Environmental, Health, Safety, and Social Management of Green Hydrogen in Latin America and the Caribbean:

A scoping study

Energy Division

Environmental and Social Solutions Unit

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TECHNICAL NOTE Nº

IDB-TN-2554

April 2023

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Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Signoria, Chiara.
Environmental, health, safety, and social management of green hydrogen in Latin America and the Caribbean : a scoping study / Chiara Signoria, Marco Barlettani.
p. cm. — (IDB Technical Note; 2554)

Includes bibliographic references.
1. Hydrogen Industry-Environmental aspects-Latin America. 2. Hydrogen Industry-Environmental aspects-Caribbean Area. 3. Hydrogen Industry-Social aspects-Latin America. 4. Hydrogen Industry Social aspects-Caribbean Area. 5. Clean energy industries-Latin America. 6. Clean energy industries Caribbean Area. I. Barlettani, Marco. II. Inter-American Development Bank. Environmental and Social Solutions Unit. III. Series.

IDB-TN-2554

Keywords: Water, sanitation, science, technology, hydrogen market, regulation, environmental health and safety, value chain, energy.

JEL Codes: H2, L38, O22, Q2.

http://www.iadb.org

Environmental, Health, Safety, and Social Management of GREEN HYDROGEN in Latin America and the Caribbean: A Scoping Study

IDB

ENVIRONMENTAL, HEALTH, SAFETY, AND SOCIAL MANAGEMENT OF GREEN HYDROGEN IN LATIN AMERICA AND THE CARIBBEAN: A SCOPING STUDY

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Table of contents

List of figures

List of tables

Abbreviation	Definition
ABNT	Associação Brasileira de Normas Técnicas (Brasil)
ACGIH	American Conference of Governmental Industrial Hygienists
ADR	Agreement concerning the International Carriage of Dangerous Goods by Road (EU)
AEM	Anion Exchange Membrane
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CCS	Carbon Capture and Storage
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
COTIF	Convention concerning International Carriage by Rail (EU)
CSIS	Centre for Strategic and International Studies
CWA	Clean Water Act (USA)
DoE	Department of Energy (USA)
EBRD	European Bank for Reconstruction and Development
ECHA	European Chemical Agency
EERE	Office of Energy Efficiency and Renewable Energy (USA)
E&S	Environmental and Social
EHSS	Environmental, Health, Safety, and Social
ESF	Environmental and Social Framework
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Monitoring Plan
ETSI	European Telecommunications Standards Institute
EU	European Union

ESD	Electrostatic Discharge
ESS	Environmental and Social Standard
FVV	Flexible Fuel Vehicle
GH	Green Hydrogen
GIIP	Good International Industry Practice
GMA	Greater Metropolitan Area (Costa Rica)
GHG	Greenhouse Gases
GH	Green Hydrogen
GIIP	Good International Industry Practice
GM	Grievance Mechanism
HFTO	Hydrogen and Fuel Cell Technologies Office (USA)
IAEA	International Atomic Energy Agency
ICE	Costa Rican Electricity Institute
ICOMOS	International Council on Monuments and Sites
ICONTEC	Instituto Colombiano de Normas Técnicas y Certificación (Colombia)
IDB	Inter-American Development Bank
IFC	International Finance Corporation
IMI-SDG6	UN-Water Integrated Monitoring Initiative on SDG 6
INN	Instituto Nacional de Normalización (Chile)
IPCC	Intergovernmental Panel on Climate Change
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
IRAM	Instituto Argentino de Normalización y Certificación (Argentina)
IRENA	International Renewable Energy Agency
LAC	Latin America and the Caribbean
LCM	Low-carbon Methanol
LPM	Low-pressure Methanol
METI	Ministry of Economy, Trade, and Industry (Japan)
MIE	Minimum Ignition Energy
MoU	Memorandum of Understanding
NCRES	Non-Conventional Renewable Energy Source
NIOSH	National Institute for Occupational Safety & Health (USA)
NPDES	National Pollutant Discharge Elimination System (USA)
OHS	Occupational Health & Safety
OSHA	Occupational Safety and Health Administration (USA)
PADHI	Planning Advice for Developments near Hazardous Installations (UK)
PAP	Project-affected Person
PEM	Proton Exchange Membrane
PHA	Peruvian Hydrogen Association
POX	Partial Oxidation
PPE	Personal Protective Equipment
PS	Performance Standard
QRA	Quantitative Risk Assessment
R&D	Research and Development

RID	Regulations concerning the International Carriage of Dangerous Goods by Rail (EU)
RO	Reverse Osmosis
SESA	Strategic Environmental and Social Assessment
SEP	Stakeholder Engagement Plan
SMR	Steam Methane Reforming
SPREP	Secretariat of the Pacific Regional Environmental Program
SSF	Small-scale Fishery
STEL	Short-term Exposure Limit
TWA	Time-weighted Average
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environmental Program
UNESCO	United Nations Educational, Scientific, and Cultural Organization
WB	World Bank
WHO	World Health Organization
WEC	World Energy Council
WF	Water Footprint

01
Executive Summary

In 2015, at the 21st Conference of the Parties in Paris, 195 countries signed a legally binding agreement to engage in outlining and implementing national strategies to keep global warming *"well below 2°C above pre-industrial levels."* Achieving this target will require a monumental change in the way we use and consume materials and energy. Energy is one of the most carbon-intensive sectors, and green hydrogen – made from the electrolysis of water powered by renewable energy – is a key element in a viable global solution.

This study focuses on the following:

1. Analyzing the main risks, impacts, and mitigation measures of logistics activities related to green hydrogen: e.g., production, transportation, and storage of GH, and associated energy carriers, including ammonia and methanol
2. Summarizing, analyzing, and comparing international best practices on EHSS matters for hydrogen management
3. Analyzing the relation with the IDB's new Environmental and Social Policy Framework ("ESPF"), which was approved by the Bank in September 2020.

The analysis is related primarily to a sample of eight countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Panama, Trinidad and Tobago, and Uruguay, which are diversified in terms of national characteristics. All the sample countries have already made some steps toward developing a GH value chain.

The GH Value Chain

The GH value chain, from production to consumption, is composed of multiple elements interlinked with the wider energy sector, each with its own barriers, challenges, and risks:

- **The production of green hydrogen:** through water electrolysis fueled by electricity that is produced from renewable sources (typically solar and wind).

- **The transformation of hydrogen:** Hydrogen has a low energy density by volume. Larger volumes of hydrogen need to be moved to transport the same amount of energy. For this reason, hydrogen is treated to reduce its volume when being transported: it can either be compressed or liquefied, or further synthesized into other energy carriers such as ammonia, methane, methanol, liquid organic molecules, or liquid hydrocarbons, which have higher energy density.
- **The transport of hydrogen:** Hydrogen can be transported in a variety of ways, including by truck, ship, and pipeline. Transporting compressed hydrogen by truck is viable for short distances and for low volumes. For longer distances, hydrogen is usually transported in liquid form, at low temperature (-253°C).
- **The storage of hydrogen:** Hydrogen can be stored in steel or composite tanks, or in underground geological formations. Tanks of various sizes and pressures are already used in industry. Underground storage is possible in different types of reservoirs, but the most feasible at the moment are salt caverns, which are also used for fossil gas storage. Underground storage is more suited to large volumes and long timeframes (weeks to seasons).

The core of the system is the cell, where the electrochemical process takes place. At the electrode, the feed water is split into oxygen and hydrogen, with ions (typically H+ or OH-) crossing through a liquid or solid membrane electrolyte. The membrane or diaphragm between both electrodes is also responsible for keeping the produced gases (i.e., hydrogen and oxygen) separate, avoiding their mixture. The principle of water electrolysis is simple, yet it allows construction of different technological variations based on various physical, chemical, and electrochemical aspects. In theory, hydrogen production through electrolysis requires nine liters of water per kilogram of hydrogen. However, due to process inefficiencies, the ratio of typical water consumption ranges between 18 kg and 24 kg of water per kilogram of hydrogen. Deionized water can also be produced through desalination of seawater or brackish water. Direct use of seawater in electrolysis currently leads to corrosive damage and to the production of chlorine, but research is being conducted to determine how to make seawater's use in electrolysis easier.

Two outputs are obtained from the desalination process: i.e., demineralized water and residual water, known as brine, which represents the main element of concern in terms of potential environmental risks and impacts.

Hydrogen generated from the electrolyser comes in gaseous form, conventionally from atmospheric pressure to 30 bar, although higher pressures are also possible. To facilitate hydrogen transport, a lower volume is needed, which implies the need for either:

- **Increasing the pressure**
- **Liquefying the gas**
- **Or converting it to ammonia, methanol, or other substances.**

While handling hydrogen, it should be remembered that hydrogen is a hazardous substance. Despite this, it is not toxic and is 14 times lighter than air and 57 times lighter than gasoline vapor. This means that when released in gaseous form, hydrogen will typically rise and disperse rapidly, greatly reducing the risk of ignition at ground level. Hydrogen also has a lower radiant heat than conventional gasoline and LNG, meaning that (i) the overall heat flux from a fire is lower, and (ii) the risk of secondary fires ignited by hydrogen (domino effect) is also lower.

Points of concern include flammability limits that are more expansive than most hydrocarbons, and that the minimum ignition energy ("MIE") of a hydrogen–air mixture is only 0.019 mJ; whereas other flammable gases – such as petrol, methane, ethane, propane, butane, and benzene – have a MIE on the order of 0.1 mJ. Thus, once hydrogen is released into the atmosphere, its ignition is highly probable if it is not dispersed. Finally, hydrogen is colorless and odorless, and its storage is problematic, because for its efficient storage and transportation, high pressure vessels or cryogenic vessels held at very low temperature are necessary, and hydrogen can embrittle the steel of containment vessels.

On the list of hydrogen carrier candidates, ammonia is unique in that the non-hydrogen part of the molecule (i.e., nitrogen) has no carbon. Many studies confirm the sustainability of ammonia production, and they mainly focus on water needs. Based on available information, water demand is ca. 9 kg of treated water and ca. 20 kg overall to produce 1 kg of green hydrogen. Considering not significant the consumption of treated water in an ammonia plant fed by GH, the water demand is 1.6 liters per kg of ammonia. This figure appears comparable with data in the literature related to water demand of an ammonia plant with natural gas reforming. If these data are confirmed by further studies, this implies that the overall water consumption for ammonia production is similar in facilities fed by GH and facilities provided with a natural gas steam reformer.

Ammonia can be transported by truck, rail, or ship, either compressed or liquefied, at conditions (pressure or temperature) and costs much more favorable than those of pure hydrogen. The drawback of ammonia is that it is a toxic gas.

GH can also be fed to plants for the production of methanol, which can be used directly as a fuel for road or sea vehicles. Though the taxonomy remains somewhat undefined, the production of more environmentally friendly methanol can be further distinguished as:

- **Low-carbon methanol ("LCM"):** produced from natural gas or other fossil fuel by adding CO2 from other industrial facilities
- **Bio methanol:** produced from organic feedstock
- **Renewable methanol:** produced from carbon dioxide and green hydrogen from renewable electricity. The source of CO2 can be the atmosphere, biogas, or flue gases from cement and steel industries.

Methanol is a liquid hydrocarbon, flammable, readily degraded in the environment by photooxidation and biodegradation processes, under both aerobic and anaerobic conditions in a broad spectrum of environmental media, including fresh and salt water, sediments and soils, ground water, aquifer material, and industrial wastewater.

Finally, hydrogen can also be utilized to produce carbon-neutral fuels, with CO2 as a raw material to source carbon:

- In the so-called e-fuels, CO2 is directly captured from the air, recycled from industrial flue exhaust gas, or derived from carbonic acid in seawater.
- In synthetic biofuels CO2 is generated through chemical or thermal treatment of biomass or waste.

However, power-to-e-fuel utilized in diesel/turbine engines offers low performance efficiency due to energy losses in electrolysis, synthesis, and in the internal combustion engine. This inefficiency means that around five times more sustainable electricity would be required to make the e-fuel diesel move a vehicle, than that needed to move the same vehicle using an electric motor. Thus, synthetic e-fuels and biofuels are more competitive in modes of transport where electricity or other alternatives cannot be easily used. One of the most promising sectors for e-fuels is the production of jet fuels.

GH National Strategies

Within the framework of this study, we reviewed the national hydrogen or GH strategies developed both at the global level and in LAC, including those developed, announced, or under development, in Chile, Brazil, Colombia, Uruguay, Panama, Peru, Trinidad and Tobago, Costa Rica, and Argentina.

Main points of interest related to hydrogen strategies that have been developed so far in the LAC region include:

- Both domestic uses and export options of GH are considered within the analyzed strategies. As an example, Peru's national strategy includes the assessment of potential hydrogen applications at small-scale, focusing on communities with limited access to energy in order to develop greater energy resilience across the country, and to provide assistance to communities equipped with isolated power systems. In other cases, GH strategies include development of large-scale, nationwide projects that can change the profile of the whole country (e.g., the H2UB plan in Panama).
- Most strategies identify the need for preliminary siting and land use planning for the development of GH projects. Local authorities are encouraged to identify suitable sites for GH initiatives in the Master Plan development phase, also taking into consideration the need to establish buffer zones separating industrial hazard facilities from residential and/or commercial areas.
- Some hydrogen strategies analyzed for this study intend to simplify permitting procedures for construction and operation of GH-related plants, including ESIA processes. At the same time, other strategies highlight the need to complete SESAs during the identification phase to identify suitable sites for GH initiatives, as referred to in the previous point.
- Most strategies highlight the need to assess water demand of GH electrolysers and potential induced water stress on local communities and ecosystems. The development and implementation of desalination technologies, that make use of seawater rather than fresh water, are encouraged.
- All hydrogen strategies encourage the development of technical (safety) standards. Current standards regulating the use of hydrogen as a hazardous substance are not designed for application to hydrogen used as an energy vector.
- Most strategies encourage awareness-raising campaigns among public authorities, workers, and local populations, addressing both promotional aspects (e.g., environmental benefits linked to GH use) and safety aspects (e.g., differences between physical characteristics of methane and hydrogen).

- Stakeholder engagement is considered crucial for quick and efficient development of the GH value chain, with extensive involvement of all interested parties commencing in the early stages of development.

Some strategies include the recommendation to conduct studies to determine the potential geological storage capacity of H2 (and CO2). The large-scale geological storage of hydrogen would make it possible to have large seasonal renewable energy reserves, which would help mitigate the impact of weather-related events such as El Niño or La Niña.

Further unique aspects identified in some strategies include the need to establish a common taxonomy (for example, distinguishing green and blue hydrogen based on their respective CO2 emissions) and designing a system of hydrogen guarantees and certifications of origin.

Regarding strategies developed by countries outside LAC, an interesting point of the EU strategy is the concern related to the hydrogen supply chain. Europe is fully dependent on the supply of 19 raw materials (out of 29) relevant to the production of fuel cells and electrolyser technologies (e.g., the platinum group metals).

Case Studies

A sample of diversified GH projects have been analysed within the framework of this study. The selection of the sample is based on the intention to show different types of projects, drivers for different solutions, and potential environmental and social implications. Some identified aspects relevant to the scope of work of this document include:

- Green hydrogen projects span from distributed and small-size production facilities to huge projects. Both greenfield and brownfield initiatives are under development, with different implications in terms of potential environmental and social aspects. Huge greenfield developments may change the socioeconomic characteristics of a vast area, while other projects, such as those related to initiatives for distributed hydrogen production for mobility, have a completely different socioeconomic pattern.
- Optimization of GH production systems' efficiency in medium-size projects completed by industrial developers within already industrialized/developed areas, is most often pursued through the definition of site-specific designs, in some cases with commercialization of oxygen, generated in the electrolyser as a by-product and normally damped into the atmosphere. Utility companies already active in power or gas sectors, seem more intent to increase efficiency of GH greenfield projects, increasing projects' scale, often developed in pristine areas.
- A single "GH initiative" may be composed of different sub-projects, differentiated in terms of technical characteristics and socioeconomic implications (e.g., wind farm, electrolyser, ammonia conversion plant, etc.). The national permitting process for more complex projects is still being defined: while in some cases, a single permitting EIA procedure is adopted for the entire value chain of a project (renewables, electrolyser, conversion/delivering facilities), in other cases, permitting is completed separately for different parts of the project. Sub-projects may be developed by separate entities at separate times.

- Land use for a medium-size electrolyser is limited and does not require more land than that typically required for medium-size industrial facilities; however, land use may become very significant in the case of development of multi-GW factories, with ammonia or methanol conversion included.

Regulatory Framework and GIIP

This Regulatory Framework Review ("RFR") provides information on mandatory regulations as well as best practices and guidelines relevant to the scope of work of this document:

- Regulations and guidelines related to permitting of facilities within national regulations, focusing on the processes in place for Environmental/Social Impact Assessment and Strategic Impact Assessment
- Regulations and guidelines to ensure process safety and the safety of communities located near industrial facilities
- Regulations and guidelines related to safety during transportation
- The standard of reference related to freshwater management, with reference to potential impacts that may be generated by water demand additionality created by GH technology
- The standard of reference for brine discharge and management, with reference to potential impacts generated by saltwater use (as an alternative to freshwater) to feed electrolysers.

Considerations Related to ESIAs and SESAs

According to IDB's 2016 *Good Practices in Environment, Health, and Safety in Latin America and the Caribbean* (33), national regulatory frameworks tend to be license-intensive, with Environmental and Social Impact Assessments ("ESIAs" or "EIAs" including under the label "environment" all aspects from biophysical to cultural and socioeconomic) acting as the basis for environmental permitting of a project.

However, for proper management of complex projects like those typically required to produce GH, an institutional and technical approach may be necessary, such as the Strategic Environmental and Social Assessment ("SESA" or "SEA") for plans and programs, as also outlined in some of the national strategies for GH development (e.g., the Chilean plan).

Documents reviewed for this study include:

- International documents
    - o UNECE SEA Protocol
    - o OECD Good Practice Guidance for Development Cooperation
    - o WB document Strategic Environmental Assessment in Policy and Sector Reform: Conceptual Model and Operational Guidance
    - o SEA Regulation in Europe (Directive 2001/42/EC on the assessment of effects of certain plans and programs on the environment)
    - o SPREP Guidelines for SEA in Pacific Islands and Territories

- The analysis of the relevant regulations in:
  - o Chile
  - o Colombia
  - o Argentina

In 2015, EBRD (in collaboration with IFC, IDB, and others) published *Good Practices for Biodiversity Inclusive Impact Assessment and Management Planning*. The document is relevant as a benchmark for the definition of a technical approach for the holistic undertaking of impact assessment in complex projects like the ones underpinning the development of a GH value chain.

The landscape of domestic regulations related to SESA in LAC appears not well consolidated and is quite fragmented across the region. However, the content of existing regulations appears substantially aligned with the relevant EU regulation, one of the first published at a global level on the subject.

Some international standards reviewed for this study appear to be more focused on social aspects than national regulations. For example, the "institution-centered approach" promoted by the World Bank (within the *Strategic Environmental Assessment in Policy and Sector Reform: Conceptual Model and Operational Guidance)* focuses on the role of institutions while performing a SESA. In addition to this, other key aspects of the process include: (i) understanding the policy process, (ii) identifying environmental priorities, (iii) strengthening stakeholder representation, (iv) analyzing and strengthening institutional capacities, (v) analyzing and mitigating institutional constraints, (vi) strengthening social accountability, (vii) and ensuring social learning.

The European regulation is the only one that explicitly mentions the need to assess impacts of plans and programs by considering incidental situations.

While the WB standard stresses the importance of adjusting the actual application of the institution-centred SESA for a certain policy/sector to the specific context, none of the national regulations reviewed for the study (neither at a global level or in the LAC region) appear to be tailored also to consider the characteristics of the jurisdiction's territory. Only the 2020 guidelines prepared by the Secretariat of the Pacific Regional Environment Program ("SPREP") represent an exception.

Process safety

Safety is among the main concerns of public authorities and citizens with respect to the use of hydrogen. Some incidents that occurred in the past century reinforce the perception that hydrogen is a high-risk substance.

The following international regulations on process and community safety were reviewed for this study:

- The ILO convention no.174 of 1993 on the Prevention of Major Industrial Accidents Convention and related recommendation No. 181

- The USA regulation, including the framework regulation, technical guidelines and risk acceptability criteria (in detail: the OSHA Process Safety Management of Highly Hazardous Chemicals Regulation – PSM; the EPA requirements for Risk Management Plan – RMP currently under the umbrella of the Clean Air Act; and related technical guidelines, specifically the 40 CFR PART 68)
- The EU Directive 2012/18/EU (also known as the Seveso Directive) and modalities adopted by member countries for its transposition within national regulations.

At the global level, existing high-level regulations for process safety in place in different jurisdictions are rather aligned, all of them substantially designed to include provisions set out by the 1993 ILO Convention on the Prevention of Major Incidents and Related Recommendations. Aside from executive details and some peculiarities related to geography, the regulatory background, and period in which they are issued, regulations in place both in the USA and Europe are substantially aligned with the ILO' Convention's overarching principles. In LAC, six of the eight countries of interest within the scope of this report have not yet ratified the ILO convention on the prevention of major accidents: Argentina, Chile, Costa Rica, Panama, Trinidad and Tobago, and Uruguay.

At a lower and more practical level, the ILO Complementary Practical Guidance to C174 offers recommendations for the implementation of the Convention, including the following ones that are of specific interest to the present study:

- Competent authorities should establish a land-use policy to separate, where appropriate, major hazard installations from people living or working nearby. Consistent with this policy, competent authorities should make specific arrangements to prevent population encroachment near existing major hazard installations.
- The off-site emergency plan should be the responsibility of the local authority and management bodies in charge of the works, depending on local arrangements. Where a major accident could result in a major spill or environmental harm requiring attention and investigation, the emergency planning officer should identify those authorities who will carry out these tasks and inform them, as appropriate, of their role in the off-site plan.
- Following a major accident, health authorities, including doctors, surgeons, hospitals, poison centers, and ambulances, should have a vital role. Where accidents with off-site consequences may require medical equipment and facilities additional to those available in the area, health authorities should arrange a "mutual aid" scheme to allow for assistance of neighboring authorities.

While framework acts in place at the national level in different continents are rather aligned with the ILO convention mentioned in the paragraph above, national technical guidelines issued by different governments are rather diversified and not always aligned with the ILO recommendation of reference. Even guidelines issued by entities that fall within a common overarching jurisdiction (i.e., countries within the EU, states in the U.S., or states or in the Brazilian confederation) are often substantially different.

It is worth mentioning that based on the European Commission, such different approaches are not reconcilable, grounded and guided as they are by historic and social values unique to each country. Relevant aspects of differentiation among guidelines in place in different countries include:

- Some technical guidelines do not explicitly refer to the concept of risk and simply establish methods for assessment of the maximum distance of hazards from facilities handling dangerous goods, based on a tabular or simplified approach.
- Some other technical guidelines (as a significant example, the regulation in place in the state of São Paulo in Brazil) require owners of plants of concern to perform a complete Quantitative Risk Assessment ("QRA") and assess individual and societal risk generated by plant operation. However, with reference to criteria for risk acceptability for human beings, while the individual tolerable fatality risk is the same in all reviewed jurisdictions (tolerable: < 10-6 y-1; not tolerable 10-5 y-1), the tolerable societal risk is specific within different jurisdictions.
- Environmental acceptability risk is not defined.

Safety in transportation

At the global level, the overarching reference document for the transportation of dangerous goods is represented by the *UN Recommendations on the Transport of Dangerous Goods*, addressed to governments and international organizations concerned with safety in the transport of dangerous goods. The first version dates to 1956; the most recent amendment was made in 2019.

UNECE countries (that do not include those in the LAC region) issued separate protocols, among which it is relevant to mention the 1957 UNECE *Agreement concerning the International Carriage of Dangerous Goods by Road* ("ADR"), which went into effect on January 29, 1968. The agreement was amended in 1975 (with amendment provisions entering into effect in 1985).

Within the LAC region, there exists a trade protocol among Argentina, Brazil, Paraguay, Uruguay, Venezuela, Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, and Suriname[1] called Mercosur (in Spanish), Mercosul (in Portuguese), or Ñemby Ñemuha (in Guarani). It is officially regarded as a Southern Common Market, established by the Treaty of Asunción in 1991 and the Protocol of Ouro Preto in 1994.

Mercosur countries signed the Agreement on the Transport of Dangerous Goods in Mercosur in 1994. The agreement states that the transport of dangerous goods must be carried out under rules that guarantee safety of people, their property, and the environment, and that is necessary to have a common legal framework for distribution across the region of goods considered dangerous, which must be transported safely for people, their goods, and the environment. The agreement is not signed by countries that are not part of the trade protocol.

1 Argentina, Brazil, Paraguay, and Uruguay are full members. Venezuela is a full member but has been suspended since 01/12/2016. Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, and Suriname are associate countries. Other Latin American nations have expressed interest in joining the group.

Regardless of the delivery or shipping modalities of hazardous substances, the literature analysed during this study related to safety in transportation of hazardous substances consistently highlights that safety can be increased through:

- Strict compliance with existing rules related to certification and verification of vehicles
- Strict compliance with existing rules related to loading/unloading modalities and transportation (including labelling and signaling)
- Operator training (including emergency management training)
- Establishment of robust control agencies.

Freshwater Supply

A detailed review of international best practices and active LAC regulations related to freshwater management is included in the IDB document *The Regulation of Public Utilities of the Future in Latin America and the Caribbean*. It should be highlighted that neither the mentioned document nor other papers reviewed within the framework of this study offer quantitative indications of the amount of water abstraction that can be considered sustainable, as a matter of example in terms of percentage of water withdrawal compared to available renewable resource.

