GREEN HYDROGEN
SOUTH AFRICA

MANAGING THE IMPACTS OF A GREEN HYDROGEN/POWER-TO-X ECONOMY:

An Environmental Impact Assessment Guideline for South Africa

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Contents

List of figures

List of tables

ACRONYMS

BA	Basic Assessment
BAR	Basic Assessment Report
BESS	Battery Energy Storage Systems
BID	Background Information Document
CA	Competent Authority
CLD	Causal Loop Diagram
DEA&DP	Department of Environmental Affairs and Development Planning
DFFE	Department of Forestry, Fisheries and the Environment
DSI	Department of Science and Innovation
DTIC	Department of Trade, Industry and Competition
EA	Environmental Authorisation
EAP	Environmental Assessment Practitioner
EAPASA	Environmental Assessment Practitioners Association of South Africa
EIA	Environmental Impact Assessment (Refer to Section 1.1)
EIR	Environmental Impact Report
Electrolysis	Refer to Section 1.2
EMF	Environmental Management Framework (Refer to Section 4.3)
EMPr	Environmental Management Programme (Refer to Section 3.4.4)
ESIA	Environmental and Social Impact Assessment
Fischer-Tropsch	Refer to Section 1.2
GH_2	Green hydrogen
GHNP	Green Hydrogen National Programme
GIS	Geographic Information System
Haber-Bosch	Refer to Section 1.2
I&AP	Interested and Affected Party
IDP	Integrated Development Plan
IFC	International Finance Corporation (Refer to Section 4.1)

ACRONYMS

LCA	Life Cycle Assessment (Refer to Section 4.9.7)
MCA	Multi-criteria Analysis (Refer to Section 4.6.1)
MWRO	Mine Water Reverse Osmosis (Refer to Section 1.2)
NEMA	National Environmental Management Act (Refer to Section 2.1)
NHRA	National Heritage Resources Act
NWA	National Water Act
O&M	Operations and Maintenance
PICC	Presidential Infrastructure Coordinating Commission
Power-to-X	Refer to Box 1
PV	Photovoltaic
REDZs	Renewable Energy Development Zones (Refer to Section 4.4)
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
SDF	Spatial Development Framework (Refer to Section 4.3)
SDGs	Sustainable Development Goals (Refer to Section 4.3.1)
SEA	Strategic Environmental Assessment (Refer to Section 5.2)
SEZ	Special Economic Zone
SIP	Strategic Integrated Project (Refer to Section 4.4)

PART I:

Introduction and context setting

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Introduction and context setting

As part of developing a framework to support evidence-informed decision-making on the topic of green hydrogen[1] (GH_2) and Power-to-X (PtX), this Guideline was drafted within the scope of the H2.SA Programme, funded by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Germany is one of the countries leading the development of a global GH_2/PtX supply chain. South African–German cooperation commenced with several initiatives like Green Hydrogen South Africa (GHSA)[2], as well as several research initiaves within the ambit of H2.SA. The overarching purpose aims to improve the conditions for companies to participate in a South African GH_2/PtX economy and enhance stakeholder knowledge of potential impacts of such an economy.

This Environmental Impact Assessment (EIA) Guideline was drafted by an interdisciplinary, inter-institutional team of experts with knowledge of the ecological and social impacts of a domestic GH_2 economy in South Africa. Authors were drawn from a 40-person working group consisting of a diversity of representation from the public sector, private sector, research organisations, and non-governmental organisations.

The purpose of this Guideline is to offer insights into the main issues that may surface when undertaking an Environmental Authorisation (EA) process for a GH_2/PtX project, and how these issues may be managed or resolved[3].

The Guideline is aimed at Environmental Assessment Practitioners (EAPs) undertaking EIAs on a day-to-day basis, specialists contributing to EIA chapters, policy- and decision-makers working in national and provincial competent authorities (CAs), project developers, and broader civil society.

1. *There are many differing perspectives on the concept of what it means to be "green". Here we use the term in the narrow sense, meaning a product developed where all upstream production facilities are supplied by renewable energy.*

2 *GHSA is a multi-stakeholder initiative that promotes South Africa as a leading GH_2 producer and investment destination of choice. It is led by The Presidency of South Africa and home of the South African Green Hydrogen Summit.*

3. *This Guideline focuses on the upstream impacts associated with the production of green hydrogen and its derivative products and does not consider impacts of downstream uses, for example, as fertilizers, aviation fuels, green methanol etc.*

Box 1: What is GH_2/PtX?

Green hydrogen (GH_2) is a form of hydrogen fuel produced through the electrolysis of water (splitting water into hydrogen and oxygen) using electricity generated from renewable energy sources.

GH_2 contrasts with other hydrogen types, where the energy source and production process vary. Blue hydrogen, for example, is produced from natural gas with carbon capture technologies to mitigate emissions, while grey hydrogen, the most common form, is also derived from natural gas but without capturing the emitted CO_2, making green hydrogen the most environmentally friendly option.

Power-to-X (PtX) is a broader concept that encompasses various technologies and processes (including GH_2) to convert electrical power, from renewable sources, into different forms of energy carriers, chemicals, or materials.

This conversion enables the storage, transportation and use of hydrogen (Power-to-Hydrogen), synthetic fuels (Power-to-Liquid), and even chemicals (Power-to- Chemicals), broadening the scope of renewable energy applications, particularly crucial for industries and sectors where green electrification is challenging, such as heavy- duty transport, maritime shipping, and aviation (‘hard-to- abate’ sectors).

For more information on what GH_2/PtX is and how it works, see the International PtX Hub funded by the International Climate Initiative, which offers useful videos and infographics.

The objectives of this Guideline are to:

1. Introduce readers to GH_2/PtX technologies and how they might be developed in South Africa;
2. Provide an integrated view of the policy and regulatory context for GH_2/PtX projects;
3. Help align new projects within existing planning frameworks and EIA best practice;
4. Outline the EIA process and other permitting requirements for GH_2/PtX projects;
5. Present a brief overview of tools which can be used to assess systemic and cumulative effect; and
6. Offer insights and learning from EAPs currently working on GH_2/PtX EIAs in South Africa.

The Guideline comprises four parts, as follows:

PART I: Describes the GH_2/PtX production process, constituent parts and development activities

PART II: Outlines the pertinent EIA regulatory requirements for GH_2/PtX projects

PART III: Provides guidance on planning and conducting the EIA process

PART IV: Offers a suite of tools for practitioners to consider during the EIA.

1.1 GH_2/PtX in South Africa

South Africa has identified a R300 billion investment pipeline under South Africa's Green Hydrogen National Programme as part of a Strategic Integrated Project (SIP) for accelerated development in the newly proposed GH_2/PtX sector. South Africa's renewable energy resources, vast coastline, port infrastructure, and platinum group metal reserves give it a competitive advantage in producing cost-effective GH_2/PtX products (Lebrouhi *et al.*, 2022). These prospects enjoy substantial backing, supported by nascent policies like the Hydrogen Society Roadmap for South Africa (DSI, 2021), the Green Hydrogen Commercialisation Strategy for South Africa (dtic, 2022), the Just Transition Framework (PCC, 2022), and several others.

The Hydrogen Society Roadmap for South Africa states:

"In its pursuit of a hydrogen society, South Africa will leverage its significant natural renewable resources, mineral endowment and capabilities to stimulate local demand for renewable hydrogen and build a viable green-hydrogen export market. This will contribute to the growth and development of the South African economy and the creation of sustainable green jobs, while moving the country towards secure and low-cost sustainable energy, promoting broader national competitiveness" (DSI, 2021: 8).

GH_2/PtX could form a significant component of the South African energy economy over the next few decades if policy aspirations are realised. For this to happen, many decisions will need to be made at different spatial scales, across different spheres of government, involving a variety of stakeholders, including the private sector and broader civil society, over a protracted period of time. Most of these decisions will be conditional rather than absolute, meaning that certain activities may be encouraged in some locations and not others, or within a requisite set of management actions.

Box 2: Five good practice principals for EIA

A recent review of EIA best practice in Africa by Sandham, Retief and Alberts (2022) revealed some essential best-practice principles. EIAs should aim to be:

1. Adaptive: Adjust to the realities, issues, and circumstances of the proposals under review without compromising the integrity of the EIA process, while also being iterative, incorporating lessons learned throughout the proposal's life cycle.
2. Participative: Provide appropriate opportunities to inform and involve the interested and affected parties, addressing their inputs and concerns explicitly in the documentation and in decision making.
3. Interdisciplinary: Ensure that the appropriate techniques and experts in the relevant bio-physical and socio-economic disciplines are employed, including use of traditional knowledge as relevant.
4. Credible: Demonstrate professionalism, rigor, fairness, objectivity, impartiality, and balance, and be subject to independent checks and verification.
5. Systematic: Ensure that full consideration is taken of all relevant information on the affected environment, of proposed alternatives and their impacts, and of the measures necessary to monitor and investigate residual effects.

An EIA, undertaken within the ambit of the National Environmental Management Act (NEMA) (Act 107 of 1998)[4], will play a critical role in the evaluation and proper design and management of such a new energy economy. South Africa has a long history of regulated EIA practice going back over 30 years. The EIA, which is now used in close to 200 countries, is both a political and technical instrument used to inform governmental decision-making on site- specific project applications (Morgan, 2012). Its purpose is, through interdisciplinary and participatory knowledge- production processes, to predict and manage the social and ecological consequences of development infrastructure and activities. While the overall effectiveness of EIAs has been questioned over the years in South Africa (Wood, 1999) and globally (Morrison-Saunders and Retief, 2012), EIA remains the preeminent decision-making instrument for promoting the principles of sustainability (Retief *et al.*, 2016).

1.2 Potential GH_2/PtX projects, technologies, and infrastructure

The nature, extent, and types of infrastructure that could be expected should a large-scale South African GH_2/PtX economy come to fruition are described in this section. In each case, the development of this infrastructure will require EA as part of a specific project development application.

For GH_2/PtX production, in the South African context, renewable energy inputs should come from windfarms and solar PV installations, providing the electricity needed for GH_2 production via electrolysis[5].

The intention is for water inputs to come from seawater reverse osmosis (SWRO) at the coast or mine water reverse osmosis (MWRO) around old mining sites, so as not to compromise potable water resources. Using the water allocations from decommissioned coal fired power plants could potentially also be considered.

The GH_2 produced could then serve as a feedstock for producing green ammonia through the Haber-Bosch process, where it reacts with nitrogen extracted from the air. Similarly, green methanol synthesis would combine GH_2 with captured carbon dioxide. All these processes would need to be interconnected by various infrastructure elements like transmission lines, roads, pipelines, storage systems, and other operational facilities.

Using Figure 1 as a template, the sections which follow describe these GH_2/PtX technologies and infrastructure in more detail.

4. *At regional and national scales, Strategic Environmental Assessment (SEA), another well-established knowledge-policy tool, may add substantial value to policy-level decision-making processes for South African GH_2/PtX implementation (Section 5.2).*

5. *It is likely that the wind and solar PV supply will come from numerous renewable energy generation sources, distributed widely over an extensive geographical area.*

Box 3: The Hive Coega Green Ammonia Project

Hive Hydrogen South Africa (Hive), backed by renewable energy companies, Hive Energy and BuiltAfrica, is developing a multi-phased Green Ammonia Project at the Coega Special Economic Zone (SEZ) in Gqeberha, Eastern Cape, South Africa. As a first phase, Hive is developing a 1 200 MW electrolyser capacity green hydrogen and ammonia production plant in the Coega SEZ, powered by 3683MW of renewables located around Beaufort West and De Aar in South Africa. The project under development is a green ammonia export plant and is strategically located close to the Port of Ngqura. It is anticipated that upon completion, the plant will produce up to 1 million tonnes of green ammonia per year for export.

The electrolyser-based hydrogen production plant, together with an air separation unit for the sourcing of nitrogen, a Haber-Bosch ammonia loop, and bulk ammonia storage will be developed on a 41-ha site within Zone 7 of the Coega SEZ, a zone dedicated to chemical industries. A pipeline from the facility to a berth in the Port of Ngqura will also be constructed. The new infrastructure required for export at the existing berths falls within the mandate of Transnet National Ports Authority. Several renewable energy sources will be required to provide sufficient power for the hydrogen and ammonia production. The bulk of the power will be supplied by solar photovoltaic (PV) projects (10 projects making up 1 420 MW) and onshore wind projects (eight projects making up 2 263 MW) in the Beaufort West and De Aar districts in the Karoo region of the Western Cape, approximately 380 km from the site. These renewable energy assets are being developed by contracted sub-developers or co-developed with Hive. Most of these projects are in an advanced stage of development or have already been permitted.

Evacuation of the renewable energy via the national grid is dependent on planned strengthening of the existing national grid. Hive is arranging concessional, Just Economic Transition-aligned funding on a BOOT-type model to build the necessary transmission lines and substations for evacuation of Hive's own generated energy. The proposed strengthening will also unlock grid access for up to an additional 14 GW of stranded renewable assets to be built and added to the national grid. The proposed project is thus serving as a catalyst for national grid strengthening. For Phase 1, power will be wheeled via existing connections between the Eskom substations to the Dedisa substation in Zone 13 of the Coega SEZ. From there, four 132 kV capacity transmission line connections will be constructed over a distance of approximately 6.8 km to the on-site production plant substation.

Another interesting component of the Hive project is that it is located in close proximity to the Cerebos Saltworks. Desalinated water for hydrogen production and cooling will be supplied to Hive under a supply agreement with Cerebos, which produces fresh water as a by-product of its salt production operations and existing reverse osmosis (RO) plant at its Cerebos Sundays River site. All brine produced by the existing desalination and future required expanded desalination capacity will be utilised within the Cerebos salt production processes - discharge of surplus brine into the sea is not required. This is an added advantage to locating the Hive project at the Coega SEZ.

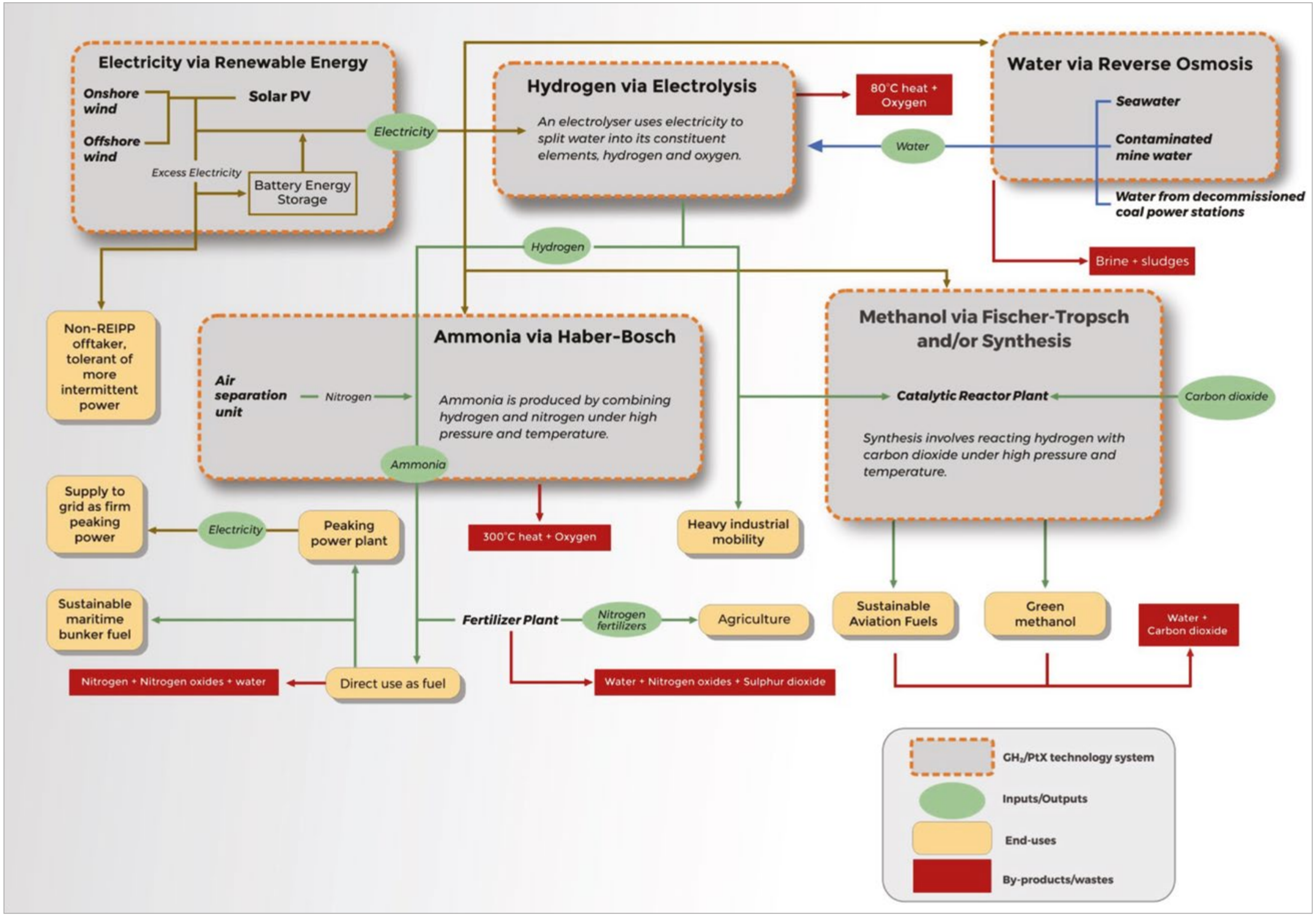

Figure 1: Wind and solar PV would be harnessed to produce electricity used to generate freshwater from reverse osmosis (or supplied from decommissioned coal power stations). Hydrogen is then produced via electrolysis and used to create a variety of PtX products including "green" ammonia and methanol, which have various end-uses.

1.2.1 Electricity generation via renewable energy

1.2.1.1 Onshore wind

Onshore (land-based) wind farms harness wind power using turbines in regions known for strong winds, like the Eastern Cape, Western Cape, Mpumalanga, and other provinces, allowing turbines to convert wind kinetic energy into electricity. The main infrastructure components include the wind turbines themselves, foundations, roads, battery energy storage systems (BESS), electrical infrastructure, transmission lines, operations and maintenance (O&M) facilities, temporary construction camps and laydown areas.

1.2.1.2 Offshore wind

Offshore (ocean-based) wind projects, potentially located in areas offshore of the Western and Northern Cape and KwaZulu-Natal coastlines, would use larger turbines installed in the sea on floating platforms to harness stronger, more consistent ocean winds. The main infrastructure components of offshore wind farms include wind turbines, underwater foundations or floating platforms, subsea cables for electricity transmission, offshore substations, boat or helicopter access facilities for maintenance, back of port facilities, and onshore grid connection facilities.

1.2.1.3 Solar PV

Solar PV farms generate electricity by converting sunlight into electrical energy using panels containing PV cells. Solar PV farms can be situated on a variety of landscapes with high solar resource potential (such as in the Northern Cape), including open fields, semi-deserts, rooftops or even water bodies like dams. The key infrastructure elements of solar PV farms include solar panels, mounting systems, inverters, electrical infrastructure for connecting to the grid, O&M facilities, temporary construction camps and laydown areas, and often BESS to store excess energy.

1.2.2 Freshwater production via reverse osmosis

1.2.2.1 Seawater reverse osmosis

Seawater reverse osmosis (SWRO) provides the freshwater input to the electrolysis process and could occur, potentially at scale, around South African coastal SEZs, for example Saldanha Bay and Coega. SWRO involves forcing seawater through semi-permeable membranes under high pressure, to filter out salts and impurities, to produce freshwater. SWRO facilities typically include large seawater intake and pre-treatment systems, high-pressure pumps, reverse osmosis membranes, post-treatment systems, and brine management systems, including marine outfalls located offshore of the plant facility to discharge brine.

1.2.2.2 Mine water reverse osmosis

Mine water reverse osmosis (MWRO) is crucial in mining regions like Gauteng and treats contaminated mine water. In a similar way to SWRO, MWRO uses high pressure to force water through semi-permeable membranes, removing heavy metals and pollutants, producing fresh water for use in electrolysis. The key components of MWRO include pre-treatment filters, reverse osmosis membranes, chemical dosing systems, and waste management systems for the concentrated brine.

1.2.2.3 Production of hydrogen via electrolysis

The use of electrolysis to produce hydrogen gas is a rapidly evolving technology which involves splitting water into hydrogen and oxygen using an electric current. Water is placed in an electrolyte medium between two electrodes. When electricity is applied, hydrogen gas forms at the cathode and oxygen gas at the anode. When the energy input comes from renewable energy, the hydrogen is called 'Green'. The main components of electrolysis facilities include electrolysers, water purification systems, renewable energy inputs (from solar PV or wind), hydrogen storage units, and distribution infrastructure like pipelines or logistics yards.

