study should be made of availability of local resources, income level of users (ability and willingness to pay), equipment availability, possible synergies with other public investment programmes and identification of opportunities to utilize electricity for productive activities.

Concentrated (some productive load) **Mini-grid**	Dispersed (mainly household lighting) **Individual systems**
• Diesel • Renewables: wind, solar PV, hydro, biomass gasifier, biomass direct combustion • Diesel – renewables hybrid	• Solar home system, wind home system, pico hydro (i.e. hydropower generation of under 5kW), battery

Source: Adapted from World Bank, 2008b, figure 1.

Box 1. Categories of sources of renewable energies

1. Combustible renewables and waste (CRW) such as:
   a. Solid biomass: organic, non-fossil material such as wood, wood waste, woody materials generated by industrial processes (e.g. paper industry) or provided by forestry and agriculture (e.g. firewood and wood chips), and wastes (e.g. straw, rice husks and nut shells);
   b. Charcoal;
   c. Biogas (mainly methane and carbon dioxide produced by anaerobic digestion of biomass);
   d. Liquid biofuels;
   e. Municipal waste: combustion of biodegradable material from residential, commercial and public service sector waste;
2. Hydropower: kinetic energy of water converted into electricity;
3. Geothermal: heat emitted from the earth's crust (steam or hot water), used directly or transformed into electricity;
4. Solar: solar radiation exploited for hot water production and electricity generation;
5. Wind: kinetic energy of wind exploited for electricity generation; and,
6. Tide, wave or ocean: mechanical energy derived from tidal movement, or the wave motion of ocean currents, exploited for energy generation.

Source: The IEA (2007, annex I).

mean that all the necessary technologies to exploit these resources are also concomitantly cost-effective or socially acceptable in developing countries.

Among the elements that must be considered in choosing a technology, site specificities figure prominently. Major factors include availability of renewable resources, the load needed and the type of utilization, the cost effectiveness of various options and investment parameters (table 3). For instance, the abundant availability of a natural resource may make certain RET options attractive in one location but not in another. In Kenya, for example, there is some cost-effective geothermal production that can feed into small grids (and even into the national grid), but this is not the case in neighbouring Uganda and the United Republic of Tanzania. Because of the impact of project design on the long-term viability of a project, the collection of baseline data on energy consumption, income and willingness to pay, and a sound understanding of local conditions and expectations is a prerequisite. For instance, it is necessary to monitor wind speeds for at least one year before building a wind turbine (World Bank, 2008b: 8).

The most promising technologies that could offer large-scale deployment opportunities in rural areas include biomass, solar, wind and hydropower. For specific remote applications, a selected number of renewables have proven not only to be cost-competitive but also to be able to overcome the barriers associated with ensuring adequate maintenance support. The most attractive options have often been applications that are income generating and are linked to existing agricultural activities or agro/forest industries. The following are notable examples (Karekezi, Kimani and Wambile, 2007):

- Wind pumps for irrigation, in South Africa (with over 100,000 wind pumps in operation) and Namibia (with close to 30,000 wind pumps);
- Small hydropower units for powering remote rural agro-processing factories in tea, coffee and forest industries in Kenya;
- Geothermal heat applications in remote areas used for rural horticultural production (flowers, vegetables and fruits) in Kenya;
- Co-generation in agro/forest industries in Côte d'Ivoire, Kenya, South Africa, Swaziland, Uganda and the United Republic of Tanzania;
- Solar water heaters, wind pumps for potable water and solar PV systems used in tourism infrastructure, particularly in Botswana, Kenya, Mauritius, Namibia, Seychelles, South Africa and the United Republic of Tanzania.

Where customers are few and dispersed, and their main utilization of electricity is for domestic lighting, World Bank-sponsored projects have opted for individual systems, such as SHS or pico hydro systems, for small farms or homes that are located near a river. Some projects have used compact wind turbines in

Table 3. Examples of small-scale, off-grid energy systems

Technology	Applications	Pros	Cons
Diesel engines	- Water pumps - Mills - Refrigeration - Lighting and communication	- Easy maintenance - Continuous energy (24h/day) - Enables income-generating activities	- High fuel costs - Noxious and CO_2 emissions
Small biomass plants	- Water pumps - Mills - Refrigeration - Lighting and communication	- Enables income-generating activities - Base load operation, continuous operation possible	- Noxious emissions
Mini/micro-hydroelectric plants	- Mills - Lighting, communication and other - Ice-making (2-10kW) - Micro-irrigation (1-3kW) - Refrigeration (0.5-10kW)	- Long life, high reliability - Enables income-generating activities	- Site-specific - Intermittent water availability
Wind	- Water pumps - Mills - Lighting and communication - Ice-making (2-10kW) - Micro-irrigation (1-3kW)	- No fuel cost - Enables income-generating activities	- Expensive batteries - Intermittent energy service
PV/solar	- Basic lighting and electronic equipment (cell-phone charging) - Water-pumps for fish farms; - Micro irrigation (1-3kW)	- No fuel cost - Enables income-generating activities	- High capital costs - High cost of battery replacement - Needs further R&D

Source: Adapted from IEA, 2002, table 13.4 and World Bank, 2008b, table 2.

wind home systems (WHS). Where customers are concentrated, it can be more economical to connect them to a small grid or a centrally located generating system, typically based on RETs, on a diesel generator or on a diesel-renewable hybrid solution. Biomass-based power plants are also an option, though less common (World Bank, 2008b: 6).

In addition to their environmental drawbacks (e.g. GHG emissions from combustion), engines powered by fossil fuels (diesel, gasoline or kerosene) have two additional drawbacks. First, they require regular, skilled maintenance. Second, isolated communities rely on the delivery of fuel, the price of which can be very high and subject to strong volatility. Yet these engines have been quite commonly deployed, particularly in 5–10kW portable systems or in hybrid combinations with RETs. This was common practice mainly before RETs reached commercial or near-commercial maturity. RETs, on the contrary, generate no or few fuel costs, but some RET equipment also requires regular skilled maintenance services (e.g. biomass gasifiers). Moreover, renewables are also subject to location specificities such as the seasonality of natural resources (e.g. water resources for hydropower generation or agricultural residues for biomass digesters). The intermittent availability of natural resources (e.g. wind, water, biomass fuel) increases the risks to off-grid renewable units and helps explain why RETs are sometimes combined with diesel generators, especially when interruptions in supply are not desirable. However, such back-up power increases the overall costs of the systems. Other types of hybrids are also possible, such as photovoltaic-wind hybrid systems, which take advantage of the varying availability of the solar resource and the wind resource, allowing each renewable resource to supplement the other, and increasing the overall capacity factor.

A new development is the deployment of technologies which have attained greater commercial maturity recently. This includes, for instance, the introduction of off-grid solar PV products that are much smaller than the traditional 20–50 watt solar PV systems (sometimes called “pico-PV”). The advantage of these systems is that they are less expensive and yet can provide a significant service to lower income households (systems of 1–5 watts), particularly when coupled with advanced technologies such as ultra-low-power light-emitting diode lamps (LED). Products using this technology include solar torches, one-piece solar lanterns, or miniature solar-home-system kits that power one or two LED lamps and often also a radio or cell phone charger (REN21, 2009).

To sum up, each technology has its own advantages and disadvantages, and therefore varying degrees of suitability to a given site's specificities, utilization and expectations. A comprehensive understanding of such factors requires site monitoring and assessment. Moreover, each technology option entails costs and a degree of acceptance which also vary from one country to another. The extent to which RETs can effectively accelerate rural electrification (and perhaps more generally improve access to modern energy) depends largely on the cost effectiveness of RETs relative to other energy options.

2. Costs

Many RETs are now commercially viable and economically more attractive than grid extension or off-grid, diesel-powered systems. PV technologies, for instance, have achieved impressive cost reductions over the past few years: every doubling of the volume produced achieved a cost decrease of about 20 per cent (IEA 2007, annex II). However, installation and operating costs vary considerably by location, configuration and context. As a result, it is difficult to draw general conclusions.

The costs of electrification are location-specific and hence very uneven across countries: the poorer and more rural the population, the more costly it is to provide electrification: for example, in 2001, the cost of connection to conventional grids was $240 in South Africa, and over $1,000 in Uganda (IEA, 2002). The cost of connecting a rural home to the national grid in Kenya is equivalent to seven times the per capita gross national income (GNI) (REN21, 2007: 35).[7] The unit costs of RET-based electrification tend to be higher than those of grid extension, particularly because of the capital costs involved. In some countries, many low-hanging fruits have already been exploited (particularly in Asia), so that investments must now focus on last-mile users that are much more difficult to reach. In other instances, there are still many easily achievable opportunities. In Africa, for example, the penetration of cheap, decentralized RETs from Asia could significantly increase with the removal of trade barriers.

The economic assessment of RET deployment has different aspects that can be more or less significant depending on who conducts it. Service providers will be interested in calculating capital costs, such as equipment and installation costs, to match those with electricity tariffs and assess rates of return. Consumers would be sensitive to the cost of the electricity generated, and hence its affordability for households and productive activities in local communities. Moreover, consumers will also factor in the costs of operation (e.g. fuels), maintenance of equipment and possible replacement of parts (e.g. batteries). Governments may be interested in knowing the amount and duration of subsidies that may be needed to ensure the viability of programmes, as well as the needs for capacity-building, technical assistance and training. Governments may also consider cost opportunities for bundling rural services together, or assessing the energy component of other public infrastructure decisions.

Furthermore, a cost-benefit analysis of investments in rural renewables-based energy supply must take into account the social and environmental benefits that these sources of energy provide. While the environmental benefits, including in the context of climate change mitigation, are obvious, social aspects are also important. Several social benefits justify investment in renewable energies. These include the fact that renewables can bring energy to the poor much faster than the expansion of centralized systems. Moreover, as mentioned earlier, renewables have direct benefits for income generation if properly linked to support for productive activities. Economic analysis of World Bank projects reveals very high returns on energy investments, with consumer surplus ranging from 27 per cent to 94 per cent for projects in Bolivia, China, Indonesia, the Philippines and Sri Lanka (World Bank, 2008b). A survey of electrified and non-electrified villages in Bhutan found that switching from kerosene to electricity resulted in a surplus of 33 per cent for consumers. The study also found that electrified households also disposed of 24 per cent more income than households that lacked access to electricity (Bhandari, 2006).

Against this background, potential welfare gains from public investment in rural energy infrastructure and RET deployment could exceed the costs associated with lack of access to energy or the utilization of unsustainable sources of energy. It is also crucial to consider the profitability of investments by private sector service suppliers who incur initial risks and market development costs. In several developing countries, examples abound of commercial deployment and interesting rates of return from RETs in rural electrification projects. For instance in India, projects involving biomass gasification for mechanical power utilized in silk and textile processing have shown payback periods

as short as one year. The drying of cardamom, rubber and bricks has also shown short payback times and improvements in productivity gains from a shortening of drying time (REN21, 2007: 34).

There are no overall quantifications of the investments needed to provide universal energy access in rural areas. Indeed, it is difficult to determine the exact number of people living in rural areas for whom off-grid renewable energy projects could be implemented. This means that there is generally no precise quantification of the size of markets and private sector opportunities (World Bank, 2008b: 3).

The IEA has calculated that completely halting the utilization of traditional biomass by 2015 would necessitate the adoption of alternative fuels and technologies, such as LPG stoves and cylinders, by 1.3 billion people at a maximum cost of $1.5 billion per year (IEA, 2006). The economic benefits of meeting that goal are deemed to far outweigh those costs. As a matter of fact, WHO estimates that meeting that goal would yield annual average benefits of $91 billion worldwide (cited in IEA, 2006: 440, table 15.6). However, these costs concern exclusively biomass and cooking fuels, and not the costs of providing other types of energy (e.g. electricity). In fact, other than project-specific information, there seems to be little information available on the costs of RETs as a source of household energy relative to fossil fuels.

The remoteness, low density and low income level of rural populations raise the costs of electrification to sometimes prohibitive levels, and reduce profitability for private investors and operators. Moreover, the training, technical assistance and capacity-building that are needed to support rural electrification schemes add to capital costs. Given large capital costs and high associated risks, service providers would need to charge high connection fees and monthly rates to recover their investments, which would undermine the affordability of electrification for poor consumers. To unlock this energy-poverty trap, governments must play an active role in partly covering the capital costs and sometimes in subsidizing monthly payments for the poorest consumers. The challenge for governments of poor countries is therefore to utilize limited resources in the most strategic manner, enhancing the attractiveness of investments for private service suppliers while ensuring maximum social, environmental and economic benefits.

E. Tapping regulatory and financial opportunities

Several governments have undertaken important reforms of their energy sectors. For example, many have embarked upon programmes of privatization of public operators, while others have reformed their regulatory environments (e.g. decoupling energy production from its distribution). The objective of these reforms has generally been to attract private capital for modernizing old or poor utilities. While these reforms have sometimes improved and enhanced electricity supply in urban areas, in most instances they have had little impact on improving the attractiveness of rural electrification projects for private service suppliers.

Financing remains a major barrier in RET deployment. There are, nevertheless, several experiences of regulatory reforms and policy incentives that have successfully provided the necessary impetus to rural electrification programmes. Moreover, innovative financing options (e.g. microfinance) and business models (e.g. concessions, public-private partnerships) offer promising avenues. Removing barriers, exploring policy synergies and creating conducive regulatory environments require the building of institutional capacity and identifying leadership sources at the national and local levels. National measures to support the demand for RET and generate RET markets can be extremely effective in inducing the production of RETs and their deployment (see Wu, Zhang and Jha in this Review).

1. Incentives and national policies

By early 2009, policies to promote renewable power generation (not only in rural areas) with feed-in tariffs existed in at least 64 countries, both developed and developing, including 45 countries and 18 states/provinces/territories. In 2008-2009, new laws and policy provisions for renewables were introduced in several developing countries, including Brazil, Chile, Egypt, Mexico, the Philippines, South Africa, the Syrian Arab Republic and Uganda (REN21, 2009). Many countries have tested the enormous potential of universal energy access for poverty reduction strategies, such as Brazil's "Luz para todos" and China's "township electrification" programmes. A number of African countries have created specific institutions (i.e. rural energy agencies and rural electrification funds) and special regulatory and legal structures to facilitate increased access to energy. Other countries (e.g. Argentina, Bangladesh, Bolivia, Brazil, Chile, China, Guatemala, Honduras, India, Indonesia, Nepal, Ni-

caragua, the Philippines, Sri Lanka, Thailand and Viet Nam) have updated national rural electrification strategies to mainstream renewables as one of the basic technology options (REN 21, 2007).

Various factors influence the long-term sustainability of projects, and hence determine their success. Among these factors, the affordability of the electricity generated is of major importance. Policymakers managing rural electrification programmes must find a balance between the affordability of energy for users and the profitability of the service for private operators. A major risk in this respect is that, even when connected to the national grid or local mini-grids, households continue to rely, either partially or entirely, on traditional biomass for their energy consumption. This can limit the environmental or social benefits of public investments, or undermine the profitability of service providers. For instance, while the electricity infrastructure has reached almost 90 per cent of the Indian population, only 43 per cent are actually connected to it because they cannot afford the costs. By contrast, the electrification process in China has been more successful to the extent that it has achieved effective access to modern electricity. Moreover, Chinese consumers pay their electricity bills to a larger extent than the poor in other countries where connections have been established (IEA, 2002: 376).

Shifting from traditional, low-quality biomass to modern energy sources depends on the availability of other energy sources, on the affordability of alternatives and on cultural preferences (IEA, 2002: 369). These factors help explain why poor households utilize several complementary sources of energy to meet their needs, rather than switching straight away to electricity when provided access to it. In other words, consumers will naturally choose energy mixes that reflect the marginal cost of different energy sources (e.g. electricity used only for lighting, television or radio, charcoal or LPG for cooking, kerosene for heating). Even when provided with affordable energy alternatives, households may not completely stop utilizing biomass (for instance, even high-income households in India maintain a traditional fuel wood stove to cook traditional dishes). The utilization of more than one source of energy (e.g. wood, LPG, electricity) may in fact enhance people's perception of energy security (IEA, 2006).

To ensure fuel switching, project design must incorporate capacity-building, to the fullest extent possible, to overcome cultural inertia or resistance. It must also include financial support to improve the affordability of initial and operational costs. This further highlights the importance of designing holistic projects, seen as developmental packages and not as mere infrastructural projects.

To improve the affordability of electricity, ensure effective access and yet guarantee the profitability of the scheme, governments can act on two fronts: the demand side (consumers) and the supply side (power generation).

2. Affordability

There are two main barriers underlying poor access to electricity:

1. The initial connection to the grid or mini-grid and in-house wiring, equipment purchase and installation costs, which are too high for poor households; and,
2. The monthly charges, which can dissuade low-income consumers from utilizing electricity (or utilizing it fully), particularly if wages are irregular or insufficient.

Governments can act on both fronts. Subsidies are a classic, often indispensable, instrument to help lower both initial and operating costs of electricity. Governments may, for instance, envisage the provision of financial assistance to reduce the burden of connection or installation costs (i.e. subsidize partly or entirely the initial installation or connection costs, facilitate access to credit, or ease payment conditions, for instance by accepting payments over a prolonged period). Subsidies provided for the manufacture, acquisition and instalment of renewables were largely responsible for the dissemination of technologies in poor countries: among others, biogas digesters in China and India, improved biomass cooking stoves in Kenya and some other African countries, and SHS in Sri Lanka and Thailand. In the case of renewables, the bulk of deployment costs relate to the purchase and installation of equipment (capital costs).

In addition, governments may subsidize electricity costs over a given period of time to ensure that the poorest households have access to a basic level of services. Governments may, for instance, provide income transfers to the poorest households to reduce the relative burden of spending for energy services and other basic services. While safety nets of this type allow targeting the neediest beneficiaries, and hence utilizing resources more strategically, they also

require rather sophisticated institutional capacity to identify needs and deliver the appropriate social benefits. Alternatively, subsidies can be incorporated in tariff structures: for instance, the first 50–100kWh consumed may be sold below cost and subsequent consumption charged at a higher rate. Since poor households tend to consume little electricity, they would likely benefit from overall reduced rates, or a "lifeline rate". Commercial and industrial users could be charged higher rates, while SMEs would need more favourable treatment. Other ways to mobilize resources through tariffs include setting a transparent surcharge applied to higher income, commercial or industrial consumers, and using the proceeds to extend the service to poorer consumers. Such a system has been successfully implemented in Brazil (Lallement, 2008).

Nonetheless, there are many risks associated with the utilization of subsidies. Typically, they might be badly targeted, and hence hardly reach the intended neediest households. In India, for example, although the Government finances about 60 per cent of the estimated subsidy needs, the benefits do not reach the intended beneficiaries due to poor targeting. Therefore, to improve access to electricity by the poor, the Expert Committee on India's Integrated Energy Policy recommended that existing subsidy programmes be better targeted. A system of lifeline tradable entitlements delivered through smart debit cards could potentially be the answer (Government of India, 2006).

Moreover, poorly targeted subsidies can distort markets. This is the case of subsidies for fossil fuels, which make the deployment of RETs less advantageous, or subsidies for certain RETs, which distort competition amongst RET options. Subsidies that lower the price of energy may encourage wasteful and inefficient energy consumption. There are many examples of subsidies that never reached the poor and discouraged efficient consumption. Besides, subsidies generate rent-seeking behaviour and, once introduced, it is very difficult to phase them out. Finally, when handed directly to energy supplying firms, subsidies can discourage innovation, technological upgrading and cost effectiveness, and may even compromise the overall quality of service. If perverse subsidies are not removed, subsidies for RETs may be needed to level the playing field and encourage their utilization.

Subsidies should benefit consumers and businesses that would not otherwise have access to energy supply. However, they must provide an encouragement, not an end, for both users and suppliers. Subsidies must foster market development, not destroy business opportunities. In sum, subsidies must effectively reach the intended beneficiaries, encourage the provision of least-cost services (e.g. avoid covering operating costs), and, overall, be cost-effective, that is, achieve maximum social benefits for each unit spent (Barnes and Halpern, 2000).

In addition to subsidies, other measures can improve the affordability of energy. For instance, in some rural areas, the greatest challenge for farmers can be that the payment cycle for electricity (connections and monthly bills) does not match the income cycle (once or twice a year, after the harvest). Simply adapting the modalities of payment to the profile of agricultural users could make the difference.

Another important and complementary tool is to provide the poorest households with access to financial services. For instance, the banking sector, when present in rural areas, does not always offer instruments adapted to the needs of rural users. In the absence of credit markets, households cannot borrow to pay the connection charge. Microfinance (e.g. in Ethiopia and Sri Lanka), extended or facilitated repayment periods (e.g. in Morocco and Senegal) and microleasing can significantly increase the consumer base for energy providers. Often, access to microcredit is a fundamental factor in the successful dissemination of RETs in rural areas, as the Grameen Bank and BRAC examples in Bangladesh illustrate. Expanding the availability of microfinance and reaching remote users often entails supporting community organizations and cooperatives, rural banks and non-governmental organizations (NGOs).

3. Profitability

Government financial support in renewable-energy-based rural electrification programmes should necessarily be temporary and time-bound. A major parameter to gauge the success of electrification programmes is whether or not initial investments have generated a developmental spiral that promotes self-sustainability beyond implementation time frames. In this sense, the long-term viability of projects requires all stakeholders to draw sufficient benefits from investments. This highlights the importance of the private sector in driving or sustaining electrification projects, and therefore includes the need to ensure profitability of investments for all operators such as commercial banks, RET retailers and service providers.