Brine Management and Discharge

The use of deionized water produced by desalination plants may reduce freshwater demand and generate the need to discharge into the environment a stream of brìne.

Current LAC legislation regulating both plant operation and wastewater discharge is non-specific. Nevertheless, research on environmental consequences of brine discharge is active in the region especially in Chile, one of the most advanced countries in GH technology. Cornejo-Ponce et al. in their paper *Analysis of Chilean legal regime for brine obtained from desalination processes* (2020) analyze the national regulatory regimes in countries that are among the main producers of desalinated water and that give rise to regulations governing brine disposal. The paper concludes that *"although progress has been made in regulating water quality, there is still no legislation that sets critical limits for the chemical components or physical properties of brine with special regard to the habitats and species that can be found and are likely to be affected."* Nonetheless, existing standards are normally referred to both:

- emission limits at the discharge point
- environmental concentrations at a certain distance from discharge (the point of compliance).

General Guidelines for Management of EHSS Aspects

International guidelines issued by IDD, WB/IFC, EBRD, ISO, GRI have been reviewed for this study. Existing guidelines appear to provide environmental standards and KPIs for most activities included in the green hydrogen value chain: i.e., power generation, power transmission, gas transmission and distribution in piping, ammonia production, port construction, and shipping. However:

- A standard specifically related to hydrogen electrolysers is not available.
- The standard related to gas distribution systems clearly refers to natural gas distribution and does not cover specific issues related to hydrogen distribution.

In terms of a technical standard, global R&D efforts seem focused on the following topics (among others):

- "Holistic" design strategies for development of inherently safer systems
- Embrittlement of metals generated by hydrogen
- Hydrogen sensors and hydrogen odorizing
- Hydrogen permeation through sealing
- Structural materials suitable for use at hydrogen's low liquefaction temperature
- Test measurement protocols and methods for materials, components, and systems (development, validation, and harmonization).

Scoping and Preliminary Considerations for a Sectoral Guideline

To derive preliminary considerations for a future GH sectoral standard, Anthesis carried out a scoping that included:

- An initial high-level desktop review of relevant materials (i.e., international guidelines and standards, relevant case studies, available policies and programs, etc.)
- Engagement of IDB specialists over regular update calls
- The organization of a brainstorming activity involving Anthesis' project experts.

This section presents some considerations relevant to the preparation of a GH sectoral guideline, considering elements mentioned above.

Initiatives potentially included in the GH value chain are very diversified and may include (non-exhaustive list):

- Greenfield-integrated developments, potentially including renewable farms, transmission lines, electrolysers, conversion units to ammonia/methanol, and shipping facilities
- Brownfield large- or medium-size developments in existing industrial areas, most often where GH (and eventually the by-product, oxygen) is utilized in existing units for power generation, or steel or ammonia/fertilizers production

- Medium-/small-size projects or distributed projects to produce hydrogen for mobility
- Projects that include hydrogen transmission pipelines or distribution systems.

This diversification of projects potentially included in the GH value chain is much wider than the diversification among facilities within the field of application of existing IDB or IFC sectoral guidelines, e.g., facilities covered by guidelines in the refining sector, conventional fossil fuel power production, or bulk inorganic and fertilizer production (that also cover ammonia production). Preparation of a single sectoral guideline that covers all different types of projects potentially within the GH value chain may be challenging, and defining the exact field of application of guidelines is recommended.

Another concern is that large-scale projects are composed of different sub-projects (like solar/wind farms, transmission lines, electrolysers, ammonia or methanol units, port facilities, and the gas network, which may be covered by existing guidelines). Different components of the whole project may be developed by separate entities at separate times. Cumulative and overall impacts of the whole project cannot be derived through juxtaposition each component's impacts. Siting of privately-owned projects may be conditioned by development plans and programs prepared by central or local governments. In these circumstances, an ESIA completed with reference to a single part of the project will likely not capture in full the entire project's social and environmental relevance. It is thus recommended to complete the assessment of environmental and social consequences of a project in an early phase, using a holistic approach, and is further recommended that a SESA be prepared during the project planning phase. Assessment of potential effects on both natural and human ecosystems is encouraged.

Finally, a third general consideration is that the GH value chain include both project components:

- not already addressed within WB/IDB EHS international standards, nor within technical reference documents, such as the European Union BAT Reference Document; and
- already addressed in WB/IDB EHS international standards and/or in technical reference documents.

To avoid duplications, such guidelines may be referenced within the sectorial guideline on GH that shall also include integrations and coordination directives as needed, without encompassing their full contents. Developing a GH sectoral guideline in the form of an overarching document should aim to:

- Provide indications on how to manage risks of large-scale (or even nationwide) projects in the concept, siting, or preliminary planning phase, using a high-level and holistic approach, to be managed with a SESA
- Set provisions for project components not already addressed by existing EHS guidelines, mainly the electrolyser
- Coordinate provisions related to different project components already addressed in existing EHS guidelines.

Any type of environmental or social risk, when not managed properly, may become significant at the project level. However, it is the authors' opinion that some risks are so unique to the GH value chain or linked to it in the public perception, that mismanagement or actual incidents related to this type of risk in just one project may generate confusion about or an actual opposition to the technology in full. It is therefore crucial to reduce these risks even below the level that would be acceptable as assessed by comparisons of risk and the cost to control it.

Among the most challenging EHS aspects to be controlled within the GH value chain, specific attention should focus on:

- Land use and land use fragmentation
- Water and wastewater/brine management; and
- Process and community safety.

Development of large-scale scale wind/solar farms, potentially in pristine areas, may induce fragmentation of territories and changes in overall structure of land ownership of vast areas, as well as environmental and social impacts.

When not avoidable, freshwater demand for electrolysers can be studied, and sustainability of impacts assessed, with existing tools specifically developed for analysis of shared uses of the resource, developed by IDB or other institutions. However, the best mitigation is to make use of seawater instead of freshwater. This raises concerns about wastewater and brine discharge.

Brine management is a typical environmental aspect: aside from its peculiarities when related to a specific industrial sector, it can be managed with an approach similar to the one already included in existing EHS guidelines: i.e., fixing emission limits and permitted environmental concentrations at a certain distance from discharge (the point of compliance). The regulatory review carried out within the framework of this study identified some reference values than can be used in preparation of the guideline, tailoring allowed environmental concentrations to the region's specific ecosystems.

Safety management in the GH value chain may imply actions at different levels, depending on guideline's application, as discussed above.

In the planning phase, a high-level approach shall be implemented, with identification of sites suitable for installation of facilities potentially capable of originating major incidents. In this phase, the role of authorities in charge of land use planning is crucial. Proper buffer zones shall be designed and enforced.
In the phases of designing, constructing, and operating facilities, the development of state-of-the-art Safety Management Systems is crucial, and QRA and BAT gap analysis are considered the best tools for safety management. Basic safety management principles are already included in high-level and rather dated ILO conventions and recommendations on prevention of major incidents; these conventions are still in effect. Most countries of the region are not signatories of such conventions, but sectoral guidelines may encourage compliance with such principles even when they are not strictly required by domestic regulation.

In cases where application of guidelines also includes hydrogen transportation and gas distribution systems, the following aspects should be incorporated in the guideline:

- Implementation of strict procedures for design, testing, maintenance, and periodic verification of vehicles and infrastructure and driver and operator training
- Conducting awareness campaigns and stakeholder engagement on hydrogen safety among end users, operators, authorities, and any other relevant stakeholder.

Finally, the authors want to highlight that in Europe and in most developed countries, there is not enough renewable generation capacity to satisfy the demand for electric power and GH generation. GH demand is indeed the driver for development of large scale projects in LAC, Africa, and Asia. However, the export of GH from emerging countries (and other countries) cannot be achieved at the cost of impeding countries of origin from achieving their own decarbonization targets.

Further relevant topics identified within the framework of this study, with reference to the IDB ESPS, are summarized below in a tabular format.

It is clear that at a high level, GH may ensure significant economic and social development in the region. More specific opportunities sectoral guidelines might incorporate include:

- Capacity-building of entities and agencies in charge of safety. Financing from project sponsors of national agencies aimed to control safety may be considered, taking into account the proper management of conflicts of interest.
- Capacity-building of entities and agencies in charge of water management. Construction of desalination plants may envisage the use of produced water for different final uses (GH production, potable uses, etc.). This may fit well within the current trend in LAC to move toward water management via the mixed enterprise model, a joint venture between public and private sectors.

02
Introduction

At present, the worldwide supply chain for green hydrogen is minimal, and its use is limited to a few projects. However, significant development of new initiatives is underway. It is within this horizon that IDB's Infrastructure and Energy Department[2], in pursuing its objective of supporting development in an environmentally and socially sustainable manner through financial and technical support to Latin America and the Caribbean ("LAC"), is developing an EHSS management study on green hydrogen development within the region.

2.1. The Context

This study focuses on the **main risks, impacts, and mitigation measures of logistic activities related to green hydrogen, transportation, and storage, or for associated energy carriers,** such as ammonia and methanol.

At the 21st Conference of the Parties in Paris in 2015, 195 countries signed a legally binding agreement to engage in outlining and implementing national strategies to keep global warming *"well below 2°C above pre-industrial levels."*

Achieving this target will require a monumental change in the way we use and consume materials and energy. Energy is one of the most carbon-intensive sectors, both globally and in many countries across the world (see Figure 2.1).

2 Mining, Geothermal and Hydrocarbon Cluster ("MGH"), in conjunction with the Environmental and Social Solutions Unit ("VPS/ESG")

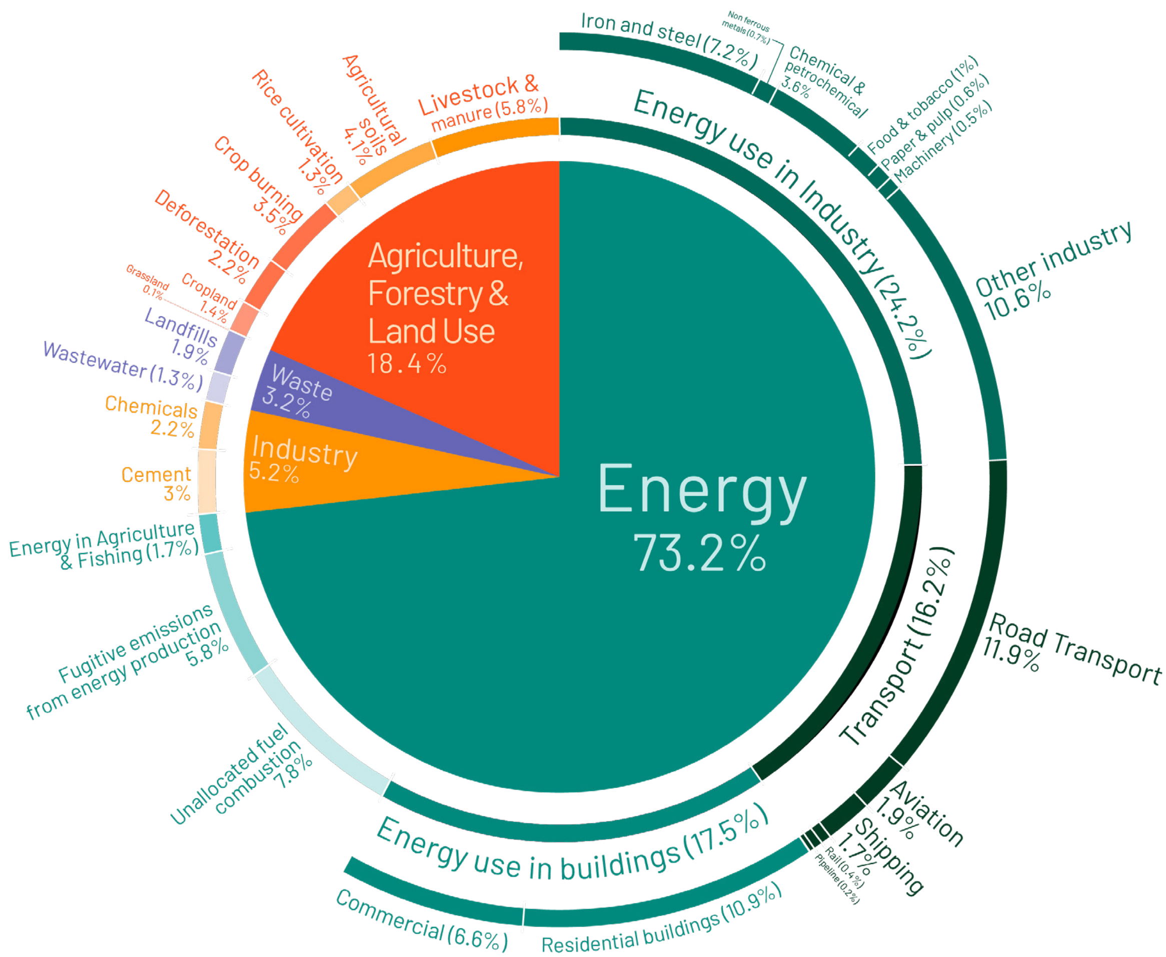


Figure 2-1 Global GHG emissions by sector in 2016, 49.9 billion tons CO2eq (Source: (1))

There is no single technological advancement or energy vector that can tackle this issue. However, green hydrogen – made from the electrolysis of water, powered by renewable energy – is a crucial component of a viable global solution.

The GH value chain (of which a visual representation is available at Figure 2.2, below), from production to consumption, is composed of multiple elements interlinked with the wider energy sector, each with its own barriers, challenges, and risks:

- **The production of green hydrogen:** through water electrolysis fueled by electricity produced from renewable sources (typically solar and wind).
- **The transformation of hydrogen:** Hydrogen has a low energy density by volume. Larger volumes of hydrogen need to be moved to transport the same amount of energy. For this reason, hydrogen is treated to reduce its volume when being transported: it can either be compressed or liquefied, or further synthesized into other energy carriers, such as ammonia, methane, methanol, liquid organic molecules, or liquid hydrocarbons, which have higher energy density and can be transported using existing infrastructure.

- **The transport of hydrogen:** Hydrogen can be transported in a variety of ways, including by truck, ship, and pipeline. Transporting compressed hydrogen by truck is viable for short distances and for low volumes. Hydrogen is usually transported in liquid form, at low temperature (-253°C), for longer distances.
- **The storage of hydrogen:** Hydrogen can be stored in steel or composite tanks, or in underground geological formations. Tanks of various sizes and pressures are already used in the industry. Underground storage is possible in different types of reservoirs, but the most feasible are salt caverns, which are also used for fossil gas storage. Underground storage is more suited to large volumes and long timeframes (weeks to seasons).

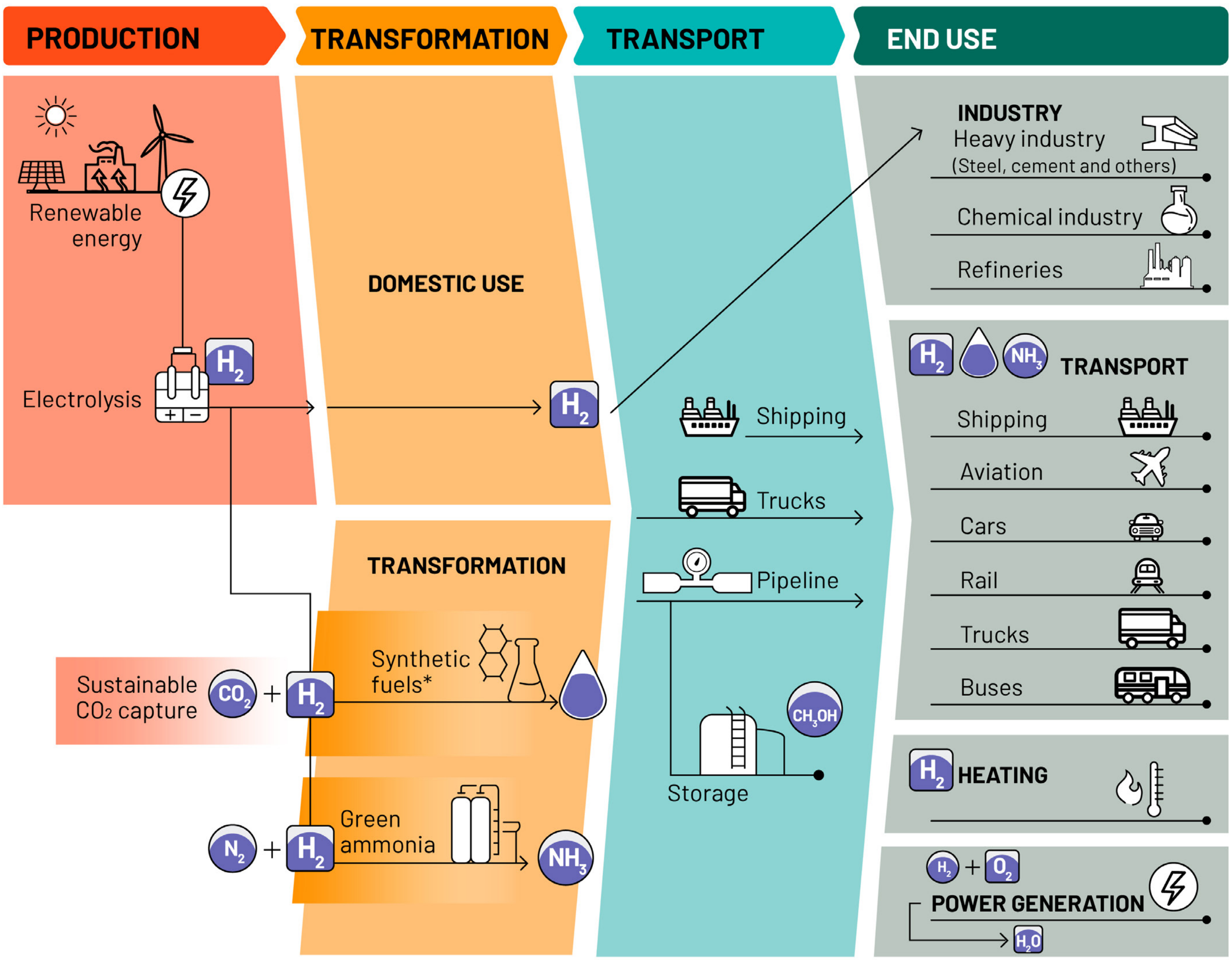


Figure 2-2 Green hydrogen production, conversion, and end uses across the energy system (Source: (2))

2.2. Scope of This Report

This study analyzes the development of a green hydrogen value chain in the LAC region, focusing on the following main aspects:

- Analyzing the main risks, impacts, and mitigation measures of logistics activities related to green hydrogen: e.g., production, transportation, and storage of GH and associated energy carriers, including ammonia and methanol
- Summarizing, analyzing, and comparing international best practices on EHSS matters for hydrogen management
- Analyzing the relationship with the IDB's Environmental and Social Policy Framework ("ESPF") that was approved by the Bank in September 2020.

The analysis focuses on eight countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Panama, Trinidad and Tobago, and Uruguay.

All countries selected for the project have already taken some steps in the direction of developing a GH value chain. Any progress in one or more of the indicators of the Hydrogen Economy Index has been considered the prerequisite necessary to be admitted into the sample. Such indicators, developed by New Energy and Hinicio (3) to easily quantify and track development of hydrogen within the LAC region, are:

- Presence and extent of public policies, incentives, and regulations
- The structuring of "Hydrogen Ecosystems" at national level
- Presence of projects already operating or in the planning stage
- Hydrogen mobility (e.g., number of vehicles, refilling stations, etc.)
- Exports and international cooperation landscapes.

This report does not include EHSS management of renewable energy plants (either onshore or offshore), as these are already a well-known and regulated feature of the value chain. Environmental and social aspects of renewables are considered only with reference to unique aspects when they are part of the GH supply chain.

2.3. Structure of This Report

The report is structured as follows:

- Section 3: Provides a brief technical introduction to the GH value chain and the physical - chemical characteristics of substances of concern (hydrogen, ammonia, methanol, further hydrogen derivates)

- Section 4: Comments on national strategies for GH value chain development issued by governments of LAC countries and other countries of reference
- Section 5: Presents some GH projects with comments on their more unique EHSS aspects
- Section 6: Offers Regulatory review, completed at a global and regional level, on matters relevant to the scope of this report
- Section 7: Includes the identification of the most significant EHSS topics related to the GH value chain
- Section 8: Provides an assessment that elaborates on topics identified within Section 7, and provides suggestions/indications for the preparation of a EHSS guideline related to GH
- Section 9: Offers conclusions and final comments.

ERM Dolphyn Project, with offshore wind farms and GH electrolysers in the UK

Credit: ERM Worldwide Limited. ERM Patented Technology

03

The GH Supply Chain

3.1. Hydrogen Production

Based on what was reported in the International Renewable Energy Agency ("IRENA") 2020 Report *Green hydrogen cost reduction* (4), water electrolysers are electrochemical devices used to split water molecules into hydrogen and oxygen by passage of an electrical current.

The description and analysis of an electrolyser consists of three different levels (see Figure 3-1, below):

- **The cell.** The cell is the core of the electrolyser, and it is where the electrochemical process occurs. At the electrode, water is split into oxygen and hydrogen, with ions (typically H+ or OH-) crossing through a liquid or solid membrane electrolyte. The membrane or diaphragm between both electrodes is also responsible for keeping the produced gases (i.e., hydrogen and oxygen) separate and avoiding their mixture.
- **The stack.** The stack level includes multiple cells connected in series and related frames (providing mechanical support) and ancillary items.
- **The system (or balance of plant).** It goes beyond the stack to include equipment for processing hydrogen, treating water supplied to the electrolyser, and auxiliary activities.

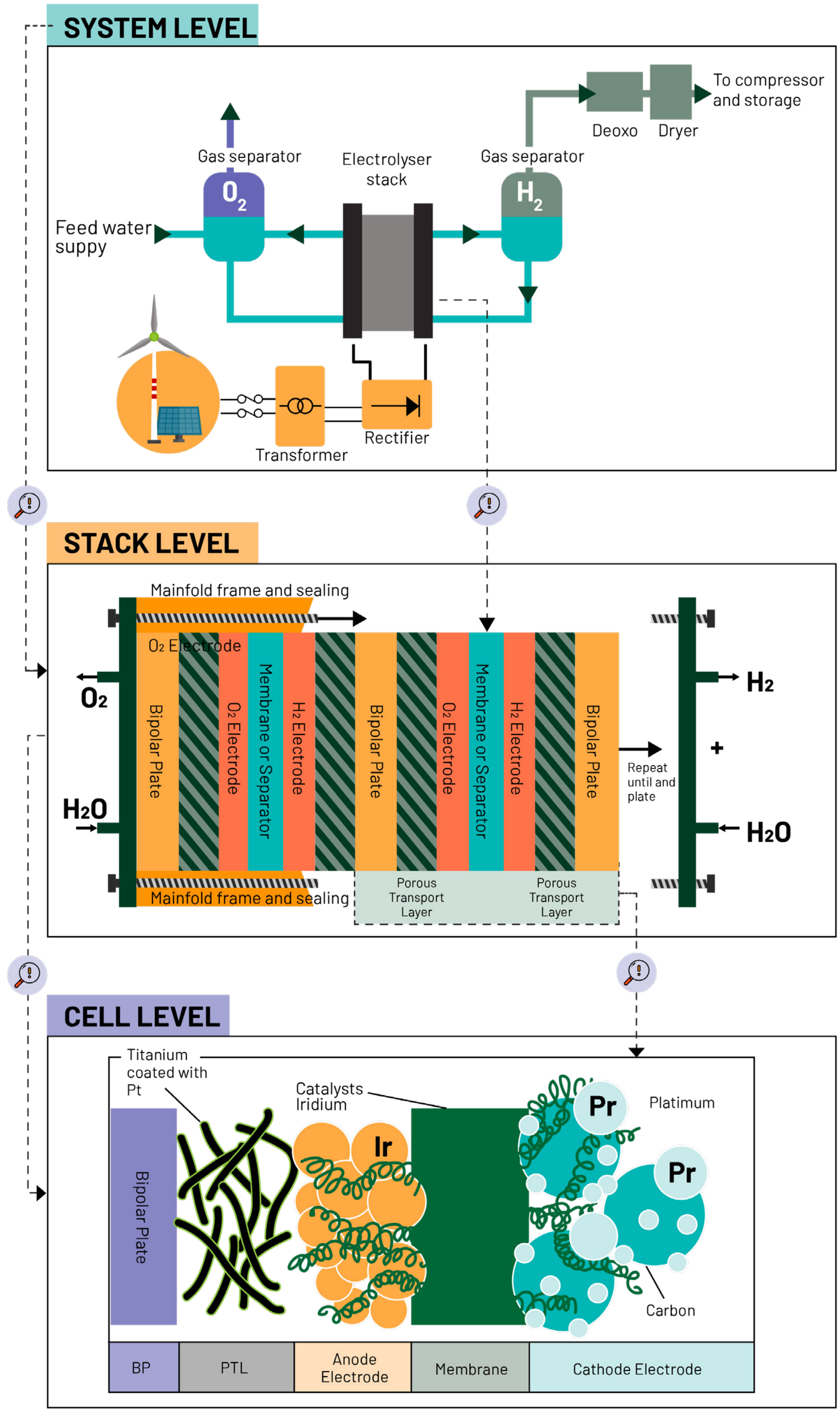


Figure 3-1 Green hydrogen process (Source: (4))

The principle of water electrolysis is simple, yet it allows the construction of different technological variations based on various physical, chemical, and electrochemical aspects.