1.2.3 Production of Green Ammonia via Haber-Bosch

Hydrogen is difficult to transport and therefore needs to be converted into ammonia as a carrier fuel. Green ammonia is produced using the Haber-Bosch process by combining hydrogen and nitrogen under high pressure and temperature in the presence of a catalyst. Nitrogen is obtained from the air. It typically involves a hydrogen input stream from electrolysers, air separation units for nitrogen extraction, synthesis reactors where hydrogen and nitrogen are combined under high pressure and temperature, and storage facilities for the ammonia produced.

1.2.4 Production of Green Methanol via synthesis

Green methanol is produced through synthesis by reacting carbon dioxide and hydrogen under high pressure and temperature in the presence of a catalyst, typically copper based. The process includes renewable energy sources for hydrogen production, carbon dioxide capture and purification systems, methanol synthesis reactors where hydrogen and carbon dioxide react, and storage and distribution systems for the methanol produced.

1.2.5 Logistical and linear infrastructure

A GH_2/PtX economy will depend on a vast interconnected network of supporting linear infrastructure. Some of this infrastructure in South Africa is pre-existing (excluding mega-projects like the proposed Boegoebaai Green Hydrogen Programme), but is in urgent need of upgrading and maintenance. Much will also need to be newly constructed. Key logistic and linear infrastructure components will provide the infrastructural backbone essential for a functioning GH_2/PtX economy. Should South Africa purposefully position itself as a large GH_2 producer, it's ports would need to import and export technologies and products respectively. Roads and railways would be used to ensure efficient product movement, pipelines would offer cost-effective and low environmental impact transport, and powerlines would deliver renewable energy to production facilities.

1.3 South African GH_2/PtX project categories

Most projects will have similar infrastructure components such as generation and transmission infrastructure, electrolyser and ammonia plant, and desalination and port facilities. However, the 'spatial layout', size and capacity, ownership (of each infrastructure component), and connection points (e.g., for water and electricity) will be different. Figure 2 provides an overview of the typical components of a GH_2/PtX project. It is vitally important that the EAP has a detailed understanding of all the different infrastructure components and their footprint and size before initiating the legal permitting process.

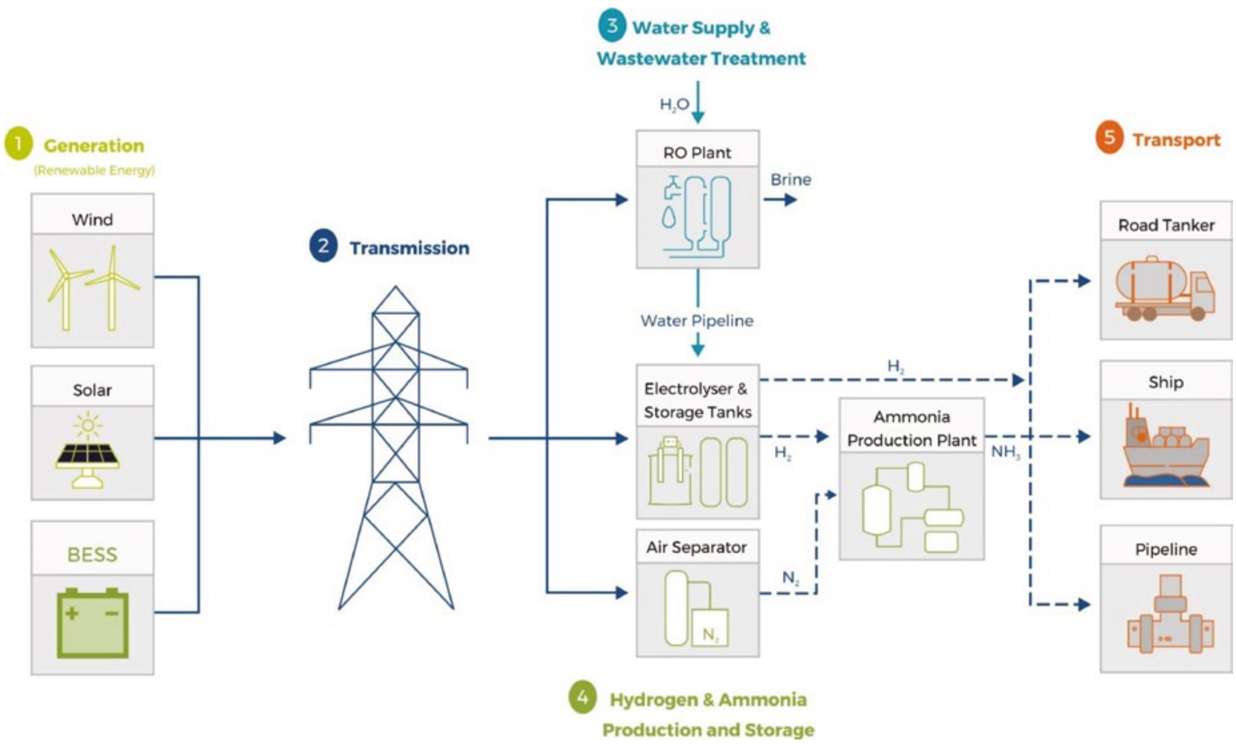

Figure 2: Typical Project Components for a Green Hydrogen/Green Ammonia Export Facility (Figure courtesy of SLR)

GH_2/PtX projects can be broadly divided into three different categories of projects:

1. Category 1: Green Ammonia and/or Methanol **export** projects;
2. Category 2: Green Hydrogen/Ammonia/Methanol projects for **local consumption**/or **inland projects;** and
3. Category 3: Green Hydrogen for **mobility/green steel/other** Each of these categories are briefly described below.

1.3.1 Category 1: Green Ammonia and/or Methanol export projects

Green ammonia and/or methanol export projects, by nature, need to be located near the coast in proximity to a port, to allow for the export of green ammonia and/or methanol. The location of these projects close to the sea also means that seawater can be extracted and desalinated to produce clean water to be used as a raw material in the production of hydrogen. Export projects are typically significantly bigger in terms of size of electrolysis plant and installed capacity for renewable energy than other similar GH_2/PtX projects.

Within the main category of export projects, there are two broad sub-categories:

a) A GH_2/PtX project that is totally independently operated where the owner is in control of all infrastructure components (e.g., wind, solar PV, transmission, pipelines, desalination, electrolyser and hydrogen storage, ammonia production and storage, and export port facilities) (Figure 3). An example of this type of project is the Hyphen Green Hydrogen Production and Export Project in Namibia and Chariot's "Project Nour" Green Hydrogen Project in Mauritania. These projects are likely to be permitted as a single integrated project i.e., a single EIA for all project facilities.

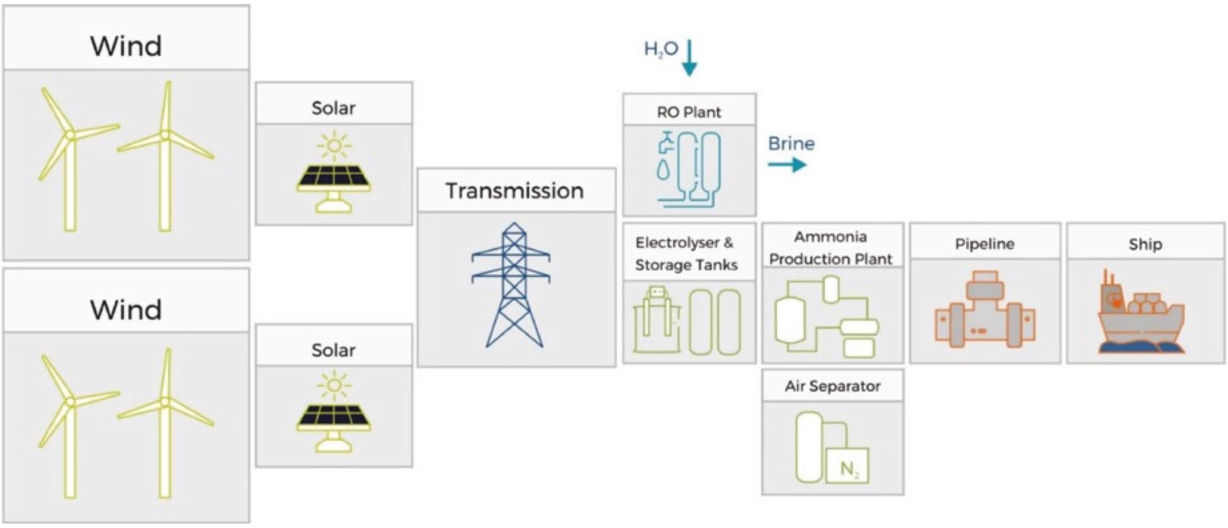

Figure 3: Sub-category 1a: Power generation infrastructure is built for the sole purpose of servicing the GH_2/PtX project, and electricity is delivered to the production plant via dedicated electrical transmission infrastructure (Figure courtesy of SLR).

b) In the case of a GH_2/PtX project where the electrolyser and ammonia production plant is located within an industrial facility or SEZ located near a deep-water port, but the power generation infrastructure (wind and solar PV) are located, in some cases, several hundred kilometres away, electricity is delivered to the GH_2 production plant using a combination of new and existing transmission and distribution infrastructure. In such cases, the development and permitting of the generation components can be undertaken by third parties, and the developer may not have control of the whole project. The project owner may purchase power from third parties (or purchase the projects outright and own and operate them) and negotiate with the utility to wheel the power using the existing or new build grids. An example of this type of GH_2 project is Hive Hydrogen SA's Coega Green Ammonia project (Box 3) and Sasol's Boegoebaai project. The project components of these two example projects are likely to be permitted separately, with the hydrogen developer permitting the electrolyser, ammonia plant, desalination plant and, in some cases, the export port facilities, and the generation (wind and PV) and transmission being permitted by several other third party entities such as independent power producers (IPPs) and Eskom.

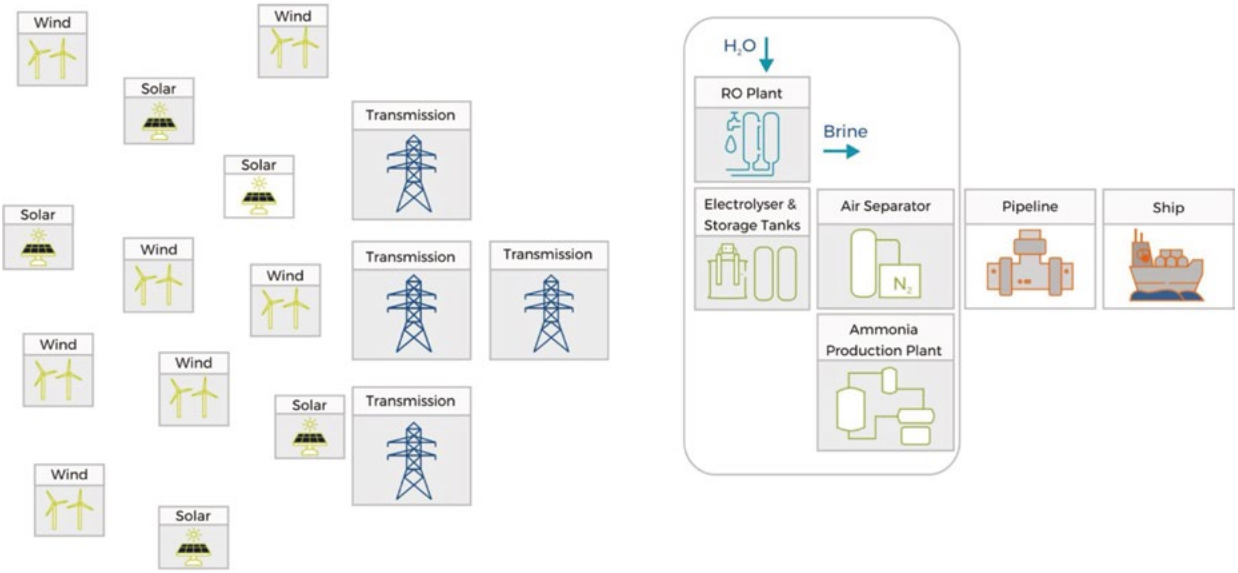

Figure 4: Sub-category 1b: Power generation infrastructure (wind and solar PV) sourced over great distances from multiple third party developers and operators (Figure courtesy of SLR).

1.3.2 Category 2: Green Hydrogen/Ammonia/Methanol projects for local consumptions/or inland projects

A GH_2/PtX project that is developed for local consumption will typically be located close to where the demand for the product is located. These projects will have the same project components as a GH_2 export project, with the main differences being the water supply and no need for port or export facilities. Being inland, the water supply option is likely to be from mine water or from the water allocation from decommissioning coal power plants[6]. While these projects may be smaller in scale to the export projects, they still have the same complexity of project components. An example of this type of GH_2 project is the Prieska Power Reserve Project and the Enertrag Hendrina Green Hydrogen and Ammonia Facility. These projects may be permitted either as a single project or as different project components.

6. *It is the opinion of the authors that surface and/or groundwater that could be used for drinking water should not be made available for the generation of GH_2. It would be preferable to use contaminated mine water (if technically feasible) or the water allocation from decommissioning coal power plants.*

1.3.3 Category 3: Green Hydrogen for mobility/green steel/ other

GH_2/PtX projects that are developed for mobility could be located anywhere where there is an available water resource and sufficient renewable energy. While this type of GH_2/PtX development is likely to be significantly smaller, it will also not require the ammonia production plant or any port facilities. Hydrogen is likely to be used directly to fuel either internal combustion engines or hydrogen fuel cells. An example of this type of GH_2 project would be Anglo American's hydrogen powered mine haul trucks.

Notwithstanding the above, as renewable energy becomes more mainstream and electrolyser technology evolves, allowing hydrogen to become a more acceptable and affordable fuel, it is likely that we will see widely dispersed smaller electrolysers, hydrogen storage, and hydrogen dispensing facilities. This form of GH_2/PtX development will present very different environmental and social risks to the three categories discussed above.

PART II:

EIA regulatory framework

PART II:
EIA regulatory framework

2.1 The EIA regulatory framework

South Africa's legal framework is sufficient to regulate the technological and infrastructural components of the GH_2/PtX economy. While further measures to integrate multiple approvals could be considered in the future, the existing framework, while no doubt subjective to change in the future, could be viewed as adequate to enable good decision-making at this early stage (Tucker, 2022).

In this section, a brief overview of the legal framework with respect to authorisations, permits, and licences that might be required for GH_2/PtX projects is provided.

2.1.1 Environmental authorisation

GH_2/PtX projects require an integrated approach to meet the legal requirements across several Acts. An integrated permitting process adds complexity and necessitates careful planning. Engagement with relevant authorities early in the authorisation process is crucial to determine the need for various licenses and to understand the regulatory framework at it relates to an EIA.

2.1.2 Listed activities

The South African EIA Regulations (as amended in 2014) have been promulgated in terms of Chapter 5 of the NEMA. Their purpose is to regulate the preparation, evaluation, submission, processing, consideration of, and decision on applications for EA for the commencement of activities, subject to an EA, to avoid detrimental impacts on the environment and to mitigate impacts to an acceptable level when avoidance is not possible, and to enhance positive environmental impacts.

NEMA and the EIA Regulations provide for "identified activities" that require an EA. There are three Listing Notices, as follows:

- Listing Notice 1 – Activities requiring a Basic Assessment (BA) process;
- Listing Notice 2 – Activities requiring a Scoping and EIA process; and
- Listing Notice 3 – Activities within specific geographical areas per province requiring a BA process.

The key identified activities that trigger the need for an EA and that are likely applicable to GH_2/PtX projects are outlined in Table 1. Other identified activities may be relevant, depending on project design and specifications.

Table 1: Likely Listed Activities (non-exhaustive) which may be triggered for GH_2/PtX projects, per technology type, across Listing Notices 1, 2 and 3[7]

Technology type	Listing Notice 1	Listing Notice 2	Listing Notice 3
Onshore wind	Activity 12; Activity 14; Activity 19; Activity 24; Activity 56	Activity 1; Activity 15	The applicable Listing Notice 3 Activities would be identified on a case-by-case basis depending on which province the project is located in and the potential triggers with regard to the thresholds or geographical restrictions outlined in the listing notice.
Offshore wind	Activity 15; Activity 17 (i) (e), Activity 19A	Activity 1, Activity 4, Activity 14, Activity 26	
Solar PV	Activity 12; Activity 14; Activity 19; Activity 24; Activity 56	Activity 1; Activity 15	
Seawater RO	Activity 9; Activity 12; Activity 16; Activity 17 (i) (e); Activity 19A; Activity 25	Activity 6; Activity 15; Activity 26	
Mine water RO	Activity 25	Activity 6; Activity 25	
Hydrogen via electrolysis	Activity 16; Activity 24(ii); Activity 25; Activity 27; Activity 28(ii)	Activity 4; Activity 7 (ii); Activity 15	
Ammonia via Haber-Bosch	Activity 16; Activity 24(ii); Activity 25; Activity 27; Activity 28(ii)	Activity 4; Activity 6; Activity 7 (ii); Activity 15	
Linear infrastructure (Roads, Pipelines, Powerlines)	Activity 9(i); Activity 10(i); Activity 11(i); Activity 24(ii); Activity 27; Activity 56(i)(ii)	Activity 9	

7. *The listed activities outlined do not reflect the full list of activities that would be applicable to a specific GH_2/PtX project. The full list of applicable Activities must be identified on a case-by-case basis by the EAP. For MWRO, Listed Activities associated with mining should also be investigated to determine whether they are applicable or not.*

2.1.3 Other permits, approvals, and licences

In this section, the following approval and licence processes are briefly described. These are presented as examples and do not necessarily represent a comprehensive list.

2.1.3.1 Heritage approval

The National Heritage Resources Act (NHRA) provides for the identification, assessment, management, and conservation of heritage resources in South Africa. Section 38 (8) of the NHRA stipulates that even when a Heritage Impact Assessment (HIA) is required in terms of legislation other than the NHRA (e.g. the NEMA), HIA requirements stipulated in the NHRA must still be fulfilled. The HIA is usually integrated into the EIA process. If an EA is not required, there are still certain activities stipulated in Section 38 (1) of the NHRA for which heritage approval is required.

Any person who intends to undertake a development categorised in Section 38(1) of the NHRA and listed hereunder must notify the South African Heritage Resources Agency (SAHRA) and furnish it with details regarding the location, nature, and extent of the proposed development at the very earliest stages of initiating such development. Development categories that could be relevant to PtX projects include:

- Construction of a road, wall powerline, pipeline, canal, or any linear development exceeding 300 m in length;
- Any development or activity that will change the character of a site exceeding 5000 m^2 in extent, involving three or more erven or subdivisions thereof; and
- The re-zoning of a site exceeding 10 000 m^2 in extent.

The notification is done via the South African Heritage Resources Information System (SAHRIS), of which SAHRA is the custodian.

2.1.3.2 Atmospheric emissions licence

While green hydrogen and ammonia production are generally cleaner than conventional methods, the process may still trigger the need for Atmospheric Emission Licenses (AEL) under the National Environmental Management: Air Quality Act (NEM: AQA; Act 39 of 2004). The NEM: AQA aims to protect the environment and prevent pollution and ecological degradation towards sustainable development.

This Act contains a list of activities which require an AEL as well as associated minimum emissions standards. Of interest is Category 7: Inorganic Chemicals Industry, subcategory 7.1 on the "production and/or Use in Manufacturing of Ammonia, Fluorine, Fluorine Compounds, Chlorine, and Hydrogen Cyanide, which applies to installations producing or using more than 100 tons per annum of the listed compounds". The AEL application process should be integrated with the EIA process.

2.1.3.3 Coastal discharge permit

The National Environmental Management: Integrated Coastal Management Act (NEM: ICMA; Act 24 of 2008) provides for relevant factors that must be taken into account for coastal activities that require an EA, including impacts on socio-economic activities, coastal environmental processes, the coastal protection zone, and coastal public property. Where effluent will be released into the ocean (e.g., brine from a seawater desalination facility), a Coastal Waters Discharge Permit (CWDP) will be required.

2.1.3.4 Use of vehicles in a coastal area

The NEM: ICMA further contains regulations on the control of the use of vehicles in the coastal area. A permit must be obtained to use vehicles in the coastal area for the construction and maintenance of infrastructure (e.g., desalination facilities and associated pipelines).

2.1.3.5 Waste licence

The National Environmental Management: Waste Act (NEMWA; Act 59 of 2008) is concerned with waste management and contains in Government Notice (GN) 921 a list of activities for which a Waste Management License (WML) is required before being undertaken, as well as activities that must be undertaken according to the relevant national norms and standards for waste management. Disposal of waste generated by water treatment processes may require a WML. This application process should be integrated with the EIA process.

2.1.3.6 Water use licence

The National Water Act (NWA; Act 36 of 1998) is concerned with the protection and sustainable management of South Africa's water resources. Section 21 of the NWA stipulates water use activities for which a Water Use License (WUL) is required. Section 22 of the NWA requires water users to apply for a General Authorisation (GA) if the activities are under a certain threshold or meet certain criteria. These activities include both consumptive water uses (e.g., taking water from a watercourse, storing water, discharging waste or water containing waste into a water resource) and non-consumptive "water uses" (e.g., impeding or diverting the flow, and / or altering the bed or banks of watercourses). The WUL/GA application process may be integrated / conducted concurrently with the EIA process.