In "pockets of opportunities" (Reiche, Covarrubias and Martinot, 2000), the private sector can penetrate markets and achieve noticeable expansion without much support through subsidies. Examples of fully commercial deployment of RETs in rural areas include solar PV systems in China and Kenya, some PV companies in India, micro-wind systems in China and Mongolia, and pico-hydro projects in the Lao People's Democratic Republic and Viet Nam (World Bank, 2008b: 11). However, in most cases, incorporating start-up costs in the costs of energy supply would exceed the ability of the rural poor to pay. Yet studies show that the poor are often willing to pay for higher quality energy services but may be deterred from obtaining those services due to high access costs (Barnes and Halpern, 2000).

By supporting start-up costs, and sometimes electricity rates, governments can greatly improve the commercial viability of investments. Subsidies can unleash demand and open business opportunities. However, there are additional and supplementary policy instruments available to improve profitability. One such instrument is to utilize public procurement (purchase of a large quantity of power-generating units) as a means of reducing capital outlay. An additional possibility is to lower capital costs by exempting off-grid renewable equipment from import tariffs and other taxes (experimented in Kenya and the United Republic of Tanzania (World Bank, 2008b)). The extent to which this is effective depends on the size of demand for these products and the rates at which such tariffs and taxes are set. However, because components and renewable equipment often have several uses, governments may be reluctant to generalize the application of such systems. (See the commentary by Vikhlyaev in this Review concerning the role of import tariffs and non-tariff barriers in the wider deployment of renewables, as well as the commentary by Zhang, who describes some additional measures needed in a package for the global dissemination of RETs.)

Another possibility for improving the profitability of investments is to stimulate demand and thereby increase the utilization of energy by consumers. This comprises chiefly capacity-building efforts and support to stimulate energy utilization in productive activities. It entails overcoming technology resistance, awareness-raising, training of local technicians, technology demonstration, and upstream involvement of the population to increase local ownership. The key element resides in the identification of business opportunities at all levels, the creation of cooperatives and the insertion of electrification investments within broader policy objectives (e.g. irrigation, product processing and diversification, and employment generation). Furthermore, the deployment of RET in public buildings and facilities (e.g. schools, dispensaries and water pumping and purification) can significantly increase demand, may justify village mini-grids, and improves investment security because of the assurance of regular monthly payments. In addition to improving profitability and reducing risks, this obviously increases the social benefits of investment, and may in turn maximize the possibility of income generation.

Finally, another tool to enhance profitability is to explore innovative service delivery models. The development of business models can be fostered through specific regulatory frameworks (Martinot and Reiche, 2000). National energy regulation is indeed crucial in promoting private sector investments, ensuring greater penetration of renewable energy source and greater cooperation among system operators with the aim of improving the security of energy supply, demand and transit. Emerging service delivery models include (Reiche, Covarrubias and Martinot, 2000):

- "Decentralized virtual utilities": the enterprises selling electricity charge a fee for their services, either through fixed monthly payments or through prepaid cards (experimented in South Africa);
- Local electricity retailers: local small businesses or cooperatives establish and run a business after accessing credit finance (for example, the establishment of independent rural power producers in India);
- Energy equipment dealers: RETs are distributed by local retailers who are able to penetrate low-income and remote areas, and secure credit for off-grid customers;
- Creative concessions: successful bidding companies are offered time-bound concessions to provide electricity in designated areas as a monopoly (e.g. Argentina, Senegal) or under competition (e.g. Cape Verde).

4. Political vision and commitment

The single most important objective of a RET-based electrification project is, of course, to ensure that the infrastructure installed produces positive changes beyond the time frame of project implementation.

The multiple benefits of RETs and their numerous possible synergies with other public policy priorities

highlight the centrality of policy coherence and institutional coordination. Fully harnessing the human development and environmental potential of electrification requires weighing multiple policy objectives, preventing or removing conflicting incentives, and exploiting synergies with other public investment decisions. Two illustrations of lack of policy coherence are subsidies for fossil fuels and the absence of microfinance to support projects.

Policy coherence in itself is a challenge, particularly in developing countries. First, because rapid economic growth brings rapidly evolving social and economic priorities, which at times can be difficult to oversee and reconcile. Second, because coherence and coordination require institutional capacity and strong regulatory frameworks, which typically are lacking in poor countries. Third, because prioritization and coherence require political leadership, commitment and vision, which might be difficult to mobilize, given the numerous competing social and political needs in poor developing countries. The inclusion of RET deployment and rural electrification goals in Poverty Reduction Strategy Papers or National Development Plans can provide a good platform to achieve greater coherence. In this respect, political leadership and commitment are likely to be more forthcoming if electrification is indeed part of a development and income-generating package.

A useful instrument for promoting coordination is to adopt a multisectoral approach to an electrification policy; that is, to coordinate action among public agencies and ministries in order to identify possibilities for joint investments, synergies and service bundling. An interesting attempt is the Senegalese CIMES/RP,[8] a mechanism created by Senegal's Rural Electrification Agency, which aims at facilitating access to energy services in rural areas, including by identifying possibilities of supporting or exploiting synergies with other sectors (e.g. water, education, health, telecommunications, gender, agriculture and the environment). It makes a direct contribution to the identification of multisectoral energy programmes, and hence for electrification for productive uses. CIMES also supports a wide range of stakeholders to enhance their awareness about the linkages between energy and development, and assists in the identification of energy components in poverty reduction strategies.[9]

In addition to high-level commitment, one of the clearest lessons from the implementation of electrification projects over the past few decades is that local stakeholders must be closely involved in the design and implementation of projects to ensure an adequate ownership of the investments. In addition, since the pattern of energy consumption has major implications with regard to the benefits that can be derived from electrification, consumer education must also be part of investment packages. For instance, after several years of an electrification programme with full subsidization of household PV systems, it was observed that many households had sold their systems (Barnes and Halpern, 2000). These systems might have made economic and financial sense, but the households concerned felt they were not useful, which clearly hindered the achievement of the intended project results. Similarly, a survey of past electrification programmes demonstrated that projects fell short of delivering their full developmental and poverty reduction potential. User dissatisfaction, difficulties in servicing equipment and lack of awareness may mean systems fall into disuse or run below planned capacity, which in turn further undermines the commercial viability of the investments. A survey of 6,000 households in the Lao People's Democratic Republic revealed that almost 85 of the SHS systems were not working properly, and that failure to replace batteries meant households benefited from only 30 minutes to one hour of electricity every day (IEG, 2008, box 5.4). It was also estimated that once electrified, 80 per cent of the electricity consumed was used for lighting and watching television, both worthwhile benefits (access to television improves knowledge and reduces fertility), but disappointing compared with the potential of electrification for income generation, productivity gains, education and health improvements (IEG, 2008). Consumer education and a focus on productive opportunities to stimulate demand and ensure that consumers derive maximum benefits at the lowest cost are therefore an essential element in any electrification programme.

The imperative to reduce poverty and achieve the MDGs certainly provides a compelling enough policy argument in favour of energy investments. However, the political attractiveness and full development potential of these investments require the utilization of energy for income-generating activities. This requires identifying and building upon "pockets of opportunity". Such pockets may consist of rural areas where successful agricultural activities are already being conducted with some degree of competitiveness and where electrification would most certainly help realize those areas' social, production and trading potentials. There is huge scope for exploiting synergies between

Table 4. Funding options for environmental programmes

Main beneficiaries	Funding mechanisms	Role and activities of government	Rationale for government role	Examples
Direct income generated by investments or productive activities	Income is directed to those working for wages or profit	Government market regulators provide regulations, subsidies, promote price stability, foster formal employment through SMEs and cooperatives	Markets do not function effectively and the poor and the environment carry the burden of continued market failure	Consumer surplus from cheaper energy bills, income from equipment manufacture, increased productivity of family businesses
No direct income but benefits accrue to the poor	Government funding from poverty relief funds	Government as buyer (on behalf of poor beneficiaries). Buys services through the funding of public employment programmes	Poor are not able to afford to pay for the benefits	Water pumping for drinking, lighting, reduced indoor pollution, better nutrition from refrigeration, access to knowledge
Benefits that accrue to third parties	Government funding, with funds raised through special levies or taxes	Government acts as intermediary: buys services through funding or develops methods for quantification of benefits to establish a fair price, sells services through taxes, levies or user charges	No existing market mechanism for beneficiaries of the services to compensate those delivering the service	Energy delivery by rural companies, water pumping for irrigation, refrigeration of medicines
Benefits that accrue to government	Government funding, derived from general taxes or cost savings	Government acts as buyer. Buys services through the funding of public employment programmes, and offsets programme costs against other savings if applicable	Government is the main beneficiary of the service	Improved ability to retain trained education and health personnel in rural areas, income streams, increased productivity
Benefits that accrue to society as a whole	Government funding or sale of services on (international) markets	Government acts as buyer for downstream beneficiaries. Buys services through the funding of public employment programmes. Sells them on international markets if applicable	Benefits are general, long term and generally not priced, and government acts in its role of investing in the long-term public interest	GHG reduction from fuel switching and carbon sequestration (mitigation), increased income resilience (adaptation), land management

Source: Adapted from UNDP, 2009.

various policies in this context (e.g. promotion of SMEs, trading or export support and capacity-building for sustainable or organic farming).

5. Finance

The argument that RET deployment for rural electrification carries multiple benefits for synergies with climate adaptation and mitigation, as well as investment opportunities, should not minimize the challenges associated with delivering universal access to energy. Even with conducive regulatory and policy environments and innovative business models, the costs of universal access to modern energy remain high. The finance needed to provide access for the remaining 1.6 billion (rural and urban) people who lack energy supply is estimated to amount to $25 billion in total by 2030. However, firms' reduced cash flows, the credit crunch and more constrained government budgets due to the current financial and economic crisis could make it more difficult to mobilize such a level of finance over the short to medium term.

One aspect of investments that could be explored strategically is to mobilize multiple sources, such as public finance, bilateral donors and international development institutions (both governmental and non-governmental), equity from local partners – including investors and cooperatives – global funds related to climate change mitigation and RET deployment, and commercial banks (table 4), as well as consumers (who should own projects and generate finance). The volume of resources involved means these various sources of finance must coordinate their actions and exploit all possible partnerships and synergies. This is already happening, although there are still tremen-

dous opportunities to be tapped. An interesting illustration of an approach that utilizes multiple sources of finance is the EmPower Partnership Programme being implemented in India (described in Sharan in this Review).

While lack of finance to cover market studies, capital costs and capacity-building is a major stumbling block for the multiplication of RET-based rural projects, one element that also deserves attention is finance to foster the emergence of energy enterprises. These enterprises can and probably should lead investments, raise finance, maintain and operate RET equipment. They are also responsible for a large share of the employment potential of RET investments in rural areas. For instance, UNEP's African Rural Energy Enterprise Development Initiative (AREED), supported by the United Nations Foundation, works with African NGOs and development organizations, helping them to identify potential energy projects and providing entrepreneurs with business support services (business start-up support, planning, management structuring and financial planning).

6. Bilateral and multilateral financing mechanisms

There are several multilateral and bilateral programmes of cooperation that aim at increasing the utilization of renewable sources of energy in the context of climate change mitigation. This offers many opportunities for the achievement of rural electrification objectives. The following is a selection of some of those funding schemes:[10]

- *The Global Environmental Facility's* (GEF) *Trust Fund,* under its Climate Change focal area,[11] finances several projects to promote the adoption of renewable energy by assisting governments to remove barriers and reduce implementation costs to make renewables more attractive. It has projects, including several focusing on rural areas, in a number of developing countries: Argentina, Bangladesh, Bolivia, Botswana, Burkina Faso, Cambodia, Chile, China, the Democratic People's Republic of Korea, Ecuador, Egypt, Ghana, Guinea, Honduras, India, the Lao People's Democratic Republic, Lesotho, Mali, Mexico, Mongolia, Nicaragua, Nigeria, Peru, the Philippines, Senegal, Sri Lanka, Uganda, the United Republic of Tanzania, Viet Nam and Yemen.
- The World Bank manages an enormous volume of concessionary lending for rural electrification all over the world. In addition, the Bank manages some funds and implements several initiatives, such as the Lighting Africa initiative,[12] which aims to use high-tech compact fluorescent light bulbs (CFLs) and LEDs powered by renewable energy sources (e.g. solar and wind power and micro-hydro) and mechanical means (e.g. hand cranking and pedal power), to illuminate homes, businesses, health centres and other sites that are not connected to the power grid.
- *The World Bank's Climate Investment Funds* is the umbrella vehicle that distributes multilateral contributions to two trust funds and their programmes:
  - *The Clean Technology Fund,* which is open to projects and programmes that contribute to demonstration, deployment and transfer of low-carbon technologies with a significant potential for long-term GHG emissions savings. The energy sector, particularly renewable energy and energy efficiency in generation, transmission and distribution, figures prominently among the Fund's thematic priorities.
  - *The Strategic Climate Fund*, which contains the recently approved Programme for Scaling up Renewable Energy in Low Income Countries. Its aim is to shift generation of energy from conventional fuels, such as oil and coal, to renewable fuels.
- The *International Climate Initiative (ICI)* of the German Government is financed through the auctioning of Germany's allowable emission permits in the EU Emissions Trading System (EU ETS). A proportion of the revenues under the initiative is earmarked for sustainable energy projects in developing countries. It is currently implementing the project on climate-neutral energy supply for rural areas in India, and a CDM project for local electrification/replacement of fuel generators in villages and small towns in Burkina Faso.

Finally, with respect to the mobilization of global resources for clean energy deployment, the G-8 energy ministers have accepted a proposal to launch an expert-level working group with the participation of G-8 countries and other countries, particularly from the African continent, as well as institutions that may wish to contribute to enabling entrepreneurs to build clean energy businesses serving rural and urban Africa. This group will promote public-private collaboration, seek ways to support small-scale power networks, and foster entrepreneurship, including local factories to manufacture fuel-efficient cooking stoves and energy services firms to provide small-scale electric-

ity access for villages and micro-scale co-generation (G-8, 2009).

7. The Clean Development Mechanism

The Clean Development Mechanism (CDM) under the Kyoto Protocol is increasingly seen as a useful and potentially large source of finance. Development and deployment of renewables constitute the lion's share of registered CDM projects (60 per cent as at 1 July 2009[13]). It includes a sizeable number of registered and validated projects involving fuel switching and the deployment of RETs, some of which concern rural communities. Related to this is the possibility of having recourse to global carbon markets. For example, in 2008, two new World Bank projects in Bangladesh were approved for 1.3 million SHS to be installed by Grameen Shakti and Infrastructure Development Company Limited (IDCOL). These projects are among the first to incorporate off-grid PV carbon finance (REN21, 2009). Financial opportunities created by the CDM for RET-based services would amply justify government support for RET deployment (as opposed to energy subsidies, irrespective of technology used).

There are, nevertheless, many obstacles to fully exploiting the potential of the CDM for small-scale projects, such as those relating to RET-based electrification of rural areas. Commonly cited barriers include high transaction and associated costs (registration, validation and verification), which are too high given the size of the projects and the fact that the small volumes of avoided or reduced CO_2 per household might be unattractive for project developers and CDM investors. Another challenge regarding the utilization of CDM is to channel the distribution of investments much more to rural areas, particularly in the poorer developing countries such as those of Africa. The geographical distribution of CDM projects is currently heavily concentrated in a few large developing countries.

According to a World Bank report (2008c), sub-Saharan Africa has an enormous potential to absorb CDM investments, including in energy generation. If all CDM projects imagined by the authors of the Report were implemented, the result would be the addition of 170GW to this subregion's power generation capacity, implying a doubling of its current installed capacity. In order for Africa to be able to participate to a larger extent in CDM projects, the authors recommend the removal of barriers such as regulatory and logistic gaps in the energy markets, appropriate infrastructure planning, technical information on mature clean energy technologies and improvement of local skills for the design and implementation of projects.

Institutional capacity is particularly important to link RET-based electrification opportunities with the CDM. Authorities and firms may lack the capacity to identify opportunities, elaborate CDM project documents in line with UNFCCC Executive Board requirements, and implement project activities leading to the certification of tradable certified emission reductions. A good starting point would be for developing countries, particularly in Africa, to include rural electrification objectives in their national appropriate mitigation action plans (NAMAs) and in their national adaptation programmes of action (NAPAs). Renewable energy and rural electrification projects have so far been given relatively little importance in NAPAs, even though the implementation of all or most other listed priority projects requires the utilization of energy.[14]

F. Conclusion

The widespread deployment of renewable sources of energy is not only an environmental and developmental imperative; it can also be strategic in multiple ways. The electrification of poor rural communities constitutes a prerequisite for poverty reduction and development. However, investing in energy utilities alone will not suffice to spur a sustainable economic growth spiral. Incorporating access to energy in rural poverty alleviation strategies can only be sustained if it offers income-generating opportunities and improves the welfare of the rural poor.

Rural electrification based on RETs is not a new concept; several programmes are already being implemented in many developing countries. The bulk of electrification projects financed by the World Bank today are based on RETs. However, the concept has been given renewed political and social impetus due to the current environmental, economic and food crises. Seizing this momentum to lock in development spirals based on sustainable sources of energy necessitates local, national and global mobilization. Action is needed in particular to multiply projects, make finance available and remove barriers which hinder such investments. This highlights the prominent role that must be played by actors that are able to promote knowledge-sharing and serve as clearing houses to link investors with investment opportunities.

A national strategy for the upgrading of RET-based rural electrification could comprise some of the following elements:

- Incorporate universal access to energy services and rural electrification in national development strategies and poverty reduction goals, utilizing PRSPs or NAPAs if appropriate;
- Support and coordinate rural electrification objectives with environmental sustainability goals, particularly those related to climate change mitigation and adaptation, to promote renewables as a strategic tool.
- Draw on road-mapping and other analytical exercises to assess and identify clean technology needs and opportunities at the national level, considering the full range of technology options, and not limiting objectives to only PVs or any other single RET.
- Assess the individual contributions of such technologies to national energy security at various levels, and to economic development and reductions in GHG emissions.
- Identify pockets of opportunities, both on the demand side (productive activities such as manufacturing of energy systems) and on the supply side (e.g. fostering the emergence of energy businesses). Identify possible synergies with other policies or public investments (e.g. opportunities to bundle public services or to equip public buildings with RETs).
- Estimate the development and deployment costs of such technologies in major sectors (power generation and transmission, appliances, buildings, transportation and industry).
- Prioritize investments in rural regions that offer good prospects to run pilot projects (e.g. good employment and productive potential, known availability of natural resources). Foster cooperation among government agencies and ministries (multisectoral approach), identify opportunities for service bundling, and facilitate the emergence of innovative supply models (concessions, village or women's cooperatives, public-private partnerships).
- Identify partners (for the financing, design and implementation of projects) as well as intermediaries that could mobilize and raise awareness among local communities. Identify and exploit multi-stakeholder platforms at the regional and international levels for providing advice on appropriate RET deployment strategies in combination with job- and income-generation programmes.
- Assess financial needs and identify a menu of options for support (e.g. subsidies, microcredit, loans, partial guarantees and revolving funds). Combine financial support with consumer education, and managerial and technical capacity-building.
- Devise concrete steps for implementing such policies, including through appropriate international collaboration and domestic reforms, monitoring progress during and after implementation.
- Identify domestic institutional gaps (e.g. lack of rural electrification agencies and/or regulatory bodies), and regulatory and financial barriers that hinder the adoption of RETs in general, and in the context of rural investments in particular.

Finally, an important element is to continue developing tools to identify, quantify, foresee and monitor the development impacts of rural energy projects. The poverty and gender impacts of rural electrification investments have been poorly integrated into projects so far, and while the poorest households tend to benefit from electrification as coverage expands, effectively reaching the most vulnerable remains a priority. Indeed, the introduction of new technologies and the promotion of income-generating opportunities can create or exacerbate social fragmentation. Truly bottom-up and participatory approaches are therefore crucial.

II. Combining Climate Change Mitigation Actions with Rural Poverty Reduction: DESI Power's Employment and Power Partnership Programme

Dr. Hari Sharan
Chairman, Decentralised Energy Systems India Ltd (DESI)

» DESI Power's EmPower Partnership Programme is an initiative that seeks social investment for a decentralized, biomass-driven electrification programme in rural India. Pilot projects already implemented illustrate how investments in electrification can and should be utilized to promote the emergence of local sustainable markets and microenterprises.

» The key is to adopt a global approach which seeks the highest possible social, environmental and financial returns on investments through the generation of self-sustained sources of revenue. For instance, energy and utility services (lighting, water for drinking and irrigation, and energy for cooking) and microenterprises are created simultaneously with the power plant. Supporting finance can be found in a combination of a government subsidy, revenues from the selling of CDM credits, soft loans from private investors, commercial project loans, and grants. The scheme is completed with capacity-building and training of local partners and microentrepreneurs to manage and run the plants and use energy efficiently for sustainable productive uses and income generation.

» The combined economic, social and environmental returns from such integrated projects make them one of the most cost-effective instruments for poverty reduction in rural villages.