Electrolysers are typically divided into four main technologies: (i) alkaline, (ii) proton exchange membrane ("PEM"), (iii) anion exchange membrane ("AEM"), and (iv) solid oxide. These are distinguished based on the electrolyte and temperature of operation, which, in turn, will guide the selection of different materials and components. The principles of all commercially available types of electrolysis cells and their main characteristics are displayed in Figure 3-2 below, while Figure 3-3 highlights construction materials required for different components of different technologies, the supply of some of which shall be considered critical, and which will be analyzed at length in later sections of this document.

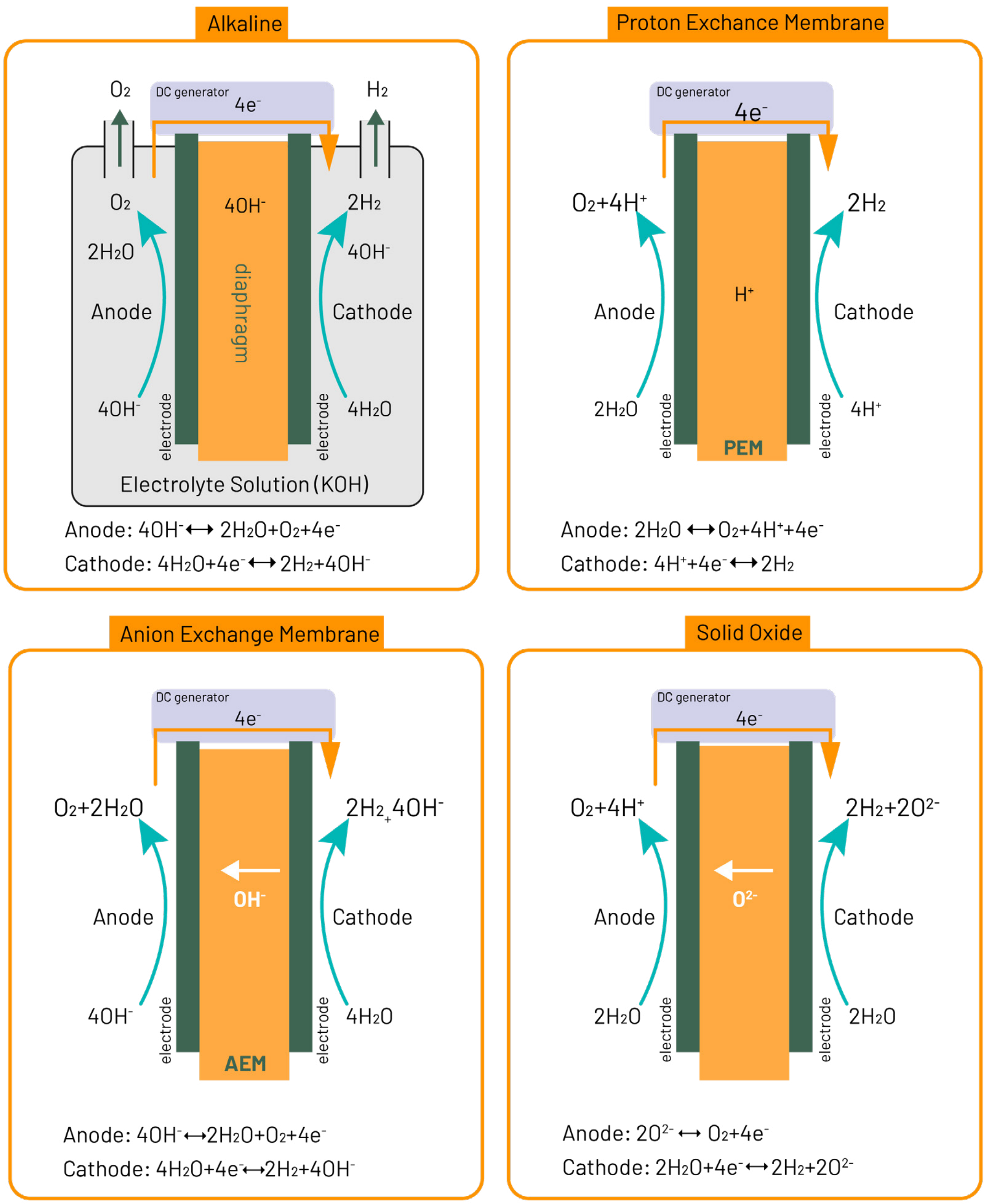


Figure 3-2 Electrolyser technologies (Source: (4))

	Alkaline	PEM	AEM	Solid Oxide
Electrolyte	Potassium hydroxide (KOH) 5-7 $moiL^{-1}$	PFSA membranes	DVB polymer support with KOH or NAHCO3 1$moiL^{-1}$	Yttria-stabilized Zirconia (YSZ)
Separator	ZrO stabilized with PPS[2] mesh	Solid electrolyte (above)	Solid electrolyte (above)	Solid electrolyte (above)
Electrode/catalyst (oxygen side)	Nickel coated perforated stainless steel	Iridium oxide	High surface area nickel	Perovskite-type (*e.g.* LSCF, LSM)
Electrode/catalyst (hydrogen side)	Nickel coated perforated stainless steel	Platinum nanoparticles on carbon black	High surface area nickel	Ni/YSZ
Porous transport layer anode	Nickel mesh (not always present)	Platinum coated sintered porous titanium	Nickel foam	Coarse Nickel-mesh or foam
Porous transport layer cathode	Nickel mesh	Sintered porous titanium or carbon cloth	Nickel foam or carbon Cloth	None
Bipolar plate anode	Nickel-coated stainless steel	Platinum-coated titanium	Nickel-coated stainless steel	None
Bipolar plate cathode	Nickel-coated stainless steel	Gold-coated titanium	Nickel-coated stainless steel	Cobalt-coated stainless steel
Frames and sealing	PSU, PTFE, EPDM	PTFE, PSU, ETFE	PTFE, Silicon	Ceramic glass

Note: Coloured cells represent condition or components with significant variation among different companies. PFSA = Perfluoracidsulfonic; PTFE = Polytetrafluorothylene; ETFE = Ethylene Tetrafloorethylene; PSF = Poly (bisphenol-A sulfone); PSU = Polysulfone; YSZ = yttriastabilized zirconia; DVB = divinylbenzene; PPS = Polyphenylene sulphide; LSCF = $La_{0.58}Sr_{0.4}Co_{0.2}Fe_{0.8}0_{3}$-O; LSM = $(La_{1-x}Sr_{x})_{1-y}MnO_{31}$S = Crofer22APU with co-containing protective coating.

Figure 3-3 Characteristics of electrolyser technologies (Source: (4))

Hydrogen has an energy density of ca. 40 kWh/kg; however, for GH production circa 50-55 kWh/kg are necessary, due to system inefficiencies and losses. Green hydrogen system design can be optimized to minimize costs and increase flexibility as necessary, depending on a variety of factors. These can include:

- the variability of electricity supply (i.e., constant consumption of grid electricity or direct feed from variable solar or wind farms)
- the technology used for the stack (e.g., alkaline, PEM, and AEM are more flexible than solid oxide)
- the flexibility of hydrogen demand (e.g., constant demand for chemical processes, general annual demand for export without hourly or daily constraints).

Storage can significantly help to decouple variable supply from hydrogen demand. This can come in the form of electrochemical storage for short-term fluctuations (before the electrolyser stack), or hydrogen storage for long-term fluctuations (after the stack, before the downstream offtakes). Similarly, hydrogen storage in tanks, caverns, and pipelines can help decouple variable hydrogen production from inflexible hydrogen demand (e.g., to produce ammonia). The type of electricity supply and hydrogen demand will drive system design, where no single electrolyser technology is better than any other, as the combination with electricity and hydrogen storage can effectively provide any level of flexibility, as illustrated in Figure 3-4, below.

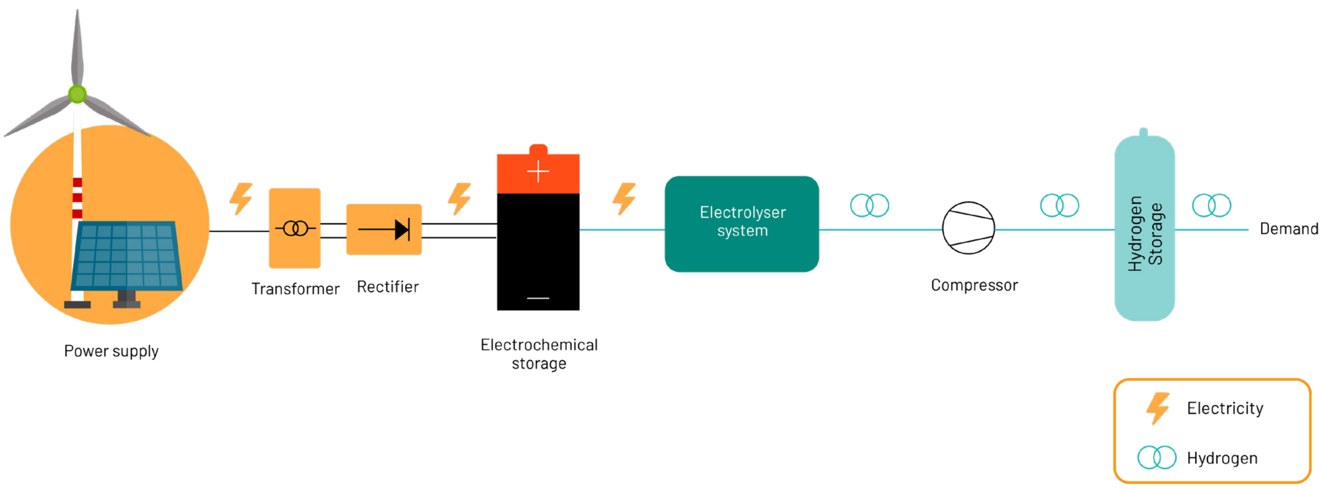


Figure 3-4 Green hydrogen production system (Source: (4))

3.2. Water Supply to Electrolyser

The electrolyser shall be fed by deionized water. In theory, hydrogen production through electrolysis requires nine liters of water for kg of hydrogen. However, due to process inefficiencies, the ratio of typical water consumption ranges between 18 kg and 24 kg of water per kilo of hydrogen.

Deionized water can be produced through desalination of seawater or brackish water. Also, desalination of pretreated municipal or industrial effluents exists, mainly for recovery uses (e.g., irrigation and production processes), but the development of municipal desalination plants is still at a very early stage, and so far, production rates are negligible compared to the other two. At a global level, desalination technologies help meet the growing demand for water for different purposes, among which, besides human consumption, are also agriculture and multiple industrial uses.

Direct use of seawater in electrolysis currently leads to corrosive damage and to the production of chlorine, but current research is looking at how to make it easier to use seawater in electrolysis.

Reverse osmosis is the most common technique for desalination, and it is deployed in 65% of the cases. Other techniques, in order of usage, include multi-stage flash distillation (21% of cases), multi-effect distillation (7%), and electrodialysis (3%); the remaining 4% of cases is covered by other techniques (5). Using reverse osmosis for desalination requires an electricity demand of 3-4 kWh per m3 of water and costs around USD 0.7–2.5 per m3 of water (6). This has only a minor impact on the total cost of water electrolysis, increasing total hydrogen production costs by USD 0.01–0.02/kg H2.

Two outputs are obtained from the desalination process: i.e., demineralized water and residual water, known as brine, which represents the main element of concern in terms of its potential environmental risks and impacts.

3.3. Hydrogen Compression and Transportation

Hydrogen generated from the electrolyser comes in gaseous form, conventionally from atmospheric pressure to 30 bar, although higher pressures are also possible. A lower volume is needed to facilitate hydrogen transport, which implies the need to:

- Increase the pressure
- Liquefy the gas
- Or convert it to ammonia, methanol, or other substances.

Compression can be done in three main ways: (i) using a standard separate compressor; (ii) by changing the operating pressure of the electrolyser; (iii) using a separate electrochemical device.

Both compressed and liquefied hydrogen can be transported by trucks or by rail, while, as already mentioned, hydrogen delivery through piping is possible at a pressure of 70 bar. Currently, the blending of hydrogen with natural gas in the piping for natural gas distribution is allowed in some countries, at the maximum ratio of 5% in most of them, although the threshold can be up to 15/20% (see Japan). Options for hydrogen transportation are shown in Figure 3-5, below.

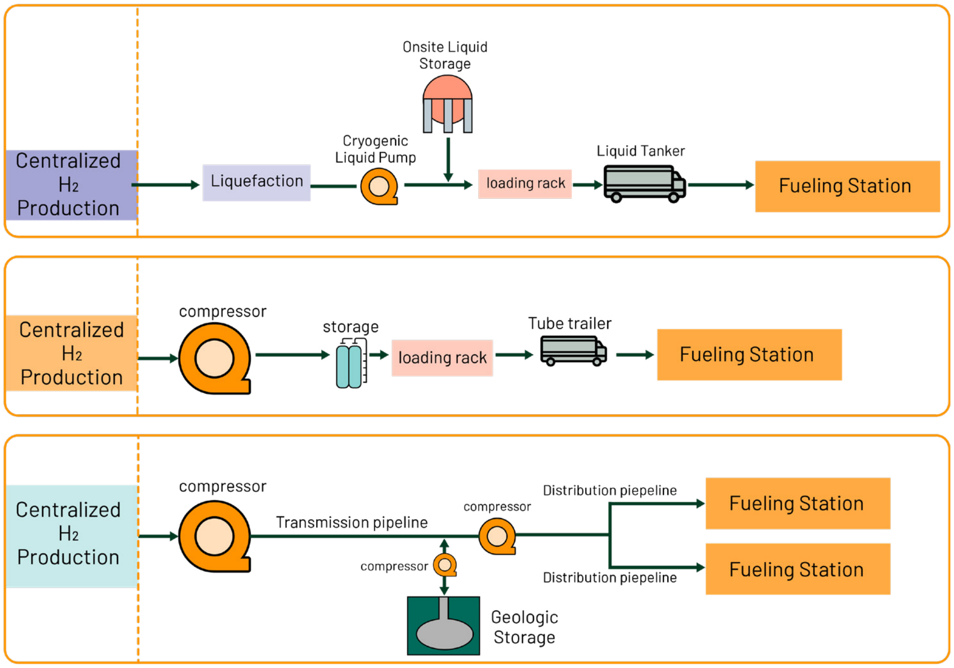


Figure 3-5 Green hydrogen transportation models (Source: (4))

3.4. Conversion to Ammonia

Ammonia is unique among hydrogen carrier candidates in that the non-hydrogen part of the molecule (i.e., nitrogen) has no carbon and – another important aspect – it does not need to be directly recovered and recycled after the dehydrogenation step (to release hydrogen).

Nitrogen originally comes from the atmosphere and is returned to the atmosphere once hydrogen has been extracted. So, providing ammonia is generated renewably in the first place (i.e., from renewable hydrogen), there is no need for any carrier "recycling" processes for it to become a true zero carbon hydrogen carrier.

Ammonia is the second-most synthesized chemical on the planet (behind sulfuric acid), with a global production that in 2018 was around 170 million metric tons (7).

The ammonia manufacturing process

The process for manufacturing ammonia is well established, invented in 1909 by Fritz Haber and Carl Bosch and first demonstrated at scale in 1914. The process reacts atmospheric nitrogen with hydrogen. At present, hydrogen is typically produced on-site at ammonia plants from a fossil fuel feedstock. The most common feedstock is natural gas, which feeds a steam methane reforming ("SMR") unit. Thus, the coupling of a hydrogen plant with an ammonia one is not a new technology; what changes with this combination is only the way hydrogen is produced.

A typical modern ammonia plant is normally large-scale (with production exceeding 500 tons per day) for it to be efficient and optimized. Thirty million metric tons per year of hydrogen are produced in ammonia plants worldwide (7). This represents 55% of global hydrogen production.

Ammonia production and transportation

Many studies are available regarding the sustainability of ammonia production and they mainly focus on water needs. Based on available information, water demand is ca. 9 kg of treated water and ca. 20 kg overall to produce 1 kg of green hydrogen (2) (4). Considering not significant the consumption of treated water in an ammonia plant fed by GH, water demand is 1.6 liters per kg of ammonia. Based on what is reported in *Renewable Hydrogen for Sustainable Ammonia Production* (7), this figure is comparable with data related to water demand of an ammonia plant with natural gas reforming.

If these data are confirmed by further studies, this implies that overall water consumption for ammonia production is similar in facilities fed by GH and facilities provided with a natural gas steam reformer.

Ammonia can be transported by truck, rail, or ship, either compressed or liquefied, at conditions (pressure or temperature) and costs much more favorable than those of pure hydrogen. Shipping of ammonia is a consolidated technology with more than 100 years of history.

Among other options currently available, there is also the opportunity to use ammonia as fuel for ships.

3.5. Conversion to Methanol

Methanol is the simplest alcohol; its chemical formula is CH3OH. It is a light, volatile, colorless, flammable liquid with a specific alcohol odor. The energy density of methanol is only 15.6 MJ/l, reflecting the fact that it represents partially combusted methane: for comparison, the energy density of ethanol and gasoline is 24 and 33 MJ/L, respectively. However, methanol can be used directly as a fuel for road or sea vehicles.

Global methanol production currently amounts to about 80 million metric tons per year and is generally produced from natural gas or coal (8).

French chemist Paul Sabatier presented the first process that could be used to produce methanol synthetically in 1905. The modern low-pressure methanol ("LPM") process was developed by Imperial Chemical Industries in the late 1960s. Solid feedstock (such as coal, biomass, and waste) or natural gas can be used as feedstock to provide hydrogen and carbon. Air or pure oxygen are used as oxidants. Methanol can be also produced from carbon dioxide (that provides oxygen and carbon) and green hydrogen.

The taxonomy remains somewhat undefined, but the production of more environmentally friendly methanol can be distinguished into:

- **Low-carbon methanol ("LCM"):** produced from natural gas or other fossil fuel by adding CO2 from other industrial facilities
- **Biomethanol:** produced from organic feedstock
- **Renewable methanol:** produced from carbon dioxide and green hydrogen from renewable electricity. The source of CO2 can be the atmosphere, biogas, or flue gases from cement and steel industries.

3.6. Carbon-neutral Fuels

Carbon-neutral fuels can be produced starting from GH and CO2 as raw materials. With reference to the figure below:

- In the so called e-fuels, CO2 is directly captured from the air, recycled from industrial flue exhaust gas, or derived from carbonic acid in seawater.
- In synthetic biofuels, CO2 is generated through the chemical or thermal treatment of biomass or waste.

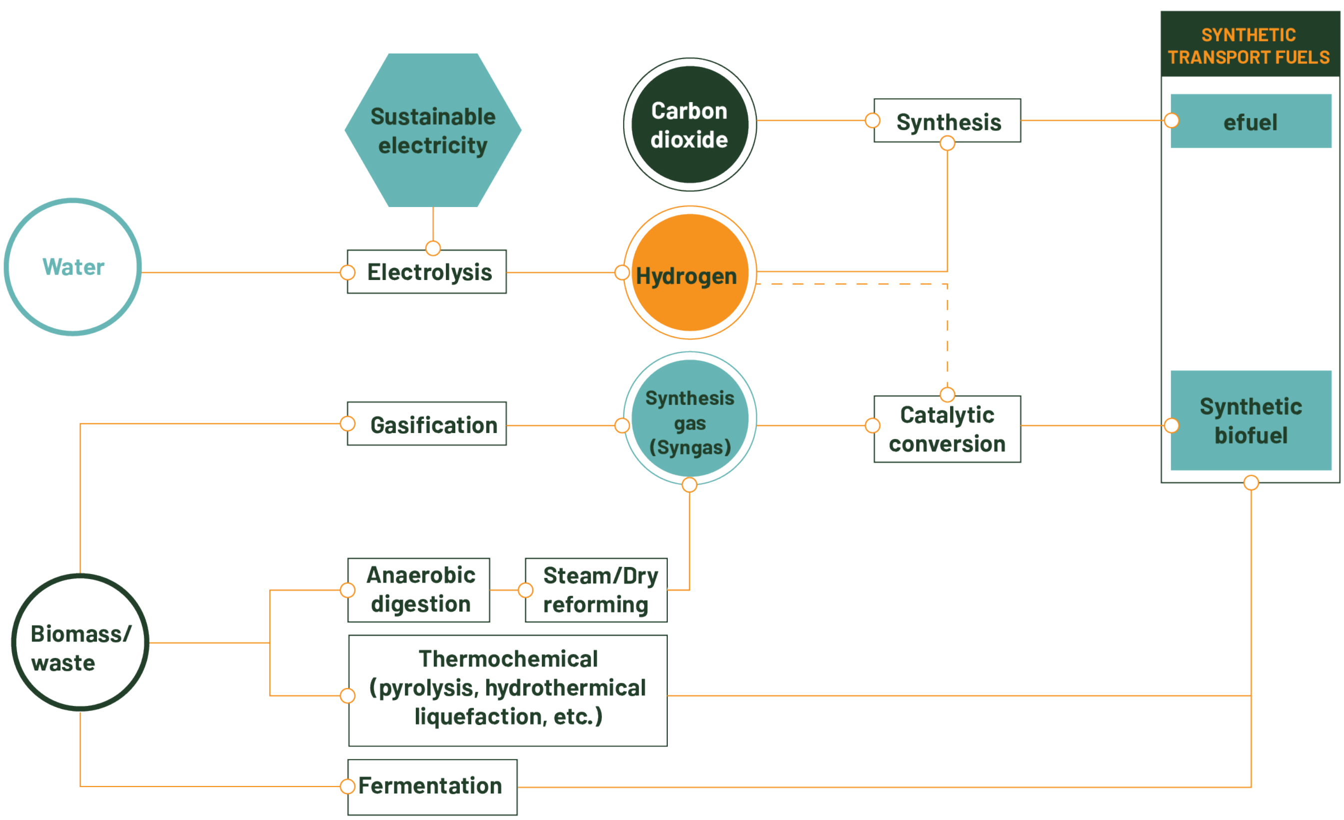


Figure 3-6 Routes to carbon-based sustainable liquid synthetic fuels
Sources: (9))

The produced fuels are like the conventional ones and can be used in any kind of vehicle, truck, or plane, without the need to adapt their fuel systems.

Aside commercial aspects, without further development and scale-up, and/or without government support, e-fuels are unlikely to be economically competitive by the 2030 period.

A point of concern for e-fuels that is linked to the scope of this study, is related to system efficiency.

Figure 3-7 below shows the comparative overall energy efficiency of powering a vehicle from: (1) renewable electricity using an electric motor, (2) a fuel cell and electric motor, and (3) an internal combustion engine. The losses are due to energy transmission and conversion (e.g., from electrical energy to chemical energy). Power-to-e-fuel diesel offers much lower efficiencies due to energy losses in electrolysis, synthesis, and in the internal combustion engine. This inefficiency means that around five times more sustainable electricity would be required to make the e-fuel diesel move a vehicle, than that needed to move the same vehicle using an electric motor.

Synthetic e-fuels and biofuels are more competitive in transport modes where electricity or other alternatives cannot be used easily. One of the most promising sectors for e-fuels is the production of jet fuels. Jet fuel demand is forecast to be around 1.4 million barrels/day in 2040 in Europe alone (9). The additional sustainable power requirements to make jet e-fuel for Europe would be between 1,400 and 2,100 TWh/year. For context, in 2016, total electricity generated in the EU was around 3,000 TWh, of which 51% came from sustainable sources.

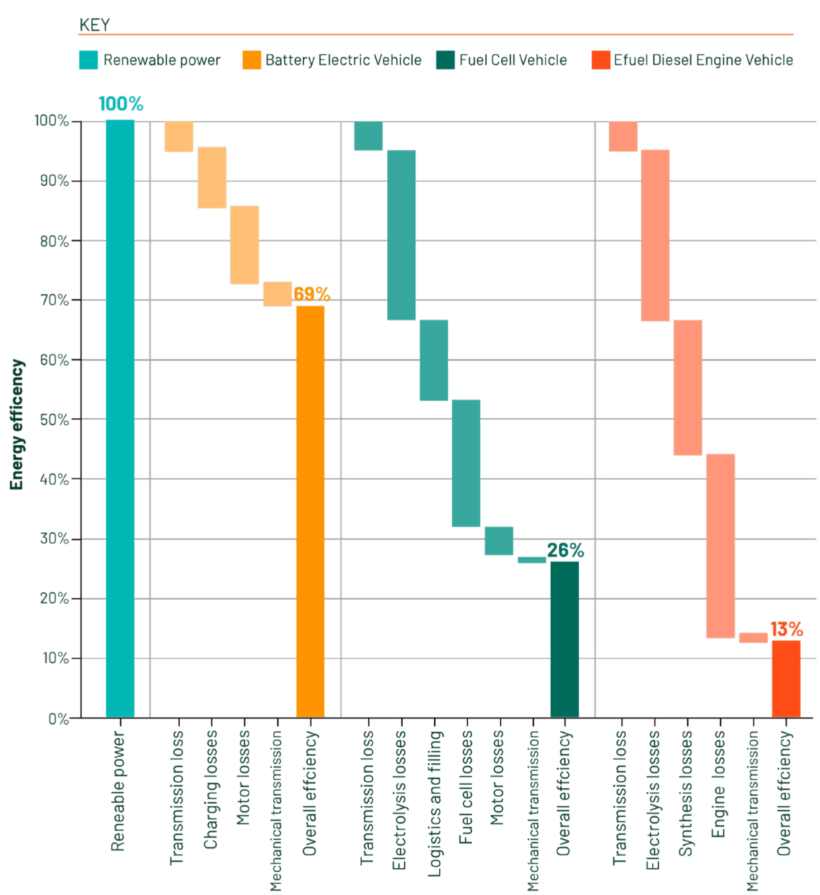


Figure 3-7 Waterfall chart of pathway efficiencies for low-carbon transport (Source: (9))

3.7. Substances of Concern

This section summarizes the hazardous characteristics of the most relevant substances of concern for this study. Methanol can be considered as a reference for a class of different light fuels that can be produced starting from green hydrogen.