Box 4: Five important determinants of public acceptance for GH_2/PtX projects

Public acceptance of individual project applications may be enhanced by being explicit about, and showing comprehensive cover of, the following issues within the scope of the EIA (Schreiner and Snyman-Van der Walt, 2023):

1. Policy alignment: Supporting and motivating need and desirability, within the ambit of powerful global and South African decarbonisation and economic growth policies, will go a long way to building legitimacy.
2. Conflicts with REIPPP: Perceived competition between GH_2/PtX roll-out and current/future REIPPP projects could contribute toward scepticism. Demonstrating how GH_2/PtX complements and aligns with the goals and implementation of REIPPP will be beneficial.
3. Growth and jobs: Emphasizing (in a transparent, objective, and credible way) the role that PtX projects might play in job creation and economic growth – detailing job numbers, role types, and industry stimulation, along with the relative contributions to national economic goals and support for initiatives like REIPPP, will boost public and political acceptance.
4. Decarbonisation potential: Detailing how GH_2/PtX technologies could contribute to a low-carbon economy, within the context of national and global climate goals, and showcasing the long-term benefits.
5. Improved infrastructure: Illustrating how GH_2/PtX projects can lead to the development of modern, sustainable infrastructure, including improvements in energy grids, transportation, and water production and usage efficiency will be beneficial.

2.1.3.7 Subdivision of agricultural land

The Subdivision of Agricultural Land Act (SALA), as amended (Act 70 of 1970), is concerned with the sustainable and productive use of agriculturally zoned land. Two approvals are required from the National Department of Agriculture, Land Reform and Rural Development (DALRRD) if a proposed renewable energy facility is located on agriculturally zoned land:

1. No Objection Letter for the change in land use. This No Objection Letter is one of the requirements for receiving municipal rezoning, and requires a motivation supported by good evidence (e.g., an opinion from an agricultural specialist) that the development will not significantly compromise the future agricultural production potential of the development site. It is advisable to apply for this as early in the process as possible. An EA will not necessarily assure a No Objection from the DALRRD.
2. Consent for long-term lease in terms of the SALA. SALA approval can only be applied for once an EA and a Municipal Rezoning Certificate have been obtained.

2.1.3.8 *Land use rezoning*

Development of industrial facilities on land zoned for agriculture or any other unrelated land use requires rezoning to an applicable category (e.g., commercial or industrial). Rezoning applications are usually considered and decided by the relevant local municipality in terms of its applicable land-use planning by-laws.

2.1.3.9 *License to operate a major hazardous installation*

A list of dangerous substances and quantity thresholds, beyond which Major Hazard Installations (MHI) must be registered or licensed, is provided in the MHI Regulations of the Occupational Health and Safety Act (OHSA). Exceeding the following quantities of ammonia anhydrous at any establishment is subject to the requirements of the MHI Regulations as follows: 15 tonnes (low hazard); 50 tonnes (medium hazard); 200 tonnes (high hazard). PtX projects involve risks such as hydrogen explosions or ammonia leaks, which must be addressed during the EIA process.

Box 5: Another 5 important determinants of public acceptance for GH_2/PtX projects

1. Winners and losers: Every major transition has beneficiaries and those who are adversely affected. Through the transition, win-win solutions will be possible, in others, win-lose outcomes are inevitable. Being explicit about these challenges, mitigating these negative impacts where possible, and creating response pathways for those negatively affected, could reduce backlash and resistance from some sectors and advocacy groups.
2. Assuaging concerns about human safety: Safety measures, risk management strategies, and emergency response plans need to be concretely and transparently communicated. Explaining how these projects adhere to strict safety standards and regulations, and how they compare with existing energy production methods in terms of safety risks, can help in mitigating fears.
3. Community engagement and beneficiation: Integrating community benefits into the core of PtX projects ensures they're not just commercially viable but also socially valuable and acceptable. This could mean prioritizing local hiring, investing in local infrastructure, or supporting community development initiatives (USDOE, 2023).
4. Good public participation: Adopting a collaborative inclusive approach during public participation ensures diverse perspectives shape the GH_2/PtX project development, in ways considered to be broadly acceptable by those stakeholders affected (USDOE, 2023).
5. Communication and media: Communication goes beyond relaying information to actively fostering a wider public discourse of understanding, highlighting benefits, addressing concerns, and building a shared vision for a South African GH_2/PtX economy (Vallejos-Romero *et al*., 2023).

PART III:

Planning and conducting the EIA

PART III: Planning and conducting the EIA

This section provides a step-by-step description of how the EAP would go about planning and conducting an EIA for a PtX project through the various phases, including: (1) Preapplication, (2) Application, (3) Scoping and Impact Assessment, and (4) Appeal. The section begins with providing a summary diagram of the EIA process, including the four major phases. Each phase of the EIA process, corresponding to Figure 5, is then discussed more in depth. This section draws on work from a variety of sources, most notably Armitage *et al*. (2023).

3.1 Appointing the environmental assessment practitioner

After the developer has conceptualised a project in some detail, in consultation with engineers, and made the decision to proceed, one of the first steps is to appoint a suitably qualified, experienced, and professionally registered EAP[8]. The primary responsibilities of the EAP are to guide the project design phase, lead, and oversee the various steps and role players in the scoping and assessment phases, and then provide overall integration at the end when making recommendations about whether the project should proceed or not, and if so, under what management action regime.

3.2 Pre-application phase

Pre-application planning helps to define the scope and extent of the project, which in turn enables the consideration of critical aspects such as proposed location, legal obligations, and what authorisations, permits or licences may be necessary. The pre-application process should identify whether an EA is required and if so, whether a BA or EIA process should be followed. At this stage, identification of the relevant decision-making authority is needed (i.e., Is the CA for the EA the national DFFE or the relevant provincial department of the environment?).

8. *EAPs must be registered with the Environmental Assessment Practitioner Association of South Africa (EAPASA), mandated in terms of Section 24H of the NEMA.*

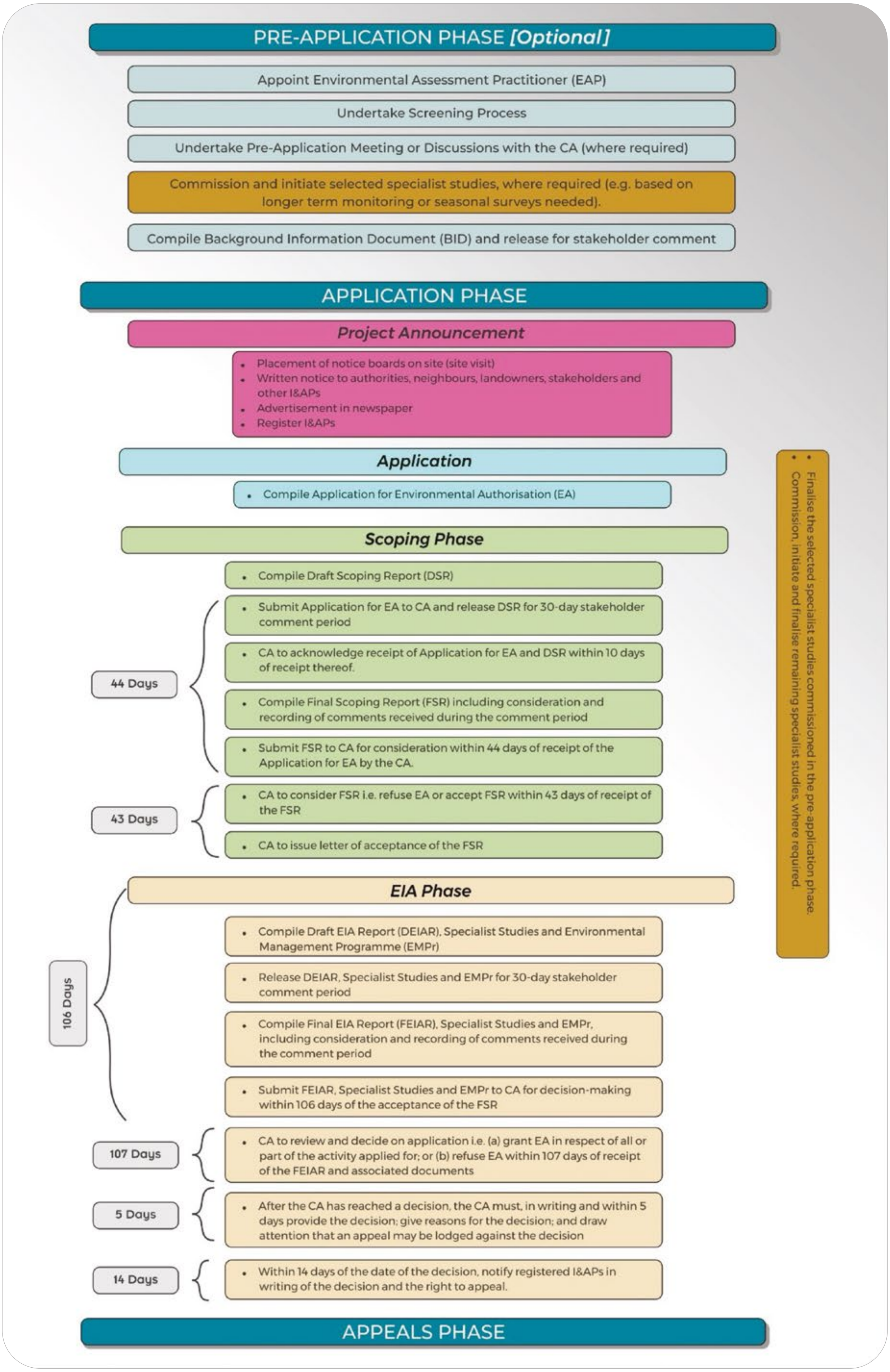

Figure 5: The South African EIA process comprises several phases starting with pre-application and concluding with appeal [Figure adapted after Armitage et al. (2023)]

Project planning benefits the developer and relevant authorities by avoiding projects that are clearly inappropriate from proceeding to the stages of detailed planning and initiation of an EIA and other regulatory processes. Several processes can be conducted during this phase. These include obtaining an adequate project description, the screening process, amending project designs based on sensitivities, considering how to structure the EA application, and considering the extent to which lender considerations have been integrated into the EIA design, submitting the notice of intent (depending on the identified CA), selecting specialist studies, compiling the Background Information Document (BID), and the pre-application public participation process. Once sufficient information is available on the project, a pre-application meeting can be requested with the CA.

3.2.1 De-risking the project

The infrastructure requirements for GH_2 projects are large and complex, and the footprint can be spread over several thousands of square kilometres, resulting in infrastructure being located in different receiving environments where very different biodiversity and social impacts could occur. Critical to the success of projects of this scale and nature is the proactive identification of potentially sensitive areas and environmental and social constraints that may impact the site layout. Avoiding sensitive biodiversity areas and culturally sensitive sites is the first step in applying the mitigation hierarchy.

Developers should engage an EAP to work collaboratively with the technical and financial teams at the earliest stages of project planning. This will allow the EAP to develop a full appreciation of the complexity and scale of the project and de-risking the project from an environmental and social perspective (Figure 6). This will enable the EAP to provide more accurate cost and schedule estimates for the Environmental and Social Impact Assessment (ESIA) that will need to be undertaken at a later stage.

As part of the de-risking work and planning for permitting, the EAP should also work with the developer to understand the socioeconomic contexts of the affected stakeholders and to develop a robust Stakeholder Engagement Plan for the ESIA, to be led by the EAP, and a Project Communication Plan to be led by the developer.

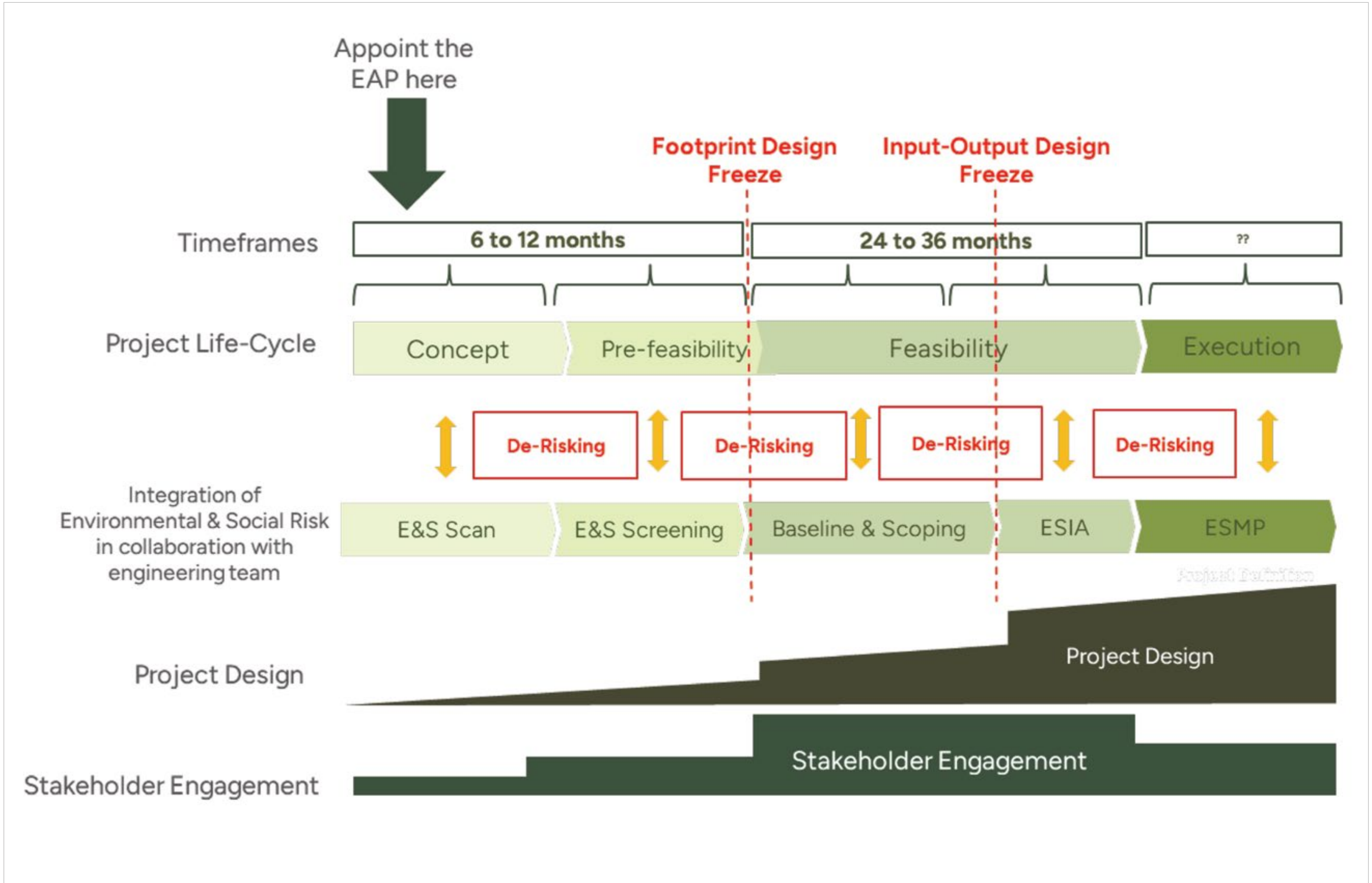

Figure 6: Integration of Environmental and Social Risks into the GH_2/PtX Project Lifecycle (Figure courtesy of SLR)

3.2.2 The screening tool

The legislated National Environmental Web-based Screening Tool should be used for various components of the screening process. Project details and coordinates are uploaded onto this online platform that then generates a report summarising the most important environmental themes in the area and their sensitivity relating to the developmental footprint. It also provides a list of Species of Conservation Concern (SCC) that need to be evaluated by the specialists. Based on this, the tool identifies a list of specialist assessments for consideration during the EIA. As captured in the Screening Tool Report, the EAP should confirm the list of assessments required and motivate where certain studies are not required.

In some cases, the screening tool might over- or underestimate the sensitivity of the site and this is why the list of environmental sensitivities, specialist assessments and SCC first need to be verified by the EAP or a specialist by means of a Site Sensitivity Verification. A Site Sensitivity Verification includes a site visit and desktop analysis. Hereafter, the specialist or EAP will amend or confirm the sensitivity rating and evaluate whether a specialist assessment or compliance statement will be required.

The level of assessment is determined by following the procedures of the Assessment Protocols published in terms of the National Environmental Management Act (No. 107 of 1998) in GN 320 (March 2020), GN 1150 (October 2020), and GN 3717 (July 2023). The Assessment Protocols apply to specific environmental themes.

3.2.3 Specialist studies

The EAP, in consultation with stakeholders, will be required to appoint specialist studies for the EIA. Each specialist assessment should include an up-to-date review of the latest literature and legislation related to the specific theme it is assessing. Impacts must be assessed according to the project phases, i.e., construction, operation and decommissioning, and in terms of their nature, extent, duration, consequence, probability of occurrence, irreplaceability, reversibility, potential for mitigation, cumulative effects, and overall significance.

3.2.4 Biodiversity offset study

A Biodiversity Offset Study undertaken in terms of the National Biodiversity Offset Guideline of 23 June 2023 requires a specialist and the EAP to assess the potential impacts of the project on specific biodiversity assets and whether potential offsets would be required should the significance of impacts post-mitigation be of sufficient concern. Ideally, this shouldn't be necessary at all and only be relevant in exceptional circumstances where avoidance of impacts cannot be achieved, for very good reasons.

3.2.5 BID and preapplication public participation

A pre-application public participation process should be conducted during the Pre-Application phase. Should the EAP proceed with the public participation, they would compile a Background Information Document (BID) for circulation during the public participation.

3.2.6 Initiating long-term monitoring

The following key long-term / seasonal monitoring requirements which are needed to support permitting processes must be considered and initiated prior to starting the EIA process:

- Bat Pre-Application Monitoring – 12 months (four seasons) – required only for wind facilities;
- Bird Pre-Application Monitoring – 6–24 months (depending on what species are identified on site) – required for both wind and solar facilities;
- Terrestrial Biodiversity Surveys – spring – after the first rains (August–September) - required for all proposed development components; and
- Marine physico-chemical environment (temperature, turbidity, dissolved oxygen, pH and salinity) – 6–12 months – for projects where marine discharge is required.

It is typically recommended that these surveys commence prior to the start of the EA processes such that the final survey results are available for inclusion in the Draft EIA or Draft BA report that are released for public review prior to final submission to the Competent Authority.

Box 6: Potential GH_2/PtX EIA specialist studies

The EAP, in consultation with stakeholders and the Screening Tool, will determine the most appropriate specialist studies for the project on a case-by-case basis, depending on the extent of the proposed project and the state of the receiving environments. The following specialist studies might be required for a PtX project:

1. Marine Ecology Specialist Assessment
2. Terrestrial Biodiversity Assessment
3. Terrestrial Plant Species Assessment
4. Terrestrial Animal Species Assessment
5. Aquatic Biodiversity Assessment
6. Dispersion Modelling Study
7. Sediment Movement Study
8. Bird Assessment (+pre-construction monitoring)
9. Bat Assessment (+pre-construction monitoring)
10. Invertebrate Assessment
11. Agricultural and Soils Assessment
12. Archaeological and Cultural Heritage
13. Palaeontology Assessment
14. Socioeconomic Assessment
15. Noise Assessment
16. Visual and Landscape Assessment
17. Hydrology Assessment
18. Civil Aviation Assessment
19. Defence Assessment
20. Traffic Study
21. Major Hazardous Installation Risk Assessment
22. Radio Frequency Interference Assessment

3.3 Application phase

3.3.1 Application for EA

The EAP should complete and submit the application form for EA for the specific project. The application form should include details relating to the project, including the project description, technology to be used, location, purpose, need, and desirability, etc. It is crucial that the Scoping Report, that has already been subject to 30-day public review, be submitted no later than 44 days after the application was received by the CA. Procedurally, the public participation process also becomes crucial here, as the requirement is not only to distribute notification letters / BIDs, but also to display notices (posters) and advertise the application in at least one appropriate newspaper.

3.3.2 Scoping

The first phase of the EIA is the Scoping Phase. The EAP has 44 days from receipt of the application by the CA to submit the Final Scoping Report to the CA for consideration.

This phase involves identifying and assessing the potential impacts of an activity, as well as determining the scope and content of the specialist studies to be included in the EIA. It is during this phase that the necessary specialist studies and assessments are determined to ensure a comprehensive assessment of the project's potential impacts.

A Draft Scoping Report is compiled and circulated to the public and other I&APs during a 30-day public participation process. The purpose of this process is to use the community's recommendations to inform the EIA and to address concerns early in the project life cycle. Comments are incorporated into the Final Scoping Report and then submitted to the CA for a 43-day review period.