A. Background

1. Access to electricity in rural India

It is commonly acknowledged that inadequate and unreliable electricity and modern energy supply services are among the main causes of the lack of progress in India's rural areas. No non-traditional productive activities are possible without those services. The record of the last 50 years of rural development therefore reinforces the special relevance of Gandhiji's vision of self-reliant villages – a vision even more valid today than it was during his lifetime for the following reasons:

- It has become painfully evident during the past decade of liberalization that it is difficult to mobilize the enormous amounts of capital required for large power stations to supply fossil-fuel-based electricity within the foreseeable future to every Indian, to every large and medium-sized industry, to new rural microenterprises, to the agricultural sector and to urban and rural public services.
- It is also clear that the present centralized system is very largely dependent on coal, which is CO_2-intensive and accelerates climate warming.
- Yet modern, mature, renewable energy systems are available now, and can supply reliable and affordable electricity, irrigation water and energy services at prices which are competitive with non-subsidized conventional fossil-fuel-based grid supplies and captive generation.
- Many more technological solutions for local value addition through small-scale industries in villages are available today. A host of traditional and new agro-based industries and microenterprises would be able to operate profitably in villages if they had access to reliable electricity supply.
- Local value addition of local resources, increased farm productivity and "export" of traditional and new products and services to nearby urban and peri-urban areas will promote faster economic growth and create local employment in villages. One such example is the supply of modern, village-processed cooking fuel based on agro-residues to replace fuel wood and fossil fuels.
- Production of goods and services will increasingly become an alternative to the poverty-driven migration of village youth to city slums.
- The costs of investments can be moderate or even negative. Apart from symbolic investment by local people, selling certified emission reductions (CERs) under the Kyoto Protocol's Clean Development Mechanism (CDM) will leverage local and external private sector investments if the projects are seen to generate profits and jobs.
- The Government needs to establish a framework of incentives, laws and regulations for large-scale

Table 5. Cost of supplying power to a village (Rs million/megawatt, MW)

	Generation		Transmission and Distribution Losses		End-use energy	
	MW	Cost	MW	Cost	MW	Cost
Centralized grid supply	1	35	0.3	5	0.7	57
Decentralized biomass power plant (gasification)	1	35	0.1	5	0.9	44

Source: Internal Report, DESI Power, 2005.

implementation of the model and to garner support from the commercial banking system.

- The liberalized economic regime and the political framework of village *panchayats* (local governments) should enable the Government to promote a long-term public-private partnership model for the financing of projects, such as the EmPower Partnership Programme.

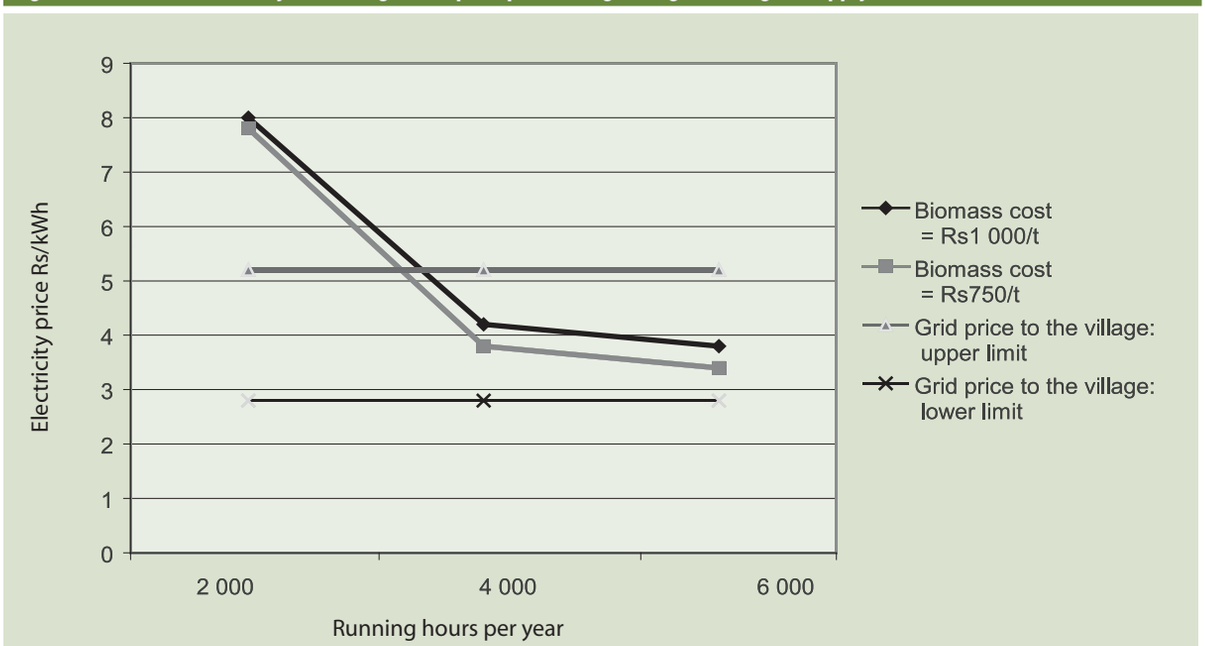
2. Financial advantages of decentralized biomass power plants

Of the more than 500,000 villages in India, about 310,000 have been declared already electrified. According to government statistics, 80,000 more villages remain in need of electrification. The state governments were directed to take up the electrification of 62,000 villages by 2007 through their electricity boards under the traditional rural electrification programmes. The Government of India has also directed the Ministry of New and Renewable Energy (MNRE) to provide renewable-energy-based electrification to 18,000 villages in remote and inaccessible parts of the country by 2012.

In actual practice, however, most of the so-called electrified villages do not have reliable, adequate or good quality power. No commercial investments in micro-enterprises can therefore be made by either individuals or companies without installing diesel generators, which have a very high generating cost, create adverse environmental and climate impacts, cause high foreign exchange outflows and reduce the country's energy security.

As the experience of DESI Power's EmPower Partnership Programme shows, grid supply to remote areas is not competitive with electricity supply from modern, decentralized renewable energy power plants, either

Figure 2. Price of electricity in a village with pure producer gas engine and grid supply



Source: Internal Report, DESI Power. 2005.

in terms of supply or at the end-use point (table 5 and figure 2 showing 2005 data, but trend is still valid). Decentralised power supply (biomass plant) saves power (smaller losses), costs, and CO_2 emissions.

B. The EmPower partnership programme

1. A 100-village commercial demonstration programme for EmPower partnership projects

In absolute terms, the proposed programme, with its goal of installing 5–7.5 MW of generating capacity, is puny compared with the planned installation of 5,000–10,000 MW of generating capacity per year in the conventional fossil-fuel-based power sector in India. However, the project is complex in the context of the many undeveloped rural areas that lack power or other infrastructure and the large number of diverse stakeholders (table 6). DESI Power's experience shows that any centralized system – be it the Government, the private sector or NGOs – will find it very difficult to implement a decentralized programme successfully and efficiently. Therefore, decentralized implementation is planned jointly with villagers, local organizations and entrepreneurs, NGOs, plant promoters, suppliers and builders, financiers and corporate entities.

Based on their experience of the past 15 years, DESI Power and its partners are convinced that centralized electrification alone will neither make electricity supply profitable nor promote the economic and social development of remote villages in India. However, for renewable-energy-based rural electrification to succeed without perpetual subsidies and losses, it is essential to satisfy two critical conditions of power supply and local demand/load:

i) An adequate number of microenterprises should buy enough electricity to enable the supply of that electricity to be commercially viable.

ii) Adequate amounts of affordable and reliable electricity should be locally available, not only for domestic lighting and cooking but also for local microenterprises and water pumping.

Self-sustained growth can take place if the rural electrification programme is linked to village microenterprises for local value addition and employment generation. The power generation based on local renewable energy resources can provide reliable and affordable electricity supply to make the microenterprises profitable, and thus bankable and attractive for private entrepreneurs. Biomass, biogas, solar thermal and PV will be the prime sources of renewable energy in a large number of villages, perhaps more than 300,000, which at present have no access to electricity.

These conditions can be met if the other government programmes on rural job creation and rural small-scale industries are implemented simultaneously in an integrated manner with the Government's programme on renewable-energy-based rural electrification. The EmPower Partnership Programme is structured to ensure that these conditions are met.

The programme could be accelerated if:

- Government support and budgeted public funds are leveraged to obtain local, private and corporate sector investments in these rural projects.
- A policy framework can be established for utilizing sanctioned funds earmarked for renewable-energy-based rural electrification as well as for other rural development programmes (e.g. schemes for promoting small-scale industries, job creation, etc.) in a more focused and integrated manner.
- A policy framework also provides incentives and regulatory support to the private sector to start a programme for the large-scale replication of models such as the EmPower Partnership Programme.

Table 6. The EmPower partnership framework

DESI Power, Development Alternatives/Tara + other companies	Village partner organization(s) (i.e. local village team)	Investors, banks, grants, subsidies, selling CO_2 emissions savings
EmPower Partnership for Village Development		
Independent rural power producer Provision of electricity and energy services	**Village enterprises** Water supply, agro-processing, small industries, fuel supply and processing, agro-forestry, workshops.	**Cluster centre** Organization and project development, training, extension services and refresher courses.

Figure 3. Activities under the 100-Village EmPower Partnership Programme

The Indian 100-Village EmPower Partnership Programme

Decentralized EmPower village projects:

- 10 Clusters with plants in neighbouring villages with a total of about 500 kW each
- Identification, organization and training of promoters / owners of each village plant
- Support for plant construction
- Cluster development
- Cluster management

Financing:

- Government subsidies and loans
- Equity: local and external.
- Commercial loans
- Grants
- CDM: sale of CO_2
- Fund management

Capacity-building/extension services

- Initial capacity-building and orientation for project development
- Technical and managerial training of local trainers, managers and staff
- Training tools for local refresher courses
- Women's capacity-building
- Performance audit and continuing support services

2. Climate change mitigation impact

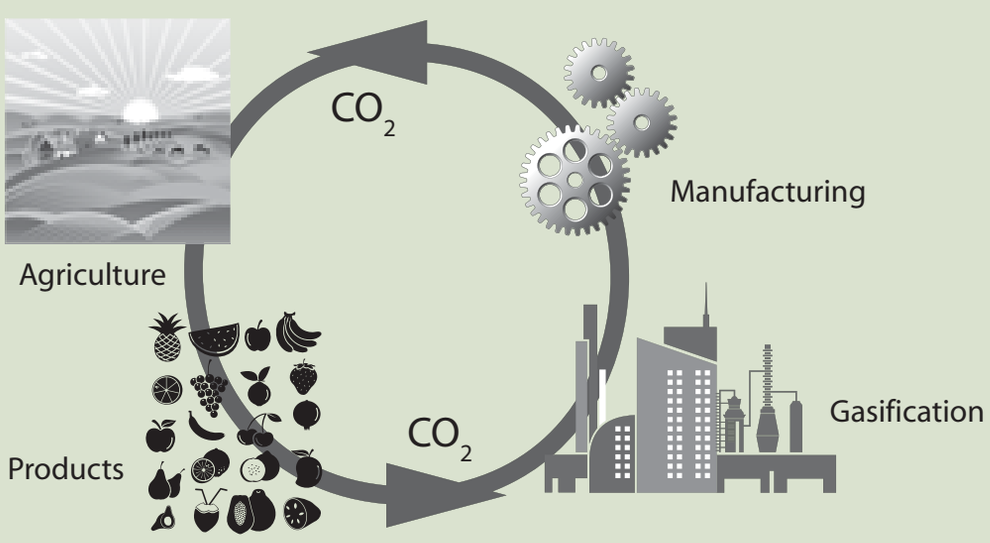
The Partnership Programme will generate savings in CO_2 emissions which will be an additional gain for the global community and an additional source of funding for EmPower Partnership Projects for providing start-up capital for poor villagers.

3. Start of the EmPower Partnership Programme

Decentralised Energy Systems (India) Pvt. Ltd. launched its 100-Village EmPower Partnership Programme for Araria District in the state of Bihar in February 2005. Its objective was to link 100 small biomass-gasifier-based power plants to energy services and microenterprises, all owned by village cooperatives (figure 3). These 100-kW plants were each expected to create at least 50 direct and indirect jobs in each village and eradicate poverty in the participating families. Since the launch, projects have been completed and operational in three villages. Technologies, processes, microenterprises and management systems used in these first three villages comprise:

- Biomass-gasification-based power plants with pure gas engines
- Water pumps for irrigation replacing diesel pumps
- Battery charging

Figure 4. The CO_2-neutral cycle for biomass gasification power plants



- Mini-grids with connections to each household in each village, replacing kerosene
- Traditional agro-processing units (husking, milling, etc.), replacing diesel
- Battery-run LED lighting charged by the power plant or solar PV panels, replacing kerosene
- Biomass processing (cutting, drying, briquetting) and management
- Energy plants and vermiculture
- Fisheries

Financing for these projects was obtained from multiple sources, including:

- Equity from local partners who formed cooperatives and societies for this purpose.
- DESI Power loan and equity from promoters and external "socially responsible" investors.
- World Bank Market Place Award 2006.
- Tech Award 2008.
- Up-front selling of CERs.
- A grant from the International Copper Association for the mini-grid.
- A loan from a foundation run by an Indian commercial bank.

Table 7. Total investment in the EmPower Partnership Project with a 75-kW installed capacity

Description	Amount (Rs million)
Total energy services, microenterprises and infrastructure	3.3
Total power plant	4.5
Project development and implementation, including coordination and travel, capacity-building, training and a cluster centre	0.8
Total investment for one village EmPower Partnership project	**8.6**

While the investment needed for one typical EmPower Partnership project based on biomass processing, a power plant, energy services and microenterprises will vary from village to village, depending on the microenterprises involved, a typical average amount will be about Rs 8.6 million (about $175,000) per village (table 7). Funding required for one cluster consisting of 10 villages is Rs 86 million ($1.75 million), the total for the entire programme of 100 villages being Rs 860 million ($17.5 million).

Table 8 below shows one model of financing such projects, combining multiple funding sources. A governmental subsidy and the selling of CO_2 emissions savings (shown as a likely source of capital for the villagers who have no capital of their own) are used for "leveraging" capital by convincing ethical investors to provide the external equity or loan. Discussions with commercial and development banks indicate they would be prepared to consider 50–60 per cent of the project cost as a loan if the other funds are assured.

Depending on the success of the commercial demonstration phase of 100 villages, replication is expected with a government framework of incentives, checks and balances to ensure that the social and environmental objectives will also be achieved. Viewed in terms of the national economy, EmPower Partnership Projects in 10,000 villages would result in a total installed capacity of 500 MW and a total saving of Rs 6,500 million ($144 million) on the conventional power supply side. Since the projects will be profitable, it might be possible to raise 30–70 per cent of this capital from direct private sector equity and loans. If the Government provides a suitable framework, ethical foreign direct investments are likely to flow to these projects, especially if they are bundled and promoted as public-private partnership schemes. Since these projects are recognized as premium CDM projects, up to 30 per cent of capital could also be raised by selling CO_2 savings. Government subsidies for rural electrification may bring another 10 per cent, and the remaining amount could be raised as loans from development banks (such as the Indian Renewable Energy Development Agency (IREDA), the Small Industries Development Bank of India (SIDBI) and the National Bank for Agriculture and Rural Development (NABARD)) or from commercial banks.

The profitability of EmPower Partnership projects (Table 9) will improve as more and more projects are built incorporating modifications in planning and implementation as a result of lessons learnt. Lessons

Table 8. Likely sources of investment

Sources of funds, % of total					
External equity	Local equity	Government subsidy	CERs	Grant for capacity- building	Bank loan
40–70	2–5	10–12	0–30	8–13	15–30

Table 9. Profitability of a pilot phase EmPower Partnership project (with an adequate number of business units and a medium plant load factor)

Based on actual data for each business unit (BU)	Pure gas engine 12 hours/day
Investment for business units (considered as a loan) (Rs)	1 143 714
Annual interest rate (%)	12
Capital repayment period (years)	8
Annual capital service rate (%)	20.1
Annual capital service payments, BU (Rs)	230 000
Annual profit of BU (after meeting capital service payments and overheads) (Rs)	120 770
Annual profit of BU (after meeting capital service and overheads (% of income)	10.56
Investment, power plant (Rs)	2 326 313
Annual profit of power plant (Rs)	116 316
Profit of power plant (%)	5
Total investment in BUs and power plant (PP) (Rs)	3 470 027
Total annual profit from EmPower Partnership project (BU+PP) (Rs)	237 086
Return on investment for total EmPower Partnership project (%)	6.8

learnt in the pilot projects lead to the reduction of costs achievable by value engineering and standardization as well as from the use of energy-efficient equipment in microenterprises and energy services. Some of the other essential ingredients of success are:

- Institutionalization of training and capacity-building of a large number of local people for the management teams and operational staff.
- Proper selection and mix of microenterprises and products to match local resources and market requirements.
- Higher investment in micro enterprises.
- Promotion of agroforestry and energy plantations.
- Offering of more energy and utility services.
- Maintaining a high power plant load factor.
- A profit-oriented financing model with easy access to equity, loans and subsidies until such time as hidden subsidies for fossil fuels are eliminated.

The first batch of projects under the EmPower Partnership Programme are now operational in three villages (three units are registered under the CDM) under commercial demonstration conditions. The second batch of 20 EmPower Partnership projects in 20 villages is ready to start. Based on learning from the first batch and their investment and operational data, a business plan for the second batch has been finalized. Figure 5 below shows one set of projected results for a typical case, with investments in the form of equity, loans and subsidies. In this case, the income from selling the resulting CERs under CDM is considered as an annual income stream. Issues related to depreciation and taxes will be clarified jointly with the equity investor once the current discussions are completed.

4. The triple return-on-investment criteria for evaluating and financing the EmPower Partnership Programme

One of the axioms of the neo-liberal economic thinking is that investments must be justified on the basis of an adequate return on investment (ROI) to attract private sector operators. Issues related to fairness and equitable sharing of common resources, external costs and long-term damages caused by economic activities carried out for private profit, and the short- and long-term monetary costs of social unrest are not taken into account in such investment decisions. One of the hardest tasks of those involved in promoting sustainable development is to try and convince policy-makers, private sector investors and financial consultants that ROI as the sole criterion is not adequate for programmes covering sustainable energy, economic and social rural development and poverty reduction. Economic, social and environmental consequences should all be considered in making investment decisions and selecting projects, and a single "triple ROI" criterion should be used for this purpose.

Figure 5. Profitability of EmPower Partnership Projects (with the total planned investment in business units to ensure high plant load factor)

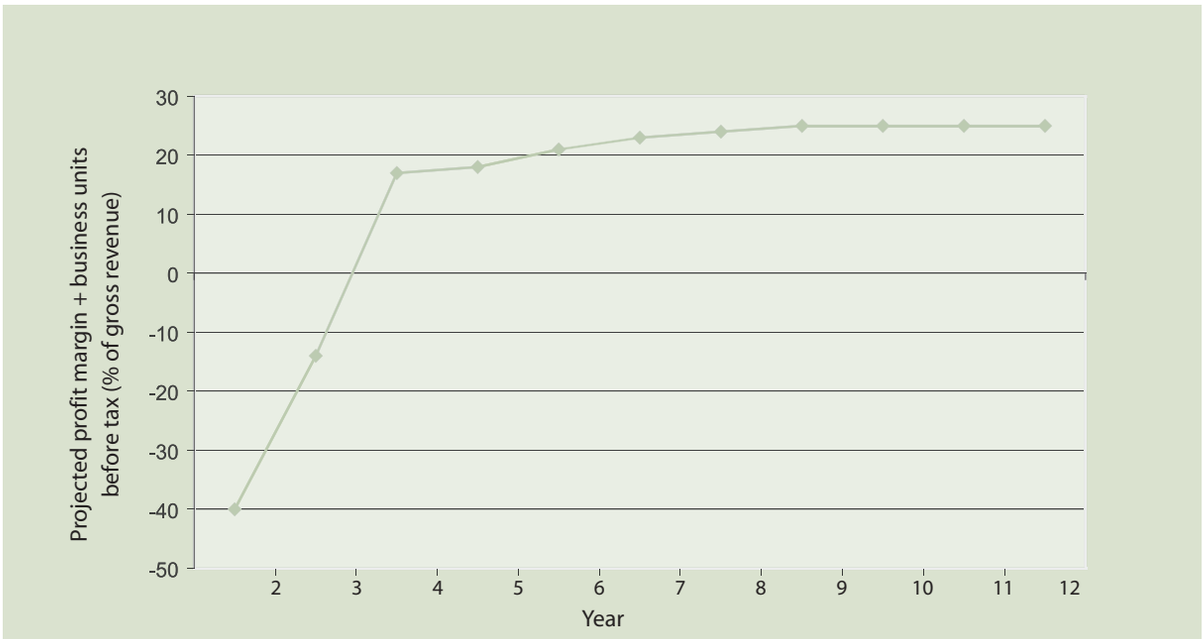


Table 10. Typical performance of a pilot EmPower Partnership project (with a low plant load factor)

	Economic performance		Social				Environmental			
Machine/ plant	Investment (dollars)	ROI (profit as % of investment)	Total direct jobs created	Invest-ment per job ($/job)	Jobs for women	Other impacts[a]	Reduction of local pollution[b]	Savings in CO_2 emissions	Cost of savings of CO_2 emissions	
Briquetting machine 125 kg	9 000	6.0	2.1	4 286	Yes	Yes	Yes	Yes		Much lower than in industrial-ized countries
Four new pumps	8 000	17.0	1.1	7 273	Yes		Yes	Yes		
Old pumps	1 000	51.0	1	1 000	Yes		Yes	Yes		
Paddy processing	30 000	8.0	5.5	5 455	Yes	Yes	Yes	Yes		
Fishery	3 000	15.0	1	3 000						
Tree planting	5 000	3.5	1.5	3 333	Yes		Yes	Yes		
Power plant	60 000	10.0	5	12 000			Yes	Yes		
Other small energy service units	10 000	10.0	2	5 000	Yes	Yes	Yes	Yes		
Project total	**126 000**	**9.8**	**19**	**6 563**						

[a] Other social impacts cover drinking water, lighting, cooking, health services, schooling and capacity- building.
[b] Local pollution covers impacts on air, water and soil.