3.7.1. Hydrogen

Among other characteristics of hydrogen, the following are highlighted:

- Positive points:
  - o Hydrogen is a flammable gas, 14 times lighter than air, and 57 times lighter than gasoline vapor. This means that when released in gaseous form, hydrogen will typically rise and disperse rapidly, greatly reducing the risk of ignition at ground level.
  - o Accidentally released liquid hydrogen will evaporate quickly to form a clearly visible cloud of condensed water. It is a common rule of thumb that the explosive part of the cloud approximately coincides with the visible part. On cessation of the release, the cloud will warm, rise, and dissolve faster compared to LNG.
  - o Puddles or pools of cryogenic liquid may form if the rate of release is high enough to compete with evaporation. The heat of evaporation per unit mass of liquid hydrogen (enthalpy of vaporization, ΔHvap) is about the same as for methane or propane, whereas it is much less per unit liquid volume. In addition, the temperature difference between liquefied hydrogen and the environment is greater with respect to LNG. Consequently, in case of release of the same volume, the initial volume of the hydrogen pool will be lower than the one of LNG. Then, the pool of liquid hydrogen evaporates faster than those of LNG and the pool fire will have a smaller extension. Finally, the pool fire will be shorter in duration than in case of LNG, due to the higher combustion and flame speed of hydrogen.
  - o Hydrogen has a lower radiant heat than conventional gasoline and LNG, as shown in Table 3-1 below, meaning that the overall heat flux from a fire is lower, and the risk of secondary fires ignited by the hydrogen (domino effect) is also lower.
  - o Unlike most liquid fuels made of hydrocarbons, ammonia, or methanol, hydrogen is not toxic and combustion fumes (made of water) are not toxic.

- Points of concern:

o The flammability limits[3] based on the volume percent of hydrogen[4] in air are four and 75%. The limits of detonability of hydrogen in air are 18.3 to 59% by volume. These limits are more expansive than for most hydrocarbons, as shown in Figure 3-8, below. However, available experimental data shows that hydrogen is not more prone to generate deflagrations[5] or detonations than other gases (due to turbulences created by an initial flash fire and the presence of physical obstacles), aside from the case of ignition within buildings (or tunnels) with a confined upper limit (i.e., a roof).

3 The limits within which a flash fire or a fire with no or limited overpressure may occur.
4 The limits within which a severe explosion may occur, with flame that propagates at the noise speed.
5 The limits within which an explosion may occur, with flame that propagates at a speed lower than that of the noise.

o The minimum ignition energy ("MIE") of a hydrogen–air mixture is only 0.019 mJ, whereas other flammable gases – such as petrol, methane, ethane, propane, butane, and benzene – have a MIE in the order of 0.1 mJ (see Figure below). Thus, once hydrogen is released into the atmosphere, if not dispersed, its ignition is highly probable, and will be very sensitive to electrostatic discharges ("ESD"). Therefore, the assessment of the electrostatic hazard for hydrogen is of paramount relevance.

o Hydrogen is colorless and odorless; thus, sensors – appropriately positioned to be suited to detect hydrogen, given its characteristics – are a crucial requirement for hydrogen leak detection.

o Hydrogen burns with a pale blue flame that is nearly invisible in daylight, so detection by human senses is almost impossible.

o Hydrogen storage is problematic because, for its efficient storage and transportation, high pressure vessels or cryogenic vessels at very low temperature are necessary.

o Another storage concern is the fact that hydrogen can embrittle steel. Hydrogen atoms can be absorbed by carbon steel alloys, either in atomic or molecular form, and diffuse to the metal grain boundaries, forming bubbles at the boundaries. These bubbles exert pressure on the metal grains, reducing the ductility and strength of the alloy. Thus, the application of robust standards is necessary in both the design phase and material/equipment testing, to ensure safety.

Substance	Radiative fraction
Hydrogen	0.17 – 0.2
Methane	0.19 – 0.23
Ethylene	0.25 – 0.38
Propane	0.30 – 0.32
Butane	0.30 – 0.37

Table 3-1 Radiative fraction of fuels
(Source: (10))

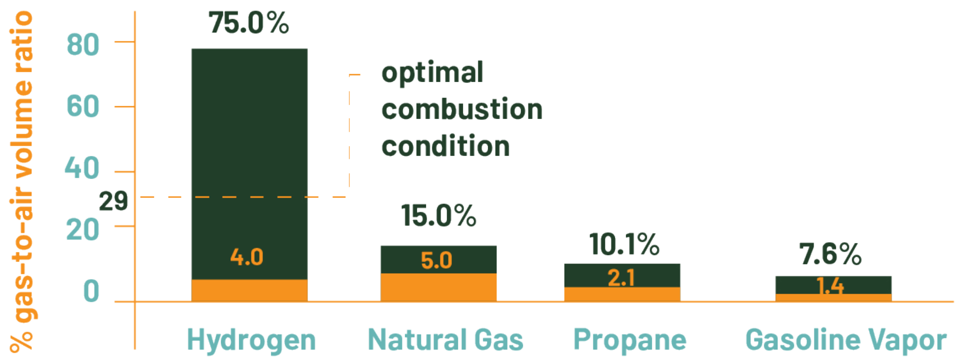


Figure 3-8 Flammability limits of hydrogen in air
(Source: (11))

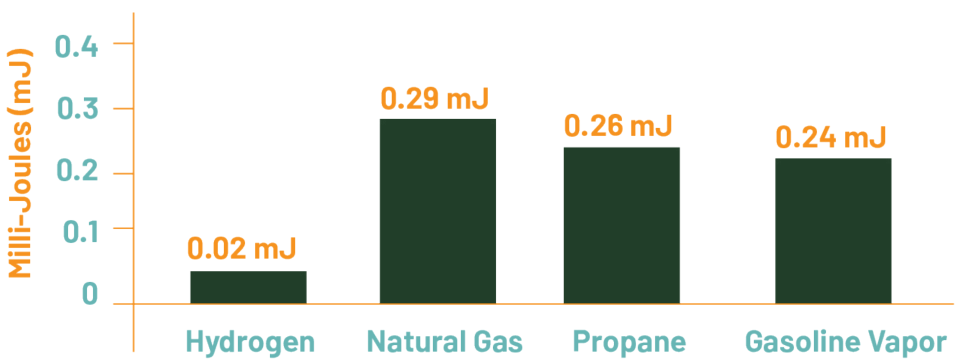


Figure 3-9 Minimal ignition energy for hydrogen
(Source: (11))

3.7.2. Ammonia

Ammonia properties relevant within the framework of this document include the following:

- Ammonia exposure is considered a health hazard because it is corrosive to the skin, eyes, and lungs. Exposure to 300 parts per million (ppm) is immediately dangerous to life and health. Numerous cases of fatal ammonia exposure have been reported. Complete recovery of affected persons may occur, depending on the extent of injury to the respiratory tract and lungs. However, long-term respiratory system and lung disorders have been observed following severe short-term exposures to ammonia. The Time Weighted Average ("TWA") established by the American Conference of Governmental Industrial Hygienists ("ACGIH") (12) i.e., the limit of exposure for workers defined as the average value for an exposure of eight hours/day, for the whole professional life, is 25 ppm. The STEL (i.e., the short-term exposure limit) is 35 ppm.
- Fortunately, ammonia has a low odor threshold (average value: 20 ppm; generally, between 0.6 and 53 ppm), so most people can perceive the danger of an ammonia release at concentrations far below thresholds at which they would be immediately hazardous.

- Ammonia is considered not flammable. However, it is also flammable at concentrations of approximately 15% to 28% by volume in air. It can explode if released in an enclosed space if a source of ignition is present, or if a vessel containing anhydrous ammonia is exposed to fire.
- Ammonia is often stored in cryogenic vessels. In case of a leakage of liquid ammonia, a vapor cloud will form, travelling close to the ground. Since the chemical plume behaves as a heavier-than-air cloud, the risk of exposure to humans is significant. The release of liquified ammonia is most often the most severe accident that may happen in an ammonia plant.

It should be highlighted that the above-mentioned considerations refer to anhydrous ammonia, the only one considered relevant in this report. When liquefied ammonia is mentioned, reference is made to anhydrous ammonia, liquefied by pressure or temperature. Aqueous solutions of ammonia are not relevant to this study.

3.7.3. Methanol

Methanol properties relevant within the framework of this document include the following:

- Methanol is a highly flammable liquid. Since the boiling point is at ca. 64°C, it may form vapors that are slightly heavier than air, which can travel close to the ground and ignite. It may burn with a non-visible or light blue flame.
- Methanol is irritating to the eyes, skin, and respiratory tract. A broad range of ocular effects have been associated with longer-term occupational exposure to lower levels of methanol. Acute oral and inhalation exposures and, to a lesser extent, percutaneous absorption of high concentrations of methanol have resulted in central nervous system depression, blindness, coma, and death. Repeated or prolonged contact of methanol with skin may result in dermatitis. Liquid methanol defats the skin. It is also an effective extracting solvent and may damage the skin permeability barrier. US TWA is 200 and TLV STEL is 250 ppm, referred to skin absorption (12).
- Methanol is readily degraded in the environment by photooxidation and biodegradation processes. Many genera and strains of microorganisms can use methanol as a growth substrate. Methanol is readily degradable under both aerobic and anaerobic conditions in a broad spectrum of environmental media, including fresh and salt water, sediments and soils, ground water, aquifer material, and industrial wastewater.

Iberdrola Project, for the supply of GH to an existing fertilizer plant, in Spain

Credit: https://img.fuelcellsworks.com/

04

GH National Strategies

4.1. Generalities and Methodology

This section includes:

- An overview of GH strategies developed at the global level
- Strategies developed by sample countries within LAC.

Reviewed strategies are at different stages of development, which may include: (i) policy discussion: an official statement and/or initial demonstration project(s) is/are currently happening; (ii) strategy in preparation; (iii) strategy developed and available. The status of advancement in the preparation of national GH strategies worldwide is shown in the table below, and is based on available data.

National hydrogen strategies published by World Energy Council ("WEC") are those available until 07/06/2021 (13), which were integrated through extensive desktop research. According to the WEC's definition, the assessment considers a national hydrogen strategy as *"an official document dedicated to hydrogen development within the country with high level support from the State. Published white papers and roadmaps are not considered national strategies if a strategy is in preparation."* (13)

	Policy discussions, official statements, initial demonstration projects			**Strategy in preparation**	**Strategy available**	**Source**
Africa	Cape Verde, Burkina Faso	Mali, Nigeria	South Africa, Tunisia	Egypt, Morocco		WEC
Asia	Bangladesh	Hong Kong, China	India	China	Australia (2019)	WEC
				New Zealand, Singapore, Uzbekistan	Japan (2017)	WEC
					South Korea (2019)	WEC

	Policy discussions, official statements, initial demonstration projects			Strategy in preparation	Strategy available	Source
Europe	Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland*, Georgia	Greece, Iceland, Latvia, Lithuania, Luxembourg, Malta	Romania, Serbia, Slovenia, Switzerland, Ukraine	Austria Belgium Italy Poland	European Union (2020)	WEC
				Russian Federation, Sweden	France (2020)	WEC
				Slovakia	Germany (2020)	WEC
				United Kingdom	United Kingdom Netherlands (2020)	WEC
					Norway (2020)	WEC
					Portugal (2020)	WEC
					Spain (2020)	WEC
					Hungary (2021)	WEC
				Turkey	United Kingdom (2021)	Online
Latin America & the Caribbean	Argentina, Bolivia, Costa Rica	Paraguay	Peru, Trinidad and Tobago	Brazil, Colombia, Uruguay, Panama	Chile (2020)	WEC
Middle East and Gulf States	Israel, United Arab Emirates			Oman		WEC
					Saudi Arabia (2021)	Online
North America	Mexico United, United States of America				Canada (2020)	WEC

Table 4-1 Overview of countries' activities toward developing a hydrogen strategy (Source: (13))

4.2. Comments about the Strategies

The summary of hydrogen strategies analyzed for this study is reported in ***Annex I.*** At a global level, the strategies developed by the European Union, the USA, and Japan have been reviewed. With reference to the LAC region, the following documents have been reviewed:

- Chile: The National Green Hydrogen Strategy, dated November 2020 (14)
- Brazil: The Brazilian Hydrogen and Fuel Cell Systems Program, initially dated 2002, amended in 2005 and renamed as Science, Technology and Innovation Program for the Hydrogen Economy; and the National Energy Plan 2050, issued in 2020 (15) (16)
- Colombia: The Colombian Hydrogen Roadmap, issued in September 2021 (17)
- Uruguay: The available information on the National GH Strategy currently under development, as announced on November 30, 2021 (18) (19) (20)
- Panama: The information available on the web related to the green hydrogen strategy that was expected in December 2021
- Peru: Technical documents sponsored by H2 Peru; the Peruvian Hydrogen Association ("PHA") established in March 2021 (21)
- Trinidad and Tobago: Available information on the web regarding progress achieved under the umbrella of the partnerships among the Energy Ministry, the National Gas Company and the National Energy Corporation aimed to transition from a natural gas economy toward a more environmentally- friendly alternative
- Costa Rica: Among other documents, the National Decarbonization Plan (2019) and available information on the national GH strategy, currently in development, announced in December 2021 (22)
- Argentina: Available technical information (23) (24).

Within the framework of this document, the main points of interest related to hydrogen strategies that have been developed so far in the LAC region include:

- Both domestic uses and export options of GH are considered within the analyzed strategies. For example, Peru's national strategy includes the assessment of potential hydrogen applications at a small-scale, focusing on communities with limited access to energy to develop greater energy resilience across the country, and to assist communities equipped with isolated power systems. In other cases, GH strategies include the development of big-size, nation-wide projects that can change the profile of the whole country (e.g., the H2UB plan in Panama).
- Most strategies identify the need for land use planning for the development of GH projects at a strategic level. Local authorities are encouraged to identify suitable sites for GH initiatives in the phase of Master Plan development, also taking into consideration the need to establish buffer zones separating industrial hazard facilities from residential and/or commercial areas. Some strategies (like the one published in Colombia) encourage the reuse of sites of existing coal power plants.

- Some of the hydrogen strategies analyzed for this study (like the one published in Colombia) aim to simplify permitting procedures for construction and operation of GH-related plants, including ESIA processes. At the same time, other strategies highlight the need to complete SESAs in the phase of identification of sites suitable for GH initiatives, as referred to in the previous point.
- Most strategies highlight the need to assess water demand of GH electrolysers and potential induced water stress on local communities and ecosystems. Development and implementation of desalination technologies that make use of seawater rather than fresh water, are encouraged.
- To ensure safety, all hydrogen strategies encourage the development of technical (safety) standards. Current standards that regulate the use of hydrogen as a hazardous substance are not designed for application to hydrogen used as an energy vector. In most strategies, the focus is more on detailed technical standards rather than on high-level safety procedures.
- Most strategies encourage awareness raising campaigns among public authorities, workers, and local populations, addressing both promotional aspects (e.g., environmental benefits linked to the use of GH) and safety aspects (e.g., differences between the physical characteristics of methane and hydrogen).
- Stakeholder engagement is considered crucial for quick and efficient development of the GH value chain, with extensive involvement of all interested parties commencing in early stages (i.e., public entities, associations and business groups, operators in the fields of power generation and production of natural gas carriers, as well as distributors, hydrogen producers and consumers, mobility services companies, engineering firms, equipment manufacturers, universities and research centers, and multilateral organizations).

Climate change risks

In addition to the above-mentioned items, the authors must mention climate change risks. It is recommended (as included in the Colombia strategy, and as addressed by some technical documents developed in Argentina) to conduct studies to determine the potential geological storage capacity of H2 (and CO2). The large-scale geological storage of hydrogen would make it possible to have large seasonal renewable energy reserves, which would help mitigate the impact of weather-related events such as El Niño or La Niña.

Other unique aspects identified during the study include:

- The need to establish a common taxonomy (for example, distinguishing green and blue hydrogen, based on their respective CO2 emissions) and designing a system of hydrogen guarantees and certifications of origin
- The need to compare the costs of GH and competing fuels, taking into consideration the internalization of social and environmental costs of the use of fossil fuels.

Generally speaking, when comparing LAC strategies to the Hydrogen Strategy of the European Union and the USA's strategy, the former appear both more ambitious and focused on country/regional peculiarities of the territory when compared to the latter two. Furthermore, the EU and USA strategies place less emphasis on social aspects, including potential adverse social risks and impacts linked to the development of a GH value chain.

An interesting point of the EU strategy is the concern related to the hydrogen supply chain. In a region that until now has been mostly dependent on African and Asian countries for oil supply and where the availability of metals is scarce, the identification of a reliable supply chain for GH production is a strategic issue. Europe is fully dependent on the supply of 19 raw materials (out of 29) relevant to the production of fuel cells and electrolyser technologies (e.g., the platinum group metals), and it relies on foreign countries for the supply of several critical raw materials for various renewable power generation technologies.

When considering hydrogen strategies from outside the LAC region, the Japanese strategy is the most diversified and innovative one and could be used as benchmark for the identification of the full set of opportunities offered by the development of a GH value chain in the region. Among other challenging targets, the Japanese strategy stresses the need to develop offshore wind farms dedicated to GH production and the use of ammonia as fuel for power plants, ships, and aircraft.

Haru Oni project, methanol and gasoline production, in Chile

Credit: https://www.siemens-energy.com/global/en/news/magazine/2022/haru-oni.html

05
Case Studies

Based on information available online (25), there were 13 large-scale green hydrogen projects in the world in December 2020, representing 50GW out of a global pipeline of 80GW. In August 2020, the gigawatt-scale pipeline alone added up to about 260GW across 26 projects, and in December 2021, when the present study was compiled, it can be reasonably inferred that the overall capacity of the existing projects worldwide was about six times greater than the preceding 12 months. Despite the massive potentialities for green hydrogen developments, the largest electrolyser in operation at the end of 2020 was only 20MW.

Some examples of diversified projects are reported within ***Annex II*** and include:

- ERM Dolphyn Project, with offshore wind farms and GH electrolysers in the UK (26)
- Iberdrola Project, for the supply of GH to an existing fertilizer plant, in Spain (27)
- Haru Oni project, methanol and gasoline production, in Chile (28)
- DEWA Green Hydrogen Plant, that makes use of hydrogen for energy storage, in United Arab Emirates (29)
- Hydrogen Mobility Joint Project, which envisaged distributed GH production for vehicles refueling, in Germany (30)
- HyDeal Ambition for 67GW, Western Europe a huge-size project promoted by energy utility company (31)
- ACME Group Project in Port of Duqm, Oman, to produce green ammonia for export (32)

The selection of the analyzed examples is based on the intention to show different types of projects, drivers for different solutions, and potential environmental and social implications, which are briefly analyzed in this section.

The figure below summarizes in graphic format some of the projects currently considered within the GH Strategy developed in 2020 in Chile (14). It provides a quick overview of how significant the diversification among projects could be, even considering the limited list of projects envisaged within a single country. Considering the differentiated nature of projects, the related environmental, social, and OHS aspects are therefore extremely differentiated. Some aspects relevant to this document include:

- Green hydrogen projects span from distributed and small-size production facilities to huge projects. Both greenfield and brownfield initiatives are under development, with different implications in terms of potential environmental and social aspects. Huge greenfield developments may change the socioeconomic characteristics of a vast area, while other projects, such as those related to initiatives for distributed hydrogen production for mobility, have a completely different socioeconomic pattern.

- Optimization of efficiency of GH production systems in medium-size projects completed by industrial developers within already industrialized/developed areas is most often pursued through the definition of site-specific designs, in some cases with commercialization of oxygen, generated in the electrolyser as by-product and normally damped into the atmosphere. Utility companies already active in the power or gas sectors seem more intent to increase efficiency of GH greenfield projects, increasing the scale of projects, often developed in pristine areas.
- A single "GH initiative" may be composed of different sub-projects, rather differentiated in terms of technical characteristics and socioeconomic implications (e.g., wind farm, electrolyser, ammonia conversion plant, etc.). Each single sub-project may fall, even if considered separately, into a Category A Project in terms of socioeconomic impacts. The national permitting process for more complex projects is still under definition: while in some cases, a single permitting EIA procedure is adopted for the entire value chain of a project (renewables, electrolyser, conversion/delivering facilities), in other cases, the permitting is completed separately for different parts of the project. Sub-projects may be developed by separate entities at separate times.
- Land use for a medium-size electrolyser is limited and does not require more soil than that typically required for medium-size industrial facilities; however, in case of development of multi-GW factories, with ammonia or methanol conversion included, soil occupation may become very significant. Based on a study prepared by the Institute for Sustainable Process Technology ("ISPT") in the Netherlands, a 1GW alkaline and PEM plant is expected to occupy 13 ha and 17 ha for a PEM and an alkaline electrolyser plant, respectively, with the potential to decrease land requirements with compact designs down to 8 ha and 10 ha, respectively.

With respect to development of a guideline applicable to the full set of projects related to the GH value chain, it should be highlighted that the range of differences of initiatives within the value chain is much wider than differences among facilities within the field of application of other IDB or IFC sectoral guidelines, such as facilities in the refinery sector, conventional fossil fuel power production, or bulk inorganic and fertilizer production (that also cover ammonia production).

Thus, specific challenges in the preparation of a sectoral EHSS guideline for the GH value chain is that the guideline shall:

- Be applicable in different situations
- Avoid conflicts with (and, in fact, be grounded on) existing sectoral guidelines addressing sub-project components, such as guidelines related to power production through renewables, power transmissions, ammonia production, etc.

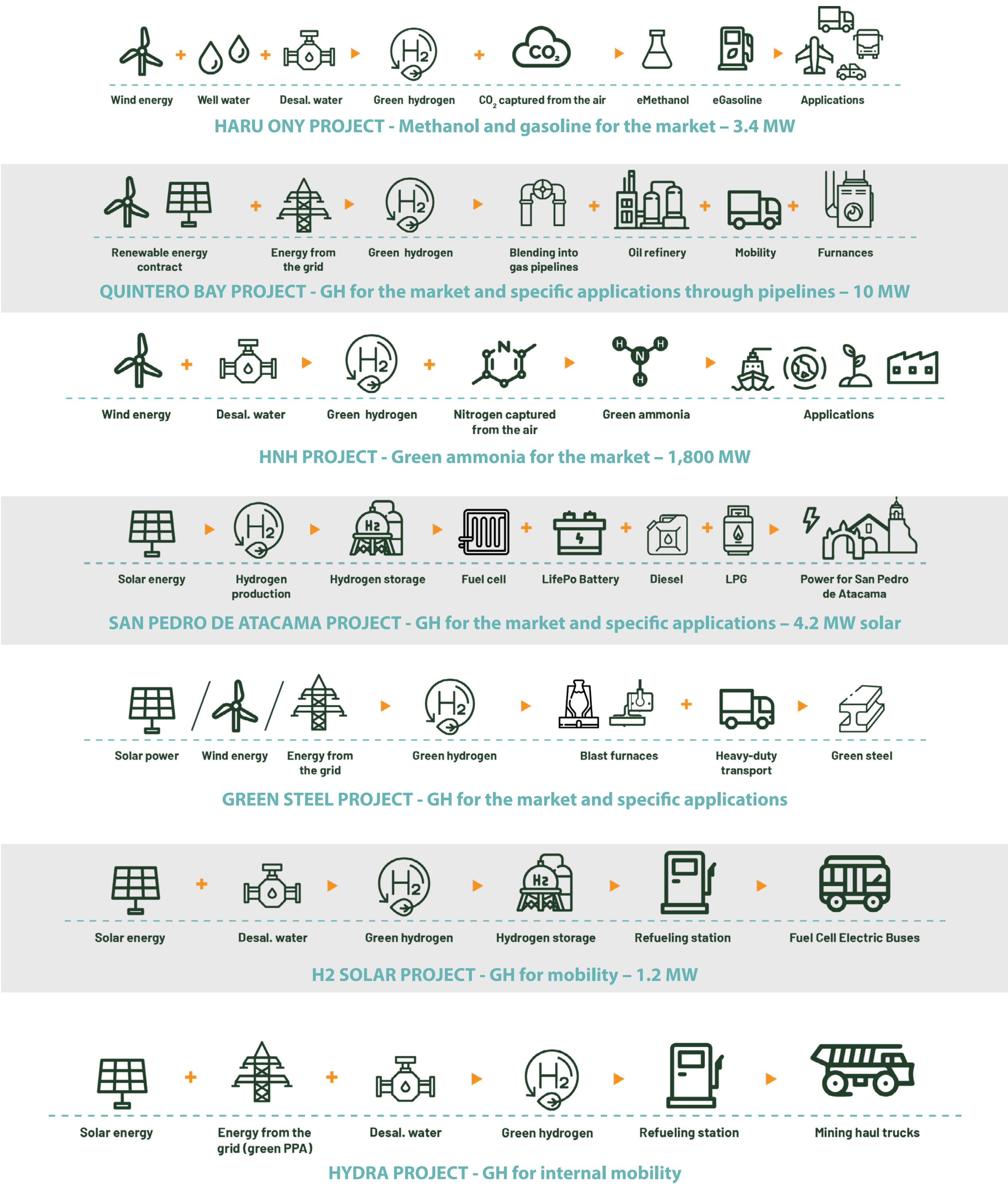


Figure 5-1 Overview of projects mentioned within the GH strategy of Chile
Source: (14)

DEWA Green Hydrogen Plant, that uses a concentrated solar plant as an energy source, in United Arab Emirates

Credit: https://www.eqmagpro.com/dubai-inaugurates-green-hydrogen-plant/

06

Regulatory Framework And GIIP

6.1. Scope of the Review

This Regulatory Framework Review ("RFR") provides information on mandatory regulations as well as best practices and guidelines on those aspects that, based on the outcomes of previous sections of this report, appeared most relevant within the scope of work. Specifically, the RFR addresses:

- The regulations and guidelines related to permitting of facilities within national regulations, focusing on the processes in place for the Environmental/Social Impact Assessment and Strategic Impact Assessment
- Regulations and guidelines aimed to ensure process safety and safety of communities located near of industrial facilities
- Regulations and guidelines related to safety during transportation
- The standard of reference related to the freshwater management, with reference to potential impacts that may be generated by water demand additionality created by GH technology
- The standard of reference for brine discharge and management, with reference to potential impacts generated by the use of seawater (as an alternative to freshwater) to feed electrolysers.