Box 7: Integrating gender aspects into the EIA process

The principles of the NEMA Section 2 (4)(q) highlight the vital role of women and youth in environmental management and development. Adverse impacts of projects can be reduced and positive ones enhanced, with the full and equal participation of both genders, particularly women, because of their decision-making capacities, organic knowledge of local topography and ecosystems, and concern regarding drinking water, sanitation, and health (Sujit and Vikrant, 2018). EIA processes could provide a good opportunity to address gender issues at an early stage of project planning and explore means to reduce adverse impacts on women. Making project-level decisions that reduce gender inequality requires knowing how gender inequality is expressed in all spheres of life. EIAs focussing on gender aspects could allow EAPs and decision-makers to understand the structural inequalities on which gender gaps are based. The European Institute for Gender Equality has published a Gender Mainstreaming Toolkit and provides guidance of how to integrate gender aspects better in an EIA process.

3.4 Impact assessment

3.4.1 Draft EIA and EMPr

The EAP has 106 days[9] from the notification of acceptance of the Final Scoping Report to submit the Final Environmental Impact Report (EIR), Environmental Management Programme (EMPr), as well as the Biodiversity Offset Report to the CA. This task will comprise compiling a Draft EIR/BAR and EMPr using the Scoping Report and information obtained from the client, specialist studies, and the EAPs own assessment.

The EIR has several components which can be broadly divided into:

1) The description of the proposed development;
2) The description of the receiving environment;
3) Public participation process;
4) An assessment of impacts; and
5) Proposed mitigation measures.

The objective of the EMPr is to anticipate and avoid environmental, social, and other risks and impacts, where possible. Each activity, together with its potential impacts, will be considered and suitable mitigation measures prescribed. The EMPr also includes timeframes for implementation and the roles and responsibilities for implementation. The EMPr is held by the Environmental Control Officer (or such designated authority) who can oversee and report on the impact monitoring and mitigation measures.

3.4.2 Public participation process

The Draft EIR, EMPr, and Biodiversity Offset Report is circulated during a second minimum 30-day public participation process. Public meetings are also held

Box 8: Green Hydrogen Community Development Toolkit

As part of the H2SA programme, a Green Hydrogen Community Development Toolkit was developed for project developers in the PtX sector. It offers practical advice and step-by-step guidance through fifteen tools on community development, tailored to the unique challenges of the GH_2 sector, particularly in South Africa and potentially applicable globally. The toolkit covers various phases of community development work, from preparation to monitoring and learning, aiming to integrate community development into GH_2 projects effectively. It's a resource for developing a social license to operate, engaging with communities, and ensuring projects contribute to local development and sustainability.

9. *This timeframe may under certain circumstances be extended in terms of Regulation 3(7) of the 2014 NEMA EIA Regulations (as amended). This will require a formal request for extension to be submitted to the CA.*

during this time if required or requested. During these meetings, the EAP will provide more detail on the proposed project and I&APs will have the opportunity to ask questions and comment on the project. All comments will be responded to and will be included in a comments and responses table along with a stakeholder consultation report detailing the method and outcome of the public participation process. These documents will then be incorporated into the Final EIR, EMPr, and Biodiversity Offset Report. For EAP guidance on public participation, The Public Participation Guideline in Terms of NEMA EIA Regulation (DEA, 2017) can be consulted.

3.4.3 Compile and submit final EIR, EMPr and biodiversity offset report

The Final EIR, EMPr, and Biodiversity Offset Report will be compiled and include all the comments and recommendations received during the public participation process. These documents will be submitted to the CA for consideration in the granting or refusing of EA and will also be circulated to I&AP's for information purposes only. The Department then has 107 days[10] to review the Final EIR and associated documents and grant a decision on EA. The EAP then notifies all I&APs and affected government departments of the EA and of their right to appeal the decision. During this stage, the department will also review the Biodiversity Offset Report and determine the suitability of the proposed offsets and offset requirements for EA and initiation of activities.

3.4.4 Environmental management programme

Any GH_2/PtX development activities that require EA, also require the submission of an EMPr to be included in the EIA. The objectives of an EMPr are to:

1) Ensure compliance with relevant regulatory requirements and guidelines;
2) Verify environmental performance through impact and management action monitoring;
3) Respond to changes and unforeseen events during project implementation; and
4) Provide feedback for continual improvement in environmental performance.

An EMPr must outline all management, mitigation, protection, or remedial measures that will be undertaken to address impacts identified during the EIA. These measures should address all development phases (planning and design, pre-construction and construction activities, O&M, environmental rehabilitation, and closure). The holder of an EA must monitor and audit compliance with the requirements of the EMPr. The EMPr

10. *Should a proposed renewable energy project fall within one of the eleven REDZs, a BA process can be followed and a reduced decision-making timeframe of 57 days (as opposed to 107 days) will be applicable. If the project is declared an SIP, it will also be submitted to a 57-day decision-making process as per the Infrastructure Development Act.*

follows an approach of identifying an over-arching goal and objectives, accompanied by management actions that are aimed at achieving these objectives (the outcomes). The management actions are presented in a table format to show the links between the goal and associated objectives, actions, responsibilities, and monitoring requirements and targets.

The management plans for the design, construction, operational, and decommissioning phases will consist of the following components:

1) Activities / aspects: The potential impacts of the development that need to be managed,
2) Outcomes: The objectives for managing impacts of each activity / aspect,
3) Management actions: The actions needed to achieve the objectives, and
4) Monitoring: Monitoring required to check whether the objectives are being achieved.

An EMPr is a highly detailed, context specific, 'living' document which must be updated as additional information or actions required to uphold the principles becomes clear during the implementation of the EMPr.

3.5 Appeal phase

If the EA is granted for the proposed development, I&APs have the right to appeal the decision. The EAP must notify all registered I&APs of their right to appeal within 14 days from the date of the EA, whereafter I&APS have a 20-day period from the date of the notification to submit an appeal (if required). The appeal process is usually managed by the EAP. The appeal process should extend over a period of 90 days, although it typically exceeds this timeframe. It is very difficult to predict the extent of an appeal phase.

PART IV:

Technical guidance and tools

PART IV:
Technical guidance and tools

4.1 Integrating lender considerations

Renewable energy projects are usually financed by third party banks, lenders, and investors who may subscribe to the Equator Principles and International Finance Corporation (IFC) Performance Standards (PS). GH_2 projects are likely to use a funding structure which relies, at least for some infrastructure, on project financing, which means that ESIAs will need to be aligned with both the local EIA Regulations as well as international lender standards. Different financial institutions have different sustainability requirements, but typically most banks or lenders will use the Equator Principles and IFC Performance Standards to identify and manage environmental and social risks for their investment.

Table 2: Summary of the Equator Principles and IFC Performance Standards

Standard	Objective
Equator Principles (2020)	The Equator Principles consist of a set of principles and procedures adopted by financial institutions to ensure that the environmental and social issues associated with a project financed by those institutions are respected. The Equator Principles are summarised below: • *Principle 1 – Review and Categorisation:* The projects are classified into three categories according to the potential environmental and social risks they represent. The categories are: - Category A – Projects with potentially significant adverse environmental and social risks and /or impacts that are diverse, irreversible, or unprecedented; - Category B – Projects with potentially limited adverse environmental and social risks and/ or impacts that are few in number, generally site-specific, largely reversible, and readily addressed through mitigation measures; and - Category C – Projects with minimal or no adverse environmental and social risks and/or impacts.

Standard	Objective
Equator Principles (2020)	• *Principle 2 – Environmental and Social Assessment:* It is necessary to carry out an environmental evaluation of the project that addresses the risks identified during the analysis and categorisation. • *Principle 3 – Applicable Environmental and Social Standards:* The projects implemented in emerging countries, apart from complying with local laws, must also follow the IFC Performance Standards and the WBG EHS Guidelines. • *Principle 4 – Environmental and Social Management System (ESMS) and Equator Principles Action Plan:* The projects must have an action plan to address the risks identified during the environmental evaluation. • *Principle 5 – Stakeholder Engagement:* It is necessary to promote and carry out consultations with the stakeholders in a culturally appropriate and structured manner. • *Principle 6 – Grievance Mechanisms:* It is necessary to establish mechanisms for ongoing involvement of interested and affected parties, to allow for the submission of grievances or issues, during all phases of project development. • *Principle 7 – Independent Review:* The environmental performance must be audited by independent experts with experience in the area covered by the project. • *Principle 8 – Covenants:* The laws and regulations, licensing, and action plans must be carried out in all aspects. • *Principle 9: Independent Monitoring and Reporting:* The projects should appoint an independent environmental and social expert to carry out the monitoring and produce additional reports. • *Principle 10 – Reporting and Transparency:* The financial institutions must publish information on the loans granted, at least annually, in accordance with the rules of the Equator Principles.

Standard	Objective
IFC Performance Standards (2012)	The IFC Performance Standards are applied to a project to manage environmental and social (E&S) risks and impacts throughout the life of an investment. There are eight performance standards which cover the following areas: PS 1: Assessment and Management of environmental and social Risks and Impacts; PS 2: Labour and Working Conditions; PS 3: Resource Efficiency and Pollution Prevention; PS 4: Community Health, Safety, and Security; PS 5: Land Acquisition and Involuntary Resettlement; PS 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources; PS 7: Indigenous Peoples; and PS 8: Cultural Heritage. Of these, PS 1 establishes the importance of undertaking an integrated approach to identifying the E&S impacts, risks, and opportunities of projects; effective community engagement through disclosure of project-related information and consultation with local communities on matters that directly affect them; and effective management of E&S performance throughout the life of the project. PS 2–8 establish objectives and requirements to avoid, minimise, and where residual impacts remain, to compensate / offset for risks and impacts to workers, affected communities, and the environment. PS 7 (Indigenous People) is not considered applicable to this project as there are no indigenous people (as defined by the Standard) living in the area impacted by the project.

The EAP will need to ensure that the ESIA process is aligned with both the local EIA regulations as well as the Equator Principles and IFC Performance Standards. While the ESIA process in South Africa is fairly well aligned with the ESIA process requirements of the IFC Performance Standards, there are a number of aspects that demand more attention and detailed inputs. The table below provides some examples of the additional inputs that may be required. This is not an exhaustive list and ultimately the EAP will need to thoroughly review the IFC Performance Standards and the local EIA regulatory requirements, identify the overlaps and gaps between the two, and plan to address these.

Table 3: Some gaps between the South African EIA Regulations and the IFC Performance Standards

Aspect of the ESIA process	Additional requirements
Stakeholder engagement	While the South African EIA Regulations require a thorough stakeholder engagement process, the IFC Performance Standards require some specific outputs. For example, there is a need to compile a Stakeholder Engagement Plan that allows for explicit stakeholder mapping and identification and engagement with vulnerable groups within the project area.
Environmental and social management system (ESMS)	There is a requirement for companies/developer to implement an environmental and social management system (ESMS) to assist with integrating environmental and social plans and standards into their core operations. Relevant company-level environmental and social policies as well as specifically allocated human resources to address these aspects become an important part of the ESMS to demonstrate the commitment of the company.
Baseline studies	In many cases, depending on the sensitivity of the affected environment, the level of effort required to define the baseline environment increases when adhering to the IFC Performance Standards. For biodiversity aspects, this may be species specific and, in some cases, require seasonal or even multi-seasonal surveys. For social aspects, this may include addressing aspects such as labour issues, gender-based violence, human rights, and vulnerable groups. Where groups of affected stakeholders may be defined as indigenous people, free, prior, and informed consent may be a requirement.
Some topic specific issues	IFC PS6: In terms of biodiversity, IFC PS6 emphasises the need to implement the mitigation hierarchy before a biodiversity offset is recommended. The need to define the affected biodiversity in terms of modified, natural, and critical habitat is also a requirement. A Critical Habitat Assessment is also often required.
Associated facilities	The project's area of influence must include "associated facilities". Associated facilities, are facilities that are not funded as part of the project and that would not have been constructed or expanded if the project did not exist and without which the project would not be viable.
Climate change	The risks and impacts identification process must in most cases consider the emissions of greenhouse gases, the relevant risks associated with a changing climate, and the adaptation opportunities.

Another important consideration that may impact the number and types of separate ESIA applications is the finance structure of the entire project. If the GH_2/PtX project is being financed as a single Special Purpose Vehicle (SPV), then a single ESIA for all project components may be required. If, for example, some of the project components, such as the transmission lines and/or the generation components will be owned by third parties, then multiple ESIA applications may be required. Unpacking this at the earliest stages of the project planning will be important.

4.2 Eliciting good project descriptions

A GH_2/PtX project consist of many different project components, including most, if not all of the following:

- Power generation facilities (wind and solar);
- Battery energy storage facilities;
- Transmission lines and substations;
- Electrolyser (hydrogen production) and hydrogen storage;
- Air Separation Unit (to produce nitrogen);
- Ammonia plant and ammonia storage;
- Desalination and demineralization plants and water storage;
- Water, hydrogen and ammonia pipelines;
- Port export facilities;
- Roads;
- Construction camps;
- Lay down areas;
- Water and fuel supply during construction;
- Waste management (construction and operation); and
- Other.

Each of these project components may have a potentially different impact on the affected environment. Aspects of the marine and terrestrial environment also need to be considered while the spatial extent of the project components adds an additional complexity. Certain project components require very specific seasonal baseline data gathering, e.g., bird and bat movements within the wind farm area and marine water quality for the desalination discharge points.

The complexity of the project, combined with the complexity of the affected environment over very large areas (sometime several thousands of square kilometres) requires sufficient time to process and understand. This thorough understanding of the project and affected environment is required to assist with firstly de-risking the project, and secondly, understanding the level of effort required to undertake the baseline studies, stakeholder engagement, and compilation of the ESIA and ESMP reports.

Assuming the EAP has been appointed at the concept/pre-feasibility phase of the project to work alongside the technical and financial teams, the first task of the EAP should be to understand the various project components, the footprints (spatial extent), and inputs/outputs of each component. To do this, it is often advantageous to compile a non-technical flow or block diagram showing the main project components and how they are linked. Examples of these are shown in Figure 7.

Because of the complexities of the project, it is advisable to unpack and understand all of the required inputs and outputs of a GH_2/PtX project when compiling the project description. For example, start with the power generation components and then systematically describe the project and various components to the export of the ammonia molecule at the end of the project. Also consider infrastructure required for the construction phase as this can be very significant (e.g., the construction phase of very large export GH_2 projects could attract as many as 15 000 workers which will require the pre-construction of a small town with accommodation and recreational areas, power supply, water supply, wastewater treatment, waste management, and various other services).

4.3 Assessing need and desirability

EIAs need to consider the project within current societal, economic, and environmental priorities, locally, nationally, and globally. Motivating the need for and desirability of a project in an EIA, set within broader sustainability parameters, should ensure that the project aligns with and balances socio-economic and environmental objectives, as holistically as possible, and adequately considers any opportunity costs, such as loss of agricultural land, tourism, or the displacement of any existing or future land uses or users (DEA&DP, 2013). In the context of GH_2/PtX projects, this needs to be done at multiple scales, across multiple policy frameworks as demonstrated in Table 4.

Table 4: Policy documents guiding GH_2/PtX need and desirability across different spatial scales

Scale	Policy frameworks to consider
Global	Sustainable Development Goals (SDGs) Paris Climate Agreement
National	The Hydrogen Society Roadmap for South Africa The Green Hydrogen Commercialisation Strategy for South Africa The Just Transition Framework The National Development Plan 2030 South Africa's Low Emission Development Strategy
Local	Environmental Management Frameworks (EMFs) Spatial Development Frameworks (SDFs) Integrated Development Plans (IDPs)

For the consideration of the EAP, in 2017, the national Department of Forestry, Fisheries and Environment (DFFE), published their Guideline on Need and Desirability. The guideline presents a list of questions which should be addressed by an EAP when considering need and desirability. These are divided for the EAP into questions that relate to ecological sustainability and to justifiable economic and social development. It is recommended that the EAP closely considers this Guideline when describing need and desirability. For projects in the Western Cape, in 2013, the Department of Environmental Affairs & Development Planning (DEA&DP) drafted a EIA Guideline and Information Document Series, of which, Part 6 focuses on need and desirability (DEA&DP, 2013).

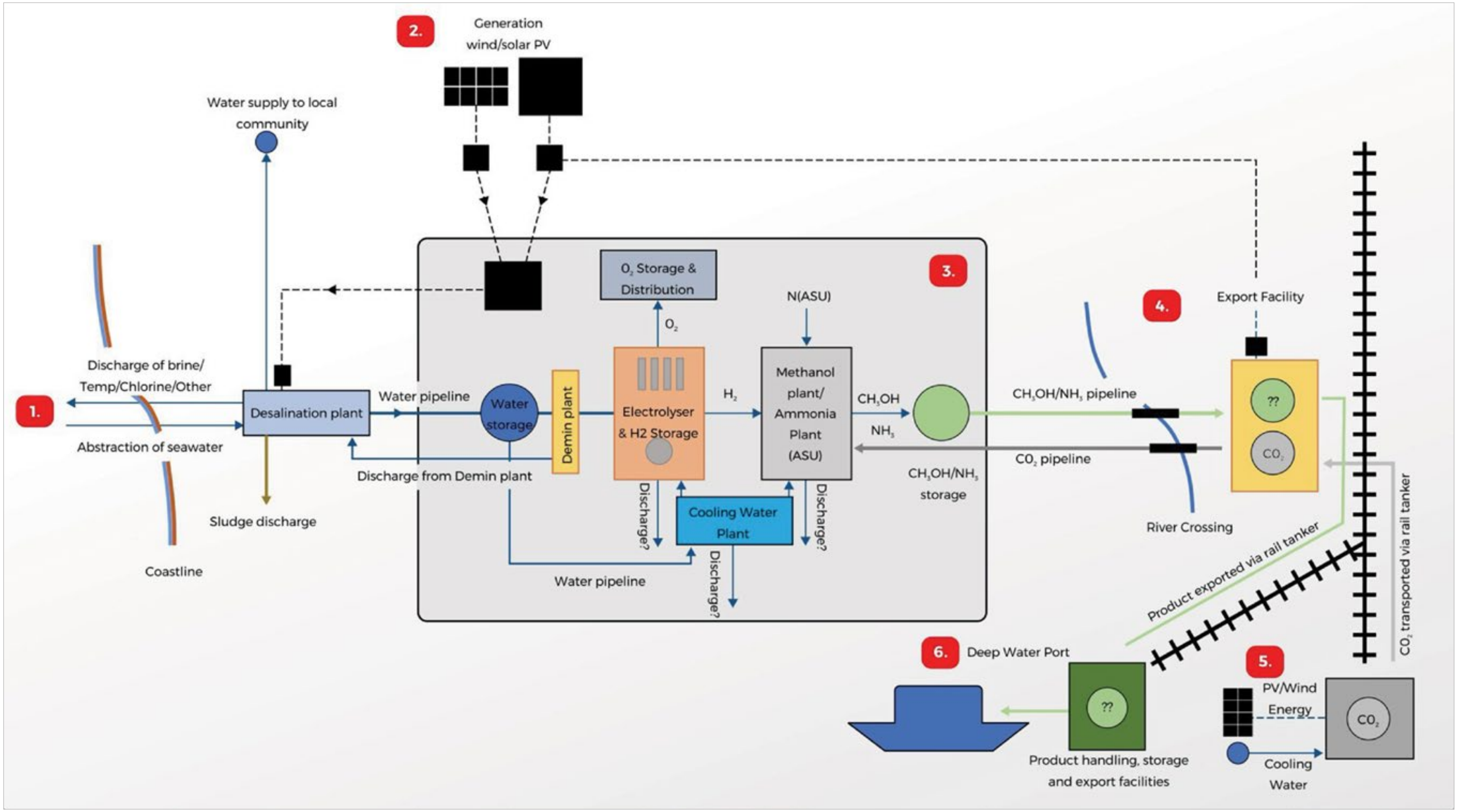

Figure 7: Example of a non-technical flow/block diagram for a green hydrogen/ammonia/methanol project (Figure courtesy of SLR)

In the sections that follow, a summary of the overarching global and national policy supporting the development of a South African GH_2/PtX economy is provided at a global/ national scale, with some guidance also offered on the types of policy frameworks that need to be considered at a local scale.

4.3.1 Global/national scale

South Africa is one of the top 20 global emitters of greenhouse gases (DFFE, 2020) and nearly one third of South Africans are unemployed (Stats SA, 2024). Achieving the Paris Agreement target of keeping the global temperature rise to below 1.5°C will require an urgent transition from fossil fuels towards renewable energy (IPCC, 2019), with a simultaneous emphasis on the National Development Plan's objective to eliminate joblessness and poverty and reduce inequality (NPC, 2012). Through this shift, there exists the substantial opportunity to create a new, secure and diversified energy infrastructure (Oliveira, Beswick and Yan, 2021) which is conscious of supporting sustainable economic growth and a 'Just Transition'[11] away from coal (DSI, 2021).

The move toward renewable energy is taking place globally, and in South Africa, at increasing speed. South Africa has already made significant commitments to integrate renewable energy sources through its Integrated Resource Plan 2019 and Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) (DSI, 2021). GH_2/PtX technology could come to play a substantial, if not pivotal, role in this transition (dtic, 2022). GH_2/PtX prospects in South Africa enjoy substantial support in the current political climate, evidenced by the publication of two seminal policies: The Hydrogen Society Roadmap for South Africa (DSI, 2021) and the Green Hydrogen Commercialisation Strategy for South Africa (dtic, 2022).