The EmPower Partnership Programme promotes projects which combine social and environmental benefits with a fair financial return (table 10). The 100-village programme will create more than 2,500 direct, year-round jobs, in addition to several indirect jobs, through increased farm production, new trading and commercial activities and energy services. It will also reduce pollution, improve women's health and reduce rural migration to city slums. Overall, the growth of the gross national product (GNP) as well the Human Development Index of the village can be quantified and demonstrated for large-scale replication of the EmPower Partnership model.

C. Conclusion

DESI Power's EmPower Partnership Project seeks social investment in the rural development marketplace under a model of public-private partnership. The EmPower Partnership Project is positioned to create local sustainable markets for decentralized power supply, energy services and microenterprises in Indian villages. Led by a network of social entrepreneurs and supported by a public-private network of partners, the project is designed for successful revenue-based financial, social and environmental returns on investment.

A government subsidy, combined with the selling of CDM credits (or credits under many existing voluntary carbon offset schemes) will provide the start-up capital – a "leveraging" component of the required investment – together with a small equity funding by the villagers. Combined with external equity and soft loans from private sector ethical and/or other investors, commercial project loans can be raised from development and commercial banks. Grants complete the scheme, particularly to cover the costs of capacity-building, training and the initial running costs.

The combined economic, social and environmental returns from projects such as the EmPower Partnership Programme make them one of the most cost-effective instruments for poverty reduction in rural villages. Overall, the growth of the GNP or GVP (gross village product) as well of the Human Development Index of the village can be quantified and demonstrated for large-scale replication of the EmPower Partnership Programme's pilot projects.

III. Powering the Green Leap Forward: China's Wind Energy Sector

Dong Wu
UNCTAD secretariat

» China has recently emerged as a global leader in wind energy industry, more than doubling its overall capacity every year since 2006 to reach an installed capacity that is second only to that of the United States.

» In addition to this impressive growth in installed capacity, China's real success concerns the emergence of a competitive local industry producing high-calibre windmills based on local research and technology.

» China's successful experience can be explained by several factors. First, a highly favourable wind energy potential. Second, supportive and flanking government policies promoting renewable energy sources (feed-in tariffs, local content requirements, tax rebates, financial support to research). Third, corporate strategies to bridge the technology gap, particularly focusing away from licensing and preferring the commissioning of original constructions delivered by international design and consulting firms. Fourthly, initiatives to foster synergies in the supply chain though the creation of local technology and industrial clusters/parks..

In recent years, China has emerged as a global leader in wind energy, more than doubling its overall capacity every year since 2006. In 2008, China's newly installed capacity amounted to 6 GW, while its cumulative installed capacity was more than 12 GW and set to rise to 20 GW by 2010 (compared with India's cumulative installed capacity in 2008 of 1.8 GW). This will make China the second largest producer of wind energy in the world after the United States, overtaking both Germany and Spain.[15] Projections are that China will reach 30 GW installed capacity by 2011 – well ahead of the target year 2020 originally set by the Government. For Chinese experts, these developments mark the beginning of "a golden age of wind power development" in the country.

However, installed capacity, is only half of China's success story; the other half is the emergence of a competitive local industry. Until recently, China relied largely on foreign companies to supply much of the equipment for its rapidly growing number of wind farms. Although there were several domestic companies manufacturing turbines, their output lagged significantly behind their main foreign competitors. Until two years ago, none of the Chinese manufacturers were capable of producing megawatt-class wind turbines (Schwartz and Hodum, 2008). Some key components such as bearings (used in gearboxes) and control systems had to be imported, since domestic suppliers lacked the necessary capabilities to produce them. Today, the situation has fundamentally changed: a number of Chinese turbine manufacturers have successfully closed the technological gap with their European and American competitors and now dominate the domestic market. Domestic manufacturers accounted for 70 per cent of newly installed capacity in 2008, up from 30 per cent in 2004. Goldwind and Sinovel, China's leading turbine manufacturers, already rank among the top 10 manufacturers in the world; Dongfang, Windey and several others are likely to follow. China's wind generator industry has also made significant progress in developing and building up an indigenous supply chain that links turbine manufacturers, component suppliers and technology services (He and Chen, 2009). A prominent example is China High Speed Transmission Group, which, within a relatively short period of time, has established itself as the major supplier of high-quality gearboxes, not only for the domestic market but also increasingly for the international market (Beijing Gao Hua Securities Company Ltd, 2009). As a result, China is poised to become a major player in the global wind power equipment market within the next few years.[16]

Several factors have contributed to the rapid expansion of the Chinese wind power sector since 2006, not

least China's highly favourable wind energy potential. According to a recent *Science* article, if China were to take full advantage of its wind potential, wind power could meet the country's entire demand for electricity by 2030, generating close to 7 trillion kWh of energy per year, and thus contributing significantly to the country's energy security (McElroy et al. (2009). However, favourable environmental conditions do not necessarily guarantee their exploitation. Three additional factors have been particularly instrumental in forcing China's recent wind power push: government policies promoting renewable energy sources, corporate strategies to bridge the technology gap, and local government initiatives to establish technology clusters that benefit the wind industry. These are discussed below.

A. Public policy

Government policies have played a decisive role in the rapid development of the country's wind energy sector. None has been more important than the Renewable Energy Law, which came into effect in 2006. The law and its implementing regulations not only confirmed the Government's commitment to the development of renewable sources of energy within Government-set targets, but also reaffirmed its commitment to provide special funds and offer financial incentives to the renewables sector to meet those targets. The goal of these policies, according to the Medium and Long-Term Development Plan for Renewable Energy of 2007, was to establish a "basic system of renewable energy technologies and industry" by the year 2010 as a foundation for the development of "relatively complete", large-scale domestic manufacturing capabilities, primarily based on China's own intellectual property rights (NDRC, 2007). In support of the policies, the National Development and Reform Commission (NDRC) and the Ministry of Science and Technology (MOST) have provided strong support to the wind sector. The development of wind technology has been accorded a prominent place in the nation's major research programmes, most notably the national basic research programme, national high-tech R&D programme, and the national key technology R&D programme. In addition, NDRC and MOST have provided financial support through dedicated R&D funds for renewable energy (Zhang et al., 2009; Lee and Ma, 2009).

Most important of all for the wind energy sector, the Government required grid companies to provide access to the local grid and offer ancillary technical services to wind power projects, as well as to purchase the full amount of energy generated by them. However, the law did not alter the wind concession system for large-scale wind farms and replace it with a feed-in tariff. Under the concession system, wind project developers engaged in competitive bidding; the winner received guaranteed long-term power purchase agreements from the grid operator. The model tended to award those developers, which offered the lowest feed-in prices. Generally, these were large State-owned energy companies eager to meet the Government's clean energy quotas, and which could offset losses incurred in the wind sector with profits made from traditional energy (i.e. coal and hydro) sources. The concession system was abolished in August 2009 and replaced by a conventional feed-in tariff model.

In order to promote China's emerging wind industry, the Government introduced a number of regulations and incentives to support domestic manufacturing capabilities. As early as 2003, the Chinese authorities mandated local content requirements, first amounting to 40 per cent in the context of the concession programme, subsequently raised to 70 per cent, and extended to all new wind installations, including those applying for financing under the Clean Development Mechanism (CDM)financing. The Government also used tax policy to steer the wind power sector in the desired direction. In 2001, for instance, the value-added tax for wind power was cut in half (from 17 to 8.5 percent); there was also a shift in customs policy. Initially, imported wind power equipment was exempted from customs duties in order to promote technology transfer. Subsequently, as the focus increasingly shifted to the development of a domestic wind power manufacturing base, the government issued graduated customs duty rates that favoured the import of components over complete turbines (Zhao, Hu and Zuo, 2009, p.2888). Once Chinese companies had mastered megawatt-level turbine technology, the Government modified the policy. In April 2008, the Ministry of Finance announced the removal of all tax breaks on imported wind turbines below 2.5 MW (Ministry of Finance, 2008). At the same time, the Government announced a VAT rebate on imported "key components and raw materials" if they were used by domestic manufacturers to develop and manufacture large systems (1.2 MW and above). The returned taxes were to be used to support "new product development and innovation capacity building" (Ministry of Finance, 2008). In August 2008 the Ministry of Finance

issued a second financial incentive package aimed at promoting domestic wind power equipment manufacturers. The policy rewards domestic manufacturers with 600 RMB per kW for each of the first 50 turbines of over 1MW, if they have been tested and certified by the Chinese authorities, put into operation and connected to the grid. Only those turbines qualify that use domestically produced components. Experts expect this policy to have a "significant impact on the future promotion of China's domestic industry's technology innovation, improving competitiveness and building domestic branding in the long run" (Global Energy Council, undated).

B. Enterprise strategies

Initially, Chinese turbine producers acquired licenses from foreign companies to reproduce existing turbine designs. This allowed them to get established in the domestic market and gain experience in the production of larger turbines. However, the Chinese manufacturers soon found out that foreign firms were reluctant to license their most recent, state-of-the art technology; instead they preferred to license turbines that were technologically outdated for fear that the transfer of advanced technology would lead to knowledge spillover, thus undermining their competitive advantage (Liu, 2006). Licensing thus soon proved to be insufficient, particularly given the ambitions of the Chinese wind energy programme, which aimed largely at the commissioning of large-scale wind farms employing megawatt turbines (1.5 MW and higher).

In response, major Chinese turbine manufacturers changed their strategy. The focus shifted away from licensing to the commissioning of "original constructions" delivered by international design and consulting firms. This has had two advantages: first, the cost of design tends to be substantially lower than licensing fees (one third, according to one Chinese expert); second, in general, once the design firm has delivered the blueprint, the Chinese client owns the intellectual property rights to the design. This strategy has allowed even newcomers to leapfrog years of wind technology development, produce relatively advanced, high-capacity machines, and thus compete with the established and more experienced domestic enterprises such as Goldwind and Sinovel (Liu, 2006).

In each of these stages, the role of German firms has been crucial. Goldwind, for instance, China's "oldest" and most experienced turbine manufacturer got started buying a licence from the German firm, Jacobs Energie (today part of REpower Systems) for a 600-kW machine. Six years later, Goldwind entered the 1 MW market by purchasing a licence from Vensys Energiesysteme, a relatively small company based in Saarbrücken, for its 1.2 MW turbine. Meanwhile, Goldwind acquired a 70-per cent share in Vensys, which has been working together with experts from the Saarland University of Applied Sciences on a 2 MW and 2.5 MW turbine for Goldwind. As a result, Goldwind has gone from "licensee to market leader" (Jensen, 2008). Other leading turbine makers, such as Sinovel and Dongfang, followed Goldwind's lead, acquiring licences from Fuhrländer and Repower respectively.

The recent shift in strategy has particularly benefited relatively small engineering and design firms, such as Aerodyn (Germany) and Windtec (Austria, a subsidiary of American Superconductor). Although Aerodyn has also sold licences (e.g. for its rotor blades), its main focus is on consulting and design. As such, Aerodyn has been instrumental in the emergence of a number of new wind energy firms in China's domestic market, such as MingYang Wind Power Technology, which entered the market with a versatile 1.5 MW turbine in late 2007, and Sewind, which in 2008 concluded a joint development agreement with Aerodyn for a 3.6 MW machine due to be delivered in late 2010 (May, Weber and Weinhold, 2008). MingYang and Sewind, like a growing number of other recent newcomers to the Chinese wind energy market, are subsidiaries of large established enterprises which have gained their reputation in the fields of mechanical engineering, tool making, and/or energy-related equipment manufacturing. These companies have built up considerable technological and engineering capabilities, which they could apply, at least in part, to the wind energy sector. Particularly for these companies, engaging the services of established design firms has been a logical step in their corporate strategy.

Established manufacturers, confronted with this new trend in wind technology acquisition, have followed suit. At the same time, however, they have started embracing a new strategy, in line with a new trend in thee global wind industry. As Andrew Garrad, chairman of the British energy consulting firm Garrad Hassan, has recently noted, in the past, the main objective was to develop "bigger and bigger" turbines in order to extract ever more power from the available wind resources. Today, however, the emphasis is increasingly on "better and better". This implies, according to Garrad,

"diversifying to produce different wind turbines to cope with more specific site characteristics" (*New Energy Focus*, 2009). A case in point is Dongfang's cooperation agreement with the Finnish company, The Switch, from early 2008. Under the agreement, The Switch will supply Dongfang with the production concept and technology for its innovative "permanent magnet generator" product package, which, according to experts, represents "the technology of choice for next-generation wind power generators, as they offer a platform of highly integrated components that are built to last and require very little maintenance."(*Penn Energy*, undated).[17] Similar considerations appear to have been behind Sinovel's cooperation deal with American Superconductor Corporation (AMSC). Under the agreement, Sinovel will have access to AMSC's core electrical components, particularly its state-of-the-art power converter which, according to AMSC sources, enables "reliable, high-performance wind turbine operation by controlling power flows, regulating voltage, monitoring system performance and controlling the pitch of wind turbine blades to maximize efficiency" (Finanzen Net, 2009). Goldwind's recent partial acquisition of the German turbine developer Vensys was similarly motivated by the desire to improve the product quality of China's leading turbine manufacturer.

C. Technology clusters

For the Chinese wind energy industry to meet the Government's ambitious targets, the development of a reliable supply chain based on indigenous R&D is of crucial importance (He and Chen, 2009: 2897). One way to foster R&D in a particular technology area is to concentrate technology firms, suppliers, and ancillary services in spatially circumscribed technology clusters (a sort of dedicated industrial park) (Porter, 2000). To a certain extent, this has happened in the Chinese wind energy sector. At present, there are at least three major local clusters, all of which are located in special economic development zones in large cities in the north-eastern part of the country: Tianjin, Baoding and Shenyang. Each one houses a mix of domestic and foreign turbine manufacturers, component suppliers and technology services.

Tianjin's wind energy cluster is located in the Binhai Hi-Tech Area, which is part of the city's Hi-Tech Industry Park (established in 1991). This cluster is home to three leading foreign turbine manufacturers (Vestas, Gamesa, and Suzlon, since 2006), in addition to the blade manufacturers, LM Glasfiber (the world leader in rotor blades from Denmark, in Tianjin since 2001) and Tianjing Dongqi Wind Turbine Blade Engineering (2007), as well as Tianjin Dongqi Wind Turbine Technology (2008). Tianjin is also home to Winergy Drive Systems (owned by Siemens), a leading supplier of gear units and complete drive systems for wind turbines, located in Beichen Economic Development Area, which is adjacent to the Binhai Hi-Tech Area. The most recent addition to the growing number of wind energy-related companies in Tianjin is Hexcel, a leading world supplier of specialized composites for rotor blades, which followed Vestas to China (Gardiner, 2008).

According to official sources, the target for the wind energy sector in Tianjin is to establish the city as China's largest wind energy equipment manufacturing base as well as a main centre for R&D, consulting, training, and certification and evaluation. Above all, the Tianjin Hi-Tech Area is supposed to become a major source of innovation in the green energy sector. In order to achieve this goal, the local government provides a panoply of financial incentives, ranging from subsidies for land and building rents as well as for the interest paid on loans, to direct financial support for institutions involved in R&D for the wind energy sector (and other high priority hi-tech sectors) (Liu, undated).[18]

Like Tianjin, Baoding has ambitious plans with regard to the wind energy sector (Delman and Chen, 2008; Koot, 2006; Reinvang, 2008).[19] A Hi-Tech Development Zone was established early in this decade. In 2003, it was declared a "State New Energy and Energy Equipment Industrial Base" by MOST. In 2006, the municipal government set out to turn Baoding into "China's Electricity Valley" centred around the renewable energy sector (wind and solar). The target was to increase, within a period of five years, turbine production to 1.5 GW and rotor blade production to 2.4 GW. In addition, the plan was to attract a range of component manufacturers and R&D facilities. In order to achieve these goals, the administration of this hi-tech zone created a number of incentive programmes to facilitate access to risk capital, and established special funds to support technology development. The expectation is that by 2050, 40 per cent of Baoding's GDP will come from the renewable energy sector. In the meantime, Baoding has become host to a number of major wind power equipment suppliers as well as R&D firms. A notable example is HuaYi Wind Power, which was jointly established by the Chinese Academy of Sciences (Institute of Engineering Thermophysics), the

Chinese Wind Energy Association and the Baoding National New Energy and Energy Equipment Industrial Base to promote and speed up the development of indigenous rotor blade technology.

Shenyang's Economic and Technological Development Zone, is home to General Electric Energy Co., A-Power, Shenyang Blower Works (which in late 2008 partnered with AMSC to develop a 2MW turbine due in 2010), China Creative Wind Energy, Shenyang Huachuan Wind Power Company, and, since January 2009, Fuhrländer. The Shenyang wind energy cluster benefits from its close proximity to the Wind Energy Research Institute of Shenyang University of Technology(SUT), a pioneer in Chinese domestic wind energy development (the Institute was the first, among other things, to build a purely indigenous 1MW and 1.5MW turbine).

The case of A-Power demonstrates the benefits of technology clusters for the rapid development of the Chinese wind energy industry. A-Power got started in the wind energy field in 2008, when it built a manufacturing base in the Shenyang Economic and Technological Development Zone with technology licensed from Fuhrländer. In early 2009, the company agreed to establish a joint venture with GE Drivetrain Technologies to produce wind turbine gearboxes in Shenyang. It also established strategic partnerships with Tsinghua University in Beijing and the China Academy of Sciences in Guangzhou, to develop and commercialize new technologies. In July 2009, A-Power entered into an agreement with Shenyang Huaren Wind Power Technology Development Co. for the acquisition of Huaren's proprietary technology to commercially produce and sell 1.5 MW-grade wind turbines. At the same time, it formed the Shenyang Power Group (SPG), an alliance that brought together a range of local wind-energy-related technology companies, ranging from power equipment makers to engineering service providers. "The alliance was created to integrate local resources and leverage the manufacturing, engineering and government initiatives in the Shenyang area so that SPG can pursue large-scale, international projects in the alternative energy sector."[20] In October 2009, A-Power announced it had won a contract to develop a 19.5 MW wind park in Shandong Province for Datang International Power Generation, one of China's top five State-owned power producers.[21] Later that month, SPG entered into a joint venture agreement with American firms to build a 600 MW wind farm in West Texas (fully financed by Chinese commercial banks), for which A-Power will supply 240 2.5 MW turbines (using GE's gearboxes) – marking "the first instance of a Chinese manufacturer exporting wind turbines to the United States market" (Rudolf, 2009).

D. Conclusion

China owes its recent rise as a major global wind energy power to the fortuitous interplay of several factors: government policies and financial support (motivated largely by energy security concerns and economic and environmental considerations); enterprise strategies in response to government regulations (particularly local content requirements), which promoted and accelerated the development of indigenous turbine manufacturers and component suppliers; and local efforts to attract new-technology firms, which led to the establishment of several technology clusters. In each of these areas, State support – financial and other – has been crucial.

Admittedly, the Chinese wind energy sector suffers from a number of problems and shortcomings, which are recognized by the authorities. Until recently, the emphasis was primarily on capacity rather than connectivity. As a result, in a number of cases capacity was installed but has remained unconnected to the main electricity distribution grid. In other cases, installed capacity has underperformed due to problems with equipment. However, recent policies, such as the August 2008 directives issued by the Ministry of Finance, suggest that there is a shift in emphasis from capacity to grid connectivity (and thus generation), which is likely to push China's domestic turbine manufacturers and components suppliers to improve the quality of their products. If the Chinese wind energy sector manages to resolve these issues, it will be in a position to make a significant contribution to China's efforts to meet its growing demand for energy while at the same time curbing its GHG emissions.

IV. Liberalizing Climate-friendly Goods and Technologies in the WTO: Product Coverage, Modalities, Challenges and the Way Forward

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» Liberalization of climate-friendly technologies, goods and services would contribute not only to increasing the choices available for importing countries, but also to lowering the costs of those choices, thus making it easier to mitigate climate change. However, finding a viable negotiating strategy for the liberalization of these goods has proved difficult in the WTO.

» In fact, most developing countries are hesitant to liberalize bound tariffs on dual-use products due to concerns about the adverse impact of such broader liberalization on their established domestic industries and jobs and, in some cases, on their tariff revenues. However, isolating products of single environmental use is technically difficult and time-consuming.

» Negotiators could therefore focus on identifying a narrow choice of climate-friendly products that would be acceptable to a broader range of countries, such as energy efficiency, renewable energy equipment, and products, technologies and services used for small-scale CDM projects (e.g. micro-hydro projects, efficient cooking and efficient lighting).