For each matter, the analysis was completed at:

- International level, for the identification of benchmarking references
- At country-level within the LAC region.

The section is then completed with a brief list of:

- Additional international standards and international agreements of reference considered during the preparation of this report
- Relevant technical standards.

6.2. Planning and Permitting of Facilities

Based on ESPS1, the operator of financed projects shall establish and maintain a process for identifying the project's environmental and social risks and impacts. The type, scale, and location of the project guide the scope and level of effort devoted to the risks and impacts identification process. Based on the project's level of risk and impact, the IDB requires the borrower to utilize one or more risk and impact assessment and management instruments, which may include, among others, an Environmental and Social Impact Assessment (ESIA), a Strategic Environmental and Social Assessment (SESA), a Regional Environmental and Social Impact Assessment, and/or a Disaster Risk Assessment.

Considering the scope of the present study, namely, the development of a green hydrogen value chain in the LAC region, it seemed logical to start the analysis of relevant policies and standards with a brief analysis of existing regulations related to both Strategic Environmental and Social Assessment and Environmental and Social Impact Assessment as essential planning and design tools, within the region and compared with similar regulations at the international level.

Considerations regarding ESIAs

Based on IDB's 2016 *Good Practices in Environment, Health, and Safety in Latin America and the Caribbean* (33), national regulatory frameworks tend to be license-intensive, with Environmental and Social Impact Assessments ("ESIAs" or "EIAs" including under the label "environment" all aspects from biophysical to cultural and socioeconomic ones) acting as the basis for environmental permitting of a project.

In LAC, the permitting and licensing process is complex and usually involves inter-institutional coordination among regulatory agencies. Most countries require public consultation as part of the EIA process and final permitting approval takes anywhere from six months to over a year. However, some countries are working to streamline the permitting process.

Another notable trend in the region is increasing transparency of the whole permitting system, thanks to the implementation of new laws and regulations requiring more robust stakeholder engagement and consultation, as well as public disclosure of project information that can directly affect communities.

Considerations regarding SESAs

For the proper management of complex projects like those typically required to produce GH, an institutional and technical approach like that offered by the Strategic Environmental and Social Assessment ("SESA" or "SEA") for plans and programs may be necessary, as also outlined in some of the national strategies for GH development (e.g., the one prepared by Chile).

It is also worthwhile to highlight that IDB guidelines on ESPS applications state that where the project is likely to have sectoral or regional impacts, a sectoral or regional ESIA may be required, and that the technical approach to complete a sectoral or regional ESIA shares similarities with a SESA.

Operating on the assumption that EIA regulation across countries in the region is rather consolidated, within the framework of this study, Anthesis reviewed regulations related to the SEA/SESA of a sample of LAC countries, benchmarking it with international guidelines of reference.

A summary of the documents reviewed is reported in ***Annex III,*** which includes:

- A commentary about:
  - o UNECE SEA Protocol (34)
  - o OECD Good Practice Guidance for Development Cooperation (35)
  - o WB document Strategic Environmental Assessment in Policy and Sector Reform: Conceptual Model and Operational Guidance (36)
  - o SEA Regulation in Europe (Directive 2001/42/EC on the assessment of the effects of certain plans and programs on the environment)
  - o SPREP Guidelines for SEA in Pacific Islands and Territories (37)

- An analysis of relevant regulations in:
  - o Chile (38) (39)
  - o Colombia (40)
  - o Argentina (41)

It shall be also highlighted that in 2015, EBRD (in collaboration with IFC, IDB, and others) published the *Good Practices for Biodiversity Inclusive Impact Assessment and Management Planning* (42). The document is relevant within this context as a benchmark for the definition of a technical approach for the holistic undertaking of impact assessment in complex projects like the ones underpinning the development of a GH value chain. As such, it was also reviewed for the preparation of this section.

The landscape of domestic regulations related to SESA in LAC appears not well consolidated and quite fragmented across the region. On the other hand, the content of existing regulations appears substantially aligned with the EU regulation dedicated to the same topic, SEA Directive 2001/42/EC, one of the first published at a global level on the subject.

Contents of any SESA report aligned with the EU SEA Directive shall include:

- The contents and main objectives of the plan or program of concern and its link with other plans or programs
- Aspects of the current state of the environment, including health, and the likely evolution thereof should the plan or program not be implemented
- Characteristics of the environment, including health, in areas likely to be significantly affected
- The environmental, including health, problems that are relevant to the plan or program
- The environmental, including health, objectives established at international, national, and other levels that are relevant to the plan or program, and the ways in which these objectives and other environmental, including health, considerations have been taken into account during its preparation

- The likely significant environmental, including health, effects
- Measures to prevent, reduce, or mitigate any significant adverse effects on the environment, including health, which may result from the implementation of the plan or program
- An outline of reasons for selecting the alternatives dealt with and a description of how the assessment was undertaken, including difficulties encountered in providing the information to be included, such as technical deficiencies or lack of knowledge
- Measures envisioned for monitoring environmental, including health, effects of the plan's or program's implementation
- The likely significant transboundary environmental, including health, effects
- A non-technical summary of the information provided.

Some other international standards reviewed for this study appear to be more focused on social aspects than the EU regulation. For example, the "institution-centered approach" promoted by the World Bank (within the *Strategic Environmental Assessment in Policy and Sector Reform: Conceptual Model and Operational Guidance* (36)) focuses on the role of institutions while performing a SESA. In addition to this, other key aspects of the process include: (i) understanding the policy process, (ii) identifying environmental priorities, (iii) strengthening stakeholder representation, (iv) analyzing and strengthening institutional capacities, (v) analyzing and mitigating institutional constraints, (vi) strengthening social accountability, and (vii) ensuring social learning.

The European regulation is the only one that explicitly mentions the need to assess impacts of plans and programs by considering incidental situations.

While the WB standard stresses the importance of adjusting the actual application of the institution-centered SESA for a certain policy/sector to the specific context, none of the national regulations reviewed for the study (at a global level or in the LAC region) appear to be tailored to consider characteristics of the territory of the jurisdiction. Within the framework of this study, only the 2020 Guidelines prepared by the Secretariat of the Pacific Regional Environment Program ("SPREP" (37)) represent an exception.

6.3. Process safety

Safety is one of the main concerns among public authorities and citizens related to the use of hydrogen. The ESPS4 states that operators of financed projects shall design, construct, operate, monitor, and decommission structural elements or components of the project in accordance with GIIP, taking into consideration safety risks to third parties and project-affected people.

Some incidents that occurred in the past centuries reinforced the perception that hydrogen is a high-risk substance; among others, the most famous incidents include:

- The first known air incident with fatalities occurred on November 21, 1783 during the attempt to fly across the English Channel with a balloon, the upper part of which was filled with hydrogen and the lower part by hot air, used to control the navigation. The flame intended to warm the air ignited the hydrogen section of the balloon.
- A disaster that occurred in May 1937 completely destroyed the Zeppelin airship LZ 129 Hindenburg by fire in a matter of seconds. This incident was enough to destroy the confidence of the public in hydrogen airships, even though this was the only significant incident that ever occurred to a Zeppelin airship, until then an appreciated transportation means.

Hydrogen, ammonia, and e-fuels are indeed hazardous substances, all of them potentially present in significant amounts within production facilities and transportation infrastructures of the GH value chain.

This section highlights some aspects of the regulations in force in different jurisdictions related to process and community safety, in production facilities and transport infrastructure.

6.3.1. International Standards and Regulations

The following international regulations on process and community safety were reviewed for this study:

- The ILO convention no.174 of 1993 on the Prevention of Major Industrial Accidents Convention (43) and related recommendation No. 181 (44)
- The USA regulation, including the framework regulation, technical guidelines, and risk acceptability criteria (in detail: the OSHA Process Safety Management of Highly Hazardous Chemicals Regulation – PSM; the EPA requirements for Risk Management Plan – RMP currently under the umbrella of the Clean Air Act; and related technical guidelines, specifically the 40 CFR PART 68) (45) (46)
- The EU Directive 2012/18/EU (also known as the Seveso Directive) (47) and modalities adopted by member countries for its transposition within national regulations.

6.3.1.1. Framework Acts

At the global level, existing high-level regulations for process safety in place in different jurisdictions are rather aligned, all of them designed to include provisions set forth by the 1993 ILO Convention on the Prevention of Major Incidents and related recommendations.

ILO international labor standards are legal instruments drawn up by the ILO's constituents (governments, employers, and workers) that establish basic principles and rights that apply to the workplace. They are either:

- Conventions (or Protocols), which are legally binding international treaties that may be ratified by member states, or
- Recommendations, which serve as non-binding guidelines. In many cases, a convention lays down basic principles to be implemented by ratifying countries, while a related recommendation supplements the convention by providing more detailed guidelines on how it could be applied. Recommendations can exist independently from a convention, i.e., without being linked to a convention.

With reference to the control of major incidents, as already mentioned above, ILO published in 1993 the Prevention of Major Industrial Accidents Convention (No. 174) and Recommendation (No. 181). Based on these two acts, for each major hazard installation, employers shall establish and maintain a documented system of major hazard control, which must include provisions for:

- Identification and analysis of hazards and assessment of risks, including considerations of possible interactions between substances
- Technical measures, including design, safety systems, construction, choice of chemicals, operation, maintenance, and systematic inspections of the installation
- Organizational measures, including training and instruction of personnel, provision of equipment to ensure their safety, staffing levels, hours of work, definition of responsibilities, and controls on outside contractors and temporary workers on the site of the installation
- Emergency plans and procedures, including:
    - the preparation of effective site emergency plans and procedures, including emergency medical procedures, that apply in case of major accidents or similar threats, with periodic testing and evaluation of their effectiveness and revision as necessary
    - the provision of information on potential accidents and site emergency plans to authorities and bodies responsible for preparation of emergency plans and procedures for protection of the public and the environment outside the site of the installation
    - any necessary consultation with such authorities and bodies
    - measures to limit consequences of a major accident
- Consultation with workers and their representatives
- Improvement of the system, including measures for gathering information and analyzing accidents and near misses. Lessons learned shall be discussed with workers and their representatives and shall be recorded in accordance with national law and practice.

In each country, the competent authority shall establish a comprehensive siting policy with specific provisions for appropriate separation of proposed major hazard installations from working and residential areas and public facilities, and appropriate measures for existing installations.

Aside from executive details and some peculiarities related to geography, the regulatory background and the period in which the regulations were put in place both in the USA and Europe are substantially aligned with the overarching principles of the ILO convention.

6.3.1.2. Technical Guidelines

The ILO complementary practical guidance to C174 aims to provide guidance for (i) setting up an administrative, legal, and technical system for the control of major hazard installations to protect workers, the public and the environment by preventing major accidents from occurring at these installations, (ii) minimizing consequences of a major accident either on- or off-site by proposing an appropriate separation of major hazard installations and housing, as well as other nearby centers of population, such as hospitals, schools, and shops, and (iii) providing guidance on appropriate emergency planning.

Among other recommendations, the practical guidance includes the following areas of specific interest within the framework of the present study:

- On appropriate separation of areas. Competent authorities should establish a land-use policy to separate, where appropriate, major hazard installations from people living or working nearby. Consistent with this policy, competent authorities should make specific arrangements to prevent encroachment of population nearer to existing major hazard installations. A plan for gradual improvement should be established for situations where existing major hazard installations are not adequately separate from populated areas.
- On the off-site emergency plan. The off-site emergency plan should be a responsibility of the local authority and management bodies in charge of the works, depending on local arrangements. Where a major accident could result in a major spill or environmental harm requiring attention and investigation, the emergency planning officer should identify those authorities who will carry out these tasks and inform them, as appropriate, of their role in the off-site plan.
- On emergency health support. Following a major accident, health authorities, including doctors, surgeons, hospitals, poison centers, and ambulances, should have a vital role. Where accidents with off-site consequences may require medical equipment and facilities additional to those available in the area, health authorities should arrange a "mutual aid" scheme to allow for the assistance of neighboring authorities.

While framework acts in place at the national level in different continents are rather aligned with the ILO convention mentioned in the paragraph above, anational technical guidelines issued by different governments are rather diversified and are not always aligned with the ILO recommendation of reference. Even guidelines issued by entities that fall within a common overarching jurisdiction (i.e., issued by countries within the EU; issued by the states in the USA or in the Brazilian confederation) are often substantially different.

It is worth mentioning that, based on the European Commission, such different approaches are not reconcilable. As a matter of example, and with reference to methods to be adopted for land use control and definition of criteria for risk acceptability, the *Handbook of Scenarios for Assessing Major Chemical Accident Risks* (48), published in 2017 by the European Commission, states that:

The Seveso Directive [the framework piece of regulation in Europe related to process safety] does not provide detailed suggestions on how EU Member States should implement this requirement into their land-use planning policies. This approach reflects a conscientious application of the EU subsidiarity principle such that the Directive recognizes that land-use planning is guided by historic and social values unique to each country. As a result, methods and criteria applied to fulfil Seveso land-use planning obligations in the different Member States are quite diverse, even though they all aim to achieve the same objective, that is, to evaluate the potential consequences of possible major accidents for use in making land-use planning decisions. In particular, each country has established its own process for evaluating the risk associated with specific chemical accident hazards. Each applies a variation of the standard risk assessment approaches to incorporate the estimated risk into land-use planning decisions. […] It has long been acknowledged that risk methods and land-use planning processes are embedded in local culture and pre-existing legal systems. However, technical aspects associated with the consequence analysis, in particular, selection of [incidental] scenarios and scenario attributes, are not subject to this constraint. […] The availability of common reference scenarios [may allow] the possibility for all authorities to consider the full range of possible outcomes when assessing risks associated with a major hazard site.

Relevant aspects of differentiation among guidelines in place in different countries include:

- Some technical guidelines do not explicitly refer to the concept of risk and simply establish methods for assessment of the maximum distance of hazards from facilities handling dangerous goods, based on a tabular or simplified approach. As a matter of example, the U.S. OSHA PSM asks operators of some categories of facilities to identify the maximum distance of hazard and design an emergency plan based on it. The concept of risk is separately addressed by concurrent regulations. The simplest methods for the assessment of the maximum distance of hazards (as the IAEA method described in detail in Section 8) make use of only three input parameters: type of substance, hold up, and storage modalities (under pressure, liquefied by temperature, etc.). The methods developed in different jurisdictions differ in the algorithms adopted and related outcomes. However, in all the analysed cases, the maximum distance of hazard is calculated with reference to potential damage to buildings or fatalities among human beings. The assessment of ultimate effects to the environment is not considered.
- Some other technical guidelines (as a significant example, the regulation in place in the state of São Paulo in Brazil) require owners of plants of concern to perform a complete Quantitative Risk Assessment ("QRA") and assess individual and societal risk generated by plant operation. Algorithms for QRA preparation and the endpoint toxic concentrations are defined differently within different jurisdictions analyzed within the framework of this study.
- With reference to criteria for risk acceptability, while the individual tolerable fatality risk is the same in all reviewed jurisdictions (tolerable: < 10-6 y-1; not tolerable 10-5 y-1), tolerable societal risk is specific within different jurisdictions. The figure below shows some examples of tolerable societal risk defined in a sample of jurisdictions.
- An environmental acceptability risk is not defined. In the literature, it is suggested that such an environmental criterion could be typically defined through a cost-benefit calculation (49).

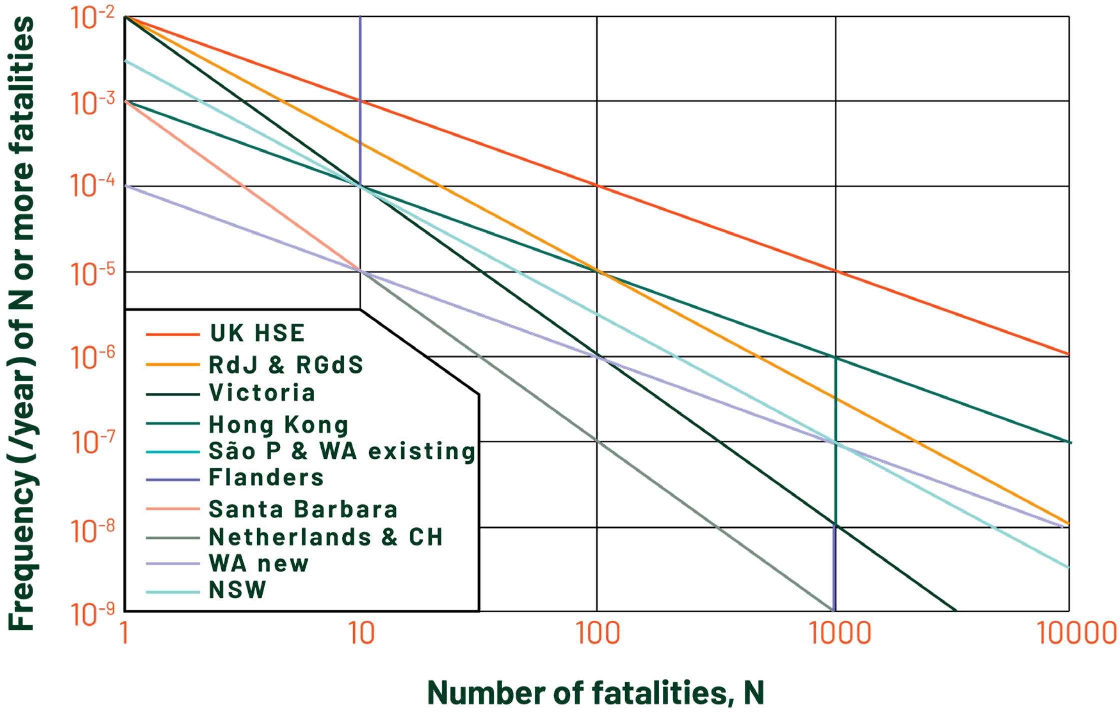


Figure 6-1 Risk acceptability criteria in different jurisdictions (Source: (49))

6.3.2. Process Safety Regulation in LAC

Six of the eight countries of interest within the scope of this report have not yet ratified the ILO convention on the prevention of major accidents: Argentina, Chile, Costa Rica, Panama, Trinidad and Tobago, and Uruguay. Some details on regulations in force in the selected countries is reported in ***Annex IV***. In this section, we focus on a summary of the federal and state regulations in Brazil.

The convention was ratified in Brazil in 2019 through Decree 10.088. It consolidates normative acts issued by the Federal Executive Branch on the promulgation of conventions and recommendations of the International Labor Organization. It should be noted that several standards and guidelines were available in Brazil for major incident prevention even before ratification of the relevant ILO conventions.

At the federal level, Regulatory Standard NR-20 issued by the Ministry of Labor refers to operations with combustible and flammable substances and requires companies to develop Process Safety Risk Analyses of operations. The methodology for risk analysis must be defined by a registered expert and may include Preliminary Risk Assessments, HAZOPs, What If, FMEA, or Decision Tree, among others. It does not include details on how to perform a QRA or criteria for risk acceptability.

At the state level, several guidelines are in place, including:

- The CETESB Norm P4.261 in São Paulo state (50)
- A manual issued by FEPAM in Rio Grande do Sul state (51)
- The INEA Nº 27 issued on 22/01/in Rio de Janeiro state.

In general, Brazilian states that have not issued similar standards use São Paulo as a reference, as well as the federal requirements in standard NR-20.

Also, the CETESB norm, published in 1990 and amended several times until the achievement of the current structure in March 2014, includes details on risk assessment for pipelines. Based on it, the operator shall:

- Assess the distance of reference (dr) based on the hold up of dangerous substances stored in single tanks (Annexes D and E of the Norm provide dr for flammable and toxic substances, based on tank volume)
- Determine the distance to the nearest population of interest (dp) from the center of each container
- When the population of interest is within the within dr radius, assess if the number of persons within it (np) is greater than 25.

If np > 25 persons, a Safety Analysis and Risk Management Program shall be produced. Otherwise, the plant operator shall only present a Risk Management Program.

The Term of Reference for the preparation of a Risk Analysis Study for specific enterprises includes detailed provisions for risk assessment. The tolerability risk is defined:

- in terms of individual risk, in alignment with international standards:
  - o Tolerable risk (of fatality): < 1 x 10-6 y-1
  - o Not tolerable risk: < 1 x 10-5 y-1
  - o Risk to be mitigated if 10-5 y-1.
- In terms of societal risk, as per the figure below.

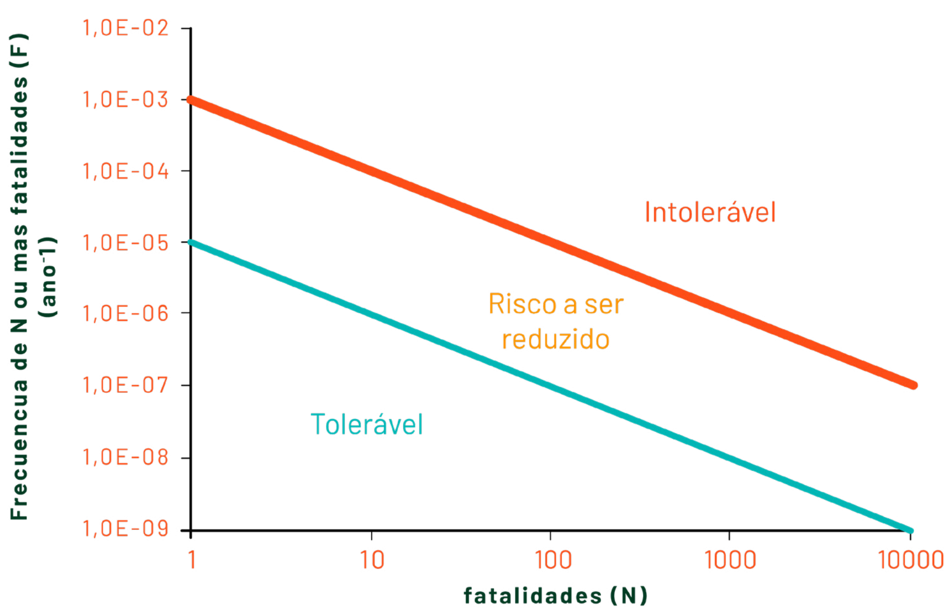


Figure 6-2 Risk acceptability criteria in São Paulo state (Source: (50))

When analyzing the FEPAM guideline of the state of Rio Grande do Sul, it is a more high-level document compared to the one in effect in São Paulo. Facilities are divided into the following categories based on the chemical characteristics of hazardous substances handled within a facility, the hold up, and the tabular approach indicated within the guideline itself:

- Category 1 facilities/activities, which can be considered of negligible risk
- Category 2 facilities/activities, which may cause significant damage at distances of up to 100m from the site
- Category 3 facilities/activities, which may cause significant damage at distances between 100m and 500m from the site
- Category 4 facilities/activities, which may cause significant damage over distances greater than 500m from the site.

The tolerable societal risk is defined according to the following figure. Note that tolerable risk is much higher in Rio Grande do Sul than in São Paulo state.

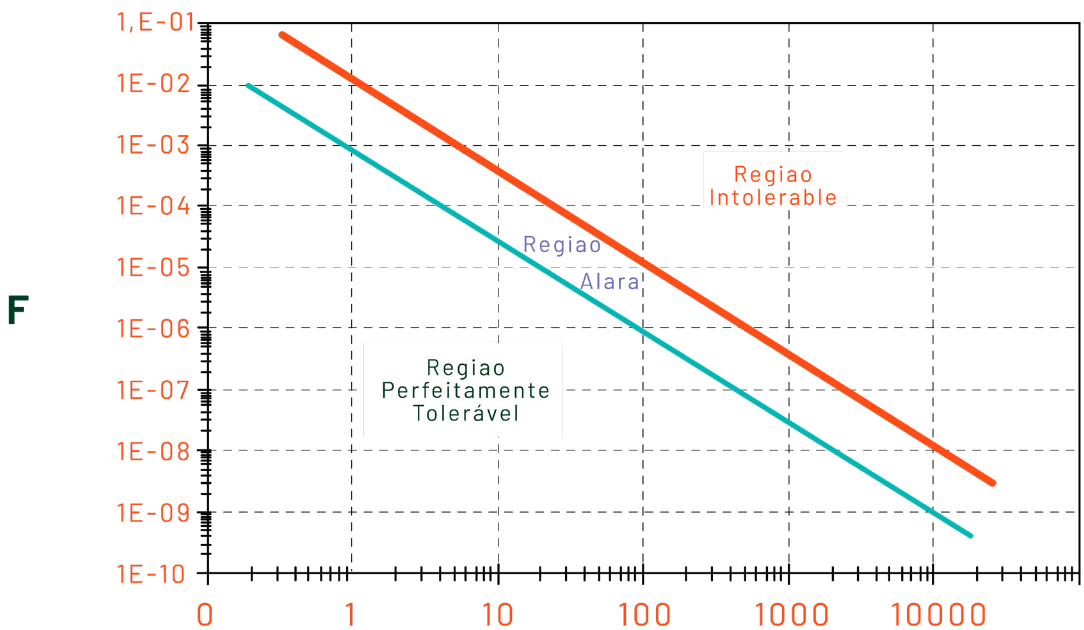


Figure 6-3 Risk acceptability criteria in Rio Grande do Sul state (Source: (51))

Notwithstanding the fact that Brazil ratified the relevant ILO documents at the federal level, as well as the presence of a federal Framework Decree, the actual technical modalities adopted in different Brazilian states for risk control are rather diversified in terms of the high-level approach adopted, the criteria used for calculating risk acceptability, and suggested algorithms for risk assessment.