GH_2/PtX enables the conversion of electricity into high energy density carrier fuels, which could replace fossil fuels in traditionally 'hard-to-abate' sectors, like heavy-duty transport and aviation. Advancements in renewable energy production and electrolyser efficiency (Ayodele and Munda, 2019; Shiva Kumar and Lim, 2022) mean that GH_2/ PtX offers a viable, affordable energy alternative (van Renssen, 2020). South Africa's abundant renewable energy resources, port infrastructure, and platinum group metal reserves, give it a competitive advantage in producing cost-effective GH_2/PtX products for both domestic consumption and international export (Lebrouhi *et al*., 2022).

11. *The Just Transition is a policy framework for managing the shift from a high-carbon, environmentally degrading economy to a low-carbon, sustainable economy in a manner that is socially equitable and inclusive. South Africa, like many other countries, is faced with the challenge of reducing its greenhouse gas emissions while still addressing issues like poverty, unemployment, and social inequality.*

GH_2/PtX development, implemented at scale in South Africa, underpins several Sustainable Development Goals (SDGs), namely:

- SDG 1 (No Poverty): By tapping into the renewable energy and GH_2/PtX potential, South Africa could see industrial growth in sectors like steel production and port development, which would contribute to poverty reduction.
- SDG 2 (Zero Hunger): GH_2/PtX can be converted into ammonia for fertilizer production, promoting agriculture by producing fertilizers, thus improving food security and reducing dependence on fossil fuels (see Section 5.1.3 regarding overuse of nitrate fertilizers).
- SDG 6 (Clean Water and Sanitation): The GH_2/PtX economy's water demands, often met through reverse osmosis desalination, could significantly increase desalination capacity, reducing costs and potentially providing clean water to local populations.
- SDG 7 (Affordable and Clean Energy): GH_2/PtX could help supply renewable power to the grid, thereby increasing access to affordable, reliable, sustainable, and modern energy for all.
- SDG 9 (Industry, Innovation, and Infrastructure): GH_2/PtX may play a role in building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation, especially in renewable energy technologies and industrial processes with low emissions.
- SDG 8 (Decent Work and Economic Growth): The production of GH_2/PtX, under fairly ambitious scenarios, could create 300 000 jobs with an associated 3% rise in GDP (IHS Markit, 2021).
- SDG 13 (Climate Action): It addresses the urgent need to combat climate change by creating a supply chain for emissions-free energy, crucial for mitigating the rise in carbon dioxide levels and global warming.

In South Africa, the macro-socioeconomic benefits of a GH_2/PtX economy could include an improved trade balance and increased foreign direct investment and gross domestic product (GDP) (Fazioli and Pantaleone, 2021). Likewise, the local benefits across the entire value chain of GH_2/PtX production, storage, transportation, and its potential end- uses, domestically and globally, could be substantial (IHS Markit, 2021). This is especially true for the renewable energy-rich rural regions of South Africa, where new investment could alleviate some of the social problems associated with endemic joblessness and poverty (Hamukoshi *et al*., 2022).

The largest expected demand for South African-produced GH_2 is for export to the international market and sustainable bunker fuel for maritime vessels calling at South African ports (Saldanha Bay, Coega/Ngqura, Richard's Bay, and Boegoebaai). The collective total demand and import targets for GH_2/PtX across the European Union, Germany, Japan, and South Korea is approximately 12 million tonnes per annum by 2030 (Schreiner and Snyman-Van der Walt, 2023).

Estimates indicate that South Africa's GH_2/PtX export potential will be approximately 1.9 million tonnes per annum by 2050, corresponding to 7% of the global GH_2 import market (dtic, 2022). More liberal estimates are around double that. If the latter were to materialise, more than 300 000 jobs could be created and an increase of around 3% to South African GDP could be realised (IHS Markit, 2021).With respect to using GH_2/PtX to augment South Africa's own energy security, the Super H2igh Road Scenario report, commissioned by Agora Energiewende in June 2021, found that production of 3.8 million tonnes per annum of hydrogen could be developed in South Africa by 2050. If half that figure (~2 million tonnes per annum) were reserved for domestic consumption, it would contribute 8% of the final energy demand in South Africa (IHS Markit, 2021).

4.3.2 Local scale

At a local scale, the potential contribution towards creating new jobs and skills, improving local livelihoods, and preserving ecological assets should be considered within the frameworks of local Environmental Management Frameworks (EMFs), Spatial Development Frameworks (SDFs), and Integrated Development Plans (IDPs).

EMFs are designed to guide decision-making in relation to environmental management at various levels. They provide a systematic approach to identifying, assessing, and managing environmental impacts and risks associated with development projects. By incorporating EMFs into the EIA process, proponents can demonstrate how their projects align with broader environmental objectives.

SDFs are crucial for integrating environmental considerations into spatial planning and land-use management. SDFs offer a vision for the spatial development of a particular area, including the distribution of activities and the management of spaces to promote harmonious and sustainable development. By aligning projects with SDFs, developers can ensure that their GH_2/PtX projects contribute to the coherent development of the area, respect land-use patterns, and minimize adverse environmental impacts, thus strengthening the case for their projects' desirability.

IDPs serve as strategic tools for coordinating the development efforts of local municipalities. They outline priorities, resources allocation, and development goals within a municipality, considering both short-term and long-term perspectives. By aligning GH_2/PtX projects with the objectives and strategies outlined in IDPs, developers can illustrate how their projects support local development objectives, meet community needs, and are integrated into the broader developmental agenda. This alignment not only enhances the projects' social acceptability but also ensures that they contribute positively to the area's socio-economic development.

4.4 Considering the strategic context

The strategic context which should be considered, for example, when determining need and desirability in relation to a GH_2/PtX project, is typically outlined in local plans, for example, Municipal Integrated Development Plans (IDPs), Spatial Development Frameworks (SDFs), and Environmental Management Frameworks (EMFs).

Processes to facilitate collaboration and participation of I&APs are integral in the development of these plans and frameworks, as part of the democratic processes at local government level (DEA&DP, 2013). These plans and frameworks therefore provide important context for the EAP regarding the fit of a potential GH_2/PtX project.

At national scale, there are numerous policy documents that provide important context, including those listed in Table 4. In addition, a Strategic Environmental Assessment (SEA) has been used for setting the strategic context for energy infrastructure. DFFE has undertaken several SEAs over the last ten years, seeking to spatially plan, streamline, and integrate decision-making for large energy-related infrastructure projects (Table 5).

The Renewable Energy (Wind and Solar PV) SEA, Electrical Grid Infrastructure SEA, and the Gas Pipeline Network SEA, completed between 2013 and 2019, produced a series of legislated outputs which provide spatial prioritisation for energy infrastructure, plus streamlined permitting procedures for projects undertaken within delimited spatial boundaries (Figure 8). It is important for the EAP to check whether the project in question falls within any of these spatial boundaries to take advantage of streamlined EIA processes, and to motivate for need and desirability, based on alignment with national strategic priorities and planning.

Box 9: Embracing GH_2/PtX, with a cautious and precautionary approach

The precautionary principle is essentially about the adequate assessment and management of risk. It implies that if a development project is suspected of causing harm to the public or to the environment, in the absence of a scientific consensus that harm would not ensue, the burden of proof falls on those advocating for the project (DEA&DP, 2013). In other words, it's the project proponents who must prove that the proposed activity will not lead to significant harm, rather than the public or environmental groups having to prove that it will. South Africa has given effect to the precautionary principle in the NEMA. All GH_2/PtX development must apply a risk-averse and cautious approach that considers the limits of current knowledge about the receiving environments and technologies and infrastructure being developed.

Table 5: GH_2/PtX relevant SEAs undertaken between 2013 and 2019 each with a series of relevant legislative outputs that will influence GH_2/PtX project planning and how need and desirability is motivated.

SEA (phases and years)	Gazetted outputs (follow SEA links to download)
Renewable Energy: Wind and solar photovoltaic energy development Phase 1: 2013 - 2015 Phase 2: 2016 – 2019	· Eleven Renewable Energy Development Zones (REDZs) (February 2018 and February 2021) · Protocols for specialist assessment (March 2020 and October 2020, updated in July 2023)
Electricity Grid Infrastructure Phase 1: 2014 - 2016 Phase 2: 2017 – 2019	· Seven Strategic Transmission Corridors (February 2018 and April 2021, updated in December 2021) · Generic Environmental Management Programme (EMPr) for substations and overhead power lines (March 2019) · Procedures to be followed for the development of electricity transmission and distribution infrastructure within the REDZs (February 2021) · Standard for the development and expansion of power line and substations within the gazetted Strategic Transmission Corridors (July 2022)
Gas Pipeline Network 2017 - 2019	· Nine Strategic Gas Transmission Pipeline Corridors (February 2021 and May 2021) · Generic EMPr for gas transmission pipeline infrastructure (April 2021)

Any projects aligning or synergizing with already designated GH_2/PtX Strategic Integrated Projects (SIPs), are likely to be viewed more favourably than those that do not. Nine GH_2 projects have been registered as SIPs as part of the Green Hydrogen National Programme (GHNP) (SIP 20e), allowing for the development of these projects to be expedited in terms of the required authorisations. An additional 11 GH_2/PtX SIPs are awaiting formal registration (Figure 9). Figure 8 also includes an inventory of current GH_2/PtX EIAs underway in South Africa.

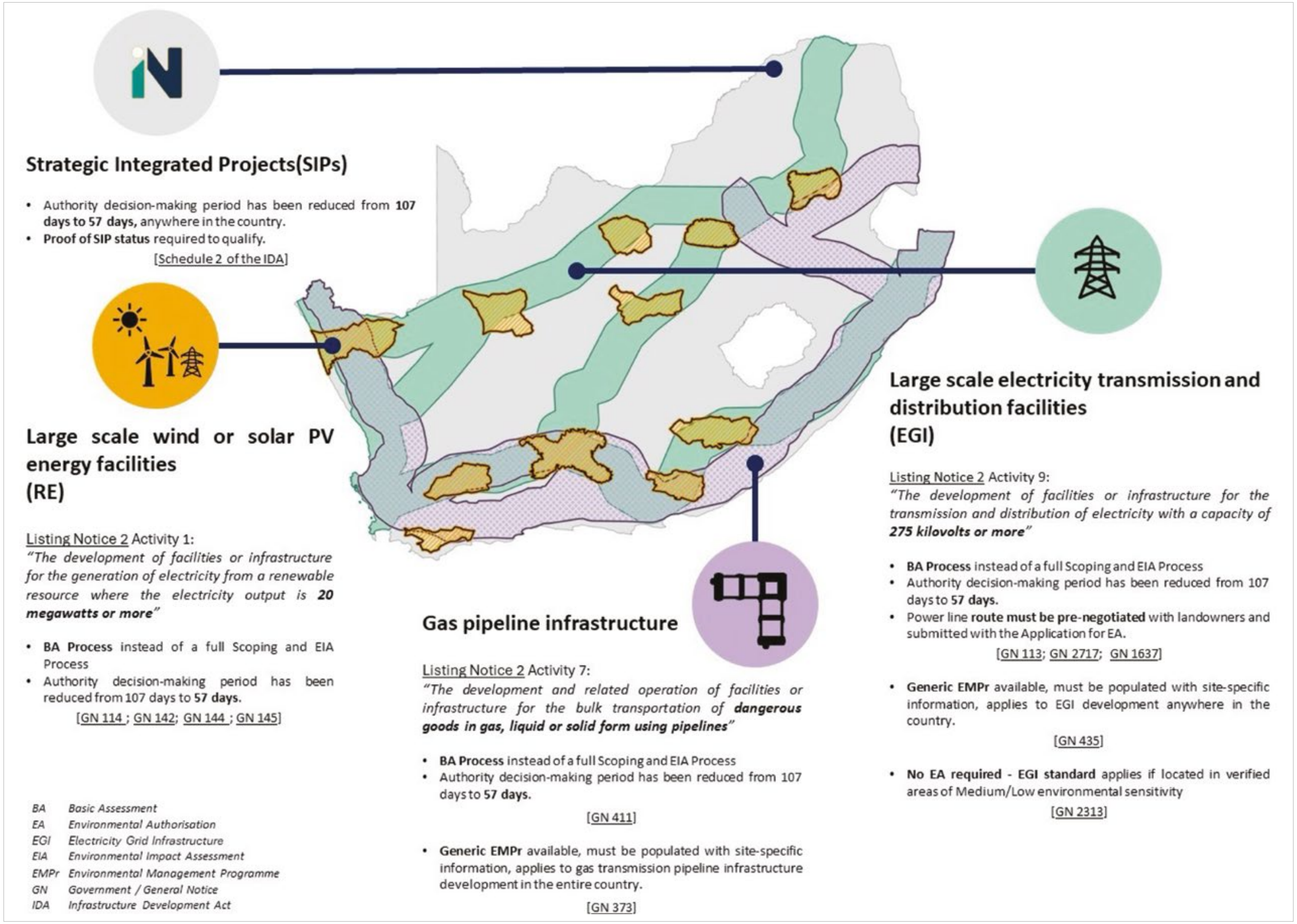

Figure 8: Strategic Integrated Projects, Renewable Energy Development Zones, Electricity Grid Infrastructure corridors and Gas Pipeline Network corridors where proposed projects within delimited spatial boundaries can undertake a 6-month Basic Assessment (BA) process rather than a 12-month EIA process.

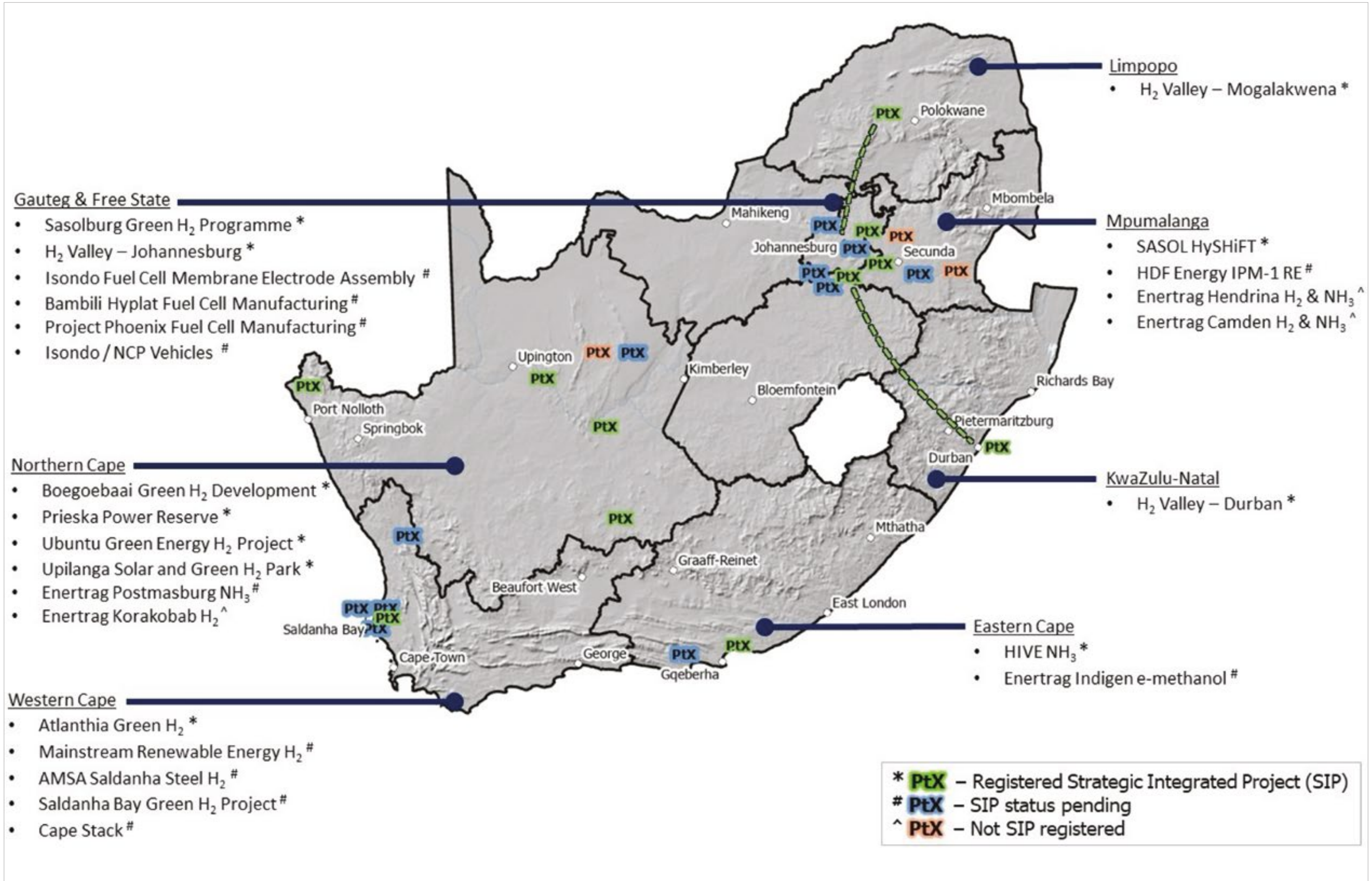

Figure 9: Strategic Integrated Projects for GH₂/PtX already registered [GREEN], awaiting registration [BLUE] and unregistered [PINK]

4.5 Describing receiving environments

South Africa is a megadiverse country with numerous unique species and ecosystems. It's social and economic systems are also diverse, with severe spatial and demographic inequalities in access to resources, making these systems fragile and sensitive to change. From greenfield, rural landscapes reliant on agriculture and tourism, to disturbed brownfields mine lands with contaminated groundwater, to the sensitive coastal zones around important SEZs, GH_2/PtX development, at significant scale, has the potential to affect a diversity of receiving social and ecological environments in a myriad of ways, both positively and negatively.

The receiving environments in Table 6 are the most likely baseline states which may be affected by large-scale PtX development in South Africa. These are generic baseline states, so on a case-by-case basis, the EAP, in collaboration with specialists and stakeholders, will need to describe the baseline receiving environment in as much detail as necessary and practicable, to identify the social and ecological features most sensitive to change induced by GH_2/PtX projects. During the EIA process and EMP drafting phases, the better the state of the receiving environment is known, the more effective the recommended management actions will be.

Box 10: Large-scale SWRO plants in sensitive coastal environments

Considering the complexity of large-scale SWRO infrastructure relating to marine and terrestrial pipeline corridors, seawater intakes, brine outfalls, operational footprints in the coastal zone and other indirect impacts, there are understandably several risks that need to be considered when planning for SWRO plants (Schreiner, van Ballegooyen and Osman, 2014). The most common public concerns include:

- Brine waste streams and impacts on seawater quality, marine ecology, and sediments;
- Intake entrainment and impingement of marine organisms;
- Place attachment in and around the coast ('sense of place');
- Other social impacts e.g., recreational users, fisheries, public coastal access;
- Noise from membrane trains;
- Ecological sensitivity in the coastal zone;
- Sediment movement and coastal erosion;
- Cost and high energy demand; and
- The risk of stranded infrastructure.

Table 6: Baseline receiving environments across South Africa which might be affected by GH_2/PtX development

Receiving environment category (ecological and social)	Generic, high-level description, most likely receiving environments for GH_2/PtX project components, but not always	National and regional examples (provided where receiving environment is geographically delimited)
Regions highly suitable for renewable energy	Rural; greenfields; relatively stable soils; water- constrained; farming with some tourism perhaps; high unemployment and poverty; resource-constrained, unskilled municipalities; deteriorating urban centres and infrastructure, crime, and feelings of hopelessness, especially among youth.	REDZ: 1.) Overberg, 2.) Komsberg, 3.) Cookhouse, 4.) Stormberg, 5.) Kimberley, 6.) Vryburg, 7.) Upington, 8.) Springbok, 9.) Emalahleni, 10.) Klerksdorp, 11.) Beaufort West
Coastal SEZ and offshore zones	Coastal and offshore zones located around SEZs; unstable sandy soils and coastal sediments; always water-constrained; green-/brownfields developments; better infrastructure/services, and municipal capacity around SEZs, compared to more rural municipalities where renewable energy project may be located.	South African SEZs such as regions around Saldanha Bay, Richards Bay, Algoa Bay, and Boegoebaai (proposed)
Inland mining zones	Often disturbed and/or contaminated lands; brownfields; unstable, disturbed soils; polluted surface and subsurface water systems; poor air quality; aged infrastructure and services; high unemployment and poverty; resource-constrained and unskilled municipalities; deteriorating urban centres and infrastructure, crime, and feelings of hopelessness, especially among youth.	Historical coal mining centres such as Emalahleni and Ermelo in the Mpumalanga Province

Receiving environment category (ecological and social)	Generic, high-level description, most likely receiving environments for GH_2/PtX project components, but not always	National and regional examples (provided where receiving environment is geographically delimited)
Transport corridors	Distributed servitude networks between infrastructure and manufacturing nodes; rural or urban depending on where they are located; sometimes ecologically sensitive within undeveloped servitudes where indigenous vegetation is undisturbed; deteriorating linear and nodal infrastructure: roads, rail, powerlines, pipelines, and ports; need for gentrification and new corridors and networks.	EGI corridors: 1.) Central, 2.) Eastern, 3.) International, 4.) Northern, 5.) Western, 6.) Expanded Eastern, 7.) Expanded Western

Receiving environment category (ecological and social)	Generic, high-level description, most likely receiving environments for GH_2/PtX project components, but not always
Energy security (generation)	National crisis stage; high uncertainty, lack of policy clarity, aged, deteriorating energy infrastructure dominated by coal; slow integration of renewables
GHG emissions	Ninety percent (90%) reliance on coal for electricity production; massive baseline GHG emissions inventory; slow integration of renewables, ambitious reduction targets
Economy	High unemployment; disenfranchised youth; high inequality; low growth; feelings of hopelessness.
State of governance	Low confidence; high corruption; low skills in many regions and municipalities; inefficient and outdated systems

To describe the social and ecological receiving environment in depth involves a comprehensive, interdisciplinary process. Initially, a thorough literature review would be undertaken to understand the existing knowledge base, encompassing existing ecological characteristics and social networks of the receiving environment e.g., meteorology, air, water, soil, and biodiversity, alongside community dynamics, including demographics, health, and economic activities. This would need to be augmented with local knowledge by eliciting stakeholder inputs during the public participation phases of the EIA. Baseline monitoring would also be used to in several instances to gain a better understanding of the sensitivities of the receiving environment.