» Options to pursue this agenda in the WTO include a sectoral agreement or a plurilateral agreement, in this area. Alternatively, EGs liberalization can be negotiated under regional or bilateral trade agreements.

» While positive, the results of tariff reduction or elimination would not be sufficient, to disseminate the use of climate-friendly goods and technologies in developing countries. High tariffs are only one of the factors that determine access to and affordability of climate-friendly goods and technologies

» Other factors which must be part of a broader EGs package include flexibility in terms of longer implementation periods and less than full reciprocity, optional participation for least developed countries as well as technical and financial assistance.

» The successful experience of the Montreal Protocol, in which effective technology transfer and financial mechanisms are widely believed to have played a decisive role, can inspire WTO negotiators.

A. Introduction

The Doha Round Agenda (paragraph 31(3)) mandates negotiating "the reduction or, as appropriate, elimination of tariff and non-tariff barriers to environmental goods (Egs) and services." This mandate offers a good opportunity for fast track liberalization of climate-friendly goods and services. Agreement on this paragraph should represent one immediate contribution the WTO can make in the fight against climate change (Lamy, 2008).

Climate-friendly technologies (or goods) refer to those the production or utilization of which reduce climate risks to a greater extent than alternative technologies for producing the same product (or alternative products that serve the same purpose). Climate-friendly technologies include those aimed at improving energy efficiency or increasing energy generation from new and renewable sources and goods. Liberalizing such technologies, goods and services would contribute not only to increasing the choices available for importing countries, but also to lowering the costs of those choices, thus enable those countries to either comply with existing and future GHG emission commitments or to limit the growth of GHG emissions. The resulting market expansion from trade liberalization will put a downward pressure on prices in home-country markets and increase competition between imported and domestic goods, thus further lowering compliance costs. By increasing the dissemination of climate-friendly goods and technologies at a lower cost, trade liberalization will make it less difficult to set stringent GHG emission targets beyond 2012.

This paper focuses on environmental goods (EGs), as that is the area in which negotiations within WTO have been more active to date. This by no means undermines the importance of environmental services in preserving the environment and mitigating climate

change. Indeed, many services directly address climate change mitigation.

B. What products to liberalize and how?

1. Negative approach versus positive approach

To indentify which goods and services to ban or promote, a basic distinction can be drawn between negative and positive approaches. A negative approach would be to identify specific goods and services that countries should be required to ban for trading. The Montreal Protocol on Substances that Deplete the Ozone Layer, which was signed in 1987 and has since been amended and strengthened, has taken this approach. The Montreal Protocol uses trade measures as one enforcement mechanism among several policy instruments for achieving its aim of protecting the ozone layer. Parties to the treaty are required to ban trade with non-parties in ozone-depleting substances (ODS), such as chlorofluorocarbons (CFCs) in products containing them (e.g. refrigerators), and potentially in products made with but not containing CFCs, such as electronic components. This latter provision has not yet been implemented primarily because of problems of detection, and also because of the small volumes of CFCs involved. These trade measures have been extended gradually to all the categories of ozone-depleting substances covered by the Montreal Protocol (Brack, 1996; Zhang, 1998). Accompanied with finance and technology transfer mechanisms, this approach has been effective in phasing out ODS and contributing to the recovery of the ozone layer (Zhang, 2009a).

It is clear which products must be banned under the Montreal Protocol, but it is less straightforward to identify products that should be banned in relation to carbon abatement and climate change mitigation. Every product or technology causes environmental harm or affects the climate to some degree. A climate-friendly product or technology is just a concept of relative environmental performance. Such a product or technology tends to be sector- and country-specific, and is subject to change over time. For example, natural gas is less carbon-polluting than coal. Shifting to natural gas has been indentified as part of the solutions for climate change mitigation. This has been the main reason why Qatar, in its submission to WTO, has proposed liberalizing natural gas and natural-gas-related technologies as a way to reduce GHG emissions. But natural gas is more carbon-polluting than wind power that emits zero carbon emissions when operating. A coal-fired power plant is more carbon-polluting than one which uses natural gas, but if coupled with carbon capture and storage (CCS) technology, it is more climate-friendly than a natural-gas-fired power plant without CCS. Besides, a country's choice of fuels and technologies depends to a large extent on its resource endowments and their relative prices. The fact that countries like China and India use more coal is not because they prefer it, but because of their abundant supplies of coal and its relatively lower price compared with its more environmentally friendly substitutes. Thus, while some countries or regional agreements (e.g. North American Free Trade Agreement) may have a negative list on services or on investments in certain technologies which are restricted, it is most unlikely that countries will broadly agree on a list of goods that need to be banned. Moreover, arguably, for the purpose of meeting a climate change mitigation objective, any likely ban or restriction would tend to be on goods that emit high levels of GHGs. This will face resistance from countries that object to the use of trade restrictions based on process and production methods (PPMs), partly because it is difficult for customs officials to distinguish between high and low GHG-emitting products. In addition, there is uncertainty about WTO compatibility in distinguishing a product based on the way that product is produced, rather than on the final product's characteristics. There is also controversy over whether WTO jurisprudence has moved beyond the PPM concept (Zhang, 2004; Zhang and Assunção, 2004; Howse and Van Bork, 2006). Thus a negative approach will not work in a post-2012 climate regime.

By contrast, a positive approach, which seeks to identify certain goods and services for enhanced market access, holds some promise. Establishing a list of goods, technologies and services in which trade is encouraged has its on problems, but is easier than having a common list of goods, technologies and services that need to be banned.

2. List, project, integrated and request-offer approaches

The question then is which EGs and services need to be encouraged. Identifying them depends on their definition. Given their conceptual complexities and a lack of consensus on their definition, WTO members have persistently disagreed over how to identify which EGSs should be subject to trade liberalization.

Three approaches have been proposed in the WTO negotiations. The OECD advocates a list-based approach, whereby goods and services on an agreed list will gain enhanced market access through the elimination or reduction of bound tariffs and non-tariff barriers (NTBs) permanently and on a most-favored-nation (MFN) basis. Such lists have been produced by the OECD and by the Asia-Pacific Economic Cooperation (APEC) group. The two lists have 54 goods in common at the Harmonized Commodity Description and Coding System (HS) 6-digit level. However, 50 goods on the APEC list do not appear on the OECD list, while 68 goods on the OECD list do not appear on the APEC list. The main difference between the two lists is that only the OECD list contains minerals and chemicals for water/waste treatment, while the APEC list includes a relatively more extensive set of goods needed for environmental monitoring and assessment. The OECD list also contains a large number of environmentally preferable products (Steenblik, 2005). Taking the OECD or APEC lists of EGs as reference points, the so-called "Friends of Environmental Goods" group of countries, comprising Canada, the EU, Japan, the Republic of Korea, New Zealand, Norway, Switzerland, Taipei, Taiwan Province of China, and the United States proposed in April 2007 a list of 153 products. Just prior to the United Nations Climate Change Conference in Bali in December 2007, the EU and the United States submitted a joint proposal at the WTO calling for trade liberalization of 43 climate-friendly goods that were identified by the World Bank (2007) from a list of the Friends' 153 products, with the aim of securing a zero tariff for these climate-friendly goods by 2013.

Many developing countries have consistently expressed concerns about using a list of environmental goods slated for expedited liberalization, noting that a number of products on such a list are primarily of export interest to industrialized countries, thus compromising the development dimension.[22] And the Indian Ambassador was quoted as saying that this EU-United States proposal was "a disguised effort at getting market access through other means and does not satisfy the mandate for environment" (ICTSD, 2007a). Another sticking point is related to the issue of dual use, in that many product categories proposed on an EGs list include, at the HS 6-digit level, other products that have non-environmental uses in addition to environmental uses. In response, India has advocated a project-based approach, whereby each WTO member would designate a national authority to select environmental projects based upon criteria developed by the Special Session of the Committee on Trade and Environment and whose domestic implementation would be subject to WTO dispute settlement. The EGs and services required for a thus selected environmental project would temporarily enjoy preferred market access for the duration of the project. India has argued that the project approach would ensure that the approved EGSs are used for environmental purposes. Argentina has proposed an integrated approach that aims to bridge the gap between the list approach and project approach. It resembles the project approach but with multilaterally agreed pre-identified categories of goods used in the approved projects. Brazil has suggested a request-offer approach, whereby countries would request specific liberalization commitments from each other on products of interest to them and then extend tariff cuts deemed appropriate equally to all WTO members on an MFN basis. Brazil has argued that this approach follows along the lines of previous GATT/WTO negotiations and takes into account developing-country interests more adequately than the common list put forward by the EU-United States submission (ICTSD, 2007a, b). An analysis of the Friends' 153 EGs list by Jha (2008) indicates that a handful of developing countries are among the top 10 importers and exporters in various categories of EGs relevant to climate change mitigation. Based on these findings, she suggests that these countries could usefully engage in a request-offer approach to ensure trade gains. In this way, while the benefits of trade liberalization may be multilateralized, the cost would be borne by only a few players. These would be the very players that have a lot more to gain through liberalization.

All these different arguments clearly suggest that some WTO members have yet to be convinced of the climate mitigation credentials of some of the products that Europe and the United States have proposed. Moreover, advancing technologies will inevitably eclipse the continuing merits of some existing products. Thus an exclusive focus on the liberalization of these existing products raises the risk of being locked into current patterns of international trade in technologically advanced climate change mitigation products (i.e. producers of technology and importers of that technology). Furthermore, the developing world is in search of both an economic and an environmental gain through these negotiations under the Doha Round – and rightly so (Lamy, 2008). Even if these negotiations are on environmental issues, they must nevertheless deliver

a trade gain if they are being conducted through the Doha Round of the WTO.

C. The way forward

There are significant export opportunities for developing countries in a large number of low-tech EGs in the core list of environmentally preferable products developed in a study by UNCTAD (2005b), and they also happen to be dual-use products (Hamwey, 2005). However, most developing countries are hesitant to liberalize bound tariffs on dual-use products due to concerns about the adverse impact of such broader liberalization on their established domestic industries and jobs and, in some cases, on their tariff revenues (ICTSD, 2008; World Bank, 2007). They insist in applying a single end-use parameter in screening EGs, and only those indentified EGs based on this parameter would then be taken up for tariff reduction negotiations (Howse and Van Bork, 2006). Isolating products of single environmental use requires assigning clearer HS codes or product descriptions for environmental goods. The HS allows countries to track trade volumes and tariff levels. The more digits there are in a code, the more specific is the description of the product. Given that HS numbers for products are currently harmonized across WTO members only up to the six-digit level, clearly identifying goods of single environmental use needs to go beyond this level. However, harmonizing the HS codes beyond the six-digit level will be time-consuming and would not be viable, given the short time horizon for a possible conclusion of the Doha Round and the timing of review cycles of the World Customs Organization (see the commentary by Vikhlyaev in this Review for a further discussion on dual-use and the limitations of the HS nomenclature).

What are the other options that need to be explored to accelerate liberalization of EGs? Arguably, countries are likely to agree upon a narrow choice of climate-friendly products that would be acceptable to a broader range of countries rather than a broader range of products that would be acceptable to only a few countries. One way forward along this line is to focus initially on specific EGs sectors in which the interests of both developed and developing countries coincide in fostering trade liberalization. Increasing energy efficiency is widely considered the most effective and lowest cost means of cutting GHG emissions, and trade in renewable energy equipment in developing countries appears sensitive to tariff reductions (Jha, 2008). Moreover, industrialized countries are set to take on higher proportions of renewable energies in their energy mix, either in order to comply with their GHG emission targets or with the aim of reducing their dependence on foreign oil, or both. Thus the initial round of liberalization should include renewable energy products and energy-efficient technologies. The World Bank (2007) estimates that the removal of tariffs for four basic clean energy technologies (clean coal, efficient lighting, solar and wind) in 18 large developing countries would result in a trade gain of up to 7 per cent. The trade gain could be boosted by as much as 13 per cent if non-tariff barriers on those technologies were also removed. These gains, which were calculated based on a static trade analysis, were considerably underestimated because they failed to take into account the dynamics of these EGs (i.e. trends in growth of their export levels and the size of their world export market). In addition to the trade gains, using these more climate-friendly technologies and products to replace those that are more GHG-polluting will translate into a significant reduction in GHG emissions. Therefore, clearly, liberalizing trade in low-carbon goods and technologies would serve both trade and climate mitigation interests.

A "procedural" area of accelerated liberalization relates to products, technologies and services used for small-scale CDM projects (e.g. micro-hydro projects, efficient cooking and efficient lighting) and programmatic CDM.[23] The CDM has been partially successful (Zhang, 2008): the global number of CDM projects registered and in the pipeline by August 2009 totalled 4,588 (UNEP Risoe Center, 2009) – well above what was envisioned by countries when they negotiated, designed and launched this mechanism. However, the lion's share of these CDM projects has gone to a handful of major developing countries like China and India, whereas many countries, especially those in sub-Saharan Africa, have been left out. One of the main reasons is that the transaction costs associated with the CDM project cycle have seriously hampered small-scale CDM projects in these countries. Although registration fees are set considerably lower for small-scale CDM projects, and simplified methodologies and procedures are also set for those projects, many other transaction costs are independent of project size and will thus have a bigger relative impact on small-scale CDM projects. Programmatic CDM, which bundles together small-scale CDM projects or a programme of activities, makes a better contribution to sustainable development and communality empowerment than a single CDM project, but it entails high transaction

costs. Thus, liberalizing products, technologies and services in this area could reduce equipment costs and contribute to lowering transaction costs for potential investors. This would facilitate capitalizing on the untapped potential of programmatic CDM and extend the mechanism's reach in terms of both project type and geographical spread.[24]

Even in these two areas, developing-country concerns about the possible impacts of liberalization on their domestic industries would need to be addressed before a deal could be hammered out. This applies particularly to environmental goods and technologies that developing countries are not competitive in producing. Fox example, with regard to wind turbines, India has imposed very high tariffs with the aim of encouraging domestic production and jobs, and China has put in place a local content requirement (Alavi, 2007; Zhang, 2008). These policies act as barriers to foreign suppliers of wind turbines, and are seen as beneficial for local wind turbine makers. Indeed, the three largest local turbine makers in China – Sinovel Wind, Goldwind Science and Technology, and Dongfang Electric – account for an increasing share of total new installations in the country. Together they now supply over 50 per cent of a market once dominated by foreign firms until 2008. However, such policies hurt home countries in financial terms. While being less costly, domestic wind turbines in China break down more often and their overall capacity factors are several percentage points lower than those of foreign models. Such a few percentage points difference might not seem significant, but could well make a difference between a wind farm that is economically viable and one that is not (Zhang, 2009b). Thus while the local content requirement may be considered necessary when the domestic market is dominated by foreign firms, it becomes questionable when local turbine makers begin to dominate the market as is now the case in China. This clearly exemplifies challenges ahead and uncertainty about whether a deal can be concluded on a desired level of trade liberalization. Needless to say, the objective of having an agreement on EGs or a subset of EGs – such as climate-friendly goods – under WTO should be pursued as the best choice. However, should WTO members fail to reach such an agreement, then alternative options, ideally still under the Doha Round, need to be explored, although business groups have even suggested removing EGs from the Doha agenda.[25]

An agreement similar to the Information Technology Agreement (ITA) is one option to consider. However, it would require a certain number of members representing a minimum percentage of trade in climate-friendly goods and services to join[26] in order for it to come into effect (World Bank, 2007). Such an agreement would be open to voluntary participation, and once in effect, the benefits of trade liberalization in climate-friendly goods and technologies would extend to all WTO members on an MFN basis. The ITA has incorporated a mechanism for review of product coverage every three years. This may have tempered the disappointment of many countries with the initial exclusion of certain products. Given that developing countries are currently not significant suppliers of climate-friendly goods and technologies, priority should be given to additional products being submitted by developing countries for inclusion in a future review. However, the downside of this ITA mechanism is that no new products have ever been added since 1997. Thus developing countries may be suspicious of this offer for review, and feel reluctant to join.

Another option is a plurilateral agreement in this area, similar to the WTO Agreement on Government Procurement. WTO members could opt to sign up to such an agreement or not, but the benefits of trade liberalization would extend only to participating members on an MFN basis, unlike the aforementioned ITA-type Agreement which would extend MFN treatment to non-signatory WTO members as well. While such a plurilateral agreement would not be ideal, it would still have value, particularly if the key trading parties were involved. Such an agreement could eventually be made multilateral once a certain number of members representing a minimum percentage of trade in climate-friendly goods and services joined.

Other options for this sort of agreement may be within the context of regional or bilateral trade agreements. Such agreements aim to liberalize substantially all goods at the HS six-digit level. As a result, product classification and the dual-use problems associated with WTO negotiations on EGs and services may be less of a concern. These agreements would liberalize EGs fully. However, the downside of the regional or bilateral trade agreement approach is that trade may be diverted from countries that are most efficient at producing certain EGs but are excluded from those agreements. Moreover, by entailing generally the zero rating of all products, this approach would remove any tariff differential between EGs and their non-preferable like products. Whether such an elimination of tariffs in EGs would be enough to encourage their larger

utilization in a competitive environment with other non-EGs would depend on their relative prices and the stringency of environmental policy in the home countries. Even if the prices of energy-efficient EGs were higher than those of their non-preferable like products, this would not necessarily put those EGs at a disadvantage. Provided energy subsidies are removed and costs are attached to emissions reductions, any higher initial costs of energy-efficient EGs may well be compensated by cost savings through energy savings over their lifetimes. The demonstration of new EGs (technologies) that a country is not yet familiar with but has a high potential to replicate plays a role in this context as well: it is the first but crucial step in showing the effectiveness of these new EGs in cutting pollution and supporting its spin-off to the rest of the economy.

This paper focuses on liberalizing climate-friendly goods and technologies through the reduction or elimination of tariffs. Undoubtedly, the results of such a tariff reduction or elimination would be positive, but would not be significant for increased uptake of these goods and technologies in developing countries. Many African countries already have very low tariffs on many environmental goods, but import few, if any, of them because of a lack of purchasing power and technical assistance. Also, as tariffs in developed countries are already very low – generally less than 3 per cent for EGs on the OECD list (Vikhylaev, 2003) – and as not all EGs are sensitive to tariff reductions,[27] the access of developing countries to developed-country markets would depend more on reduction or removal of trade restrictions in terms of NTBs, such as technical standards and certification requirements, labelling requirements, and tied-aid that grants tariff preference for a donor country's goods and services, as well as tax and subsidy measures. All these NTBs are considered significant impediments to developing countries' access to developed-country markets. Developing countries constantly refer to intellectual property rights as a barrier to access much-needed and advanced low-carbon technologies, in addition to their high licensing fees or royalty payments. All this suggests that high tariffs are only one of the factors that determine access to and affordability of climate-friendly goods and technologies, and thus that action beyond tariff reduction or elimination is also needed.

Therefore to serve the best interests of developing countries and enable them to access both climate-friendly goods and technologies at an affordable price and developed-country markets, there is a need to consider other efforts rather than adopting an exclusive focus on tariff reductions or elimination. Special and different treatment provisions will also be essential to take into account the concerns of developing countries. These include less than full reciprocity and flexibility in terms of longer implementation periods – or both – for developing countries, and optional participation for least developed countries. In addition, a package of technical and finance assistance is badly needed to ensure that all developing countries are able to benefit from the rapidly growing world market for climate-friendly goods and technologies. At least one WTO developed-country member – Canada – in its submission has recognized the importance of such assistance and has pledged to provide it. All these aforementioned initiatives could be made part of the EGs package for it to work. Moreover, WTO EG and services talks need a boost from other areas. Effective technology transfer and financial mechanisms are widely believed to have played a decisive role in making the Montreal Protocol work effectively (Zhang, 2009a). Given that the scope of economic activities affected by a climate regime is several orders of magnitude larger than those covered by that Protocol, technology transfer and deployment, financing and capacity-building are considered to be even more essential components of any post-2012 climate change agreement that developing countries would agree upon to succeed the Kyoto Protocol. If and when such a post-2012 climate change deal is reached, it would significantly enhance the possibilities of a breakthrough in reaching an EGs and services deal under the WTO.

V. WTO Negotiations on Environmental Goods and Services: the Case of Renewables

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» The momentum created by the move towards a new international climate agreement is bound to influence the modalities for international cooperation, including in the WTO, be it as a separate WTO climate initiative or in the context of the Doha Round negotiations. In fact, climate friendly goods in general, and renewables in particular, have emerged as the strongest candidates for "outcome testing" in the negotiations on environmental goods.

» How important is the role of trade and trade policy with respect to these goods? What is the level of the competitive relationship between developed and developing countries? How is it possible to ensure that the environment and, in broader terms, sustainable development, becomes the most important part of the complex scale by which success in the negotiations will be measured? Finally, are there enough markets – or are these markets strong enough – to cause concern by WTO members about access to them?

» The search for the answers would benefit tremendously from the real-life economics as well as a horizontal analysis of existing WTO agreements from the trade and environment perspective. Clearly, linking trade and climate change is impossible without linking trade and energy. The link involves competition and investment issues, and the WTO rules are still in the making in these areas. And whether we are talking about the environment, energy or climate change, it is "markets" and "market creation" rather than "trade" and "market access" that inform the core of policy concerns in these areas."