6.4. Safety in Transportation

Since transportation is one of the four main segments of the GH value chain considered within the study, it was relevant to include a paragraph on main standards and regulations at national and international levels.

6.4.1. International Standards

At a global level, the overarching reference document for the transportation of dangerous goods is represented by the *UN Recommendations on the Transport of Dangerous Goods* (52), addressed to governments and international organizations concerned with the safety in the transport of dangerous goods. The first version dates to 1956 and the last amendment was made in 2019.

UNECE countries (that do not include those in the LAC region) issued separate protocols, among which it is relevant to mention the 1957 UNECE *Agreement concerning the International Carriage of Dangerous Goods by Road* ("ADR") (53), which entered into force on January 29, 1968. The agreement was amended in 1975 (with provisions entering into effect in 1985).

The key article of the ADR is the second one, which, aside some exclusions, states that dangerous goods may be carried internationally on road vehicles subject to compliance with:

- The conditions established in Annex A for the goods in question, as regards their packaging and labelling; and
- The conditions established in Annex B, as regards the construction, equipment, and operation of the vehicle carrying the goods in question.

Annexes A and B have been regularly amended and updated since the entry into force of ADR. Consequently, a revised consolidated version to the amendments that entered into force on January 1, 2021, has been published as document ECE/TRANS/300, Vol. I and II (ADR 2021).

The structure is consistent with that of (i) the United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations, (ii) the International Maritime Dangerous Goods Code (of the International Maritime Organization), (iii) the Technical Instructions for the Safe Transport of Dangerous Goods by Air (of the International Civil Aviation Organization), and (iv) the Regulations concerning the International Carriage of Dangerous Goods by Rail (of the Intergovernmental Organization for International Carriage by Rail).

The layout of the document is as follows:

- Annex A: General provisions and provisions concerning dangerous articles and substances
    - Part 1: General provisions
    - Part 2: Classification

- o Part 3: Dangerous goods list, special provisions, and exemptions related to limited and excepted quantities
- o Part 4: Packing and tank provisions
- o Part 5: Consignment procedures
- o Part 6: Requirements for the construction and testing of packaging, intermediate bulk containers (IBCs), large packaging, tanks, and bulk containers
- o Part 7: Provisions concerning the conditions of carriage, loading, unloading, and handling

- Annex B: Provisions concerning transport equipment and transport operations
  - o Part 8: Requirements for vehicle crews, equipment, operation, and documentation
  - o Part 9: Requirements concerning the construction and approval of vehicles.

6.4.2. Transport Safety Regulation in LAC

With respect to the LAC region, it is relevant to highlight the presence in the region of a trade protocol among Argentina, Brazil, Paraguay, Uruguay, Venezuela, Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, and Suriname[6] called Mercosur (in Spanish), Mercosul (in Portuguese), or Ñemby Ñemuha (in Guarani). Mercosur is officially regarded as a Southern Common Market, established by the Treaty of Asunción in 1991 (54) and the Protocol of Ouro Preto in 1994 (55).

Initially, a free trade zone was established in which signatory countries would not tax nor restrict each other's imports. As of January 1, 1995, the area became a customs union, in which all signatories could charge the same quotas on imports from other countries (common external tariff).

With reference to the transport of dangerous goods, Mercosur signatory countries signed in 1994 the Agreement on the Transport of Dangerous Goods in Mercosur. The agreement states that that the transport of dangerous goods must be carried out under rules that guarantee the safety of people, their property, and the environment, and that is necessary to have a common legal framework for distribution across the region of goods considered dangerous, which must be transported safely for people, their goods, and the environment. Within the framework of this study, the most relevant articles and provisions include:

- Article 2. Transport of goods and hazardous waste shall be governed by provisions of the Agreement and by specific rules laid down by competent bodies of each of the states' parties.
- Article 4. The entry or exit of dangerous goods carried out in accordance with requirements established by the International Maritime Organization (IMO) or the International Civil Aviation Organization (ICAO) shall be accepted by the states' parties.
- Article 6. For the purposes of transport, dangerous goods shall be placed in packaging or equipment that complies with the requirements set out in the United Nations Recommendations for the Transport of Dangerous Goods.

6 Argentina, Brazil, Paraguay, and Uruguay are full memebrs. Venezuela is a full member but has been suspended since 01/12/2016. Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, and Suriname are associate countries. Other Latin American nations have expressed interest in joining the group.

- Article 7. The transport of dangerous goods may only be carried out by vehicles whose technical characteristics and state of conservation guarantee safety, compatible with the risk corresponding to the goods transported. During the operations of loading, transport, unloading, trans-shipment of dangerous goods, or cleaning and decontamination, vehicles shall carry the elements identifying the risk and the safety panels identifying goods and risks associated with them.
- Article 8. Documentation for the transport of dangerous goods shall include information that perfectly identifies the material and indicates procedures to be implemented in the event of an emergency.
- Article 9. All personnel involved in the transport and handling of dangerous goods must receive specific training for the functions incumbent upon them and have adequate protective equipment.
- Article 10. Certifications and test reports issued in one state party shall be accepted by the others when required in the context of this agreement.

The agreement is not signed by countries that are not part of the trade protocol.

6.4.3. Safety Considerations in Transportation

Regardless of the delivery or shipping modalities of hazardous substances, the literature analyzed during this study related to safety in transportation of hazardous substances consistently highlights that safety can be increased through[7]:

- Strict compliance with existing rules related to certification and verification of vehicles
- Strict compliance with existing rules related to loading/unloading modalities and transportation (including labelling and signaling)
- Operator training (including training for emergency management)
- Establishment of robust control agencies.

Transport of dangerous goods is perceived as a complex problem, which calls for widely understood support and cooperation of various direct (senders, carriers, and receivers) and intermediate (society, rescue teams, security forces, and the media) participants in the road transport chain.

Issuance of technical standards specifically addressing provision for vehicles, wagons, vessels, or even pipelines intended for hydrogen transportation is ensured by existing international technical agencies and is something that cannot be addressed within the framework of this study. Compliance issues, however, are considered within the scope of the work.

7 This consideration is based on the review of numerous papers. This one appears to describe well the improvement that can be achieved through proper management of procedures: Michailiuk, B. (2016). Safety of the road transport of dangerous goods, *Journal of Environmental Protection, Safety Education and Management*, 7(4), 34-42.

Figure 6-4 LPG tank wagon explodes after the collapse of an axle due to the growth of a fatigue crack, not detected during inspections Viareggio (Italy), 2009

6.5. Freshwater Supply

ESPS3 states that when a project is a potentially significant consumer of water, the borrower shall adopt measures that avoid or reduce water usage so that the project's water consumption does not have significant adverse impacts on people and biodiversity.

A detailed review of international best practices and regulations in place in LAC related to freshwater management is included in the IDB document *The Regulation of Public Utilities of the Future in Latin America and the Caribbean* (56). It should be highlighted that neither the mentioned document nor other papers reviewed for this study report quantitative indications on the amount of water abstraction that can be considered sustainable, as a matter of example in terms of percentage of water withdrawal compared to available renewable resource.

The paper *Review of methods to assess sustainability of industrial water use,* by J. Willet and others (57), of specific interest in this context, shows Sustainable Systems Indicators (SSIs) that relate resource use to the carrying capacity of the local environment. SSIs for water use evaluate whether water use exceeds the natural water renewal (quantity) and whether emissions remain within the assimilation capacity of ecosystems (quality). The paper includes a review of methods used to assess industrial water use, and of these, which methods incorporate SSIs. In total, 82 different assessment methods were identified in 340 papers.

The review allowed the authors to conclude that there are not consolidated methods or KPIs for the assessment of the sustainability of freshwater demand of the industrial sector at the global level.

The mentioned IDB guideline on *Good Practice in Environment, Health, and Safety in Latin America and the Caribbean* includes suggestion for Integrated Water Resource Management ("IWRM"):

A river basin or watershed is a complex system where multiple stakeholders interact, on occasions with conflicting interests. Thus, water security of a river basin or watershed requires joint collaboration between the public and private sector and the civil society, with an organization that can overcome market failures caused by water users that do not internalize negative externalities that generate the consumption or contamination of water resources. The current paradigm in water resource governance is to take a comprehensive approach to managing the resource, meaning that all stakeholders living within a river basin or watershed should be involved in the decisions that affect them and should develop consensus-based plans that are environmentally and socially sustainable. Nevertheless, successful cases are limited. Several entities have proposed tools and guidelines for IWRM, developing the application of good practices such as: (i) long-term planning of which the planning follows an evolving, gradual and participative process, within a framework of land management of the urban and rural territory; (ii) recognition of change drivers and the need to adapt to the changes in the river basin and watersheds; (iii) incorporation of all relevant, internal and external stakeholders with adequate information and communication systems; (iv) create river basin and watershed organizations as institutional mechanisms to plan, regulate and control interventions for recovery and conservation of water resources; and (v) improve information and accountability systems by the water managers, among other aspects.

Examples of potential applicable tools for IWRM include the use of GWP IWRM Toolbox , a free, online database about IWRM, developed by the Global Water Partnership ("GWP"). GWP is a global network with over 3,000 partner organizations in 179 countries. The network has 69 accredited Country Water Partnerships and 13 Regional Water Partnerships; accredited countries include Argentina, Brazil, Costa Rica, Chile, Colombia, Panama, and Uruguay.

6.6. Brine Management and Discharge

The use of deionized water produced by desalination plants may reduce freshwater demand and generate the need to discharge a stream of brine into the environment.

Despite desalination technologies dating to the late 19th century , legislation in the LAC region regulating both plant operation and wastewater discharge is non-specific. In fact, although several countries worldwide and within the LAC region regulate effluents' discharge from industrial processes or sewers to ground, surface, or marine water bodies, they often do not refer to maximum emission values for the main component of brine, i.e., sodium chloride (NaCl).

Nevertheless, research about the environmental consequences of brine discharges is active in Chile, which is one of the most advanced countries in terms of GH technology. Cornejo-Ponce et al. in their paper Analysis of Chilean legal regime for brine obtained from desalination processes (2020) (5) analyze the national regulatory regimes in countries that are among the main producers of desalinated water and that give rise to regulations governing brine disposal.

The paper concludes that *"although progress has been made in regulating water quality, there is still no legislation that sets critical limits for the chemical components or physical properties of brine with special regard to the habitats and species that can be found and are likely to be affected."* (5)

Notwithstanding this, existing standards, summarized in the table below as presented by Cornejo-Ponce (5), represent a valuable reference for future development of guidelines and regulations in this respect.

Country	Applicable to/About	National regulation	Applicable limits
USA	All desalination facilities discharging brine into ocean waters, including plants blending brine and wastewater.	(i) Water Quality Control Plan for the Ocean Waters of California; (ii) Clean Water Act; (iii) National Pollutant Discharge Elimination System Permit Program; (iv) National Environmental Policy Act.	Does not state maximum permissible limit of salinity, expressed as NaCl. The only relevant indication is on discharges that shall not exceed a daily maximum of 2.0 parts per thousand (ppt) above natural background salinity***
Saudi Arabia	Requires compliance with national guidelines described in the discharge permit.	Public Environmental Law (Royal Decree No. M/34 2001); Guidelines for concentrations in discharge and at the edge of the mixing zone (size determined on a case-by-case basis).	Only chlorine (residual) 0.5 mg/L. Does not state maximum permissible limit of salinity expressed as NaCl
	Direct discharge of water desalination plants.	General Environmental Regulations and Rules for implementation – Appendix 2.1: Guidelines for classification of industrial and development projects; Key principles for environmental assessment.	
Spain	A wastewater treatment plant in any of the following cases: (i) plant capacity exceeding 150,000 equivalent inhabitants; (ii) effluents affect an aquatic environment classified as sensitive; (iii) rivers, when the discharge point is close to intakes for human supply.	Royal Decree 1302/1986 and successive modifications. In particular, Group 8 – Hydraulic engineering and water management projects.	Does not state maximum permissible limit of salinity, expressed as NaCl
	Projects subject to EIA with desalination facilities	Law 21/2013	Refers to volumes greater than 3'000 cm3/d. Does not state maximum permissible limit of salinity, expressed as NaCl

8 The GWP IWRM Toolbox official website is available at https://www.gwp.org/en/learn/iwrm-toolbox/About_IWRM_ToolBox/ (last access 03/01/2022).
9 The region's first desalination plants were constructed in Chile. They date back to 1872, when the first solar desalination plant was installed in the office of Las Salinas Nitrate Mine in the Atacama Desert.

Country	Applicable to/About	National regulation	Applicable limits
Other Mediterranean countries*	Agreement limiting physical-chemical discharge rates (e.g., salt, chlorine, temperature, etc.) and requiring an EIA.	Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (1995). In particular: (i) Annex I: A1; B; (ii) Annex II: A13 (i.e., Substances that, even without being toxic, may be harmful to the marine environment or hinder any legitimate use of the sea as a consequence of the amounts discharged)	Does not state maximum permissible limit of salinity, expressed as NaCl
Chile	National effluent standards	Environmental norms established in Supreme Decree No. 90/00	Does not state maximum permissible limit of salinity, expressed as NaCl
Mexico	It refers to (i) rejected water discharge works, (ii) discharging rejected water into the sea, (iii) infiltration/injection of rejected water into wells, (iv) discharging rejected water in maritime beaches, (v) discharging into evaporation ponds, and (vi) in lotic bodies	Proy-NOM-013-CONAGUA/SEMARNAT-2015**	Does not state maximum permissible limit of salinity, expressed as NaCl

* "Other Mediterranean countries" include: France, Greece, Israel, Italy, Lebanon, Libya, Malta, Morocco, Monaco, Syria, Tunisia, Turkey.
** Regulatory criteria proposed by the Mexican Ministry of the Environment by the National Water Commission (Conagua/Semarnat) that establishes specifications and requirements for the intake and discharge works that must be fulfilled in desalination plants or any other processes generating saline or saline rejection waters within Mexican territory.
***Considering ocean water to have a salinity of approx. 35'000 mg/L.

Table 6-1 Examples of standards for brine discharge (Source: (5))

A different paper, *Management of Brine Discharges to Coastal Waters. Recommendations of a Science Advisory Panel* (58) of the Southern California Coastal Water Research Project, includes the following table with environmental relevant standards.

Region/Authority	Salinity Limit	Compliance Point (relative to discharge)	Source
US EPA	Increment ≤4 ppt		
Carlsbad, CA	Absolute ≤40 ppt	1,000 ft	San Diego Regional Water Quality Control Board 2006
Huntington Beach, CA	Absolute ≤40 ppt salinity (expressed as discharge dilution ratio of 7.5:1)	1,000 ft	Santa Ana Regional Water Quality Control Board 2012
Western Australia guidelines	Increment ≤5%		
Oakajee Port, Western Australia	Increment ≤1 ppt		The Water of Victoria State Environment Protection Policy
Perth, Australia/Western Australia EPA	Increment ≤1.2 ppt at 50 m and ≤0.8 ppt at 1,000m	50 m and 1,000 m	Wec, 2002
Sydney, Australia	Increment ≤1 ppt	50-75 m	ANZECC (2000)
Gold, Coast, Australia	Increment ≤2 ppt	120 m	GCD Alliance (2006)
Okinawa, Japana	Increment ≤1 ppt	Mixing zone boundary	Okinawa Bureau for Enterprises
Abu Dhabi	Increment ≤5%	Mixing zone boundary	Kastner (2008)
Oman	Increment ≤ ppt	300 m	Sultanate of Oman (2005)

Table 6-2 Examples of standards for brine discharge
(Source: (58))

Notably, Mexico's draft standard, published in 2015, establishes specifications and requirements for supply and discharge installations in desalination plants or processes that generate brackish or saline wastewater. The proposed regulation deals with parameters such as turbidity, pH, total suspended solids, chemical oxygen demand, total N, total P, aluminum, copper, cadmium, and total chromium, even though it does not include references to chloride, sodium, or salt expressed as salinity.

With reference to countries in the European Union:

- Spain, one of the countries with the highest production of desalinated water, does not have specific legislation addressing the concentration or any other physical–chemical parameters of brine discharge from processes of desalination.

- The overarching European Union Water Quality Directives[10] establish maximum permitted limits for effluent discharge into receiving water bodies and are overall aimed at avoiding damage to existing water resources. Nonetheless, they do not include maximum limits for the physical-chemical properties of brine.

In Israel, desalination plants are usually permitted when the salinity within 1,000 m from the discharge point does not exceed 1.7 times the ambient salinity.

6.7. General Guidelines for Management of EHSS Aspects

The following documents have been analyzed with reference to the management of EHSS aspects relevant to the development of a GH value chain in the LAC region.

Issuing entity	Name and date	Comments
IDB	Environmental and social policy framework (2020) and related guidelines for the environmental and social policy framework (2021)	Applicable to all projects
IDB	Update to the Institutional Strategy 2010–2020	Applicable to all projects. Provides strategic direction to the IDB Group ("IDBG") over the next four years. The UIS identifies three main development challenges: • Social exclusion and inequality • Low productivity and innovation • Lack of regional economic integration
IDB	SECTOR FRAMEWORK DOCUMENTS	The *water and sanitation sector framework document* appears to be one of the most relevant documents, especially for what has been reported with reference to integrated water resource management
IDB	Good Practice in Environment, Health and Safety in Latin America and the Caribbean, 2016	Applicable to all projects
IDB	Disaster and Climate Change Risk Assessment Methodology for IDB Projects: A Technical Reference Document	Applicable to all projects

10 It is a broad corpus of regulations addressing various topics, from river basin management (Water Framework Directive 2000/60/CE) to marine waters (Marine Strategy Framework Directive 2008/56/EC), from wastewater (e.g., Urban Wastewater Directive 91/271/EEC, and Directive 2006/11/EC on pollution caused by certain dangerous substances discharged into the aquatic environment of the community) to drinking water (Drinking Water Directive 2020/2184). All references are available at https://ec.europa.eu/environment/water/index_en.htm (last access 25/11/2021).

Issuing entity	Name and date	Comments
WBG - IFC	General EHS Guidelines, 2007	Applicable to all projects
WBG - IFC	Environmental, Health, and Safety Guidelines for Large Volume Inorganic Compounds Manufacturing and Coal Tar Distillation, 2007	Includes provisions to produce ammonia, including environmental standards of effluents and efficiency KPIs
WBG - IFC	Environmental, Health, and Safety Guidelines for Nitrogenous Fertilizer Production, 2007	Includes provisions for production of ammonia, including environmental standards of effluents and efficiency KPIs
WBG - IFC	Environmental, Health, and Safety Guidelines for Gas Distribution Systems, 2007	-
WBG - IFC	Environmental, Health, and Safety Guidelines for Shipping, 2007	-
WBG - IFC	Environmental, Health, and Safety Guidelines for Ports, Harbors, and Terminals, 2017	-
WBG - IFC	Environmental, Health, and Safety Guidelines for Electric Power Transmission and Distribution	-
WBG - IFC	WB EHS Guidelines for Railways	-
WBG - IFC	Environmental, Health, and Safety Guidelines for Wind Energy, 2015	-
European commission	Reference Document on Best Available Techniques for the Manufacture of Large Volume Inorganic Chemicals - Ammonia, Acids, and Fertilisers	It includes the BAT for ammonia plants
European commission	Best Available Techniques (BAT) Reference Document for the Production of Large Volume Organic Chemicals	It includes the BAT for methanol plants
European commission	Best Available Techniques (BAT) Reference Document for Common Wastewater and Waste Gas Treatment/Management Systems in the Chemical Sector	It includes the BAT for wastewater treatment
ISO	ISO standards for management systems of quality (ISO 9000 family), environment (ISO14000 Family), OHS (ISO45000 Family), and energy (ISO5001)	
GRI	Universal standards	The GRI Standards on reporting environmental and social impacts, revised to incorporate reporting on human rights

Table 6-3 Relevant international EHSS standards
(Source: Authors' own elaboration)

Existing guidelines appear to provide environmental standards and KPIs for most activities in the green hydrogen value chain, i.e., power generation, power transmission, gas transmission and distribution in piping, ammonia production, port construction, and shipping. However:

- A standard specifically related to hydrogen electrolysers is not available. Some of the analyzed standards are rather old and a holistic approach for the GH supply chain is not available.
- The standard related to gas distribution systems clearly refers to natural gas distribution and does not cover specific issues related to hydrogen distribution.

6.8. Technical Standards

There is broad consensus on the need for shared technical standards on GH.

Technical standards more generally related to hydrogen have been developed on all the continents and thousands of different standards are available. Each country or jurisdiction may adopt its own, either based on internationally adopted standards or independently produced. ***Annex VI*** includes a brief list of international and regional agencies that regularly publish technical standards.

The best open-source database known to Anthesis on standards and codes specifically related to hydrogen is the *Hydrogen Fuel Cell Codes & Standards* portal. The database covers mainly the USA's hydrogen standards, but also European and Australian ones, and is available at the following address: https://h2tools.org/codes-standards.

Based on the review completed by Anthesis, high-level standards under development specifically dedicated to GH address the following topics (among others):

- A shared taxonomy for green hydrogen, aimed at avoiding confusion about different nomenclatures (green, blue, grey hydrogen, renewable hydrogen, bio-hydrogen, etc.), and to ensure a common basis for project financing and distribution of incentives
- Overarching standards for the use of hydrogen as a fuel rather than other dangerous substances.

Worldwide technical R&D efforts seem focused on the following topics (among others):

- "Holistic" design strategies for development of inherently safer systems
- Embrittlement of metals generated by hydrogen
- Hydrogen sensors and hydrogen odorizing
- Hydrogen permeation through sealing
- Structural materials suitable for use at hydrogen's low liquefaction temperature
- Test measurement protocols and methods for materials, components, and systems (development, validation, and harmonization).

6.9. International Agreements

In previous paragraphs, some international agreements relevant to the production or transportation of hydrogen have been already mentioned. They are listed below again for quick reference:

- UN Recommendations on the Transport of Dangerous Goods
- UNECE Agreement concerning the International Carriage of Dangerous Goods by Road ("ADR")
- Agreement on the Transport of Dangerous Goods in Mercosur
- ILO convention no.174 of 1993 on the Prevention of Major Industrial Accidents Convention and related recommendation No. 181

Further acts that are potentially relevant include:

- IMO (International Maritime Organization) International Convention for the Prevention of Pollution from Ships (MARPOL). The Convention includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations - and currently includes six technical Annexes. Special areas with strict controls on operational discharges are included in most Annexes. Please refer to the dedicated IMO web site (https://www.imo.org/en/About/Conventions/Pages/ListOfConventions.aspx) for further details.

While hydrogen might have some effects on climate change and protection of the stratospheric ozone layer (please make reference to Section 8), neither the Protocol of Montreal nor conventions on GHG emissions establish limitations directly applicable to the GH value chain (aside from general provisions generally applicable to the industrial sector).

Hydrogen Mobility Joint Project, which envisaged distributed GH production for vehicles refueling, in Germany

Credit: https://www.h2-view.com/

07
Scoping

The present section illustrates the process that Anthesis followed to scope the subject of the present study, to derive preliminary considerations for a future sectoral standard.

This section aims to identify potential areas of concern, and is based on a systematic analysis of the Environmental and Social Policy Framework (ESPF). Section 7 is structured according to the logic of the ESPS and the main output of this part is the list of unique EHS aspects within the GH value chain.

In fact, while potentially all the ESPSs and ESPS's topics are relevant to the whole GH value chain, the sections below highlight aspects that have been deemed particularly relevant to the GH value chain in the LAC region:

- Identify impacts and risks that are specific to the GH value chain, mainly with reference to ESPS2, ESPS3, ESPS4, and ESPS6
- Identify impacts and risks that may have different magnitude according to the location of the projects, generally more relevant to ESPS5, ESPS7, and ESPS8
- Analyze the transverse provisions of ESPS1, ESPS9, and ESPS10 as they apply to all the projects, highlighting potential critical aspects.

The findings identified in Section 7 are then analyzed in Section 8, which includes a preliminary indication of actions aimed to control and mitigate potential risks and impacts. As most identified findings and areas of concern are transversal to several ESPSs, Section 8 is mostly structured in paragraphs separately addressing each single finding or area of concern, not necessarily following the structure of ESPS.

The main activities of the scoping phase were:

- An initial high-level desktop review of relevant materials (i.e., international guidelines and standards, relevant case studies, available policies and programs, etc.)
- Engagement of IDB specialists over regular update calls
- Organization of a brainstorming activity involving Anthesis' project experts.

Each of the above activities and the materials prepared for/as a consequence of their completion, were designed and implemented against IDB's Environmental and Social Performance Standards ("ESPSs").

7.1. ESPS 1

Drawing on the elements of the established management process of "plan, do, check, and act," the ESMS entails a methodological approach to managing environmental and social risks and impacts in a systematic and structured way on an ongoing basis.

A good ESMS appropriate to the nature and scale of the project promotes sound and sustainable environmental and social performance and can lead to improved financial, social, and environmental outcomes. The ESMS will incorporate the following elements: (i) project-specific environmental and social framework; (ii) identification of risks and impacts; (iii) management programs; (iv) organizational capacity and competency; (v) emergency preparedness and response; (vi) stakeholder engagement; and (vii) monitoring and review.