4.6 Consideration of alternatives

Alternatives are defined as different means of meeting the general purpose and requirements of the activity. A range of alternatives exist (Table 7), not all of which are necessarily appropriate for each EIA. Alternatives that maximise resource use efficiency (e.g., energy and water-use efficiency) and minimise waste production must be sought by the EAP. Although alternatives are to be considered as early as possible in the process, the necessity to consider modifications and changes, to prevent and/or mitigate impacts identified during the assessment process, may also arise. Whereas discrete alternatives are therefore generally identified during the early stages of a project (pre-feasibility and feasibility) and comparatively assessed during the assessment phases, incremental modifications and changes to activities might also have to be considered when a development proposal is amended in an incremental manner throughout the EIA process to address impacts and issues, as and when they are identified. Both the identification, investigation, and assessment of alternatives, and the generation and consideration of modifications and changes to activities must be well documented by the EAP (DEA&DP, 2013).

Table 7: Types of alternatives that should be considered during a GH_2/PtX project, adapted after DEA&DP (2013)

Type of alternative	Explanation
Location	Refers to both alternative properties at regional or national scale, as well as alternative sites on the same property.
Activity	Where it is possible to undertake an activity which has the same project outcome but comes with less ecological and social costs.
Design or Layout	Different architectural styles, engineering designs, and technologies, or consideration of different spatial configurations on a particular site (e.g., siting solar PV away from wetlands).
Input	Input alternatives are applicable to applications that may use energy sources in their process (e.g., GH_2/PtX projects considering wind versus solar PV inputs).
Routing	Consideration of alternative routes generally applies to linear developments such as power line servitudes, transportation, and pipeline routes.
Scheduling and timing	Where several measures might play a part in an overall programme, but the order in which they are scheduled might contribute to the overall effectiveness of the end result.

Type of alternative	Explanation
Scale and magnitude	Activities that can be broken down into smaller units and can be undertaken on different scales (e.g., sizing of solar PV facilities).
'No-Go' option	EIAs must include the "no-go" option as a baseline against which all other alternatives must be measured. The option of not implementing the activity must always be assessed and to the same level of detail as the other feasible and reasonable alternatives.

In the sections that follow, multi-criteria analysis and suitability mapping are briefly described as examples of tools that can assist when considering alternatives within EIA.

4.6.1 Multi-criteria analysis

Multi-criteria analysis (MCA) is commonly used in EIA to evaluate the alternatives described in Table 7 to increase the transparency and robustness of decision-making. MCA evaluates options based on several criteria. It involves weighting these criteria according to their importance, standardizing their quantitative scores to a common scale, and calculating an overall score as the weighted average of these scores. In theory, this approach can enhance objectivity and replicability in the consideration of alternatives (Janssen, 2001). On the other hand, MCA can be prone to bias and may provide a false sense of accuracy due to its technocratic, 'black box' nature. It is therefore important that the EAP pay particular attention to designing transparent MCA approaches, thus aiding in more informed, systematic, and accountable project decision-making. There are many MCA methods which could be used to compare complex alternatives in EIA for GH_2/PtX projects[12].

4.6.2 Suitability mapping

4.6.2.1 National scale

Geographic Information Systems (GIS) is a crucial tool for the planning of GH_2/PtX projects and holistic identification of impacts. As part of the H2.SA, CSIR developed a GIS model to identify suitable regions in South Africa for GH_2/PtX production, considering both export and local use options. Spatially explicit siting variables which constituted 'push'- and/or 'pull'-factors included environmental conditions and sensitivities, political planning contexts, uses and users of the environment, and technical/engineering requirements. Variables were weighted with scores developed

12. Broniewicz and Ogrodnik (2020, 2021) for example, identify some of these methods for the comparison of alternatives for transport projects viz. Analytic Hierarchy Process, TOPSIS and DEMATEL. For examples of methods used in comparing hydrogen production projects, refer to, for example Oner and Khalilpour (2022).

through interdisciplinary consultations within the WG. Weighted scores were used to develop two different models: One for PtX export (Figure 10) and one for domestic PtX use (Figure 11). The export market model assumed development of the likely 'ultra' PtX projects and off-takers, all concentrated around export ports around South African SEZs. The local market model assumed smaller scale PtX projects with decentralised off-takers from the chemicals, fertilizer, heavy mobility, steel, and cement industries.

Box 11: Anchor MCA site selection tool

Impact Water Solutions (Pty) Ltd (IWS), Anchor Environmental Consultants (Pty) Ltd (Anchor) and WML Coast (Pty) Ltd were appointed by GIZ to undertake research into the economic, technical, legal, environmental, and social suitability of desalination plants as a water source for GH_2 projects in South Africa.

Part of this work entailed developing a criteria matrix for a preliminary site selection for an RO plant for GH_2 production and the application of these criteria to four potential hydrogen production sites in South Africa. The report by Bovim, Clark and Retief (2023) provides a description of the assessment criteria and background information used to inform the criteria matrix and risk analysis, and the application of these criteria to the four selected sites. The following criteria were used:

1. The oceanographic and physical criteria include wave exposure, currents and tides; sediments; bathymetry; water quality in terms of suspended sediment levels, algae and hydrocarbons; hydrogeology; and flooding risk.
2. The spatial constraints criteria include Ecosystem Threat Status; Ecologically or Biologically.
3. Significant Marine Areas (EBSAs); Critical Biodiversity Areas (CBAs); Protected Areas; and Estuaries.
4. The biodiversity criteria include marine biodiversity; aquatic biodiversity; and terrestrial biodiversity.
5. The social, economic, and cultural criteria include economic opportunities; existing and future development; fisheries; aquaculture; agriculture; archaeological and cultural heritage; palaeontology; and landscape or visual impacts.

Based on these criteria, the four sites were analysed individually to produce categorical risk diagrams according to user-defined weight percentages given that each criterion would not necessarily bear the same analytic importance. In addition, the report does not aim to compare the sites against each other and recommended a preferred site, but rather allow these user inputs to assist in determining which site is potentially more suitable for the user and then allow the user to decide what to focus on during a subsequent project feasibility phase. The accompanying interactive tool called H2Desal summarises this report, amongst others, and allows users to produce such categorical risk diagrams, so this report provides details into the data utilised and the underlying assumptions and analysis, whilst providing a few example outputs.

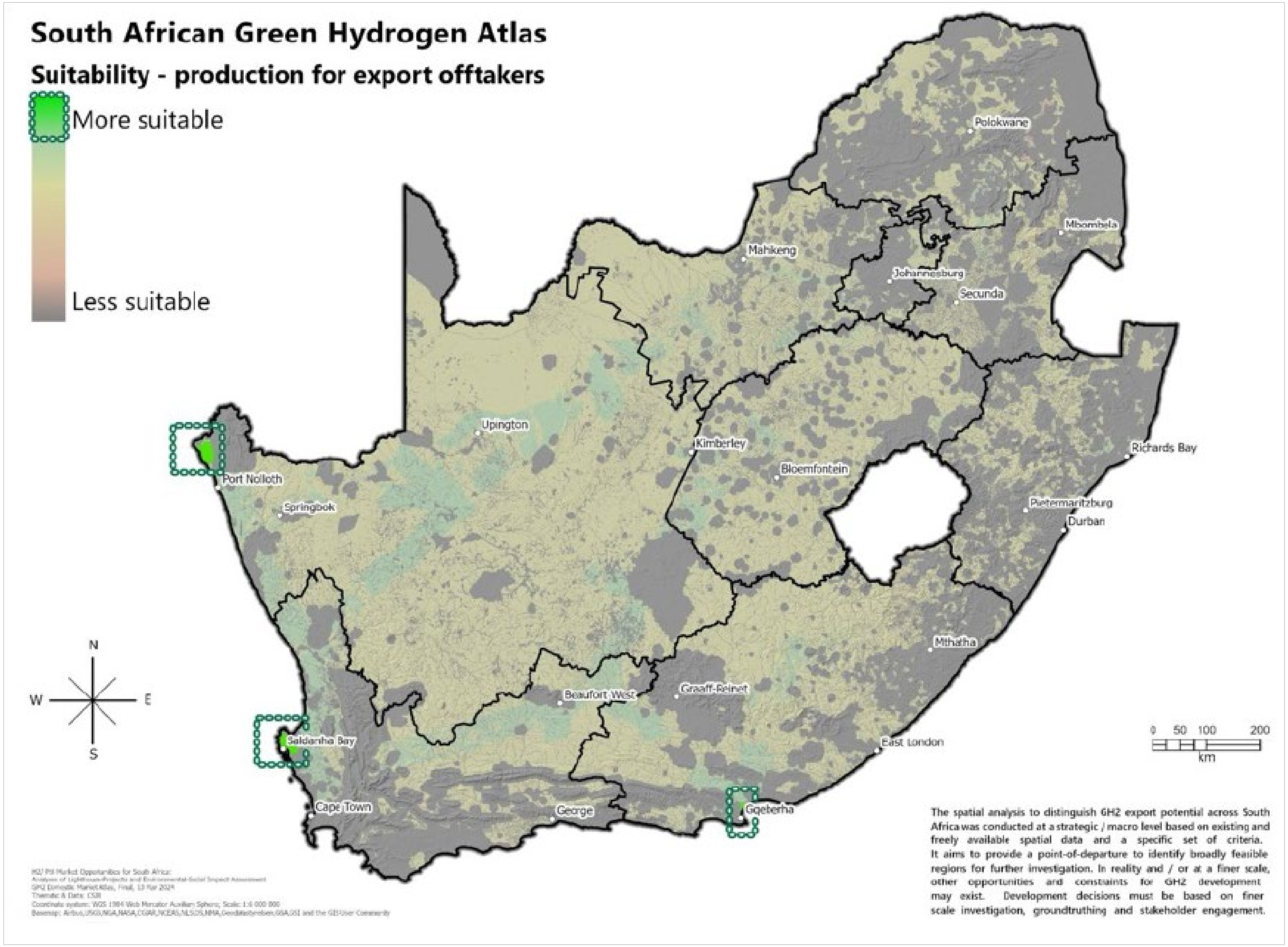

Figure 10: National scale GIS suitability model for GH_2/PtX export

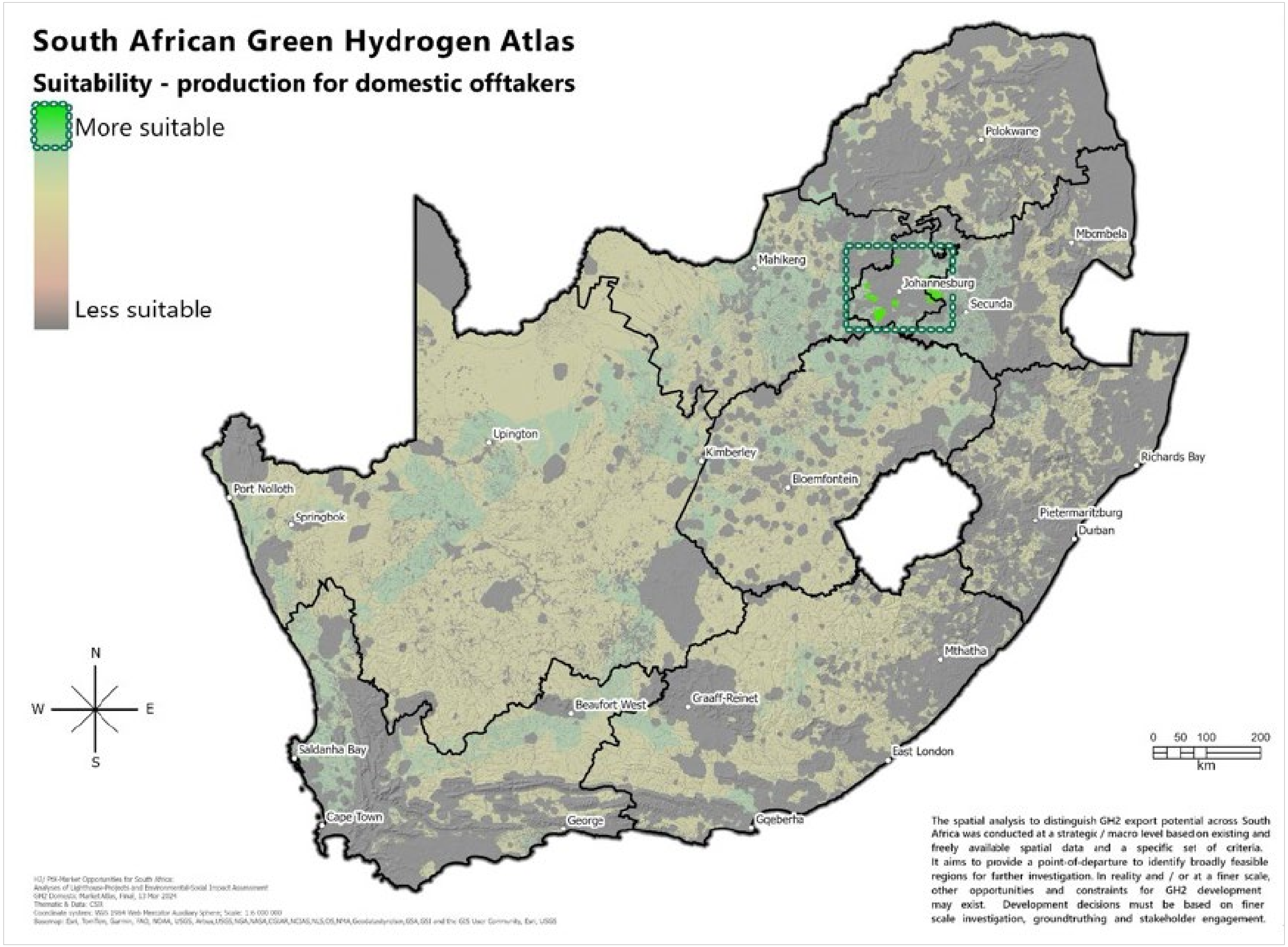

Figure 11: National scale GIS suitability model for GH_2/PtX domestic use

4.6.2.2 Local scale

Good spatial screening, site identification, and avoidance of sensitive features increases the chances of EA success and sustainable outcomes (Slootweg and Kolhoff, 2003).

During the prefeasibility and screening phases, interdisciplinary geospatial suitability mapping is best approached in a stepwise manner, starting at broad scales to identify regions which could be investigated further, before conducting more detailed site screening at local scale, considering project alternatives, within the constraints of mapped sensitivities.

Where a project proponent does not have in-house capabilities to use and/or interpret geospatial data, an independent EAP should be commissioned to conduct an interdisciplinary screening study looking for fatal flaws. At the screening stage, there are several key factors that make a site attractive for GH_2/PtX development, such as:

1. Favourable resource potential for wind, solar PV, and water;
2. Renewable Energy Development Zones (REDZ) and Electricity Grid Corridors – geographic areas where environmental permitting is streamlined;
3. Conformance with existing land-use planning and zonation;
4. Proximity or access to existing infrastructure and services; and
5. Disturbed and/or uninhabited areas with little or no conservation or social value.

Box 12: Taking care when working with spatial data

While spatial screening is essential for EIA, EAPs need to be conscious of its limitations. A recent review by Cilliers *et al.* (2022) found that spatial data used in South African EIAs is often inaccurate, especially at course scale. The authors make the following suggestions to EAPs trying to improve the quality and accuracy of spatial data informing their EIA:

1. Transparently acknowledge that spatial data is limited – it can misrepresent and/or omit important features.
2. Understand the impact of data scale on geospatial accuracy, favouring finer scale data for more detail, over coarser scale data.
3. Use data calibration techniques like specialist site visits, and/or other technologies such as drones and remote sensing.
4. Integrate inclusive and participatory processes into the screening process, drawing from a range of stakeholders with spatial knowledge.

The pull factors should be considered in view of sensitive features that may constrain the suitability of the GH_2/PtX development site. After regional mapping and a thorough consideration of pull factors, the EAP should consider the following five steps for generating local scale sensitivity maps during screening:

1. Gather relevant push geospatial data, including protected areas, critical biodiversity areas, watercourses, threatened ecosystems, agricultural fields, heritage features, human settlements, issues with land claims, mining rights, and other land-use planning information.

2. Combine collected data into a GIS database, assign sensitivity scores, and overlay the layers to identify areas with varying levels of sensitivity. Calculate a composite sensitivity score for each site alternative[13].
3. Generate a sensitivity map that visually represents the suitability of areas for GH_2/PtX project installations based on the composite sensitivity scores (an example is provided in Figure 12).
4. Divide the sensitivity map into four- to six-tier zones (e.g., very high, high, moderate, low) and provide mitigation recommendations in the EMPr for each zone.
5. Document the entire process in a comprehensive screening report, engage with stakeholders and decision- makers for review and feedback.

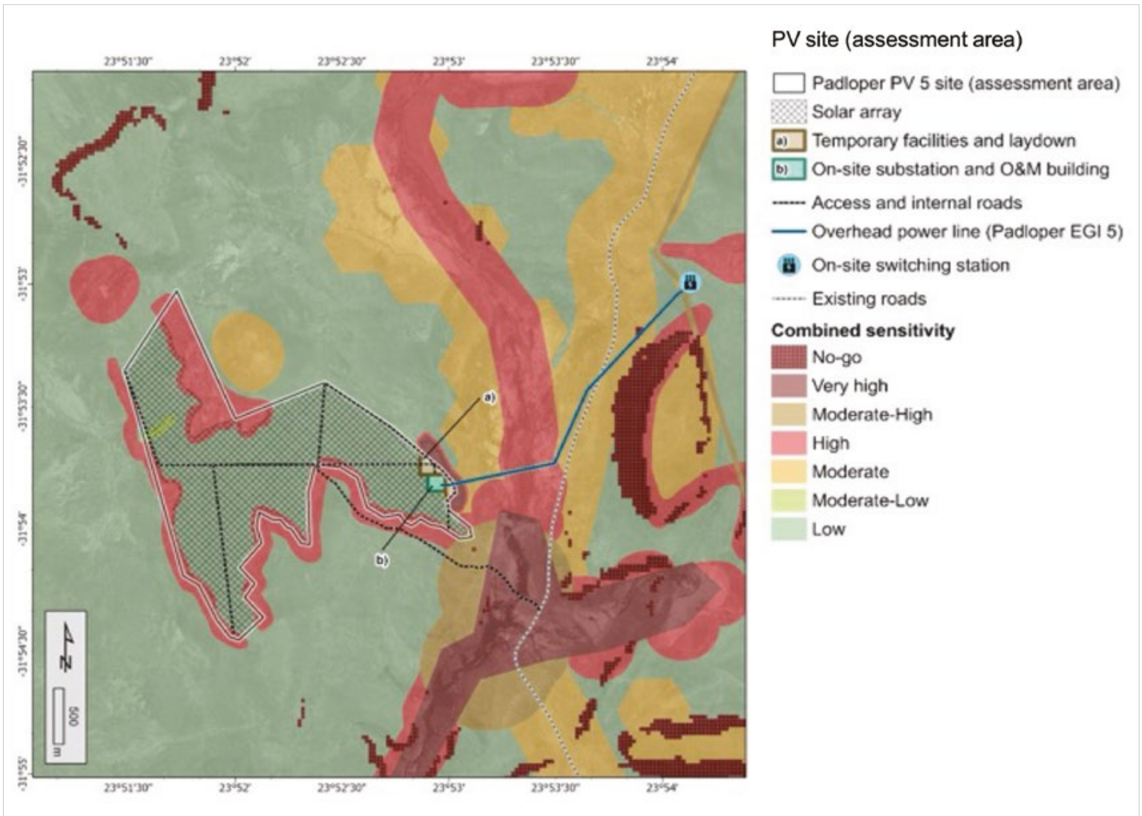

Figure 12: Example suitability map demonstrating various zones indicating sensitivity ranging from 'No-go' to 'Low' (this example is a six-tier sensitivity profile, although four-tier is more common). It also shows the planned locations for the solar array, temporary facilities, on-site substation, O&M buildings, access roads, and power lines within the assessment area, in relation to the receiving environment sensitivity.