A. Introduction

The momentum created by the move towards a new international climate agreement is bound to influence the modalities for international cooperation, including in the World Trade Organization (WTO), be it as a separate WTO climate initiative or in the context of the Doha Round negotiations. A first sign of that is the focus on the interface between energy and environmental goods and services. Indeed, energy – its production, transmission and use – is arguably responsible for as much as half of the world's environmental problems.

Since the trade ministers' dialogue in Bali in December 2007, a new policy discourse has developed which favours the idea of including renewables[28] and technologies for cleaner utilization of conventional energy within the scope of the negotiations on environmental goods and services. Arguably, other climate-friendly goods, such as energy-efficient construction materials and appliances, or even goods derived from more GHG-efficient processes and production methods, would also be considered.[29] Whether the negotiating proposals that have followed suit are essentially a political move or are here to stay is subject to debate.

Should the negotiators choose to focus on climate friendly goods and services as a matter of priority, they will have to seek a better alignment between the mission and means. WTO Director-General Lamy suggested that the WTO Members could work along two simultaneous tracks. One track is for technical discussions in the negotiating groups. The other is for "outcome testing" through bilateral or plurilateral discussions as Members seek to clarify the deal, its value and the scope for flexibilities.[30]

On a technical level, there are open questions relating to product coverage and negotiating modalities. Is there a scope for a sectoral agreement on tariff reduction or elimination? Are there alternatives, considering climate friendly goods are, by definition, environmentally preferable products (EPPs)? Can they be redefined as a class of their own based on the source of energy, i.e. the resource rather than their use? And would it not make more sense to refocus the negotiations on non-tariff barriers to trade?

On a higher plane, "outcome testing" could shed light on some important – and somewhat counterintuitive – questions. Does a straightforward approach to the liberalization of trade in climate-friendly goods and services square with the real life economics? How

important is the role of trade and trade policy? What is the level of the competitive relationship between developed and developing countries in the environmental area? How is it possible to ensure that the environment and, in broader terms, sustainable development, becomes the most important part of the complex scale by which success in the negotiations will be measured? Finally, are there enough markets – or are these markets strong enough – to cause concern by WTO members about access to them?

B. Should renewables be fast-tracked?

Renewables can certainly present the negotiators with a telling case study of the substantive links – or the absence thereof – between the mandate provided for in paragraph 31(iii) of the Doha Ministerial Declaration and the negotiations. However, can they also serve as a litmus test for the various approaches to the liberalization of trade in environmental goods and services? After all, renewables are a special case.

The value of trade in renewables is still relatively low. Much of that trade is internal to a few multinationals. Developed countries dominate the high-technology end of exports (although China is rapidly moving into the high-tech segment, as can be seen from the commentary of Dong Wu in this Review). On the low-tech side and in biofuels, developing countries are significant exporters, but only as a group (UNCTAD, 2005a).

Trade in individual parts and assembled components is several times bigger than that in complete systems. For example, in modern wind technology assembled turbines are produced mainly by Denmark, Japan, Spain, the United States and more recently China, but the turbines consist of a number of components that are produced by a much larger number of countries (e.g. gear boxes of the kind used in wind turbines are currently manufactured in and exported from more than 80 countries).[31]

There is considerable disparity in tariffs on renewables – from 0 to 40 per cent, and in some cases even 100 per cent – but it is the tariffs in the 20–30 per cent range that seem to restrict most trade. However, some relatively high tariffs on finished goods are found in those few developing countries that may actually need those tariffs to protect their developing industries and where the scope for other support measures is limited. For instance, the duties may be set at 3 per cent for individual parts, at 8 per cent for assembled components, and at 17 per cent for entire pre-assembled turbines. Biofuels are a case apart, since tariffs depend on whether biofuels are regarded as an agricultural product, and therefore subject to higher rates under the current WTO Agreement on Agriculture, or as an industrial product, with relatively low tariffs. For instance, the current EU tariffs on biodiesel are around 6.5 per cent, while tariffs on ethanol range between 40 and 100 per cent, depending on the price.[32]

Some experts argue that lowering or even eliminating tariffs only on finished renewables would choke off new opportunities for their production and exports by developing countries (UNCTAD 2005a). Hypothetically, it may even lead to negative protection, with tariffs for complete systems being lower than those applied to individual parts and assembled components.

This argument would favour a more sophisticated approach to trade liberalization based on the chain of manufacturing; breaking down the various categories of renewables into specific parts and components and identifying which countries have – or can develop – the capacity to supply them.[33] However, such an approach would significantly aggravate the problem of dual use. Moreover, it is not clear whether that approach would be technically feasible and politically acceptable.

The markets for renewables are extremely distorted by subsidies and preferential procurement policies of governments in developed countries, and by tied aid and multilateral projects that carry tariff waivers and offer long-term concessions (up to 25 years), as well as by local content requirements in developing countries (local content requirements are used by some developed countries as well.) In addition, winning bids may be fast-tracked through the approval procedures to develop project sites, with guaranteed grid interconnection, financial support for grid extension and access roads, and preferential loans and tax treatment. These measures are much more important than tariffs, including from the market access perspective.

How important are tariff considerations with respect to renewables? So far, special incentives for market creation[34] have played a major role because conventional energy policies do not fully value energy security, economic development and environmental benefits – the so-called 3Es. As a result, renewable energy technologies, particularly the most dynamic, second-generation ones such as those based on wind, solar and new bio-energy, tend to be concentrated in only a few

countries. For instance, 85 per cent of the world's total wind energy is produced by five countries: Denmark, Germany, India, Spain and the United States, and 86 per cent of PV systems by three countries: Germany, Japan and the United States. This is a challenge and a barrier (OECD and IEA, 2004).

In order to analyse the likely path for renewable energy development, it is not sufficient to conduct technical studies providing a breakdown of wind, PV, geothermal and biomass steam generating technologies into their major components, and identify those components by HS codes.[35] It requires a more detailed picture, building on an analysis of locational factors such as market size (to the extent that the census of manufacturing activity permits), efficient radius of shipping, technical capacity and local customization. The analysis would have to consider the energy and regulatory sectors of each country, looking at market size, current power generation profiles, regulatory policies, the use of renewables and other variables. In the absence of such an analysis, it is not entirely clear how the negotiating proposals currently on the table in the WTO would balance the market opportunities offered by climate-friendly technologies with access to those technologies by developing countries.

Clearly, the development of renewable energy could take place along two quite different paths. One path would see the bulk of demand for renewables met by finished products exported from a handful of developed countries to developing-country markets. The other path would see an increasing allocation of at least a portion of the component manufacturing to developing-country industries, with those components then used in the final assembly of the renewable generation technology. Either of the paths could supply the necessary energy generation, but their development effects would be quite different.

In principle, developing countries have two very substantial assets that favour their competitiveness in renewables: (i) abundant renewable resources, and (ii) in many cases, lower costs of production of equipment, components and biofuels. Taken together these factors point to considerable scope for trade and cooperation, particularly since more mature renewable energy technologies (e.g. hydropower, geothermal and biomass combustion) are close to reaching saturation in developed countries.

However, there are a number of factors that complicate developing countries' participation in renewable energy markets. These include their up-front investment needs, very limited availability of long-term loans (i.e. loans of more than seven years), limited cross-border financing opportunities (e.g. because of loss of tax incentives, unproven technologies for local needs, such as available equipment being too large or too sophisticated), gaps in infrastructure, such as lack of a grid network, complexity and uncertainty of the regulatory environment, especially for small projects, and of due diligence and monitoring requirements, and drawbacks in the tendering process, all of which may create non-tariff barriers to trade.[36]

While the main drivers for renewable energy in developed countries lie in environmental protection becoming an increasingly important public policy objective, particularly the role that renewable energy can play in meeting GHG reduction targets, in developing countries it is the shortage of energy that is the main factor.

In any case, it seems clear that the liberalization of trade in renewables, to be commercially meaningful and financially viable, should lead to – or be accompanied by – market-creation measures, expanding the number of countries that are shouldering deployment policies, and enhancing international cooperation. Financial flows and official development assistance targeting climate-friendly technologies can play a catalytic role in the uptake of renewables in developing countries through increased trade, investment and technology transfer. In this regard, it is worth noting the G-8 financial ministers' initiative to set up climate investment funds with a view to assisting the efforts of developing countries (G-8, 2008). Furthermore, the World Bank is working to deepen the reach of those funds in cooperation with the regional development banks in Asia, Africa and the Americas. Innovative financing in dealing with climate change is needed now, more than ever, to confront what has emerged as the major threat to the development priorities of the poorest countries and communities.

C. Listing of environmental goods: what could be a logical outcome?

The negotiating proposals based on the idea of listing environmental goods draw from the APEC Early Voluntary Sectoral Liberalization, which, in turn, was an attempt to replicate the Information Technology Agreement (ITA) for other sectors, including the environment. The ITA is a rather successful example of

negotiations based on *critical mass* in a sector where advanced economies saw themselves as net exporters. Other examples are basic telecommunications and financial services.

The sectoral negotiations contemplated by some delegations in the current negotiations on non-agricultural market access that are based on a critical mass criterion may be a problem in itself: there are members opposed to the idea of sectoral agreements in general, and with respect to climate-friendly goods in particular.

Besides, the agreements from the "build-in agenda" period were not so much about *critical mass* as about going with the flow of markets, commercial logic and technological change. All the three agreements - telecoms, ITA and financial services - were concluded in exceptional circumstances: structural changes in the telecoms sector, the Asian financial crisis, the pervasive nature of information technology and the need to do away with taxing own inputs. Does climate change provide similarly compelling reasons?

Were it not for the pervasive problem of dual use concerning most environmental goods, the very idea of achieving reciprocity in this particular negotiation would seem an aberration. Even a cursory look at the interface between the environmental and energy industries reveals a basic asymmetry: while the developed countries are looking for winning propositions in terms of market access, for developing countries, it is market creation that is more important. Logically, this means that environmental benefits should mainly go to one set of countries and trade gains to another. Reciprocity defies this logic.

Besides obscuring the real-life economics underlying the negotiations, dual use creates intractable technical problems. While the HS can capture most renewables, the ubiquitous nature of some goods and their component parts means that the dual use problem will remain over and above what could be sorted out by introducing greater specificity in the HS tariff codes. As for GHG-efficient goods or goods produced in a GHG-efficient way, there are simply no HS codes to match. Moreover, climate or energy efficiency include fast evolving technologies, hence the identification of such goods in a closed list is a moving target. The inclusion of goods derived from GHG-efficient process and production methods (PPMs) is especially problematic as it may dramatically increase the scope for protectionist measures.

The two types of renewable energy equipment that can pass the single use test at the HS 6-digit level are: (1) hydraulic turbines (8410.11, 8410.12, 8410.13)[37] and (2) wind powered electricity generating sets (8502.31). Ethanol (2207.10) and methanol (2905.11) fail the single use test as these are common chemicals in many synthetic hydrocarbon reactions, in addition to being "green fuels". Biodiesel is exclusively used for transportation or energy production but is an *ex-out* [38](3824.90 ex) as it is categorized under the large subheading of "products, preparations and residual products of the chemical or allied industries". Solar cells also form part of a large subheading (8541.40), which includes semiconductor devices and light-emitting diodes.

The problem with dual use may arise either because the HS is not specific enough to capture "environmental goods", or because dual use is inherent to these goods. Creating *ex-outs* in national nomenclature may serve to address the former problem, but not the latter. Experts tend to agree that for the vast majority of renewables, dual use is a function of their ubiquitous nature, whereby they can be employed for uses other than environmental. Therefore, using ex-outs to "drill down" to single use from dual use does not seem a viable option (OECD, 2006).

Experience with the ITA – and this Agreement is often cited as a possible model for a "list-based" approach to negotiations on environmental goods – has revealed the problem of ensuring a consistent interpretation of customs classifications. This problem has led to disagreements among trade negotiators as well as between customs authorities and traders, to the point that some analysts are questioning the relevance of the Agreement and the technological assumptions it was based on.[39] If there is an overall lesson to be drawn from the ITA and other sectoral agreements, it is that ex-outs have been – and should remain – the exception rather than the rule.

The recent legal challenge to the application of the ITA Agreement reveals the drawbacks of the Agreement. A positive list, based on precise nomenclature, proves self-limiting and does little to solve the structural problem of dual use. The all but inoperable review mechanism has largely failed to manage the product coverage.

Will litigation help develop a case law regarding the tariff classification issues for dual use products? We do not know, but the ruling may serve as a basis for

renegotiating the ITA in such a way that it becomes more accommodating of technological change. In the meantime, analysts converge on the following conclusions. To be manageable, the product list should be negative, i.e. only exceptions should be listed. There should be disciplines on handling dual use products at customs, especially those products that embody technological change.

Since the existing definitions of climate positive goods are as much about the resources as they are about the environment, the negotiators could, in principle, consider a particular category of *environmentally preferable products* (EPPs) as "single source" or "single process", from an environmental impact perspective. For instance, there could be agreement that renewables constitute EPPs based on the *source* of energy (i.e. the *resource*) rather than on the *use* of the products, as their categorization is not so much based on the specific category of technologies (e.g. electricity-generating motors, power converters or inverters) as it is on the *source* of the power (e.g. biofuels, low-head hydro, solar, wind or geothermal). Other goods using a particular source of energy could be classified as a single source within a category (e.g. electric cars or trains which fall under HS 8703 or HS 8601).

Certain climate-friendly goods can be differentiated easily on the basis of their physical characteristics alone. However, the majority of these goods owe their environmental performance to a combination of features, and can only be definitively identified through testing. In such cases, standards and (third-party) certification or labels are the only mechanisms of product differentiation. Energy and fuel efficiency standards are particularly relevant in this context.

Given the special interest in climate-friendly goods, difficulties in capturing some of these in the HS and the generally low tariffs that have prevailed with respect to these products, it might prove easier and more productive to focus the negotiations largely on non-tariff barriers (NTBs) (UNCTAD, 2004). Indeed, unless WTO members address the NTBs affecting trade in these goods, all the noble discourse and environmental claims with respect to these products will remain empty gestures.

However, there is a contradiction in attempting negotiations on NTBs and at the same time slamming the door on PPMs, particularly since PPMs pose a problem for the negotiators only if there are no other means of product differentiation. Besides, PPM-free does not necessarily mean problem-free. Some (climate-friendly) goods may still be problematic since they require agreement on a relative standard (i.e. the products in question must be better than some baseline). The judgment of a standard is itself difficult; for instance, is a fuel-efficient car a green good? How efficient must it be? Moreover, technology evolves, and today's "green goods" become tomorrow's baseline.

D. How to negotiate non-tariff concessions

Interestingly, it is the sectoral approach that has been instrumental in promoting a comprehensive treatment of all factors affecting trade, including NTBs. In fact, negotiations encompassing both tariffs *and* NTBs constituted the original meaning of the term *sectoral approach*, the meaning that prevailed for a relatively long time.

The various sectoral initiatives have gradually raised the level of ambition with respect to NTBs, often making them the necessary parameters of a well-balanced negotiated package. However, these NTBs usually had nothing to do with the sectors in question! More often than not, sectoral negotiations had been tried for several sectors in parallel, and it is cross-sectoral demands and linkages that contributed towards a balanced overall outcome.

Again, the ITA provides a striking example. Contrary to a common view, the ITA is not a "stand-alone" deal; rather it is a number of product groups repackaged under an appealing name. The negotiating history is very telling. Early on, some participants took the position that, because the results of an ITA would not benefit all participating countries evenly, "balancing measures" would be needed outside the IT sector. At one point, trade ministers exchanged lists of sectors where they would like to expand the IT package of commitments. The various proposals aimed at broadening the package prompted a comment about the ITA being a short-hand for "Information, Textiles and Alcohol" agreement.[40]

Could NTBs be used as a balancing tool in addressing this asymmetry in the negotiations on environmental goods in general, and climate-friendly goods in particular? This seems unlikely, as environmental goods do not exhibit any specificity as far as NTBs are concerned, which is not surprising since they are essentially industrial goods used for a variety of purposes.

On the other hand, negotiating NTBs raises some serious concerns. First, there is an apparent link between product exclusion and NTBs, i.e. sensitive products are the ones for which NTBs are particularly important. Second, the greater complexity of negotiations on environmental goods invariably raises questions about the usefulness – and the administrative costs – of addressing NTBs in this context. Third, there may simply not be enough time to equip the negotiators with the necessary data and tools. This is of course assuming that the Doha Round does not collapse. One of the reasons for the ITA's success was the determination of some parties to postpone NTB negotiations to a second phase of the ITA.

For instance, several issues arise in the context of the Agreement on Technical Barriers to Trade (TBT Agreement). Certain technical regulations that create obstacles to trade in renewable energy or renewable technologies are necessary on legitimate environmental grounds (e.g. risks to wildlife). Other regulations may be designed, intentionally or inadvertently, to be based on the traditional predominance of fossil fuels or nuclear generation. A number of questions await their authoritative interpretation. For instance, to what extent do regulatory regimes recognize metals as being distinct from synthetic chemicals? Can biofuels or substances that compose biofuels (e.g. secondary biomass) receive regulatory treatment based upon assumptions that they are being traded as waste or for purposes other than the production of renewable energy and which may make the substances more hazardous? How justified are technical regulations that limit the use of ethanol blends? Answers to these questions will determine the extent of the regulatory burden on photovoltaic manufacturers and biomass companies.

Subsidies for oil, coal, gas and nuclear power are often cited as a very significant barrier to renewable energy. On the other hand, breaking out of this pattern of just a handful of countries participating in renewable energy deployment would necessitate a shift away from subsidies and preferential public procurement in the renewable energy sector itself. It is important to examine whether and to what extent trade regulations could be used to challenge or discipline policies (regulatory barriers) that disadvantage renewables. A reverse question – whether and to what extent government policies to promote renewables may be disciplined as non-tariff measures – is equally valid. With some foresight, one can see the "subsidization" angle in the international trade in carbon emission permits and carbon offset arrangements.

A large number of countries have implemented special requirements or labelling schemes for energy and fuel efficiency. Can one assume that the differential regulatory or tax treatment of products based on energy and fuel efficiency would be permissible under the WTO rules?

The main criterion of *likeness* since the *EC-Asbestos* [41]case is the competitive relationship between products. Arguably, in some (developed) markets, and to the extent that energy or fuel efficiency affects their competitiveness, the products in question – one efficient the other not - could be considered *unlike* in the sense of GATT Article III. After all, such differences normally depend on the design and therefore translate into physical characteristics. More importantly, consumers in these markets may have compelling reasons, environmental or economic, to prefer energy or fuel efficient goods.

However, even if considered *like* because they do compete in the same market, there is still Article XX, which can serve to justify different regulatory or tax treatment on the basis of (a) the importance of the value proposition - environment or sustainable development in this particular case - and (b) whether or not the regulation or tax in question is apt to contribute materially to the government's objective.

In most cases though, energy or fuel efficiency requirements will be put in the language of technical regulations and therefore come under the TBT Agreement, which, in a way, merges Article III and Article XX and stipulates that technical regulations serve a legitimate government objective and be not restrictive on trade more than necessary.

Taking recourse to Article XX or to the TBT Agreement is bound to lead to the same results, although in different ways. Regulations and labelling programmes to do with energy efficiency and based on (few) international standards set by the International Electrotechnical Commission or the ones that follow closely the guidelines, methodologies and best practices developed by expert bodies such as the US-led Collaborative Labelling and Appliance Standards Programme (CLASP), and the APEC Energy Standards Information System (ESIS) are less likely to be challenged as unnecessary obstacles to trade within the meaning of the TBT Agreement. The situation with fuel efficiency is less certain as there are no international standards.

With respect to biofuels, it is not clear, how the Agreement on Agriculture may affect fuel farming and bioenergy in general. Under the current regime, there is a structural bias against some important biofuel products. SPS measures mainly affect feedstock due to their biological origin. Where the product's end-use cannot be determined at the border, strict regulations on residues are applied equally to crops destined for animal or human consumption and to biomass feedstock. Sustainability standards and regulations are increasingly important to trade in biofuels.

The question is, whether the negotiators would be willing to take on the task of addressing these and other related issues in order to take better account of the specificities of trade in climate-friendly goods? And how far would they be prepared to go?

E. Living agreement instead of a living list?

If the case of climate friendly goods in general, and *renewables* in particular, proves anything, it is that a search for the meaning of environmental goods is a poor substitute for clarifying the meaning of trade in environmental goods, which is much broader than the General Agreement on Tariffs and Trade (GATT), and extends to cover at least some aspects of the movement of capital, services and technology, as well as people. One-dimensional obligations, with concessions limited to one type of transaction (i.e. cross-border imports) and one trade policy instrument (i.e. tariffs), may not be of much use to WTO members that lack much negotiating leverage to solve access problems caused by regulation or subsidization in major markets.

The alternative negotiating proposals exhibit an almost intuitive grasp of these issues. Take, for instance, the project-based approach by India, with its emphasis on the delivery of environmental services and technology transfer, or the joint Argentina-India approach, which is about companies: importers and service providers. The proposals essentially argue for opening up tariff rate quotas either under Article XX or under the Agreement on Government Procurement. They also suggest a different kind of coordination system for the negotiations, perhaps even a multidimensional agreement, with a view to finding a reasonable balance between environmentally meaningful commitments and their broad application across member States.