Each operation financed by IDB shall have an ESMS proportional to the nature, scope, risks, and impacts of the operation. The seven pillars of an Environmental and Social Management System (ESMS) include:

- An Environmental and Social Management Framework specific to the operation (legal regulations, international commitments, Bank policies; see also Section 6.9)
- Process for identification of impacts and risks
- Process and plans for mitigation of impacts and risks
- Organizational capacity to mitigate and manage risks and impacts
- Processes for responding to emergencies and contingencies
- A Stakeholder Engagement Plan (SEP)
- Processes for monitoring and reporting.

While all the pillars and related provisions included in ESPS1 are relevant to any project, the phase of risk identification is specifically critical with reference to GH projects and shows several peculiarities.

From the analysis of case studies coupled with an extensive literature review, it is indeed reasonable to expect a diversification of projects both in terms of footprint (including large-scale projects), and in terms of being green or brown field developments. GH projects may involve both government actors and private investments and may consist of several components, namely:

- Solar/wind farm(s)
- Dedicated transmission line
- Hydrogen production plant
- Conversion facilities (for ammonia/methanol production)
- Shipping/transportation facilities.

Such relevant projects may affect and determine the development of vast areas and numerous communities (both at the renewables and H2 production sites, and along the transmission line), with different positive and negative impacts. The projects, which include both linear and punctual components, may induce fragmentation of the territory, in a region (LAC) characterized by vast areas with uniform land use, ecosystems, and landscape, with consequent potential effects on the social and demographic development of the area.

The peculiarities of the risk assessment of GH projects have been studied with reference to the following two phases:

- Siting and preliminary risk identification
- Decommissioning.

All other provisions of ESPS1 shall be applied to GH projects according to the consolidated best practice, without specific deviations/peculiarities.

Siting and preliminary risk identification

A key aspect of the process of developing a GH value chain is represented by the identification of potential sites for developments, with preliminary identification of potential environmental and social risks and impacts. The siting of facilities may directly trigger or affect several risks and impacts addressed by ESPS3, 4, 5, 6, 7, and 8. The phase of risk identification, transversely completed considering all the ESPSs, is indeed crucial. There are two main aspects to be mentioned as significant in relation to siting of GH projects:

- **Accounting for cumulative impacts.** Generally, cumulative impacts of a development cannot be accounted for through the simple juxtaposition of impacts identified within separate ESIAs for each component, some of them linear and some punctual. An ESIA that is completed with reference to a single part of a GH development project (e.g., the wind farm, electrolysers, transmission line, etc.) will likely not be able to capture in full the social and environmental relevance of the entire project. The assessment of cumulative impacts shall also be considered when the financedpProject only includes a single component of the overall project (for example, the electrolyser), because in this case all other components (for example, the wind farm and transmission line) shall be considered associated facilities, i.e., new or additional infrastructures that, irrespective of the source of financing, are deemed essential for the financed project.
- **Accounting for impacts of large-scale projects.** The size of the renewable plant may be very large. Currently, wind turbines (more than 200m tall) may have a capacity of 6.5MW. Thus, the development of a wind farm of 1GW capacity requires at least 155 wind large-scale towers, that will occupy a surface of tens of km2. Moreover, while renewable plants are more commonly located in rural areas, an H2 production site is likely to be in an area more connected to existing infrastructures (i.e., roads, pipelines, port areas), and the construction of rather long and dedicated transmission lines cannot be excluded, with different impacts to the communities whose territory will be crossed by the lines.

Decommissioning

With reference to the development of a GH value chain in the LAC region, the identified risks include:

- **Ensuring proper dismantling of large-size industrial facilities.** As some facilities will be built in rather pristine areas where industrial or urban development may not occur, there exists the risk of abandonment of the industrial facilities at the end of their lives. The novelty implied in many aspects of the industry makes it difficult to assess the average lifetime of a project, which could be much less than the average 20-30 years of plants in similar industries, depending on the pace of plant obsolescence and achievement of new advancements.
- **Considering effective waste management as an integral part of decommissioning.** It is already possible to foresee that the decommissioning of electrolysers and related renewables plants will generate a large amount of electric and electronic waste, containing hazardous substances. The assessment of the type and amount of waste to be managed will depend on the specific technology used within each single project and on the development of the electrolyser technology.

7.2. ESPS 2

Pursuit of economic growth through employment creation and income generation should be accompanied by protection of the fundamental rights of workers.

With reference to working conditions, potential peculiar aspects of the GH value chain include:

- **Considering human rights in the supply chain.** Potential adverse impacts on human rights are linked to the sourcing of conflict minerals and other critical materials to produce GH technologies, fuel cells, and electrolysers.
- **Considering capacity building for local workers.** Developing a GH value chain also implies potential positive impacts on the local workforce, to the extent to which projects may include educational initiatives for local capacity building. Being able to recognize positive impacts associated with capacity building efforts at the local level within GH projects, and supporting coherent investments in this direction, helps create a positive narrative around the development of a GH value chain in the region.

Depending on the siting of the project, the following may be also significant:

- **Managing worker influx.** Significant influx of workers, both unskilled and skilled, is likely. The likely presence of migrant workers -- in particular, the less skilled workforce employed during construction of large plants-- implies the need to properly manage relevant provisions of ESPS2 (and aspects related to the control of the outbreak of communicable disease, treated under ESPS4).

Occupational Safety and Health is analyzed under two perspectives:

- The OHS risks to which workers are exposed during normal plant operation; and
- The safety process, i.e, the risk of incidents caused by faulty equipment and loss of process control that potentially may affect both workers and external communities.

The safety process (including risk of fire and explosions) is analyzed with reference to ESPS4. OHS aspects of concern more typical of GH projects include:

- Exposure to intense electromagnetic fields (within the electrolyser building)
- Exposure to toxins (including methanol and ammonia, in conversion and storage units)
- Presence of cold surfaces (in cryogenic storage units).

GH technology implies the handling of dangerous substances, but a safe workplace can be ensured by applying best practice methods for safety management adopted in the industrial sector, without the need to develop specific guidelines related to the GH value chain.

7.3. ESPS 3

The project-related risks and impacts associated with resource use and the generation of waste and emissions need to be assessed in the context of project location and local environmental conditions.

When scanning potential risks and impacts associated with the development of a GH value chain in the LAC region against the provisions of *ESPS 3 – Resource efficiency and pollution prevention,* the main aspects that are unique to the sector and the related technologies were identified:

- **Resource efficiency:**
  - o Water additionality

- **Pollution prevention:**
  - o Brine discharge
  - o Wastewater from ammonia and methanol plants
  - o Waste, sludge, and wastewater management

Resource efficiency and GHG emissions

Water additionality

Water demand for GH production is significant. The sustainability of freshwater consumption depends on the environment of reference. The impact assessment shall consider the shared (current and potential) use of the water resource, to be analyzed through proper forecasting models, also taking into account both the current level of water stress and the medium/long-term effects of climate change, which may worsen conditions.

GHG emissions (and ozone depleting substances)

GH will likely play a significant role in the process of decarbonization of LAC economies, especially in those sectors that are hard or nearly impossible to electrify, such as air transport.

However, the production and use of GH may imply the use of fossil fuels and GH emissions in different phases within the value chain (with specific reference to the plant construction and product transportation phases), that shall be taken into account. It shall be also highlighted that the overall energy efficiency of the GH value chain may be significantly low (as highlighted in Section 3.6) and this may affect the specific GHG emissions rate (kgCO2 eq per kWh actually delivered to end users), when emissions of the whole GH life cycle are considered.

An aspect of potential concern is that based on still uncertain data, hydrogen released into the atmosphere by leakages may increase the lifetime of methane, increasing climate effects and depletion of the ozone layer. Thus, when used on a large scale, it is important to limit as far as possible the leakages into the atmosphere.

Pollution Prevention

Brine discharge

The use of reverse osmosis for desalination of seawater may avoid the need for freshwater for electrolysers.

However, two outputs are obtained from the desalination process: demineralized water and residual water, known as brine. Potential environmental impacts generated by brine discharge that must be considered include:

- Increase in salinity and density of water in the receiving body, which may lead to higher water stratification and reduced oxygen exchange in the water column.
- Eutrophication due to phosphate enrichment if polyphosphates and organic cleaning solutions are added to the brine.
- Discoloration of receiving waters, due to high concentration of ferric substances, also with high-suspended solids and turbidity.
- Impact on the composition and distribution of biota.

Wastewater from ammonia and methanol plants

Hydrogen is gaseous and non-toxic, while both ammonia and methanol are not persistent and biodegradable. However, in case of continuous discharge or leaks into water bodies, these may represent an immediate danger to aquatic life, with subsequent impacts also on the livelihood of communities depending on it.

Waste, sludge, and wastewaters

Topics related to generation of sludge or wastewater from (fresh) water purification for electrolysis seem not well documented in the literature. The quantity of the sludge depends on the level of contaminants originally present in the raw water and the purity of the water requested by the specific electrolysis process adopted. Based on the authors' experiences in chloro-alkali facilities, the amount of produced sludge can be significant.

Both ammonia and methanol production processes make use of catalysts, and spent catalysts are among the most typical hazardous wastes of these projects. The capacity of treatment of the spent catalyst within the host country of production facilities represents a crucial aspect to be investigated and managed to ensure proper treatment.

7.4. ESPS 4

> *Project activities, equipment, and infrastructure can increase community exposure to risks and impacts, including those caused by natural hazards and climate change.*

Physical Safety of Works and Equipment

Process safety is a major concern in facilities where hydrogen, ammonia, or methanol are produced and stored. Fire, explosions, and accidental toxic releases may affect areas well beyond the plant area and endanger lives of communities in the area of influence.

Points of concern in relation to safety, that are specific to the GH industry include:

- The most challenging operational condition of electrolysers in GH projects is that, in most cases, the plant will be connected to a renewable energy project in an isolated power supply system (not connected to the grid). In such systems, the control of fluctuations of available power is limited and the plant will operate under a fluctuating regime. The need to manage power fluctuations is a significant deviation from common industrial practices in electrolysers used for chlor-alkali or other chemical production, and it may imply difficulties in ensuring a similar level of safety.
- New electrolysers are based on innovative design and materials and are much bigger in size than in the past. Past experience is useful, but data on reliability of process equipment and material durability are not necessarily readily available nor valid. The technology should be considered (partially) "not consolidated" and "innovative."
- In integrated hydrogen-ammonia plants, storage of significant amounts of hydrogen will be necessary, because electrolysers and ammonia plants are separate facilities with different regimes. This may generate the risk of domino effects with propagation of incidents between storage units.
- In small-size projects for GH production for mobility where there is distributed generation capacity, the size of hydrogen electrolysers will be very limited, with skid mounted devices, operated unmanned. This will imply a "distributed" risk, at numerous locations, potentially close to or within an urban environment.

Specific guidelines shall be developed to support the safe management of the aforementioned topics.

Once produced, hydrogen will be transported by different solutions, each triggering specific environmental, OHS, and social considerations. The development of a GH value chain will likely increase the trade of hazardous substances (hydrogen itself and ammonia or methanol) and potential related environmental, OHS, and social considerations, including community safety.

Existing EHS guidelines related to the construction of port or gas distribution systems are a useful reference for the management of EHSS topics within the GH value chain (i.e., the WBG/IFC *Environmental, Health, and Safety Guidelines for Ports, Harbors, and Terminals,* 2017).

Ecosystem Services and Exposure to Diseases

The critical phase of risk identification related to ESPS1 shall also consider potential impacts and risks related to ESPS4 and, specifically, on ecosystem services and exposure to diseases.

The IDB Environmental and Social Policy Framework identifies four types of ecosystem services:

1. Provisioning services, which are the products people obtain from ecosystems
2. Regulating services, which are the benefits people obtain from the regulation of ecosystem processes
3. Cultural services, which are the non-material benefits people obtain from ecosystems
4. Supporting services, which are the natural processes that maintain the other services.

With reference to Type 1 and 2 ecosystem services, the diminution or degradation of natural resources, with specific reference to the sources of freshwater or fishing stocks, may result in health-related risks and impacts. Land use changes entailed by large-scale GH projects and related large-scale renewable farms may imply the loss of natural buffer areas such as wetlands, mangroves, and upland forests that mitigate the effects of natural hazards such as flooding, landslides, and fire; these may result in increased vulnerability and community safety-related and health-related risks and impacts.

Land use and land use fragmentation may also impact cultural services (please reference ESPS8 for details).

Impacts related to land use changes and potential degradation of resources are analyzed within Section 8, and make reference to ESPS1, 3, 4, 5, 6, 7, and 8.

Climate Change-related Aspects

ESPS4 requires the borrower to identify and assess potential risks caused by natural hazards, such as earthquakes, droughts, landslides, or floods, including those caused or exacerbated by climate change. GH projects may be negatively impacted by effects of climate change at local and regional levels, among others, because of climate change-induced water scarcity, sea level rise, and other extreme events increasing in magnitude and frequency, which may cause structural damage to infrastructure and facilities.

With respect to ESPS 3, 4, and 6, GH projects, if improperly designed and managed, may also play a role in exacerbating effects of adverse climate events, as a consequence of required water additionality, land use fragmentation, and potential deforestation, as well as soil erosion caused by development of large renewable farms.

Thus, there are links between the risk to which the facilities are exposed, and the risk generated by projects themselves, that shall be properly identified and analyzed in the phase of plant siting and again in the phase of project design.

Security

GH facilities management requires security forces (aimed to protect the site), engaged with modalities similar to those applied at other industrial facilities.

Based on the experience of the authors of this report, security topics related specifically to facilities within the GH value chain include:

- Facilities are characterized by large volumes of hazardous substances. There is the risk that war actions or terror attacks could result in major incidents (explosions, toxic releases) that would affect surrounding communities
- Within facilities, some mechanical and electric items are made of precious metals. Minor theft cannot be excluded as a risk, and based on the personal experience of the authors of this report, in some cases, such tampering may lead to OHS or process incidents, due to malfunctioning of tampered devices.

7.5. ESPS 5

> *Impacts of project-related land acquisition, including restrictions on land use and access to assets and natural resources, which may cause physical displacement (relocation, loss of land, or shelter), and/or economic displacement (loss of land, assets, or restrictions on land use, assets, and natural resources leading to loss of income sources or other means of livelihood).*

As Simon Ticehurst, Oxfam Regional Director for the LAC region, notes in his prologue to the 2016 Oxfam Report Unearthed: Land, Power, and Inequality in Latin America (59): *"Land distribution is an historical structural problem in Latin America; for two centuries, this issue has caused more wars, population displacements, social conflicts, hunger, and inequality than any other. 'The land belongs to those who work it,' was the rallying cry of Emiliano Zapata during the Mexican Revolution. Land distribution was also the issue that gave rise to the internal armed conflict in Colombia more than half a century ago and gave birth to the Landless Workers' Movement in Brazil in 1970".*

Access to land and land distribution is a well-known issue in the LAC region, in particular in connection with the economic model labeled "extractivism,"[11] in promoting large-scale extraction and exploitation of natural resources, which has disproportionally affected low-income and disadvantaged communities worldwide.

When looking at the development of a GH value hain in the LAC region and analyzing it against IDB *ESPS 5 – Land Acquisition and Involuntary Resettlement*, there is one main point of concern emerging, namely, the risks and impacts associated with processes of land acquisition, including involuntary physical and/or economic displacement of local communities, as well as landscape and land fragmentation.

11 A production model based on extraction and exploitation of natural resources to obtain large volumes of raw materials. For a reflection on extractivism, please refer to Acosta (2011). Extractivism and neoextractivism: Two sides of the same curse. Available at https://www.tni.org/files/download/beyonddevelopment_extractivism.pdf (last access 02/12/2021).

In fact, construction of large plants for renewable energy production and associated infrastructure in connection with GH production raises concerns in relation to potential negative impacts on land, both in terms of: (i) acquisition of large areas, and (ii) fragmentation of territories, which would in turn trigger several cumulative impacts, not only in the form of direct social impacts but also on ecosystems and their services, which include those upon which local communities depend for their livelihood and well-being, especially in rural areas (also with reference to ESPS4 and 6).

However, the land acquisition process for GH facilities is similar to the process adopted for different industrial facilities, with no unique variables. The specific aspects of the GH value chain related to land use are more linked to effects of land acquisition (in terms of land use changes, land use fragmentation, effects on ecosystem services, and resource availability, and gender aspects, all of which are addressed within this report under different ESPSs), rather than to the land acquisition process itself.

7.6. ESPS 6

> *Protecting and conserving biodiversity, maintaining ecosystem services, and sustainably managing living natural resources are fundamental to sustainable development.*

Protection and Conservation of Biodiversity and Ecosystem Services

It has already been mentioned that construction of large-scale plants for renewable energy production and associated infrastructure in connection with GH plants may imply significant impacts that cut across several ESPSs, related to land use modification and fragmentation of land use of territories. Land use modifications and land use fragmentation may induce direct and indirect impacts to species conservation. Proper identification of related impacts, referencing ESPS1, shall also take into consideration provisions for biodiversity conservation and ecosystem services, mentioned in ESPS4 and 6.

Aside from considerations of impacts related to land use, biodiversity conservation can be affected by impacts of excessive pressure on water resources, whether freshwater or seawater, receiving brine discharge from desalination plants.

Water is a natural resource, a commodity as well as a perceived human entitlement. The development of a GH value chain across the LAC region may exert significant pressure at the local level and at each project site, affecting the livelihood and quality of life of communities, and in terms of the overall availability of the countries' water resources.

Primary Suppliers

Based on IDB PS6, where a borrower is purchasing primary production *"… that is known to be produced in regions where there is a risk of significant conversion of natural and/or critical habitats, systems and verification practices will be adopted as part of the Borrower's ESMS to evaluate its primary suppliers".*

The construction of renewable production technologies, as well as electrolysers, relies on availability of several critical raw materials, such as iridium (Ir) and other metals of the platinum group (Pt). Iridium production will more than double by 2030 (see Section 8 for details and references) to allow for development of GH projects in the pipeline, with potentially relevant impacts on the mining sector.

It is worthwhile to mention here that a high level of GHG emissions is among the main impacts caused by mining and refining iridium, as reported by ACF, Chemistry For Life[12]. Other significant impacts are related to physical impacts of mining, which currently occurs primarily in South Africa and other sub-Saharan countries, often in conflict areas and with significant issues in terms of respecting workers' and local communities' human rights.

7.7. ESPS 7

> *Indigenous peoples are particularly vulnerable if their lands and resources are transformed, encroached upon, or significantly degraded. […] This vulnerability may include loss of identity, culture, and natural resource-based livelihoods, as well as exposure to impoverishment and disease.*

The development of GH production plants and associated infrastructure, including that for transportation as well as transformation plants, may create risks and impacts for the region's indigenous communities, as a consequence of primary impacts identified with reference to other ESPS: land fragmentation, water stress, mining in the supply chain, etc.

While no specific issues have been identified with respect to projects in the GH value chain, it is obvious that proper analysis of the territory during the project siting phase will allow stakeholders to avoid, limit, or mitigate potential direct impacts to indigenous people, as well as indirect impacts on cultural resources, intellectual resources/property, etc.

The risk identification phase, carried out with reference to provisions of ESPS1, shall lead to spotting potential criticalities. When there are risks related to ESPS7, free, prior, and informed consultation is required.

12 https://communities.acs.org/t5/GCI-Nexus-Blog/Critical-Elements-Series-Iridium-An-Amazingly-Useful-Element-but/ba-p/15493?author=2012%2F10

Of carefully designed, planned, and implemented, the development of a GH value chain within the LAC region may represent a chance to grant needed attention to human rights and human potential of indigenous communities and to ensure that development policies recognize their unique potential for contribution and capacity.

7.8. ESPS 8

> *To protect cultural heritage from the adverse impacts of project activities and support its preservation. To promote the equitable sharing of benefits from the use of cultural heritage.*

The International Council on Monuments and Sites ("ICOMOS") acknowledges that cultural heritage can be significantly impacted by human activities (ICOMOS, 2000) (60).

No specific issues have been identified with respect to GH value chain projects and impacts on tangible cultural heritage. Proper territory analysis during the phase of project siting, as well as proper project design, will allow project developers to avoid, limit, or mitigate potential impacts.

At the same time, large-scale projects may originate risks to intangible cultural heritage with respect to:

- Free community access to sacred sites and areas of importance for recreation and aesthetic enjoyment (that are relevant in terms of ecosystem services) or aggregation places
- Loss of landscape amenities and loss of related fruition opportunities by residents and tourists
- Continuity of traditional lifestyles, if rural/remote communities are improperly impacted by industrial developments.

7.9. ESPS 9

> *Gender inequalities interact with other inequalities, such as socioeconomic, ethnic, racial, disability, and other factors, and this intersectionality may exacerbate barriers to accessing project benefits, limit the ability to deal with negative project impacts, and create other vulnerabilities.*

When the development of a GH value chain in the LAC region was analyzed through the lenses of IDB's *ESPS 9 – Gender Equality*, the following aspects emerged as potential risks:

- Land fragmentation and land take: The issue of land fragmentation and land acquisition may affect women disproportionately, also taking into consideration that land acquisition processes occur within a framework of inequalities rooted in all dimensions of land rights: i.e., ownership, management, transfer, and economic rights, in particular those associated with agricultural lands.
- External workers' influx: A large influx of external male workers may lead to an increase of gender-based violence against women and young girls, particularly in socio-economic settings where there is an existing gender differentiation in terms of power and norms.
- Access to water resources: If projects will induce additional water stress, women will likely bear a disproportionate impact of lack of access to safe water for drinking, sanitation, and other purposes. Without safe access at home and/or in work and study places, it is significantly harder for women and girls to lead safe, productive, and healthy lives.
- Threats to indigenous communities: Overall, impacts on indigenous people or impacts induced by water stress may specifically affect indigenous women, who are already experiencing multiple forms of discrimination and oppression.

General aspects to be considered, even if not strictly related to unique aspects of the GH value chain:

- Labor issues: Women may be discriminated against or subject to abuse in the workplace, due to gender and/or sexual identity and orientation.
- Equitable participation: Alongside other disadvantaged groups and minorities, women risk being left out of and/or underrepresented within consultation processes and activities of stakeholder engagement.

A potential positive impact of developing a GH value chain in the LAC region includes capacity building. In fact, capitalizing on increasing momentum of GH could allow targeting of women (alongside indigenous peoples and other disadvantaged and vulnerable groups) to foster their skill and knowledge development and involvement in STEM disciplines.

7.10. ESPS 10

> *The importance of open and transparent engagement […] as a key element that can improve the environmental and social sustainability of projects, enhance project acceptance, and contribute significantly to the project's successful development and implementation.*

As noted in previous sections of the present report, in particular in connection with SEA regulations worldwide and within the LAC region, for their nature and their likely scale (e.g., in terms of spatial impacts, duration, magnitude, etc.) and impacts, GH development projects may require the arrangement of extensive consultation processes, which may involve extremely heterogenous communities in terms of language, culture, values, and interests, as well as unequal access to opportunities, and to subsequently incorporate outcomes into the project design.

This may become particularly relevant in case of transboundary impacts and/or impacts that may interest different regions within a single country or across two or more countries, such as during the development of linear infrastructure for GH transportation, posing significant challenges to the organization and positive outcomes of consultation processes.

Among the most relevant provisions for stakeholder engagement, which is also common to other ESPSs, (namely ESPSs 1, 2, 4, 5, and 7), is the establishment of effective grievance mechanisms ("GMs"), tailored to relevant stakeholders. One GM should address workers' grievances, while another GM should be dedicated to address grievances forwarded by affected local communities.

7.11. Conclusions

Many aspects identified during the scoping phase and that have been reported in this section are common to more than one ESPS.

Therefore, in the following section, further details of each aspect are presented separately, distinct from the ESPSs, in order to favor a more focused analysis.

HyDeal Ambition for 67GW, Western Europe a huge-size project promoted by energy utility company

Credit: https://deepresource.wordpress.com/2021/03/29/hydeal-ambition-95-gw-eu-solar-hydrogen-project/

08
Preliminary Considerations for a Sectoral Guideline

In this section, some preliminary considerations are provided to form the foundation for building a GH sectoral ESHS guideline.

The section focuses on aspects highlighted in the scoping phase, ordered according to the following criteria:

- Topics more related to environmental issues are addressed first
- Safety and security aspects are then analysed
- Followed by the assessment of potential social impacts, addressing both direct social impacts and secondary impacts to communities and project-affected peoples ("PAPs"), mainly generated as a consequence of primary/direct environmental impacts.

8.1. Plant Siting and Permitting

As mentioned, a large-scale GH project may include several components, sometimes developed by different entities at different times: i.e., solar/wind farm(s), transmission lines, hydrogen plants, ammonia/methanol plants, port/transportation facilities.

The method usually adopted for completion of Environmental and Social Impact Assessments of projects (especially if applied separately to each individual component) may be inadequate to prevent potential negative effects of complex large-scale GH projects, especially considering that ESIAs are normally completed when projects are in a phase of rather advanced development and plant siting is already decided.

With this in mind, the following two considerations are essential to assess environmental and social consequences of such complex and vast GH projects: (i) a holistic approach is needed in the early phases of development, aimed at analyzing the area's suitability to host the project, and (ii) the preparation of a SESA should be encouraged during the project planning phase, and should include the assessment of potential effects on both natural and human ecosystems.

These considerations are aligned with recommendations included in most GH strategies of countries reviewed within this study, which encourage:

- The preliminary identification by public authorities of land to be used for such projects, to be selected taking into consideration issues best managed in the siting phase, including community safety, potential impacts originated by water demand, and overall land use planning; and
- The simplification of the permitting process for GH projects located in such areas.