13. *This integrated approach is suitable for the screening phase, however, EAP experience suggests it is not suitable for the EIA process. CAs may request that a combined sensitivity map be disaggregated to reflect each individual aspect in terms of their sensitivity.*

Integrating suitability and sensitivity maps into the EIA process offers several advantages, including improved communication with stakeholders, issue integration and systems thinking, support for alternative assessments, and the ability to demonstrate regulatory compliance e.g., legislated buffer zones around important ecological and social features. These empower EAPs to make and communicate decisions more clearly, increasing the likelihood of being issued with an EA and achieving sustainable outcomes. By global standards, South Africa has good geospatial data which should be capitalised upon. Many of the tools and data sets to build suitability maps are freely available online and listed in Table 8.

Table 8: List and description of freely available spatial software, tools and data sources useful for suitability mapping, site selection and alternatives assessment

SOFTWARE	Description
QGIS	GIS software used to create, view, and analyse spatial data in various formats. Some technical capability required.
Google Earth	Software that superimposes satellite images, aerial photography, and GIS data onto a 3D globe. Data in compatible KMZ/KML format can be viewed and created.
TOOLS	**Description**
Screening Tool	Geographically based web-enabled application which allows a proponent intending to apply for EA in terms of the (EIA) Regulations 2014.
SAHRIS PalaeoMap	Fossil sensitivity map for palaeontological and geological heritage resources that guides and assists developers, heritage officers, and practitioners in screening paleontologically sensitive areas at the earliest stages of the development cycle.
Property Search	Property Search Web Application, curated by the Chief Surveyor-General, allows for the search and viewing of South African cadastral data (incl. farm / land parcel name and number, surveyor general code).
South African GH_2/PtX Atlas	An online GH_2/PtX Potentials Atlas representing the relative suitability to produce GH_2 and its derivatives across South Africa, focussing on the export and local GH_2 markets.
Global Solar Atlas	Quick and easy access to solar resource and PV power potential data globally.
Global Wind Atlas	Web-based application developed to help policymakers, planners, and investors identify high-wind areas for wind power generation virtually anywhere in the world, and then perform preliminary calculations.

TOOLS	Description
BGIS	Spatial biodiversity information, curated by the South African National Biodiversity Institute (SANBI). Notable datasets include provincial conservation planning (incl. Critical Biodiversity Areas) and outputs from the National Biodiversity Assessment.
EGIS	Spatial environmental information, curated by DFFE. Notable datasets include the South African Protected Areas Database, National Land Cover, Renewable Energy EIA Application Database, REDZ, EGI Corridors.
SAHRIS Heritage Sites	Heritage sites repository, recording, geocoding and archiving all known, recorded heritage sites, including archaeological, cultural, living and built heritage. Datasets of particular interest include declared and graded heritage sites. Curated by SAHRA.
StepSA	Census data on population, employment and economic production per economic sector aggregated as mesozones. Developed by CSIR.
WASA	South African wind resources mapped through the development, verification, and employment of numerical wind atlas methods to enable large scale of exploitation of wind energy in South Africa.
SolarGIS	Collection of solar resource maps to help the solar industry with development of solar projects.

4.7 Social and ecological impact pathways

The following sections, in a broad, generic sense, discuss the positive and negative impacts which might manifest during a GH_2/PtX project, and how they might contribute to a broader GH_2/PtX economy. Each of these opportunities and risks will need to be considered by the EAP in the context of their respective projects and EIA processes, in consultation with project developers, domain specialists and other I&APs, to determine exactly how these issues should be scoped, assessed, and managed, if the project proceeds to construction.

4.7.1 Economic growth and job creation

The development of a diversified, sustainable GH_2/PtX economy, leveraging renewable energy resources, could drive substantial economic growth, involving major capital investment and boosts in the technology sector, providing the basis for South Africa to become a leader in green energy exports (Fazioli and Pantaleone, 2021). GH_2/PtX could assist historically disadvantaged populations to access modern energy sources. When complemented with energy access provided by a modernised energy infrastructure, communities in the immediate area of GH_2/PtX could benefit directly and indirectly via the broader macro-economic benefits, reduced energy system costs, and an environmentally cleaner power system.

Long-term macro-economic benefits from GH_2/PtX projects will depend on how the proceeds of GH_2/PtX are used. Effort will need to be directed at ensuring that most proceeds accruing to government are invested to enhance the long-term prospects of the country. Like other industries, precaution of 'boom and bust' cycles would need to be observed given the volatility of the global energy market and rate of technological innovation which makes change fast and unforgiving.

Box 13: Opportunities potentially created by the Camden Renewable Energy Cluster

The Camden Renewable Energy Cluster is a large, integrated GH_2/PtX programme consisting of eight different projects. Part of the programme is located in the Gert Sibande District Municipality. It recorded an unemployment rate of 26.7% in 2017 with the majority of the employed in the trade and community services sectors. It is envisaged that the construction phase of the Camden Renewable Energy Cluster will extend over a period of approximately 18-24 months and create in the region of 100-150 employment opportunities that will benefit members from the local communities in the area, specifically Ermelo. These opportunities would include opportunities for low, semi and highly skilled workers. Most of the employment opportunities will accrue to historically disadvantaged members of the community. A percentage of the wage bill will be spent in the local economy which will also create opportunities for local businesses in the local towns in the area, specifically Ermelo. Given relatively high local unemployment levels and limited job opportunities in the area, this will represent a significant, if localised, social benefit. The proposed development will create in the region of 20 full time employment opportunities during the operational phase.

4.7.2 Greenhouse gases

GH_2/PtX could undoubtably play a major role in decarbonising energy generation, transportation, and industrial and agricultural processes in African economies (AbouSeada and Hatem, 2022). Adopting GH_2/PtX technologies in South Africa could greatly accelerate domestic carbon reduction efforts, supporting targets of a 75% decrease in emissions by 2050 (IHS Markit, 2021). On the other hand, large-scale GH_2/PtX production could have negative greenhouse gas consequences if hydrogen is leaked during production and transportation activities (Derwent, 2023; Sand *et al.*, 2023). Although hydrogen is not a greenhouse gas itself, it can indirectly contribute to global warming if it reacts with other gases in the atmosphere. Advanced leak detection and repair protocols for storage and transportation will mitigate this risk.

4.7.3 Local services, infrastructure and governance

GH_2/PtX requires sophisticated, robust infrastructure, including enhanced power grids for renewable energy, desalination plants, and linear transportation networks like roads, railway, and pipelines. Construction of such infrastructure will have impacts on local settlements and people. Towns near GH_2/PtX activities will experience growth exceeding projections based on past trends.

Enhanced resource and institutional capacity to plan for and address increased service delivery demands for housing, water provision, social services, electricity, and roads will be needed. Integrating new GH_2/PtX projects into existing planning schemes will demand careful planning to avoid overburdening existing public services and under resourced, financially constrained municipalities. These infrastructure aspects will need to be considered within the scope of the EIA process, as far as possible.

Substantial opportunities also need to be considered. GH_2/PtX developments could help to improve public infrastructure such as oversizing desalination plants to provide water to both GH_2/PtX facilities and local communities or improving energy generation and distribution infrastructure. GH_2/PtX could also be used to augment South Africa's own energy security. The Super H_2igh Road Scenario report, commissioned by Agora Energiewende in June 2021, found that production of 3.8 million tonnes per annum of hydrogen could be developed in South Africa by 2050. If half that figure (~2 million tonnes per annum) were reserved for domestic consumption, it would contribute 8% of the final energy demand in South Africa (IHS Markit, 2021).

4.7.4 Habitats and species

The expansion of renewable energy and other GH_2/PtX infrastructure like SWRO can affect local habitats and species. A concern is that, unless properly mitigated, the site and linear infrastructure associated with GH_2/PtX development could result in fragmentation of landscapes via loss of connectivity, edge effects, and disruption of ecological processes (Hamed and Alshare, 2022). Impacts on species, ecosystems, and ecological processes could extend well beyond the physical footprint of the GH_2/PtX development footprints.

Box 14: Loss of terrestrial biodiversity due to the Camden Renewable Energy Cluster

The grassland vegetation types that occur around Camden are highly sensitive, but the natural grassland on site was in moderate to poor condition, primarily due to heavy overgrazing. There were significant areas of low grass cover and bare areas, and plant species composition has been degraded by grazing. The proposed layout of the Camden Renewable Energy Cluster avoided sensitivities to a large degree. Wetland crossings were at existing roads, and all other wetlands were avoided. There was some infrastructure within the natural grasslands, but most road infrastructure, the component of wind energy projects that usually has the highest impact, was mostly along existing roads or within disturbed or transformed areas. On this basis, the project was therefore deemed acceptable from a terrestrial biodiversity perspective.

For many species, the impacts of noise, erosion, dust, and other disturbances during construction and operations could extend substantial distances from the from the source of the activities, especially in arid environments. A GH_2/PtX economy could have regional cascading effects on other species and processes at large-scale. Avoiding sensitive ecological features and processes subverts all these impacts entirely, while mitigation and offsetting can also reduce them substantially if well implemented.

4.7.5 Human health

The switch to cleaner energy sources could have substantial positive effects on human health in regions such as Gauteng and Mpumalanga where much of the country's coal-based electricity is produced, at substantial cost to local people and environments. Human health in regions around GH_2/PtX production sites could also be substantially improved with investment into local services and infrastructure by GH_2/PtX project developers and funders e.g., more potable water from oversized desalination plants, new roads, transmission lines, and clinics in rural, underdeveloped settings.

On the other hand, an EAP may encounter public apprehension about the safety of manufacturing, storing, and transporting compressed gases and fuels, which can cause explosions if engineering systems fail. Assuaging public fears would require strict technical safety guidelines, regulatory oversight, and continuous monitoring. The regulatory framework for safety in South Africa is reasonably well established, but depends significantly on the institutional capacity to implement the regulations in a competent, trustworthy fashion (Vallejos-Romero *et al*., 2023).

4.7.6 Landscapes and heritage

Much of the infrastructural footprints of GH_2/PtX projects would be located in receiving environments like arid rural interiors and coastal zones around SEZs, landscapes known to contain important heritage resources (archaeological, palaeontological, built, cultural) as well as being sites of aesthetic and recreational value to local people and tourists. These heritage resources will be distributed at varying densities across South African receiving environments and may come into conflict with the large spatial footprints required for GH_2/PtX project development.

4.7.7 Freshwater quantity and quality

Water-intensive processes, like electrolysis in hydrogen production, could conventionally strain freshwater resources. Desalination and both SWRO and MWRO offer the obvious solution to this problem, without placing additional strain on local potable supplies. There is also the potential to develop non-potable (brackish) groundwater within or near GH_2/PtX sites at a limited scale for non-electrolysis application e.g., solar PV panel washing, with adequate consideration of the risks associated with the transport and storage of brackish water. Assuming water for electrolysis is derived from desalination processes, stresses to South African potable water resources should not occur. The prospects of oversizing desalination plants to add additional supply into bulk municipal systems is very promising.

Regarding surface spills on-site and along transport networks, these are the most likely source of water resource contamination, although they are relatively easy to mitigate. In terms of protecting sensitive water resources like wetlands from development footprints, especially in the case of linear infrastructure, the most effective management action is avoidance of high sensitivity water areas during project screening and EIA phases.

4.7.8 Geophysical and hydrological processes

GH_2/PtX developments can disrupt soil integrity. The construction process necessitates land clearing, which removes vegetation cover, leaving soil vulnerable to erosion (Hamed and Alshare, 2022). Heavy machinery used for installation compacts the soil, reducing its porosity and impairing water infiltration. This could lead to increased surface runoff during rains, exacerbating soil erosion. The disturbed soil can be carried away by wind or water, leading to loss of fertile topsoil, degradation of land quality, and potential impacts on nearby water bodies due to sedimentation.

The construction and operation of SWRO plants can significantly influence sediment movement in coastal areas if not considered in the design phase (Lattemann and Höpner, 2008). During construction, dredging and land reclamation activities disturb the seabed, leading to increased sediment suspension and redistribution. These changes in sediment dynamics can lead to coastal erosion, affecting marine habitats and potentially causing loss of biodiversity. Altered sedimentation patterns can impact nearby beaches and coastal structures, requiring costly mitigation and management strategies to preserve the coastal integrity if not properly avoided.

4.7.9 Land-use conflicts

Aside from biodiversity, the primary land-use conflicts which may be associated with a South African GH_2/PtX economy will be with agriculture, tourism, and recreational users, and to a lesser extent, mining. Given the expanses of land required for renewable energy, SWRO, and associated linear infrastructure, any interventions that weaken land-based livelihoods are likely to have a long-term impact on the resilience of both the affected regions and their land users. Some agricultural land may be taken out of production though leasing or purchasing while PtX development is underway, which could have a positive impact on the incomes of agricultural land users. Local economic development associated with PtX projects will likely stimulate local markets for agricultural products.

Significant numbers of locally based staff of GH_2/PtX companies should also increase demand for agricultural products. Changes in land character and sense of place in rural regions or near the coast could negatively affect tourism markets and recreational users. Proper siting of projects and mitigation of impacts during the EIA phase will drastically reduce the significance of the negative impacts, while appropriate local-scale management actions could enhance the positive ones.

4.7.10 EAP perceptions of potential impacts

As part of Work Package 3 (Schreiner and Snyman-Van der Walt, 2023), 25 impact statements were identified and transcribed into an online survey which was disseminated to WG members. The survey was designed in such a way that for each negative impact, respondents were required to express their level of concern. They chose from three gradations: 'Very Concerned', 'Concerned', or 'Not Concerned'. Conversely, for positive impacts, respondents were prompted to convey their level of optimism, with choices spanning 'Very Optimistic', 'Optimistic', or 'Not Optimistic'. Analysis of the WG responses provided an integrated, interdisciplinary perspective, highlighting which negative impacts posed the greatest risks, and which positive impacts promised the greatest opportunity (Table 9).

Positively, GH_2/PtX is seen as a key driver for decarbonizing South Africa's energy economy, spurring economic growth, and creating jobs (top 3 ranked benefits). However, concerns are significant, including negative environmental impacts like loss of habitats and species, soil erosion, and coastline alteration due to construction and operations. Notably, issues like bird and bat mortality from wind turbines, strain on local infrastructure due to labour migration, and potential conflicts in land-use also feature prominently. Overall, GH_2/PtX presents a mix of substantial opportunities and potential challenges.

Table 9 :Findings of the survey from 11 EAPs, actively working on GH_2/PtX projects, for both positive and negative impacts, with their relative rank, mean (SD) and median responses for each survey statement.

	Impact	Rank	Mean (SD)	Median
1	Renewable energy generation and use of green PtX products decarbonise South Africa's energy economy	1	2.54 (0.52)	Very optimistic
2	Investment into PtX projects creates new revenues, markets, and supply chains, leading to economic growth and renewed confidence in the Just Transition.	2	2.45 (0.52)	Optimistic
3	Construction and operations of PtX projects create new businesses, supply chains, and jobs and skills for local people in the regions within which they occur.	3	2.36 (0.81)	Very optimistic
4	Turbine blades used at operational wind farms lead to bird and bat mortality.	4	2.36 (0.67)	Concerned
5	Capital spends on PtX-related transport (rail, roads, ports, pipelines, powerlines) create superior quality infrastructure at important transport networks and nodes e.g., national road connections.	5	2.27 (0.65)	Optimistic
6	Energy from PtX projects displace fossil fuels, improving the environmental quality of regions e.g., Mpumalanga, where coal mining, coal combustion, and Acid Mine Drainage (AMD) are prevalent.	6	2.18 (0.75)	Optimistic
7	Brine from seawater reverse osmosis operations discharged to the marine environment causes a loss of habitats and species, affecting marine living resources and the people who depend on them.	7	2.18 (0.75)	Concerned
8	Job seeker and labourer in-migration during PtX project construction and operations place strain on already constrained municipalities, services, and infrastructure	8	2.09 (0.70)	Concerned

	Impact	Rank	Mean (SD)	Median
9	Renewable energy construction and operations, and electricity transmission (powerlines) in rural, agricultural landscapes lead to vegetation clearance and the loss of habitats and species.	9	2.09 (0.83)	Concerned
10	Seawater reverse osmosis construction and operations, and transport (pipelines) in coastal zones lead to vegetation clearance and the loss of habitats and species.	10	2.09 (0.70)	Concerned
11	Developing PtX projects and transport corridors (roads, rail, pipelines, powerlines) in regions that would otherwise be used for conservation leads to land-use conflict.	11	2.09 (0.83)	Concerned
12	Investment into PtX projects leads to better local infrastructure and services e.g., roads, water supply, wastewater treatment etc.	12	2 (0.77)	Optimistic
13	Seawater reverse osmosis operational infrastructure alters coastal sediment movement regimes, causing coastline accretion and erosion.	13	2 (0.77)	Concerned
14	Explosions, leaks, and spills at PtX project operations, or during transport and handling, contribute toward human death or injury and ecological contamination	14	2 (0.63)	Concerned
15	PtX project linear infrastructure construction (roads, rail, pipelines, powerlines) leads to vegetation clearance causing a loss of habitat and species.	15	1.91 (0.83)	Concerned
16	Renewable energy construction and operations, and electricity transmission (powerlines) in regions dependent economically on agricultural and tourism contribute to loss of local incomes.	16	1.9 (0.94)	Concerned
17	Renewable energy construction and operations, and electricity transmission (powerlines) in rural, agricultural landscapes lead to changes in aesthetics and heritage resources, causing an altered s...	17	1.81 (0.87)	Concerned

	Impact	Rank	Mean (SD)	Median
18	Traffic, noise, dust, and physical collisions during PtX project construction, operations, and transportation lead to losses of habitats and species e.g., animal roadkill.	18	1.81 (0.75)	Concerned
19	Seawater reverse osmosis construction and operations, and transport (pipelines) within coastal environments lead to changes in aesthetics and heritage resources, causing an altered sense of place.	19	1.73 (0.79)	Concerned
20	Fugitive emissions, leaks, and purges from PtX project operations and transportation lead to increased greenhouse gas emissions	20	1.72 (0.79)	Concerned
21	Use of scarce water resources during renewable energy construction and operations in rural, water-stressed regions leads to increased water scarcity	21	1.72 (0.79)	Concerned
22	Authorising seawater reverse osmosis construction in coastal regions leads to constrained public access to the beach and coastal resources.	22	1.45 (0.69)	Not concerned
23	PtX project construction and operational activities (renewable energy, desalination, transport infrastructure) lead to soil instability and soil erosion.	23	1.45 (0.69)	Not concerned
24	PtX project construction and operations cause nuisance impacts to human health e.g., flicker, glare, noise, traffic, dust etc.	24	1.36 (0.50)	Not concerned
25	Authorising PtX projects and increasing competition within Special Economic Zones for prime property with port access leads to land use conflict.	25	1.36 (0.67)	Not concerned

4.8 Management actions

Management actions are the designs, activities, methods, processes, technologies, rules, and infrastructure that could be implemented, before, during, or after the project, to enhance benefits of the project, and mitigate, or altogether avoid, negative ones. This section briefly describes what should be included in an EMPr and offers a broad typology of management actions which might be applicable for best managing PtX project impacts.

4.8.1 A typology of management actions

Several hundred management actions may be recommended in an individual EMPr for a large-scale GH_2/PtX project. These will need to be precisely determined on a case-by-case basis within the individual EIA process, depending on the nature of the receiving environment, the types of the developments proposed and the views of local stakeholders. As a generic overview, the following categories of management actions may be useful to the EAP for GH_2/PtX developments (Table 10).

Table 10: Management action typology for GH_2/PtX projects which may be included by the EAP during the impact assessment and EMPr drafting.

Management action type	Description	Where they can be used	Example of resources
Avoidance	Proactively identifying and steering clear of sensitive areas. Usually includes GIS mapping of areas with fragile ecosystems, or places of cultural and historical importance, so they are identified as early as possible.	Initially, at regional scale during feasibility studies and project screening, then again at site scale during the EIA.	IUCN: Mitigating biodiversity impacts associated with solar and wind energy development (Bennun *et al.*, 2021)
Mitigation or enhancement	In the case of negative impacts, when avoidance is infeasible, mitigation can minimise effects. Impact enhancement should be sought by the EAP when impacts may result in beneficial outcomes.	Undertaken in collaboration with specialists, primarily in the impact assessment phase during EMPr drafting.	