While the legal analysis of the negotiating alternatives may be fraught with uncertainties, WTO members are free to negotiate a new agreement, irrespective of existing WTO law, in order to accommodate any approach they deem fit and thus bypass the systemic problems that may seem insurmountable based on the status quo. Such an agreement would form part of the WTO system, on a par with other agreements, and will prevail as *lex specialis* over more general provisions.

Forging a framework agreement would require elevating the negotiations to the political level with a view to outcome testing, endorsing an overall approach to negotiating climate-friendly goods and services on a priority basis and securing coordination with other negotiating groups. Once the agreement is in place, WTO members could go back to more technical negotiations within the WTO Committee on Trade and Environment Special Session (CTESS) and other relevant groups to see the Agreement through in the respective fields of the WTO law. The proposal for a framework agreement was argued by Cottier early on in the negotiations. More recently, it was developed in a series of studies undertaken for UNCTAD (Cottier, 2006a; and Cottier and Baracol-Pinhao, 2008).

This is how Cottier and Baracol-Pinhao (2009) envisage the scenario with respect to climate-friendly goods and services. In the first instance, members would have to do some scoping. They may opt to implement the entire range of activities and sectors under the Kyoto Protocol, including electricity generation, transport and industrial processes, or they may agree on a particular sector to be taken as an initial target, e.g. electricity generation.

The negotiations on energy services in the current Doha Round may present an opportunity for ensuring that the commitments made reduce barriers to renewable energy. For instance, renewable energy obligations for electricity imposed on grid operators and retailers constitute commitments under the General Agreement on Trade in Services (GATS), and may be specified in their schedules accordingly.[42]

A potential overlap with certain aspects of GATS negotiations on energy services is not without problems, in particular with respect to the scheduling of commitments. Traditionally, the industry has not distinguished between energy-related goods and services. The current classification does not cover new services, which have arisen owing to structural changes in energy markets since 1991 when the services list was drawn

up - the emergence of new technologies, concerns about energy efficiency or environmental protection.[43]

In the Doha Round, the request-and-offer process for energy services is based on the concepts of technological neutrality and neutrality of energy source.[44] However, members always have the possibility of makings commitments based on the type of energy they prefer. In other words, an energy-neutral classification can always be made energy-based in a schedule of commitments of a member.

A check-list may be required to deal with so-called energy related services that can be used for other purposes, too. For instance, Tier One in the EU–United States proposal covers energy-related services (e.g. engineering and maintenance services to optimize the environmental performance of energy facilities), and services for the design and construction of energy-efficient buildings and facilities. Tier Two covers a broad set of environmental and climate-related services, including energy, construction, architectural, engineering and integrated engineering services.[45]

Once the picture on the services front is sufficiently clear, the negotiators would proceed to identify the *goods* essential to the delivery of the selected environmental and energy services and negotiate tariff concessions using the proposed modalities and taking into account national priorities and programmes.

As far as NTBs are concerned, those most commonly discussed are *subsidies* and *standards for energy* and *fuel efficiency*. The introduction of sustainability standards and regulations may prove important to trade in biofuels.

Two options exist with respect to subsidies. Assuming subsidies to renewables are legitimate (in order to level the playing field with subsidized conventional fuel), an obvious choice is the revival of Article 8.3, known as non-actionable subsidies. A set of green box renewable energy subsidies may be identified and Members may agree, on a consensus basis, to refrain from challenging these because of their positive environmental effects. Some experts point out that the expired category of non-actionable subsidies falls short of fully achieving its goals since it is both over-inclusive - in the case of R&D subsidies to producing firms - and under-inclusive - for instance in the case of subsidies targeting energy efficiency. Alternatively, a provision modelled after GATT Article XX and complete with a necessity test similar to GATT Article X (b) could be introduced in the Agreement on Subsidies and Countervailing Measures (ASCM).

An even more obvious - but considerably more challenging - option is to use the ASCM to pursue climate protection objectives by effectively discouraging fossil fuel subsidies, which may take a variety of forms. Taking the cue from the negotiations on fisheries subsidies, one can envisage negotiations within the WTO with a view to Members agreeing to cap and reduce subsidies in the energy sector that are questionable on environmental grounds. Arguably, such negotiations could be linked to the fulfillment of commitments under international environmental regimes such as climate change (Howse, 2008, 2009)

There are possible approaches to dealing with regulatory barriers. An agreement on climate friendly goods may include pilot projects, as did the ITA II. Members might also consider a “smorgasbord” approach, along the lines of the current trend in the ISO towards declaring specific national, or regional or international standards as equivalent rather than having one standard as the only option. Such an approach could serve as a relatively efficient way for this negotiation to reduce transaction costs and distortions arising from multiple standards and technical regulations in major global markets.

The labelling of sustainable biofuels offers a possibility to rebalance, to an extent, the export interests and environmental sustainability objectives in the developing countries concerned. It can be pursued through specific provisions in the framework agreement. The agreement may also help coordinate the negotiations in NAMA with the negotiations on agriculture in dealing with the structural bias against some important biofuel products.

The Agreement might just be able to equip the negotiators with some means to address issues arising at the intersection of trade and the transfer of climate positive technologies. The most promising avenue, it would seem, is exploring the negotiating approaches enshrined in GATS, which affords Members a degree of flexibility to pursue transfer of technology policies. Thus, Members may design their GATS commitments in a way that facilitates technology transfer by specifying limitations and conditions in their schedules with a view to supporting such policies. They may also choose to liberalize types of services and define a sectoral coverage in such a way as to maximize the potential for technology diffusion.

F. Conclusions: market access or market creation?

There is an implicit contradiction between the tendency to include new issues and attempts to keep the negotiations within the remit of the GATT, and therefore restricted to tariffs on goods and market access.[46] What is the point of having opportunities if there are no capabilities? Even full market access does not mean climate-friendly goods will suddenly flow into countries in dire need of them. In fact, turning these needs into effective demand remains the main objective. And in the pursuit of this objective, market creation should take precedence over market access.

Of course, the WTO is not a development agency; its essential role is to regulate conditions of competition between domestic and imported goods. Thus the concept of competitiveness should be key to determining a negotiated outcome – as it is when determining likeness in evaluating environment-related trade actions. Right or wrong, all the negotiating approaches on the table make sense only when they concern goods that are a priori competitive. Where a competitive relationship exists, a negotiated outcome should ensure that competitive opportunities for the members are reasonably equal. Where a competitive relationship does not exist, or does not yet exist, WTO negotiations or disciplines are not, or not yet, commercially necessary.

In another study, not related to environmental goods, Cottier argues in favour of the idea of progressive regulation - as opposed to progressive liberalization (Cottier, 2006b). The idea finds explicit recognition in Article 27:5 of the Agreement on Subsidies and Countervailing Duties, which relates the phasing in of disciplines to export competitiveness in specific sectors and products. Importantly, it concerns products and not countries.

Environmental – or energy – subsidies are good examples. Given that the capacity to subsidize depends on the level of economic development, strict disciplines are necessary for developed countries or sectors, while more lenient standards could apply to countries and sectors at lower levels of development. The classical approach of differentiated transition periods is always an option.

Indeed, why take on new commitments or adopt additional rules or forge a new agreement if there is little or no competition? Would it not make more sense to wait until the environmental industries in developing-country members of WTO become competitive and graduate into a different regulatory league? And even then, should the scope for commercially significant free riding be limited, do the future disciplines necessarily have to include a market-access dimension?

The traditional approach to market creation in the WTO is through special and differential (S&D) treatment. However, this approach has largely failed, and a more effective set of measures is in order. Such measures may be developed by promoting the concept of issue linkage, i.e. coherence and multilateral cooperation in several dimensions and agreement over multiple issues, or an issues tie-in, i.e. the requirement that a particular agreement must span multiple dimensions of interaction, thus ruling out a single-issue agreement (Conconi and Perroni, 2002).

An issue tie-in is a stronger option, which could be pursued on two levels: (i) as an "extended coherence" in the relationship between the WTO and other international instruments (e.g. multilateral environmental agreements (MEAs), where part of an agreement becomes an *acquis* of another agreement); and (ii) within the WTO treaty itself, in terms of interfacing issues that are usually dealt with separately. In the former case, members States could pursue the objectives of the Kyoto Protocol within a framework agreement on environmental goods and services, and vice-versa, whereby the framework requirements of the WTO could be taken into account in negotiations under the Kyoto Protocol. In particular, members collectively could undertake to provide the necessary technical support, capacity-building and infrastructural needs of developing-country members in order to enable them to participate in the agreement and derive tangible benefits from such participation. For instance, aid-for-trade could become part of the agreement on environmental goods and services, making cooperation in trade conditional on resource and technology transfer.

The idea of a tie-in is not new, but so far its implications have been examined mainly in the context of bilateral negotiations. WTO negotiations on trade facilitation could create a precedent in the multilateral trading system by making aid-for-trade (almost) legally binding and trade concessions conditional upon the transfer of the necessary resources and technology. To define what necessary means in this particular context, a necessity test could be devised, identifying assistance needs. The main reason to believe this option could be agreeable to WTO Members is that po-

tential recipients of assistance would undertake trade facilitation commitments in any case, with or without the negotiations. Would not the same logic apply to the environmental negotiations, especially if they were to turn to universally important objectives such as climate change mitigation?

Can the WTO be used to create incentives for developing countries? Cossy and Marceau (2009) stress the need to involve developing countries, both in the WTO and in the UNFCCC, while taking into account their development needs and priorities. The case law (EC - Tariff Preferences)[47] suggests that market access preferences can be conditioned on development-related criteria. The main question is whether or not preferences relating to climate change could be directly linked to sustainable development.

What about a tie-in within the WTO itself? The main question is whether trade rules and non-trade rules should be combined in the WTO in a different way than they are at present. The search for an answer would benefit tremendously from an analysis of the horizontal relationship among existing WTO agreements from the trade and environment perspective.

Cossy and Marceau (2009) point out that linking trade and climate change is impossible without linking trade and energy. The latter link involves competition and investment issues, and the WTO rules are still in the making in these areas. Put in Lamy's words, "…it is "markets" rather than "trade" that inform the core of policy concerns in the field of energy. Such policy concerns… have not really been the core focus of the GATT/WTO's work over the years." However, "…trade and trade rules are still relevant". The most intriguing question, and that is assuming the WTO has an increasingly important role to play, is whether the WTO should adapt existing rules to or, define new, specific rules for, energy?[48] And what if we were to replace the word "energy" with the word "the environment" or "climate change", for that matter? Would not the statement and the question still ring true?

In any case, the problems of scope and linkage are essentially political in nature. They can be solved only in the political arena, by political actors in the system, and not by quasi-technical discussions and negotiations. Some governments may well prefer to deal with issues they regard as remote from the WTO's agenda under different instruments or in other fora.

VI. The WTO Negotiations on Environmental Goods and Services: Need for a Change in Mindset Away from a Free-standing Sectoral Deal

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» Given the cross-sectoral nature of environmental goods (EGs) the question arises as to whether a WTO sectoral agreement on EGs is a workable option. In theory, negotiating a sectoral agreement allows the simultaneous negotiation of tariffs and Non-Tariff Measures (NTMs), thus tackling all the measures affecting trade of EGs.

» However, the Information Technology Agreement and other agreements have shown that a sectoral approach may not be particularly well suited and effective for dealing with NTMs.

» The elimination of tariffs on EGs can be negotiated under WTO non-agricultural market access negotiations, as part of a broader tariff-cutting deal, using request-offer or other negotiating approaches, which should facilitate cross-product and cross-sector trade-offs.

» NTMs, particularly behind-the-border regulations with legitimate environmental policy intent but with a potential trade impact, must be negotiated in the context of rules-based negotiations, by seeking to either improve existing disciplines or elaborate new ones.

Given the cross-sectoral nature of environmental goods (EGs) included in the various lists that countries have proposed in the WTO negotiations, the question arises as to whether a sectoral agreement on EGs is a workable option. Not only is it an artefact to speak of an EG sector, but there are also many dissimilarities between the economic and political context in which the Information Technology Agreement (ITA) and other sectoral agreements were negotiated, and the context of negotiating an agreement for environmental goods and services (EGSs). EGSs clearly do not benefit from the many favourable conditions that made the ITA possible. Among them,

- industry is not pushing hard for trade liberalizing actions for EGs, not even in developed countries;
- unlike information and communication technologies (ICTs), markets for renewable energies and other EGs either do not yet exist or are weak in many developing countries;
- the sector is dynamic but not yet considered as vital as IT products to the broader economy;
- the number of developing countries that are major players in markets for EGs is smaller, although this depends on the products selected for consideration in the negotiations; and
- there are no deadline-setting events that would guide negotiations.

While the ITA has been successful in eliminating tariffs, it has failed to deal with barriers to trade related to non-tariff measures (NTMs)[50]. This is a lesson negotiators on environmental goods need to reckon with.

In theory, negotiating a sectoral agreement allows the simultaneous negotiation of tariffs and NTMs, thus tackling all the measures affecting trade of a product or group of products. However, the ITA and other agreements have shown that a sectoral approach may not be particularly well suited and effective for dealing with NTMs (perhaps along with tariffs). Some observers believe that focusing on a specific sector or list of related products would make it feasible to evaluate and negotiate specific barriers (tariffs and sector-specific NTMs) that affect that sector, and would bring together the most interested parties (the most important exporters and importers, or the critical mass), which in turn would drive the process of exchanging concessions. The use of the sectoral approach in international negotiations (regional, plurilateral or multilateral) is, however, relatively limited, and has never entailed an exhaustive coverage of actual or potential barriers to trade.

Why then should EGs be negotiated as a free-standing agreement? There appears to be nothing special about the types of tariff and non-tariff barriers to trade that these goods face, or the negotiating objectives. On the other hand, there is substantial political consensus that EGs (and services) should be given priority or special attention in current efforts to liberalize trade.

Concerning tariffs, instead of hoping that a sectoral deal covering tariff and non-tariff barriers to trade can be brought about, WTO Member economies could pursue tariff elimination or reduction under WTO non-agricultural market access negotiations, as part of a broader tariff-cutting deal. The objective would be to make sure that HS six-digit groups, including a certain percentage of environmental goods, are all part of the tariff package and are among the items with the deepest tariff cuts or tariff elimination. Dealing with them as part of a broad-based tariff reduction exercise using request-offer or other negotiating approaches should facilitate cross-product and cross-sector trade-offs.

When the issue is NTMs rather than tariffs, particularly behind-the-border regulations with potential trade effects, the goal of negotiation shifts from adopting a market-access perspective to a trade-rules one. The reason for this is compelling. Most NTMs are implemented with legitimate objectives or concerns of public policy in mind (e.g. technical regulations, sanitary standards or safety and health requirements). Here the challenge is to move towards a more harmonized approach to non-border regulation through the elaboration of rules that acknowledge the legitimacy of government intervention while seeking to minimise negative trade effects. Towards that end, governments commit to apply tests and other evaluation procedures, in addition to honouring general principles such as transparency and non-discrimination. The rationale for a rules-based approach to NTMs is that such measures should not be eliminated but regulated in order to ensure that governments select among available options those measures that interfere least with free trade.

Rules-based negotiations are not about exchanges of concessions in the tariff-reduction tradition. In general, NTM negotiations are difficult to manage with a request-offer approach and on a product-specific basis because of the intrinsic problems of quantifying those barriers and agreeing on equivalence among them. The process becomes even more complicated as the number of participants in the negotiations increases. At best, the request-offer method can be a complement to specific stages or parts of the negotiating process. For example:

- It could be applied at the beginning of the negotiating process to "clean" the most burdensome or urgent NTBs among parties and those that be easily identified.
- It could be applied as part of a sectoral negotiation for dealing with the elimination of important NTBs in specific sectors or subsectors. However, elimination is most often not the issue or goal.
- When rules are negotiated to regulate NTMs, request-offer negative or positive lists could be elaborated to exempt or apply the rules-based disciplines of the agreement to specific products or institutions (as in government procurement).
- The approach could be used to elaborate annexes of exemptions or specific rules.

There are two ways of dealing with NTBs for EGs of any kind: by seeking to either improve existing disciplines or elaborate new ones. In the former case, the task would be to identify what existing rules need clarification or amendments, leading to either procedural or substantive modifications. This requires technical homework. The latter case would require writing new rules from scratch.

In pursuing the first option, a starting point could be for standing committees overseeing the implementation and operation of WTO agreements on NTBs to set up working groups with, say, a two-year mandate to review measures or policies restricting trade in EGs, and recommend actions, including possible reforming of rules. For example, the WTO Agreement on Technical Barriers to Trade mandates or encourages meaures that facilitate trade by, inter alia, working towards harmonization of technical regulations, using international standards and diverse methods for recognizing the equivalence of trading partners' conformity assessment procedures. A work programme could ensure that these measures are being applied for designated groups of environmental goods. A similar process could be built into the work of the Committee responsible for the WTO Agreement on Subsidies and Countervailing Measures, as well as that of other committees. While the Committee on Trade and Environment Special Session (CTESS) may be reluctant to delegate its mandate, it lacks the specialized technical expertise to go beyond a non-technical discussion and an (overdue) NTB data-collection exercise, and negotiate on its own multiple NTBs simultaneously.

The second track – elaborating a set of new rules – makes sense only where or when the first track is unavailable or does not deliver.

One also needs to bear in mind that where NTBs are mainly a two-country issue, they can be settled bilater-

ally. Negotiations in a larger group are only necessary where NTMs have wider application.

It is important to note that NTBs faced by EGs are no different from those faced by other goods, as has been broadly confirmed by various studies, including work done by OECD.[51] With multilateral rules covering a vast array of barriers that are reported, the need for new agreements dealing specifically with EGs is not obvious. The reason why barriers to trade in environmental goods (and services) should be dealt with separately from existing agreements has yet to be explained.

VII. Environmental Goods: a Reality Check

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» In theory, liberalizing trade in environmental goods (EGs) and services could help developing economies build more environmentally sustainable economies. However, analysis shows that continued trade growth in EGs depends not only on policies supportive of freer trade in these goods and services, but also on viable domestic consumer markets for them.

» In fact, trade in EGs is restricted to a handful of middle-income countries, which have adequate purchasing power to sustain a dramatic rise in imports of EGs. Poor countries import almost no EGs, which points to the need for environment-related technical assistance projects to focus on poor countries, especially in Africa.

» Moreover, tariffs were found to be important in explaining imports of EGs by developing countries in only one category of EGs while the presence of high tariffs in two other categories was actually associated with more trade. Nevertheless, trade in almost all categories of EGs is found to be highly sensitive to growth in GDP and FDI as well as with the presence of technical assistance projects.

» This shows that while lowering tariffs may increase imports of EGs, several other factors may play a more decisive role. For instance, policies to promote viable domestic consumer markets for EGs as well as policies to improve the general competitiveness of exports may have a more crucial role to play in enhancing trade in EGs.

The growing importance of environmental issues has generated a parallel interest in evaluating the opportunity for trade in environmental goods (EGs) and services. Sustainable development strategies worldwide have contributed to the overall growth of the global environment industry, which is currently estimated at over $650 billion. However, trade in EGs and services is estimated to be only a tenth of that amount.

In theory, liberalizing trade in EGs and services could help developing economies build more environmentally sustainable economies. However, continued trade growth in this area depends not only on policies supportive of freer trade in these goods and services, but also on viable domestic consumer markets for them. Our analysis[52] shows that trade in EGs is restricted to only a handful of countries. Thus not all environmental hotspots are serviced by trade in EGs. The main reason behind this is the absence of viable markets.

A. Environmental goods do not reach all potential users

We analysed trade flows with regard to products on WTO's so-called "153 list " (WTO JOB(07) 54), which is a consolidated list of products proposed by the "friends" of liberalization of trade in environmental goods at the WTO. The study shows that the products on the list do not necessarily end up in the areas most in need of them. For example, environmental problems in Africa have reached critical levels, yet African countries import minimal amounts of EGs. This is because effective markets and paying capacity exist only in middle-income countries, which have seen a dramatic rise in imports of EGs. In addition, technical assistance or tied-aid projects appear to be directed to countries with adequate purchasing power. This gap in EGs imports in a large number of developing countries points to the need for technical assistance projects in poor countries, especially in Africa. Bilateral and multilateral donor assistance in this area has focused on the relatively higher income developing countries, notably Brazil, China, Mexico and the Republic of Korea.

The scope for addressing environmental problems by changing the set of EGs to be liberalized is limited, and there is no direct link between environmental problems and the list currently under discussion at the WTO. The picture is further complicated by the dual and often multiple uses of environmental goods (see also the article by Vikhlyaev in this Review).[53]

B. Restricting the scope of EGs

One way forward would be to initially liberalize only products that have an environmental end use. Our study shows that if environmental performance indicators were used to identify an environmental end use, EGs would be restricted to only a few categories of products from the "153" list of products. These categories include environmentally preferable products (EPPs), natural risk products, renewable energy, waste management, and clean-up, waste and potable water products. This list would also cover the category of products that have shown particular tariff sensitivity.

C. How important are tariffs?

Tariffs were found to be important in explaining imports of EGs by developing countries in only one category of products: heat and energy management products. Trade in renewable energy products was also sensitive to tariff reduction at the 5 per cent level. It is possible that these two categories comprise high-technology products, most of which tend to be imported by developing countries. Thus the initial list of EGs could be further narrowed to include only these sub-items for the initial round of liberalization. It should, however, be noted that the elasticity of these products with respect to tariffs is low, with a tariff reduction of 1 per cent leading to only a 0.15 per cent increase in trade.

For two other categories, the tariff response of trade in EGs is in the opposite direction. For both environmentally friendly products and natural-resource-based products, the higher the tariff, the higher is the trade. This could be attributed to the fact that trade in these products may be linked more directly to incomes rather than to tariffs: as incomes rise, trade in these categories increases, irrespective of higher tariffs.

D. What happens with rising GDP?

Trade in almost all categories of EGs is found to be highly sensitive to GDP: trade in air pollution equipment, EPPs , and products aimed at addressing natural risks increases as GDP increases., the Environmental performance index (EPI) surveys show that with an increase in GDP air pollution is the first to increase. In most countries, legislation to combat air pollution follows as GDP rises, which could account for the increase in trade in this category of products. Natural disaster mitigation also becomes a high priority when GDP rises, leading to an increase in trade in EGs in this category. As explained above, even amongst developing countries the preference for EPPs rises as incomes rise.

Trade in management of solid and hazardous wastes, clean-up and remediation, renewable energy products, and natural-resource-based products shows a significant negative correlation with GDP. While the generation of waste increases significantly with rising GDP, middle-income countries have been proactive in developing their own waste management systems. Equipment imports have generally been low, except in a few South-East Asian countries. For example, India and a number of other countries have relied mostly on indigenous solar and wind turbines. Their increase in GDP provides them with the necessary resources, often coupled with high levels of foreign direct investment (FDI), to develop and produce such equipment.

The most important justification for liberalizing trade in EGs is the improvement in developing- country environmental performance. For three categories of EGs, the correlation between the relevant environmental performance index (EPI) and trade is significant, at the 1 per cent level. These products, which are included in the categories of clean-up or remediation of soil and water, renewable energy, and heat and energy management, account for about 40 tariff lines. This high correlation could therefore be interpreted to imply that goods in these categories probably are being put to some environmental end use.

E. FDI growth correlates with trade in environmental goods

There appears to be a robust correlation between trade in environmental goods and FDI. As FDI increases, so too does trade in goods related to air pollution control, management of solid and hazardous waste and recycling systems, clean-up or remediation, renewable energy, natural risk management, and noise and vibration abatement equipment covered by the WTO list. This high correlation can be explained by the fact that most of these products have dual uses. Another explanation could be that higher levels of FDI are associated with better environmental practices, which necessitates the import of a wide range of environmental goods. Also, it is likely that the delivery of environmental services especially in these categories of services necessitates the import of these EGs. However, as the variable used is overall FDI, rather than FDI in specific categories of EGs, the most likely explanation is the first one. A counterintuitive result

is seen in the category of EPPs, where the lower the FDI, the higher is the trade in EPPs. This result can be explained by the fact that the top EPP exporters are low-income Asian and African countries that have not attracted significant levels of FDI.

F. The importance of technical assistance

The most direct, significant and positive correlation is found with respect to technical assistance projects. This correlation is robust and positive for eight of the ten categories of EGs. In most cases the elasticities are also very high – significantly more than one – indicating the crucial role of technical assistance projects in explaining trade in EGs. The profile of these projects indicates that tied aid may be an important factor contributing to trade in EGs to developing countries. The lack of trade with low-income African countries could be because developed countries have very few projects in African countries. Increasing EG trade with Africa would therefore require the development of such projects.

G. Developing-country negotiating strategies

An analysis of factors influencing the import of EGs shows that while lowering tariffs may increase imports, several other factors may play a more decisive role. Supporting policies that improve the general competitiveness of exports is also likely to improve trade in EGs. Developing countries would not necessarily benefit in either environmental or trade terms from fast-track liberalization of environmental goods.

Dynamic comparative advantage appears to be shifting in favour of developing countries for a number of categories of goods identified in the "153" list. In the medium to long term, developing countries are likely to benefit from tariff liberalization. However, as developed countries already have low tariffs, developing countries may find it more beneficial to focus on non-tariff barriers. With a growing comparative advantage it will be in developing countries' interests to examine the role that non-tariff barriers play in their export markets. Since only a handful of developing countries feature among the top 10 importers and exporters of EGs, these players could usefully engage in a request offer approach to exchange market access concessions. In this way, while the benefits may be multilateralized, the cost of liberalization will have to be borne by only a few players. These would be the very players who have a lot more to gain through liberalization.

H. Environmental services

The link between trade in EG and ES has been widely acclaimed. For negotiating purposes, it is important to pursue liberalization of EGs and ESs separately; the link should not be used to slow down liberalization in either of these two areas.

Liberalization of ES particularly in public utilities needs further evaluation. Experience with privatization has been mixed. In many cases, the delivery of public services has not improved with privatization and has exacerbated social exclusion.

These caveats do not imply that trade liberalization in ES should be restricted, but rather that liberalization will not deliver the expected benefit unless a supportive infrastructure such as regulations and community participation is in place. The supportive infrastructure would be equally important for absorbing and disseminating environmentally sound technologies.

Another area of ES which has been little explored is that of outsourcing environmental consultancy services. The comparative advantage of developing countries in this area needs to be carefully investigated.

Notes

[1] A survey of rural households in India found that 96 per cent of the households use biomass energy together with other energy sources (kerosene and liquefied petroleum gas (LPG)) to meet their needs. The study found that 5 per cent of adults suffer from bronchial asthma, 16 per cent from bronchitis, 8.2 per cent from pulmonary tuberculosis and 7 per cent from chest infection (Parikh et al., 2005).

[2] See, for instance, "Energy missing Millennium goal – U.N. climate chief", Reuters, January 21, 2009 (citing Rajendra Pachauri, IPCC chairperson); accessible at: www.reuters.com/article/homepageCrisis/idUSDEL270134._CH_.2400.

[3] Paragraph 9(a) of the Plan; available at: www.un.org/esa/dsd/dsd_aofw_ene/ene_index.shtml.

[4] See, for instance, UNDP, La Plate-forme multifonctionnelle: introduire des sources d'énergie, ouvrir la voie au changement pour le bien des communautés rurales du Burkina Faso – a UNDP-supported programme in Burkina Faso; available at: www.pnud.bf/DOCS/Plate-forme_FRA.pdf, January 2009.

[5] The World Bank (2006a) notes that during peaks in oil prices, poverty increases significantly: it estimates that during the price increase of oil in 2006, poverty increased by as much as 2 per cent in 20 developing countries.

[6] The Millennium Project was commissioned by the United Nations Secretary-General in 2002 to develop a concrete action plan for the achievement of the MDGs. In 2005, the independent advisory body headed by Professor Jeffrey Sachs, presented its final recommendations to the Secretary-General in a synthesis volume entitled, Investing in Development: A Practical Plan to Achieve the Millennium Development Goals. For further information, see: www.unmillenniumproject.org/.

[7] The Kenyan GNI per capita was $1,550 in 2007 (World Bank country profiles, available online at: www.worldbank.org/countries.

[8] Comité intersectoriel de mise en œuvre des synergies entre le secteur de l'energie et les autres secteurs stratégiques pour la réduction de la pauvreté (CIMES/RP).

[9] Similar structures exist in some other West African countries, and are supported by the White Paper for a Regional Policy: Geared toward increasing access to energy services for rural and periurban populations in order to achieve the Millennium Development Goals of the Economic Community of West African States (ECOWAS). See: www.energyandenvironment.undp.org/undp/indexAction.cfm?module=Library&action=GetFile&DocumentAttachmentID=1675.

[10] Examples of projects were drawn from www.climatefundsupdate.org.

[11] See: www.gefweb.org/projects/Focal_Areas/climate/climate.html.

[12] See: www.lightingafrica.org/.

[13] See: www.cdmpaipeline.org/cdm-projects-type.htm#2.

[14] See UNFCCC, National adaptation programmes of action: Index of NAPA projects by country, at: http://unfccc.int/files/adaptation/application/pdf/napa_index_country.pdf; and UNFCCC, National adaptation programmes of action: Index of NAMA projects by sectors, at: http://unfccc.int/files/national_reports/napa/application/pdf/napa_index_sector_march_09.pdf

[15] By comparison, Germany, a leader in the exploitation of wind energy, added some 2 GW of newly installed capacity in 2009 (see Der Tagesspiegel, China macht mehr Wind als die USA, ,24 July 2009). On the future outlook, see Global Wind Energy Council, US and China in race to the top of global wind industry, 2 February 2009; available at: www.gwec.net/index.php?id=30&tx_ttnews[tt_news]=177.

[16] See Reuters, China seen surging to top wind turbine maker in 09. (Interview with Steve Sawyer, secretary of the Global Wind Energy Council), January 8, 2008; available at: www.reuters.com/article/latestCrisis/idUSL0773451. Among other things, Sawyer called on member companies to prepare "for the onslaught of relatively inexpensive Chinese turbines onto the world market," which he thought was imminent.

[17] On the Dongfang deal, see Reuters, Dong Fang Electrical Machinery and The Switch Sign Windpower Generator Co-operation Agreement, June 30, 2008; available at: www.reuters.com/article/pressRelease/idUS115462+30-Jun-2008+MW20080630.

[18] For the targets, see the website of TEDA (Tianjin Economic and Technological Development Area) at: http://en.investteda.org/aboutteda/keyindustriesbrief/wind/default.htm.

[19] See also Baoding High-Tech Industry Development Zone website at: www.bdgxq.cn/english/jjfz_eng.asp.

[20] Cielo Wind Power press release, October 29, 2009, announcing a joint venture with Shenyang Power Group to build wind farm in Texas; available at: www.cielowind.com/news/press-releases/us-renewable-energy-group-china%E2%80%99s-shenyang-power-group-and-cielo-wind-power-to-develop-a-600-mw-wind-farm-in-texas.

[21] GE press release, GE Drivetrain Technologies signs LOIs with A-Power to supply 900 wind turbine gearboxes and establish joint venture to build wind turbine assembly facility, 12 January 2009; available at: www.genewscenter.com/content/detail.aspx?releaseid=5471&newsareaid=2&menusearchcategoryid=; and PR Newswire Asia, A-Power Energy Generation Systems Ltd. to acquire 1.5MW wind turbine proprietary technology from Shenyang Huaren Wind Power Technology Development Co., Ltd., 28 July 28 2009; available at: www.prnasia.com/pr/09/07/09500311-1.html; PR Newswire Asia, A-Power Energy Generation Systems Ltd. to develop a 19.5MW wind farm in Shandong Province, 14 October 2009; available at: www.prnasia.com/pr/09/10/09711711-1.html.

[22] The United States Trade Representative rejected complaints that the EU-United States list consisted only of products of export interest to industrialized countries, pointing out that in 2006 the United States was in fact a net importer of the 43 products, with $18 billion in imports of such products, surpassing exports by $3 billion, and citing China and Mexico as the two top sources for those products (ICTSD, 2007c).

[23] Van der Gaast and Begg (2009) argue that programmatic CDM is highly suited to energy efficiency improvement projects in households (e.g. cooking, lighting) and industry (e.g. one technology applied within an industrial sector at different locations but under similar circumstances).

[24] In liberalizing trade in EGS, priority should be given to products, technologies and services used in small-scale CDM projects and programmatic CDM. In other words, such products, technologies and services should be included in any list of EGSs for accelerated liberalization. While the motivation would be to facilitate small-scale CDM projects and programmatic CDM, any agreed tariff reduction or elimination would apply to all these EGSs, irrespective of whether these are used for CDM projects. This makes it conceptually different from the Indian proposal for a project-approach that ties the liberalization of any EGS to specific projects.

[25] In a letter to United States President Barack Obama on 3 August 2009, the National Foreign Trade Council and eight other United States business groups urged his Administration to "use all possible channels" to pursue an agreement on reducing barriers to trade in EGSs, even if that meant going outside the Doha Round (Palmer, 2009).

[26] It would make more sense in the context of climate change mitigation to define critical mass as a share of emissions rather as a share of trade. After all, any agreement on climate-friendly goods aims to cut GHG emissions by providing more choices at lower costs. However, this approach depends on how such climate-friendly goods are produced and what goods they would replace. However, it is much more difficult to calculate emissions than to calculate trade value/volume, and it is an area unfamiliar to WTO negotiators. Taken together, while the approach sounds very appealing theoretically, these complications would make it hard to implement, in practice.

[27] An analysis by Jha (2008) of 84 energy supply products in the Friends' 153 EGS list reveals that only 30 per cent of those products are sensitive to a tariff reduction.

[28] The term renewables is used here and throughout the text to signify goods, equipment and technologies used in conjunction with renewable energy sources and biofuels.

[29] See Pascal Lamy , "WTO culture of international trade cooperation is relevant to the energy sector", a speech delivered at a conference organized by the Centre for Trade and Economic Integration (CTEI) at the Graduate Institute of International and Development Studies, Geneva, 22 October 2009.

[30] Statement by the WTO Director General Pascal Lamy at a joint press conference with Australia's trade minister Simon Crean after an informal meeting of trade ministers in Paris on 25 June 2009, www.wto.org/english/news_e/news09_e/dgpl_25jun09_e.htm.

[31] As tracked by the Renewable Energy International Law Project (REILP) in 2005. Quoted from an informal briefing paper for UNCTAD Expert Meeting on Strengthening Participation of Developing Countries in Dynamic and New Sectors of World Trade: Trends, Issues and Policies, Geneva, February, 2005.

[32] Swedish National Board of Trade, Trade aspects of biofuels, 2007; available at: www.kommers.se/upload/Analysarkiv/In%20English/Trade%20Aspects%20of%20Biofuels.pdf .

[33] For example, some of the major components of a wind turbine are rotors, drive trains and generators, while

subcomponents are even more diverse, such as blades, high-speed and low-speed shafts, gear boxes, brakes and plastic products. These intermediate goods are identifiable in the Harmonized System (HS), which classifies traded products, as ex-6 digit items; some, such as rotors and generators, are specific to wind energy, while others, such as gearing equipment, have multiple uses.

[34] Market-creation measures underwrite the costs of introducing renewables into the market, improving technical performance and encouraging the development of the industry.

[35] The Harmonized Commodity Description and Coding Systems generally referred to as "Harmonized System" or simply "HS" is a multipurpose international product nomenclature developed by the World Customs Organization (WCO).

[36] These factors are not specific to *renewables*, of course.

[37] Hydraulic turbines >10 MW (8410.13) are generally not considered environmentally friendly.

[38] In the trade negotiators' parlance, ex-outs are goods that are not identified separately at the 6-digit level (internationally harmonized) of the Harmonized Commodity Description and Coding Systems and have to be identified in national tariff schedules at the 8- or 10-digit level.

[39] While one list in the ITA is relatively straightforward and contains few ex-outs, there has been extensive ongoing technical work to correct some of the problems created with a second list which is essentially all ex-outs. After many years, a significant number of these have been rectified through changes to the HS nomenclature (internationally harmonized 6 digits) by the World Customs Organization (WCO).

[40] The negotiating history of the ITA is described by Barbara Fliess, Pierre Sauvé, in: Of Chpis, Floppy Discs and Great Timing: Assessing the WTO Information Technology Agreement, Paris, Institut Francais des Relations Internationales, 1998.

[41] European Communities - Measures Affecting Asbestos and Asbestos-Containing Products - AB-2000-11 - Report of the Appellate Body, WT/DS135/AB/R.

[42] The negotiations on financial services could deal with the status and treatment of tradable renewable energy certificates in the future.

[43] The Services Sectoral Classification List, MTN.GNS/W/120, 10 July 1991, generally known as W/120, contains three specific sub-categories that have been identified as part of a potential "energy services" sector, namely "services incidental to mining", "services incidental to energy distribution" and "pipeline transportation of fuels". Those activities constitute sub-categories of other services sectors listed in W/120 (i.e. business services for the first two and transport services for the latter). It is not the classification that determines the scope of GATS though.

[44] It has been argued that different activities in the energy chain exist depending on the type of energy involved. Thus a definition of the sector could consist of separate subsectors for each type of energy source involved. The alternative to that suggestion would be to identify the services of the energy sector as a whole regardless of the source of energy, which has been referred to as an energy-neutral approach.

[45] See the "Proposal for a result under paragraph 31 (iii) of the Doha Ministerial Declaration", Non Paper by the European Communities and the United States JOB(07)/193/Rev.1, 6 December 2007 Committee on Trade and Environment Special Session Council for Trade in Services Special Session.

[46] For an interesting discussion see The Multilateral Trade Regime: Which Way Forward? The report of the first Warwick Commission. University of Warwick, 2007.

[47] European Communities - Conditions for the Granting of Tariff Preferences to Developing Countries, WTO, WT/DS246/AB/R, 2004.

[48] Pascal Lamy's speech , "WTO culture of international trade cooperation is relevant to the energy sector", at a conference organized by the Centre for Trade and Economic Integration (CTEI) at the Graduate Institute of International and Development Studies, Geneva, 22 Octobre 2009, www.wto.org/english/news_e/sppl_e/sppl139_e.htm.

[49] The views expressed in this paper are the author's alone, and do not necessarily reflect the views of the OECD or of its Members.

[50] The author prefers the term Non-Tariff Measures to Non-Tariff Barriers (NTBs).

[51] See Barbara Fliess and Joy Kim, *Business perceptions of non-tariff barriers facing trade in selected environmental goods and services,* OECD Trade and Environment Working Paper 2007-02, Parts I and II, OECD, Paris.

[52] This short commentary is a summary of the paper prepared by the author for the International Centre for Trade and Sustainable Development, Geneva in 2008. For downloading the full paper visit the ICTSD website at: http://ictsd.net. ICTSD will be publishing another paper on environmental goods, climate change and the renewable energy sector by the same author later in 2009. Further work on trade in EGs in the buildings and transport sector is also planned.

[53] For example, while the Environmental Business International sets a market value of over $650 billion for EGs, it states that only about 15 per cent of that value may be traded. The value of traded EGs on the WTO "153" list is about $430 billion. This implies that there are several multiple-use products on the "153" list. This points to the need to further restrict the scope of EGs.

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Key messages

The global economic and financial crisis and the interrelated climate, food, and water crises have imposed themselves as defining parameters for policy-making today. Understanding the causes and consequences of these crises and drawing lessons from them should spur dramatic economic and policy changes. Indeed, economic crises tend to trigger major changes in conceptual and ideological thinking as well as the emergence of new policies, technologies and management practices.

While embracing change is always a political challenge, the key message of the Trade and Environment Review 2009/2010 (TER 2009/2010) is that the occurrence of these crises offers a window of opportunity to embark on a path of more resilient and sustainable economic growth. The key challenge is to avoid responding to the crises with measures that perpetuate economically, socially and environmentally unsustainable production and consumption patterns. The key opportunity is to seek ways to respond to the crises by identifying dynamic synergies to initiate change.

Developing countries can seize real opportunities for cleaner growth, including low-carbon growth. TER 2009/2010 argues that, while complex and long, the process of greening economies can and should be gradually piloted towards selected "poles of clean growth". A successful combination of sound economic and ecological management of such poles would steer economies towards more environmentally friendly development and, hopefully, generate positive spillover effects in other sectors, even under conditions of no or imperfect internalization of many key externalities. TER 2009/2010 offers three illustrations of promising poles of clean growth, especially relevant to developing countries:

1. Energy efficiency
Gains in energy efficiency, often utilizing well-known policy frameworks and technologies, are the fastest and most economical way to increase access to energy, mitigate climate change, reduce national expenditure on imports of fossil fuels and control air pollution, while saving costs and enhancing national competitiveness. While up-front costs may be significant, improvements in energy efficiency often pay for themselves through saved energy costs. Energy efficiency is often implemented in combination with material and resource efficiency.

2. Sustainable agriculture
Agriculture is of strategic importance for growth and poverty reduction in many developing countries. The adoption of coherent national and international policies to encourage the use of more sustainable production methods, including organic agriculture, could help save costs, develop new markets, improve revenues and enhance food security, while also providing considerable scope for climate change mitigation and adaptation.

3. Renewable energies for rural development
Renewable sources of energy, available in abundance in a number of developing countries, can be economically exploited with readily available technologies. For instance, the provision of electricity and mechanical energy offers enormous potential for improving rural welfare and accelerating poverty reduction, while at the same time unlocking the productive potential of isolated rural communities, including by enhancing their productive capacity and value addition in agricultural production.

Clearly, investment in these poles of cleaner growth will not automatically solve the current problems relating to poverty and climate change, but it will constitute a much-needed first step in the structural transformation towards a lower carbon economy. Moreover, investment in these poles of clean growth will yield economic, employment, social, technological and environmental dividends that will contribute directly to achieving the Millennium Development Goals.

However, the changes required to accelerate the emergence of clean growth poles will not occur spontaneously or effortlessly. As highlighted in TER 2009/2010, governments will need to take the lead in fostering the emergence of cleaner growth poles, particularly by introducing strong regulations as well as financial incentives, ensuring policy coherence and generating societal support for a new vision. The key question is whether developing countries will have the administrative and financial capacity to take the necessary actions. Global efforts to mitigate climate change could provide a platform for capacity-building and financial and technological cooperation to support developing countries, for instance in the context of nationally appropriate mitigation actions and sustainable development policies and measures.

Despite the enormity of the challenge, change is possible: TER 2009/2010 shows that this strategic agenda is accessible to developed and developing countries alike, including the poorest among them.

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