Management action type	Description	Where they can be used	Example of resources
Restoration	Aims at returning disturbed or degraded ecological habitats, or social and cultural assets, to their original state post- construction, so they can continue to support humans and nature.	Post-project completion, in cases where the receiving environments have been altered or degraded.	FAO: The road to restoration: A guide to identifying priorities and indicators for restoration monitoring (Buckingham *et al*., 2019)
Offsetting	Where residual impacts cannot be avoided or mitigated. Restoration involves creating or enhancing equivalent habitats or areas in other locations to compensate for these impacts.	As a part of the project's final EA or as an ongoing obligation.	DFFE: National Biodiversity Offset Guideline (DFFE, 2023)
Technology/ design alternatives or colocation synergies	Some PtX technologies may be more environmentally friendly and/or synergistic with existing land-uses or infrastructure. An example is Agrivoltaics, which combines the installation of solar panels with agricultural activities.	During the initial planning and feasibility assessments, where opportunities for synergistic development can be identified, and elaborated in the EMPr	Agrivoltaics: Opportunities for Agriculture and the Energy Transition (Fraunhofer I.S.E, 2022)

Management action type	Description	Where they can be used	Example of resources
Local beneficiation and local contracting	At local scale, applying rules like those required in the enhanced Social and Labour Plans (SLPs) in the mining industry could ensure that socioeconomic opportunities are maximised for local people.	Early in the planning process and throughout the EMPr.	Social and Labour Plan Series Phase 3: Alternative Models for Mineral-Based Social Benefit (Snyman *et al.*, 2018) Green Hydrogen Contracting for People and Planet (GH_2, 2022) Green hydrogen for Sustainable Industrial Development (UNIDO, 2023)
Regulatory / planning instruments	Enforcing regulations and standards, integrating planning strategies like IDPs, EMFs, SDFs to minimise harm or increase benefits of the proposed PtX developments.	Considered by the EAP throughout screening, impact assessment and EMPr phases.	EIA Guideline and Information Document Series (DEA&DP, 2013).

4.9 Tools for doing holistic assessments

Taking a systems perspective in conducting EIAs from the outset and integrating particular tools in the process that assist in gaining deeper insight into project impacts on complex receiving environments can lead to more accurate and meaningful EIA outcomes.

A system is a set of things – people, plants, animals, cells, molecules – interconnected in such a way that they produce their own pattern of behaviour over time. Systems thinking is about seeing the relationships between structure and behaviour (Meadows, 2008). It is a way of thinking that gives us the freedom to identify root causes of problems and see new opportunities. This way of thinking is supported by a language and a diverse set of tools (Monat and Gannon, 2015).

EIAs tend to separate system elements into discrete 'boxes' supporting administrative and bureaucratic efficiency (Bond *et al*., 2015). The structure of an EIA report, separated amongst specialist studies, is an outward representation of this reality. This makes it difficult to predict systemic effects, which can be several orders of magnitude more significant than direct impacts, (Lenzen *et al*., 2003).

Novel ways of approaching the identification and consideration of systemic impacts, integrating concepts like, for example, resilience (Wenning *et al*., 2017), are seen as one potential solution. Repeated calls are made for the adoption of practicable systems thinking tools in EIAs (Retief *et al*., 2016). A growing number of such tools are currently being experimented with, offering a variety of approaches for EA practitioners to use (Wiek and Binder, 2005). A small selection of these tools and approaches and their application in EIAs is described in this section. In addition to enabling the perception and identification of effects in systemic connections, these tools can also assist in considering secondary, tertiary, and cumulative effects, as well as to address the issue of uncertainty.

4.9.1 Narrative

Most EAPs, knowingly or unknowingly, use text narratives to communicate relationships between system elements. For example: "The clearance of vegetation may lead to unstable soil which erode resulting in the loss of agricultural productivity. Erosion also causes sedimentation of watercourses which has adverse effects on aquatic species, such as fish, which could impact the livelihoods of communities reliant on fish for income and subsistence".

Narratives are an excellent way to describe these relationships and are widely used by EAPs, but can easily become lengthy and confusing, often being full of technical jargon. This can be a challenge, especially within a mandated, time-restricted decision-making exercise like an EIA (Audouin and Sitas, 2020). But when done skilfully (i.e., using correct grammar, writing succinctly, using simple vocabulary, and avoiding unexplained jargon), the use of narrative is a highly effective method for describing interconnected systems, so that system elements and relationships can then be assessed more deeply during the EIA, thereby opening the potential for improved assessments, management actions, and project outcomes.

4.9.2 Systems mapping

In contrast to narratives, describing systems graphically is often favoured as a means of understanding systems when conducting EIAs (Perdicoúlis and Glasson, 2012). Systems mapping is a way to reveal the perceived structure and relationships within systems. There are many tools which can be used to visually describe and illustrate systems, including Bayesian Belief Networks, Rich Pictures, Social Network Analysis, Fuzzy Cognitive Mapping, Participatory Systems Mapping, Causal Loop Diagrams[14], Theory of Change Mapping, Iceberg Models, and Connected Circles. For more information on these approaches, see Integration and Implementation Insights – Seven methods for mapping systems. EAPs must remember that any representation of a system is based on the interpretation of those creating the map or graphic illustration, and it is not possible to illustrate the system exactly as it is in reality. Regardless of the specific mapping tool used, EAPs should try to embrace uncertainty by being humble, assuming that the models they have created, while impressive and potentially beautiful, are probably quite flawed (Audouin and de Wet, 2012).

4.9.3 Cross-Impact matrices

EAPs will be familiar with the use of a matrix for the evaluation of potential impacts that have been identified for project activities. In such a matrix, potential impacts are cross-tabulated against criteria (status, extent, duration, consequence, probability, reversibility, residual impact, irreplaceability), for the purposes of determining impact significance. These matrices are easy to understand and user friendly, as well as being easy to compile and explain, but important interdependencies and interactions cannot be identified nor shown. Cross-impact matrices can be helpful to further explore important interrelationships. In a cross-impact matrix, lists of potential impacts are duplicated on two axes, and then cross tabulated to find relationships. If two impacts are linked by secondary or tertiary interactions, they are scored ranging from strong positive to strong negative, depending on the level of the interaction. If they are not impacted by multiple levels of interaction, they are marked neutral (Table 11). Text narratives are then used to further expand upon the nature of the identified interrelationships.

14. *While Causal Loop Diagrams (CLD) are not commonly used in EIAs (Glasson et al., 2013), they are powerful visualization tools which could help the EAP to (Systems Innovation, 2020): (1) Describe and diagnose the current state of a given system; (2) Understand how system structure creates observable outcomes; and (3) Create a shared vision of the system. Audouin and Sitas (2020) provide a detailed step-by-step explanation of how to construct CLDs in Towards Nature-based Resilience in Infrastructure Development and Assessment. models they have created, while impressive and potentially beautiful, are probably quite flawed (Audouin and de Wet, 2012).*

Table 11: An example Cross-Impact Matrix showing the relationships

Impact		Impact 1	Impact 2	Impact 3	Impact 4	Impact 5
Construction phase impacts	Impact 1			-		-
Discharge of brine to marine environment	Impact 2			--		-
Effect on fisheries and tourism	Impact 3	-	--		+	+
More potable water in the bulk system	Impact 4	+		++		++
Job and skills creation	Impact 5	-	-	++	++	

++	Strong positive
+	Positive
	Neutral
-	Negative
--	Strong negative

4.9.4 Scenario analysis

Comparative analysis of scenarios is often applied in SEAs, but seldom in EIAs other than for cursory consideration of project alternatives. There is scope for broader use of scenario evaluation in EIAs (Duinker and Greig, 2007). Uncertainty about future conditions and drivers of change in natural and social systems is increasing, which means that EIAs have the potential to be increasingly inaccurate, in their assessments and prescribed management actions (Retief *et al.*, 2016).

Scenario analysis can be used to imagine possible futures in which different decision pathways are enacted. In an EIA process, scenario analysis would: (1) Provide insights into need and desirability based on changing trends over long-term time horizons, whether it be, for example, through climate change mitigation (reduced GHGs), adaptation (new desalination infrastructure) or socioeconomic impacts like skills and job creation; and (2) Define contextual change and future developments so that cumulative effects assessment can be more comprehensively undertaken within the scope of the EIA.

See Using Scenarios for Environmental, Nature and Spatial Planning Policy Guidance Document (Dammers, van't Klooster and de Wit, 2019) published by PBL Netherlands Environmental Assessment Agency, for more insights into how to use scenarios in processes like EIAs.

4.9.5 Ecological modelling

Ecological modelling entails the use of mathematical equations and algorithms to represent and simulate the interactions within and between ecosystems. An example of this type of modelling often used in South African EIAs is brine dispersion modelling, which could be necessary if a GH_2/PtX project proposed SWRO as a freshwater input, with brine released as waste into the marine environment (Lattemann and Höpner, 2008).

Other examples of ecological modelling in EIAs include: habitat suitability models (Oldeland *et al.*, 2023), landscape ecology models (Harker *et al.*, 2021), agent-based models (Gontier, Mörtberg and Balfors, 2010), climate change models (Jiricka-Pürrer *et al.*, 2018), GIS models (Gharehbaghi and Scott-Young, 2018), hydrological models, air emissions modelling, and several more.

The mathematical nature of ecological modelling allows for the quantification of processes and phenomena, making it possible to predict changes under various scenarios and to understand complex dynamics within the receiving environment, to a high degree of specificity. However, integrating the findings of ecological modelling into EIA can be challenging. The diversity and complexity of models which can be used, and the format of data produced, are not necessarily compatible with a uniform framework for interpretation.

Data availability and differences in quality pose challenges, with gaps and inconsistencies affecting outcomes. Furthermore, interdisciplinary integration necessitates communication among experts from various fields, often complicated by differing terminologies. There is also a shortage of professionals trained in both scientific and regulatory aspects of the various models, and therefore ongoing training and capacity building is needed. These challenges can add to the cost and time taken to complete EIA processes if not integrated skilfully.

4.9.6 Geographic Information Systems (GIS)

GIS is effective in representing the spatial extent of system elements, dynamics, and flows in a visually attractive way (Gharehbaghi and Scott-Young, 2018). GIS is particularly useful for communicating large amounts of overlayed information in a way that is easy to understand (Audouin and Sitas, 2020).

Typically, two or three elements are included in a composite map in an EIA, although more sophisticated and weighted overlay models are certainly possible, accounting for dozens of spatially explicit social and ecological elements. Bias towards information that can be spatially depicted and/or converted into spatial elements is the biggest challenge, plus the inherent subjectivity of determining overlay weightings. For this reason, weighted overlay models should be constructed transparently with interdisciplinary inputs from multiple stakeholders and specialists.

Geodesign is an innovative and integrative design approach that combines geography with design by utilizing GIS to aid in the design and planning process. It incorporates spatial analysis and data-driven insights into the design process, enabling planners, architects, and EAPs to simulate the impacts of their designs on the environment, social systems, and economic viability, integrating complex interactions within an ecosystem, urban area, or any geographic space. Geodesign could be used in EIAs. Geodesign's utility would be in it's ability to visualise data, to create design scenarios, enhance stakeholder engagement, and test proposed management actions (checking for conformance with regulatory requirements.

4.9.7 Life-cycle assessment (LCA)

Impact evaluation in EIAs typically comprise a qualitative analysis of the various aspects of a proposed project for potential social and ecological impacts. LCAs on the other hand provide a consolidated framework and a methodology to identify and quantify potential impacts on social and ecological systems, of entire life cycles of proposed products, processes, or systems. These life cycles include resource extraction, manufacturing, use, and end-of-life, in much more detail than would usually be considered in EIA (Rybaczewska-Blażejowska and Palekhov, 2018).

In the context of GH_2/PtX projects, this might include the analysis of social and environmental costs of project components such as wind turbines, PV cells, lithium batteries, RO membrane trains, and many others. LCAs have been tested in EIAs in a few case studies, but

Box 15: LCA of ammonia production at a coastal facility and utilised for heavy-duty transport in Germany

South Africa is a promising location for green ammonia production. However, the environmental implications are not yet fully understood. Furthermore, the carbon certification systems for GH_2 and green ammonia are still emerging and have discrepancies in how "green" is defined in terms of carbon intensity thresholds and where the boundaries are drawn within the supply chain for emissions counting. This LCA contributes to the discourse with it's findings contributing to the current development of a certification standard for GH_2/PtX in South Africa as part of an expert working group under the auspices of the Department of Forestry, Fisheries and the Environment (DFFE). To that end, the study also serves as a high-level reality check of the requirements and specifications that potential importers, such as the European Union and Germany, have set for green ammonia export as part of their regulatory framework.

this is not yet common (Larrey-Lassalle *et al*., 2017). LCAs could be used to provide information for comparing GH_2/PtX technology alternatives and mitigation measures (Finnveden *et al*., 2003), and would increase the level of detail and accuracy of EIA findings (Manuilova, Suebsiri and Wilson, 2009). In An innovative implementation of LCA within the EIA procedure: Lessons learned from two Wastewater Treatment Plant case studies, Larrey-Lassalle *et al*. (2017) offer a step-by-step procedure for how to integrate LCAs into the EIA process.

4.9.8 Network analysis

Network analysis is a group of techniques which can be used to assess relationships between social actors, providing insights into empirical indicators for how social structures are influenced by behaviours and attitudes (Hevey, 2018). Principles of network analysis are commonly used in EIAs, typically for graphical representation showing the relationships between system elements, activities, and impacts (Perdicoúlis and Glasson, 2012). Network analysis has also been used in EIAs to determine impact significance.

Methodologies to determine impact significance typically rely on judgments made by specialists based on the characteristics of the impacts. Network analysis, on the other hand, uses an understanding of how different, interconnected elements of a system cause and influence each other. In A Complex Network Approach to Environmental Impact Assessment, Martínez, Toro and J. León (2019) present a proposal for how network analysis could be adopted for determining impact significance, in a more objective, interdisciplinary, and unbiased fashion, compared to what is conventionally applied during an EIA.

4.9.9 Delphi techniques

Another tool sometimes used in EIAs to integrate diverse perspectives is the Delphi technique. This is a group decision-making method, through which the advice of a group of knowledge holders is solicited through a survey- type questionnaire in several iterations. Feedback is then provided to all participants on the statistical summaries of the responses, and this provides an opportunity for the panel to revise their opinions and reach consensus (Noble and Storey, 2001). The proportions of experts, stakeholders, and facilitators participating depends on the needs of the individual EIA, although a minimum of 10 participants is required, with closer to 20 being best. Delphi techniques could be integrated into EIAs during screening for the assessment of alternatives, or with specialists during the assessment phase, to determine impact significance. In either instance, the EAP would need to:

1. Select a panel: Gather a diverse group of experts with knowledge of the environmental, social, economic, and technical aspects of PtX projects.
2. Conduct an initial survey: Distribute an initial survey or questionnaire to the panel, focusing on the potential impacts of the project, including aspects like severity, extent, and duration, if the panel is used for significance assessment.
3. Analyse and share responses: Summarise and anonymise the responses to identify consensus and divergences. Share these findings with the panel for review.
4. Iterative feedback: Conduct successive rounds of surveys, refining questions based on feedback, aiming to narrow down the range of opinions and move towards a consensus.
5. Incorporation into EIA: Analyse the final round of feedback to assess and integrate the findings into the EIA report, used for guiding management actions and decision-making.

Delphi approaches can be statistically complex and require a certain degree of familiarity with software packages and data collection systems. If an EAP needs to bring on an independent Delphi facilitator to manage the interactions with the panel and subsequent analyses, this will add time and cost. Alternatively, for simpler Delphi setups, using Excel spreadsheets and email exchange would enable the EAP to manage the process themselves.

PART V:

Conclusions and policy-level recommendations

PART V: Conclusions and policy-level recommendations

If GH_2/PtX projects were to form a considerable component of the South African energy economy over the next few decades, the macro socioeconomic benefits could be substantial. Likewise, the local benefits across the entire value chain of GH_2/PtX production, storage, transportation via rail, pipelines, powerlines, roads, ports, and its potential end-uses, domestically and globally, could help to create new opportunities, jobs, and skills.

The technologies and infrastructure required to create the electricity and water inputs for a burgeoning GH_2/PtX economy, such as wind turbines and solar PV panels, seawater, and MWRO plants, plus the thousands of kilometres of linear transport infrastructure, are major infrastructure developments, with a complex array of social and ecological impacts. If undesirable impacts are not avoided in project planning and mitigated during operations, they could, individually or in accumulation, result in unacceptable consequences, which might undermine the substantial sustainability advantages offered by a PtX economy in the first instance.

This makes it necessary to both openly embrace the prospects of a large GH_2/PtX economy and supporting infrastructure, acknowledging its benefits when compared to the coal-based status quo, while at the same time remaining conscious of the risks and unknowns, and committing to stepwise, evidence-informed decision-making for the future development of GH_2/PtX projects. At the project-scale, achieving good decision-making will depend, by in large, on well executed EIAs, led by the contents of this Guideline.

Additionally, the authors provide the following policy-level recommendations, which might also assist to surface and better understand, at a strategic level, the opportunities and risks of a future South African GH_2/PtX economy.

5.1.1 Recommendation #1: Integrated, proactive decision-making

GH_2/PtX projects are being pursued by the private sector on an ad hoc basis, with a scramble for industrial land in close proximity to ports and a scramble to acquire renewable energy projects (wind and solar PV) across the landscape, with limited thought as to how transmission will need to be developed.

Developers find themselves wedged between having to rely on two parastatals – Eskom for transmission and Transnet National Ports Authority for export port facilities. Apart from this, hydrogen/ammonia export projects are likely to require similar port infrastructure to the gas-to-power projects that are being planned by the DMRE. In this context, it is suggested that the Government of South Africa adopt a more strategic approach to facilitating the development of GH_2/ammonia export projects.

This could include:

- Assessment of the industrial land requirements for the placement of electrolyser, ammonia production plants and desalination plants;
- Assessment of the location of renewable energy projects in relation to the placement of the electrolyser/ammonia plants at the port facilities;
- Assessment of the transmission lines required to transmit the power from the renewable energy projects to the electrolyser;
- Assessment of the berthing requirements for the export of ammonia within the various ports; and
- Assessment of the potential benefits of developing these projects in terms of fresh water supply to the adjacent communities i.e., oversizing the desalination plants to provide cost-effective desalinated fresh water.

These assessments should be initiated within the ambit of an integrated research campaign, championed by a ministerial task team, undertaken in collaboration with researchers from the public sector, private consultancies, and other interested stakeholders.

5.1.2 Recommendation # 2: The need for a South African SEA

One type of tool for providing guidance on these types of issues is a Strategic Environmental Assessment (SEA). SEAs are a systematic decision support process aimed at ensuring that environmental and other sustainability aspects are considered effectively in policy, plan, and programme making. In a broader sense, the purpose of an SEA is to integrate environmental and social considerations into strategic decision-making processes. To facilitate responsible decision-making on GH_2/PtX projects in the future at EIA-level, it is suggested a strategic-level, national scale SEA is undertaken for GH_2/PtX development in the country.

An SEA of this size would take around 24 months to complete and should focus spatially on one or several regional GH_2/PtX development hubs such as those proposed in the SIPs and around important South African SEZs. The study should consider all development aspects and activities associated with a South African GH_2/PtX economy, ranging from enabling upstream infrastructure (e.g., renewable energy and seawater reverse osmosis), to competing land uses (e.g., tourism, conservation, and agriculture), to socio-economic issues of poverty, employment, human migration, social fabric and service infrastructure, as well as exploring the links with adjacent industries, and provinces and countries also looking at GH_2/PtX development, e.g., Namibia.

SEAs should develop GH_2/PtX production and export scenarios, from which it would be possible to properly estimate macro and local socio-economic impacts, and potential changes to regional ecology. Based on factors such as resource availability, socio-economic, ecological, and infrastructure features, it would be possible to identify GH_2/PtX development zones where GH_2/PtX-related projects could be incentivised or streamlined. Additionally, it would be necessary to identify regions unsuitable for GH_2/PtX development activities based on the sensitivity of their social and ecological receiving environments.

5.1.3 Recommendation # 3: Future research on planetary boundaries

Additional sustainability work undertaken within the concept of planetary boundaries could also be considered (Rockström *et al*., 2023). Beyond potential climate change impacts, impacts on and potential transgression of the Safe Operating Space for other planetary boundaries could be considered, e.g., biogeochemical flows, freshwater and land system change, and biosphere integrity. GH_2/PtX production using renewable energy, as opposed to other forms of hydrogen production (e.g. blue hydrogen), may potentially limit adverse impacts to within the Safe Operating Space for at least the climate change boundary (Weidner, Tulus and Guillén-Gosálbez, 2023).

The full upstream supply chains and all side chains for production of components and inputs to GH_2/PtX plants and connected infrastructure, as well as all downstream outputs, including waste streams and emissions, should be considered for real or potential contributions to transgression of the Safe Operation Space of each of the planetary boundaries. A key consideration in project development is the risk of burden shifting from transgressing one planetary boundary, for example climate change, to another, for example biogeochemical cycles (D'Angelo *et al*., 2021). This is particularly pertinent in the case of possible GH_2/PtX production of ammonia and downstream mineral fertilizer, potentially impacting the nitrogen cycle via unmanaged emissions.

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