SESA can be either prepared by authorities or project sponsors in the land use planning phase and identification of suitable sites for large-scale projects. With reference to technical provisions for SESA preparation, it is worth mentioning that:

- International guidelines on SESA (such as those prepared by the WB, that are more focused on social aspects) may be used as a reference. The European SEA regulation is the only one that mentions explicitly the need to assess impacts of plans and programs, also taking into consideration incidental situations.
- To ensure that a SESA process is meaningful and tailored to specific contexts, governmental authorities at various levels, as well as companies, communities, and civil society, should engage in regular consultations during the entire SESA phase. Local communities play a big role in the execution of any project, and they should be informed and engaged at a very early stage.
- In the SESA phase, attention should be focused on the land acquisition process (see, specifically, Section 8.6.2), as well as water management and safety aspects, as detailed in the following paragraphs.

ESIAs/SESAs shall analyze the 11 risk factors mentioned within the document *Disaster and Climate Change Risk Assessment Methodology for IDB Projects* (Drought, Earthquake, Flood, Heat Wave, Hurricane Storm, Surge/Storm Surge, Hurricane Wind, Landslide, Sea Level Rise, Tsunami, Volcano, Wildfire), completed according to the five-step methodology defined by the IDB (see figure below). The following paragraph addresses some considerations with potential reference to drought/water stress and sea level rise as these relate to GH projects.

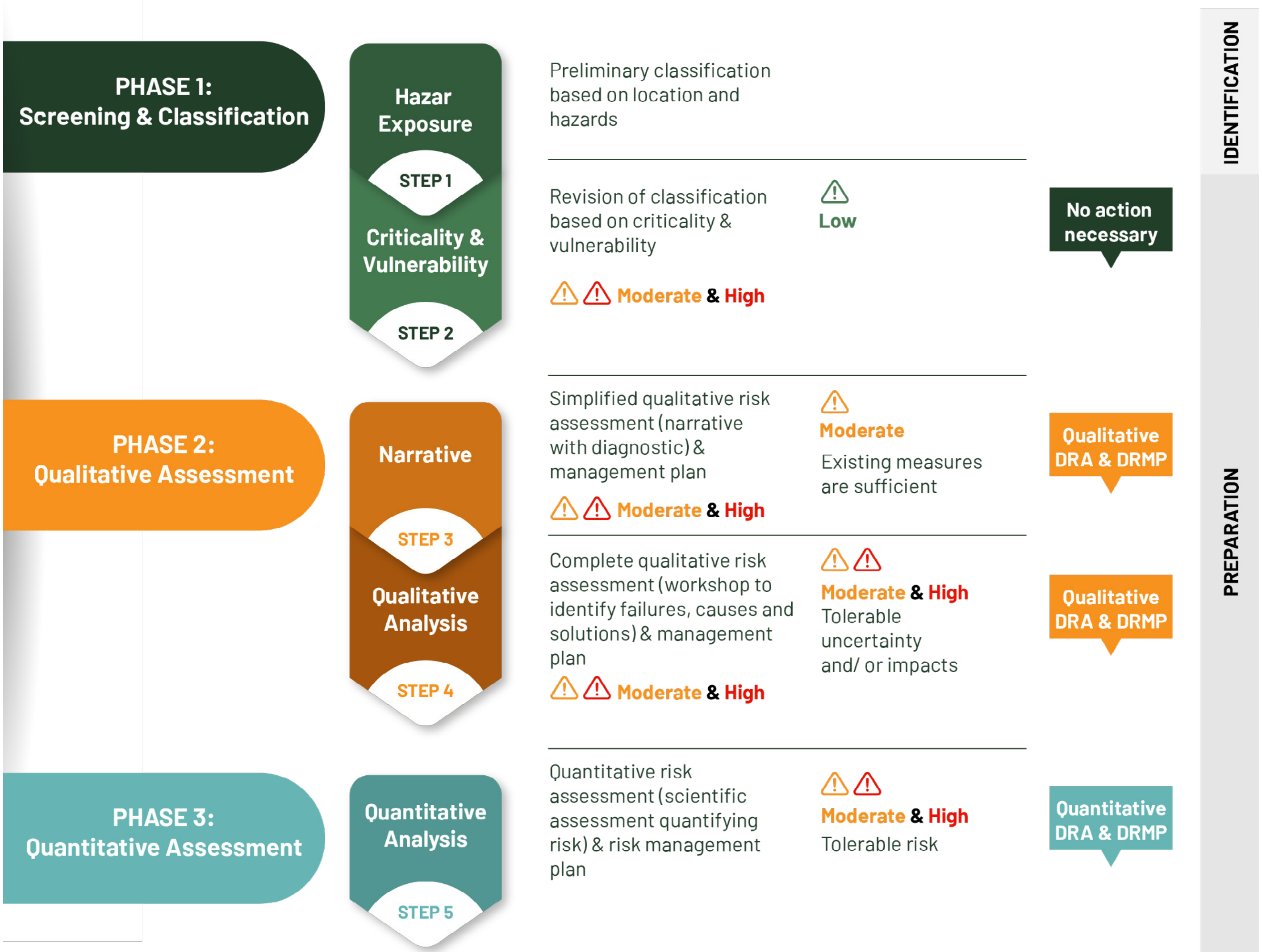


Figure 8-1 The five-step methodology defined in the Disaster and Climate Change Risk Assessment Methodology (Source: IDB, 2019)

8.2. Climate-related Impacts and Resilience

8.2.1. GHG Emissions

GH projects may favor decarbonization of the energy sector, at both a national and global level. In this positive context, the following aspects shall also be considered when assessing positive impacts of GH:

- Commercial and market factors may favor development of large-scale projects located in LAC with export of energy carriers such as ammonia and methanol. This process will result in a net embedded export of natural resources from LAC (including water, land use, and renewable primary energy) to other regions.

- As highlighted in Section 3, some projects plan for use of hydrogen or its derivatives (ammonia, methanol) as fuel, either in power plants or engines for vehicles. Overall efficiency of these processes is extremely low, even below 20%. From an efficiency perspective, production of electric energy by renewables to produce GH and to burn it in a power plant to produce electric energy means significant loss. However, commercial reasons linked to daily/seasonal fluctuations of the price of energy and the possibility to export hydrogen/ammonia, may favor these developments (see also Section 5). Projects that plan for the use of hydrogen as a chemical, or in fuel cells (a process several times more efficient), or in applications where the alternative use of fuel cells is not possible (as in the case of aircraft fueling or cooking and heating) shall be encouraged. At the same time, development of electric vehicles with fuel cells shall be favored with respect to vehicles with hydrogen combustion engines.

At a project-scale perspective:

- Utilization of oxygen produced as a by-product shall be favoured, to optimize overall project efficiency.
- Project design shall be coupled with a BAT gap analysis, ensuring that the facility implements state-of-the-art measures for energy efficiency optimization.

The authors want to highlight two aspects that currently cannot be listed among main concerns of the public, but that based on results of an internal brainstorming session may become of primary relevance in the near future.

In Europe and in other most developed countries, there is not enough renewable generation capacity to satisfy demand for electric power and GH generation. Europe's GH demand is indeed one of the drivers for the development of large-scale projects in LAC, Africa, and Asia. However, the export of GH from emerging countries (and other countries) cannot be done at the cost of impeding countries of origin from achieving their own decarbonization targets. For example, Germany's GH strategy as reported in *Opportunities and challenges when importing green hydrogen and synthesis products,*[13] (101) states that:

> *One of the policy measures in Germany's National Hydrogen Strategy makes the following reference to pilot projects in partner countries: attention will be paid to ensuring that importing green hydrogen or energy sources based on it to Germany takes place on top of domestic energy production in the respective partner countries and does not impede the supply of renewable energy, which is inadequate in many cases, in the developing countries. Also, the sustainable supply of water in arid regions of these countries must not be impaired by the production of hydrogen. The aim is to achieve sustainable production along the entire supply chain.*

13 ISI, FRAUNHOFER INSTITUTE FOR SYSTEMS AND INNOVATION RESEARCH. Opportunities and challenges when importing green hydrogen and synthesis products. [Online] 2020

It should be considered if and at which level the development of the GH value chain shall also support decarbonization of the host country's economy, ensuring achievement of a minimal set of results in the jurisdiction.

A second aspect of potential concern is that, based on still uncertain data, hydrogen released into the atmosphere by leakages may increase the lifetime of methane, increasing climate effects and depletion of the ozone layer. Thus, when used on a large scale, it is important that hydrogen does not leak significantly into the atmosphere.

8.2.2. Resilience to Water Stress

GH electrolysers fed with freshwater may be potentially impacted by water scarcity caused by climate change. However, in case of increased water stress, operation of freshwater-fed GH electrolysers may also be impacted by competition over water use, development of opposition among populations, and, potentially, by modifications of water management regulations (transitional risk).

To control risk, it is important:

- To ensure proper water management, as indicated in Section 8.3, below; and
- To ensure proper stakeholder engagement and listening to community needs, as indicated in Section 8.9.

8.2.3. Resilience to Sea Level Rise

Coastal facilities are among the most vulnerable to climate change and, specifically, to sea level rise. Resilience of projects to sea level rise and sea level surge due to extreme meteorological events, including port and harbors for the shipping of ammonia and methanol, shall be ensured. The figure below shows forecasted sea level rise, as reported in the IDB guideline, The Regulation of Public Utilities of the Future in Latin America and the Caribbean.

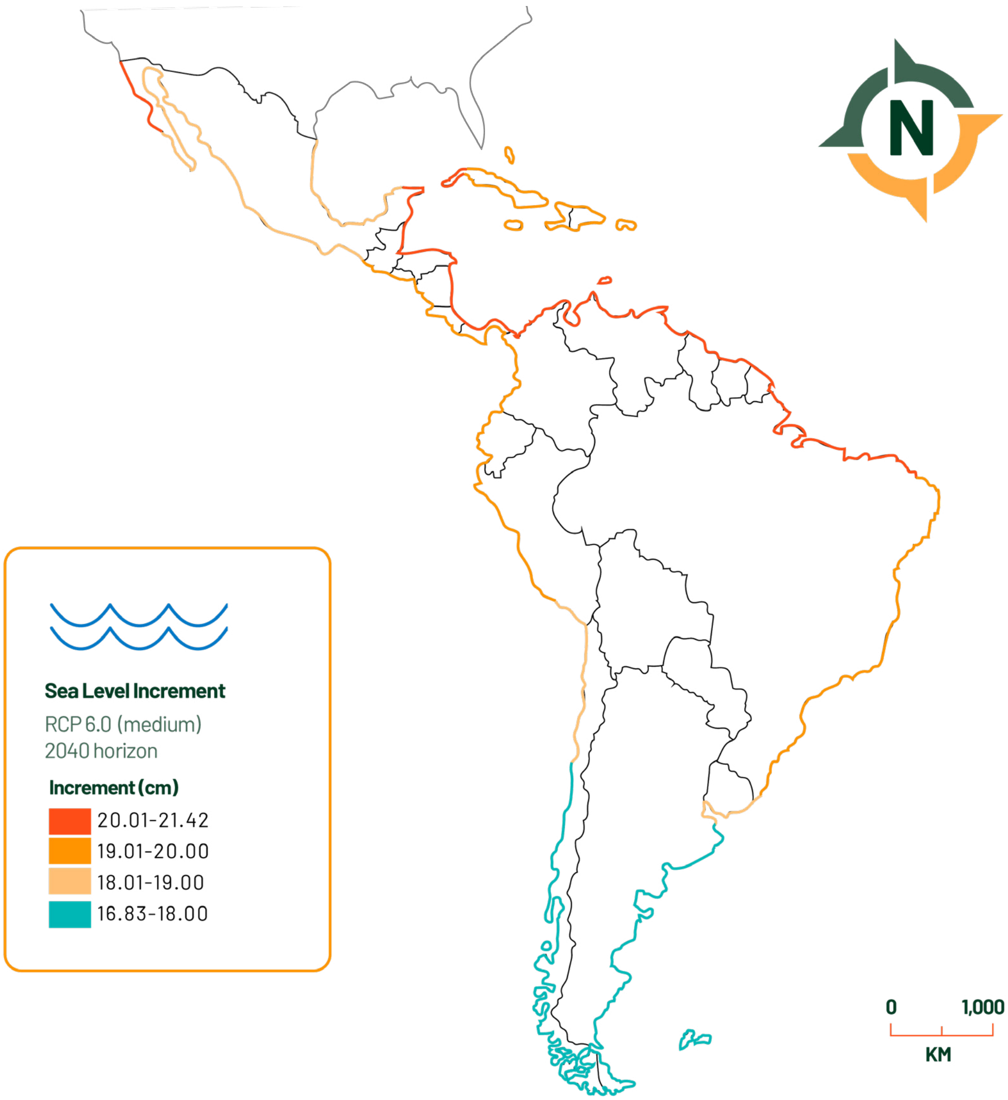


Figure 8-2 Forecasted sea level rise
(Source: (56))

8.3. Water Additionality

Access to clean water and sanitation are recognized as a universal human right by the United Nations, and the lack of access to safe, sufficient, and affordable water, and sanitation and hygiene facilities is acknowledged to have *"… [a] devastating effect on the health, dignity and prosperity of billions of people, and has significant consequences for the realization of other human rights. People are rights-holders and States are duty-bearers of providing water and sanitation services. Rights-holders can claim their rights and duty-bearers must guarantee the rights to water and sanitation equally and without discrimination."*[14]

14 From the UN Water Portal. Available at https://www.unwater.org/water-facts/human-rights/ (last access 23/11/2021).

In ***Annex V***, an overview is presented on the status of water resources in the LAC region, informed by the latest available information on climate change and how it will affect the region and its water resources over time. The latest available aggregated data have been used (for the year 2015) for regional statistics, while for the sample of countries considered within this study, the reference year is 2018 (the latest available data on the FAO portal, AQUASTAT.)

This section illustrates challenges connected with potential conflicting interests in water use for different purposes, including GH production.

8.3.1. Water Use in Green Hydrogen Production

The consumption of electrolysers in the range of 100 -1,000 MW is equivalent to the domestic consumption of a city of approximately 3,800-38,000 inhabitants located in the LAC region (in the literature, there are different assessments of the number of inhabitants equivalent to an electrolyser, that span from lower numbers up to nearly double what are reported here; the data here suggest it is regionally referred, based on average water consumption of LAC inhabitants).

When the full life cycle assessment of the GH value chain is considered, it is observed that the highest water consumption is upstream, and it is highest when the electrolyser is coupled with PV[15] (IRENA (4)). Currently, water consumption for green hydrogen from PV varies between 22 and 126 kg of water per kg of hydrogen, depending on solar radiation, as well as the PV plant's lifetime and silicon content of the panels[16] (61). Furthermore, most downstream applications for hydrogen require it to be combusted or pumped through a fuel cell, which converts hydrogen gas into electricity and water. While most water can be recovered, it is not generally returned to the original body of water and should be treated as consumed.

8.3.2. Case Study: Water Demand to Meet National Strategy Goals in Chile

According to the Green Hydrogen National Strategy of Chile (14), published in November 2020, the country will have:

- 5 GW of electrolysis capacity operating and under development by 2025
- 200 kton/year from production of GH in at least two hydrogen valleys in Chile by 2025
- 25 GW from production of GH via electrolysis by 2030, i.e., almost 3,000,000 t/y of GH[17]

15 International Renewable Energy Agency, Abu Dhabi. IRENA Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5ºC Climate Goal. 2020. ISBN: 978-92-9260-295-6.

16 Renyuan Li, Yusuf Shi. Photovoltaic panel cooling by atmospheric water absorption–evaporation cycle. https://repository.kaust.edu.sa/handle/10754/662817: Nature Sustainability, 2020. DOI 10.1038/s41893-020-0535-4

17 Assuming 55 kWh per kg of hydrogen (see Section 3) and an actual production of electrolyser in the range of 75% of the equivalent full capacity.

Given these ambitious goals, it is worth posing the question of how much water the country would actually need to meet its GH production targets. For the purpose of this study, a water demand of 20-liter H_2O per Kg H_2 is considered, accounting for consumption by electrolysis and auxiliary units only.

It is therefore inferred that Chile is set to consume about 4,000,000 m^3/y of water by 2025 and almost 60,000,000 m^3/y by 2030 if the country wants to reach its GH production targets.

According to the latest available data, the country's total water withdrawal is in the range of 32.7 billion m^3; therefore, water demand for GH production by 2030 will be in the range of 0.2% and 0.22% of the overall current water demand of the country and for agricultural uses only, respectively, a quota apparently almost negligible at the country level, approximately 5% of current withdrawal for municipal uses and 4% of industrial uses.

Although the figures reported above appear reassuring, it should be kept in mind that water is a "local" resource: even if the water demand averaged at country level appears limited, water stress caused by large-scale GH on the local watershed may be (extremely) significant.

8.3.3. Aspects of Concern for a GH Sectoral Guideline

Three aspects are considered relevant with reference to provisions of ESPS3 with respect to resource and water management:

- Use of freshwater shall be avoided to the furthest extent possible. The alternative use of seawater shall be encouraged. Potential impacts of using seawater are analyzed in paragraph 8.4.1, below
- In case the use of freshwater cannot be avoided, it should be limited as far as possible
- Sustainability of the impacts of freshwater consumption shall be analyzed, taking into consideration the shared uses of the resource.

Water demand reduction

Actual water demand for hydrogen electrolysis also depends on the selected cell option and overall plant configuration. Specific water consumption (water demand per kg of H_2) should be considered a primary environmental KPI for GH production.

Within the framework of this study, it was not possible to fix a target related to the KPIs, as the technology is still under development and actual operation data are not yet completely available. The possibility to fix targets may be further analyzed in the phase of preparation of the GH sectoral guideline.

The guideline shall include provisions for completion of a BAT gap analysis to ensure that the plant is designed with state-of-the-art techniques to reduce water demand.

Assessment of the sustainability of impacts

Assessment of sustainability of water demand for GH plants shall be assessed on a case-by-case basis, through the application of tools designed to study shared uses of water resources. The analysis shall include:

- A high-level assessment of water management at watershed scale, that can be performed in the project planning phase and SESA preparation
- A more detailed study at the local level, to be completed either in the project concept phase (within the SESA) or in the EIA preparation phase for the electrolyser plant.

The sustainability of water withdrawal can be assessed using tools designed for Integrated Water Resource Management ("IWRM"), mentioned in Section 6, and forecasting models, which factor in both the current level of water stress and the medium/long-term effects of climate change that may worsen conditions.

8.4. Waste and Wastewater Production

8.4.1. Brine Discharge from Electrolysers

Discharged brine as a by-product of seawater desalination will have approximately twice the concentration of ambient seawater, and will contain: (i) additives, i.e., anti-scalants (polyphosphates, polymers), coagulants (ferric sulfate, ferric chloride), and sodium bisulfite, used as a membrane preservative; (ii) pre-treatment and post-treatment backwash water containing concentrated wastes (in particular, suspended solids, which may lead to increased turbidity and ferric waste); and (iii) cleaning solutions used for maintenance of membranes and during pre-treatment (both organic and inorganic cleaning).

Desalination of brackish water entails mainly the reduction of chloride or nitrate concentrations. Output of concentrated brine will have salinity levels approximately corresponding to a third or a half of that of ambient seawater and will contain (i) nitrogen due to the high recovery rate and the high raw nitrate concentration, and (ii) additives, i.e., antiscalants (polyphosphates, polymers).

There are several alternatives for brine disposal, and the choice among them depends mainly on: (i) location of the desalination plant, (ii) type of plant, and (iii) costs associated with brine disposal.

Of the above-mentioned alternatives, the most common methods are discharge into the sea (41% of cases), disposal into sewers (31% of cases), deep well injections (17%), and evaporation ponds (2%).

In general, brine management is very important when analyzing the viability of a desalination plant since a large part of the project budget is determined by the final make-up of the brine, and technologies that will be necessary to dispose it properly: between 5 and 33% of the total cost of the process is usually related to brine disposal, depending on the features and volume of the brine, disposal option, and the level of brine treatment before disposal.

Prior to discharging brine, treatment should always be considered to reduce the direct potential impact on the environment. Currently, the following options for brine management and disposal exist:

- Deep well injection
- Evaporation ponds
- Discharge into surface water bodies
- Disposal into municipal sewers
- Concentration into solid salts (e.g., salt harvesting and on-site generation of sodium hypochlorite)
- Irrigation of plants tolerant to high salinity
- Reusing the brine
- Zero liquid discharge
- Aquaculture
- Application in soils

Potential impact can be minimized and regulated by treatment and recycling technologies, by limiting concentration values of brine at the discharge point, as well as by imposing concentration values within a prescribed circular mixing zone in coastal waters via outfall design.

Given the above, when choosing the site for constructing a green hydrogen production plant equipped with a desalination plant, as well as in determining the best technical solution to manage brine discharge, it will be essential to complete related impacts assessments.

It is recommended to include the following within the sectoral GH guideline:

- Provisions for the completion of a BAT gap analysis to ensure that the plant is designed considering state-of-the-art techniques to reduce impacts of brine discharge
- Environmental KPIs in terms of both emission limits and environmental standards (in terms of an acceptable increase of salinity of the receiving body, as regulated in some jurisdictions as already shown in Section 6 above).

However, it should be stressed that environmental standards included in national regulations are mostly based on environmental sensitivity of ecosystems present within the jurisdiction, that could be rather different from those present in LAC coastal areas. Therefore, regional characteristics should be factored into the definition of environmental standards applicable to LAC.

A detailed analysis of effects of brine discharged to different ecosystems and organisms is reported within *Management of Brine Discharges to Coastal Waters: Recommendations of a Science Advisory Panel*, reported in ***Annex IV*** (58).

8.4.2. Wastewater from Ammonia and Methanol Plants

With respect to ammonia plants, the IFC EHS guidelines on inorganic compounds state that plant discharges, during normal operation, may occur due to process condensates or due to scrubbing of waste gases containing ammonia and other products. Recommended measures to prevent, minimize, and control effluents from ammonia plants include the recovering of ammonia absorbed from purge and flash gases in a closed loop system so that no aqueous ammonia emissions occur.

For methanol plants and according to European regulations, the BAT to reduce wastewater volume, the pollutant loads discharged to suitable final treatment (typically biological treatment), and emissions to water, is to use an integrated wastewater management and treatment strategy that includes an appropriate combination of process-integrated techniques, techniques to recover pollutants at source, and pre-treatment techniques.

The table below shows the emission limits considered BAT by the European Commission as reported within the BAT Reference Document ("BREF") on common wastewater treatment systems (62).

Parameter	BAT-AEL (yearly average)	Conditions
Total organic carbon (TOC) ([1]) ([2])	10-33 mg/l ([3]) ([4]) ([5]) ([6])	The BAT-AEL applies if the emission exceeds 3,3 t/yr.
Chemical oxygen demand (COD) ([1]) ([2])	30-100 mg/l ([3]) ([4]) ([5]) ([6])	The BAT-AEL applies if the emission exceeds 10 t/yr.
Total suspended solids (TSS)	5,0-35 mg/l ([7]) ([8])	The BAT-AEL applies if the emission exceeds 3,5 t/yr.

([1]) No BAT-AEL applies for Biochemical Bxygen Demand (BOD). As an indication, the yearly average BOD_5 level in the effluent from a biological waste water treatmente plant will generally be ≤ 20 mg/l.
([2]) Either the BAT-AEL for TOC or the BAT-AEL for COD applies. TOC is the preferred option because it's monitoring does not rely on the use of very toxic compounds.
([3]) The lower end of the range is typically achieved when few tributary waste water streams contain organiz compounds and/or the waste mostrly contains easily biodegradable organic compounds.
([4]) The upper end of the range may be up to 100 mg/l for TOC or up to 300 mg/l for COD, both as yearly averages, if both of the following conditions are fulfilled:
- Condition A: Abatement efficiency ≥ 95% as a yearly average (including both pretreatment and final treatment).
- Condition B: If a biological treatment is used , at least one of the following criteria is met:
    - A low-loaded biological treatment step is used (i.e. ≤ 0,25 kg COD/kg of organic dry matter of sludge). This implies that the BOD_5 level in the effluent is ≤ 20 mg/l.
    - Nitrification is used.

(5) The upper end of the range may not apply if all of the following conditions are fulfilled:
- Condition A: Abatement efficiency ≥ 95% as a yearly average (including both pretreatment and final treatment).
- Condition B: The influent to the final waste water treatment shows the following characteristics: TOC > 2 g/l (or COD > 6g/l) as a yearly average and a high proportion of refractory organic compounds.

(6) The upper end of the range may not apply when a main pollutant load originates form the production of methylcellulose.
(7) The lower end of the range is typically achieved when using filtration (e.g. sand filtration, microfiltration, ultrafiltration, membrane bioreactor), while the upper end of the range is typically achieved when using sedimentation only.
(8) The BAT-AEL may not apply when the main pollutant load originates form the production of soda ash via the Solvay process or from the production of titanium dioxide.

Figure 8-3 BAT emission limits for wastewater discharge (Source: (62))

Even more relevant, it is crucial to control emissions in other than normal situations. Based on the BREF on large organic plants (63), BAT is to use all the techniques shown in the table below to prevent or reduce emissions from equipment malfunctions.

	Technique	Description
A	Identification of critical equipment	Equipment critical to the protection of environment ('critical equipment´) is identified on the basis of a risk assesment (e.g. using a Failure Mode an Effects Analysis)
B	Asset reliability programme for critical equipment	A structured programme to maximise equipmente availability and performance which includes standard operating procedures, preventive maintenance (e.g. against corrosion), monitoring, recording of incidents, and continuous improvements
C	Back-up systems for critical equipment	Build a maintain back-up systems, e.g. vent gas systems, abatement units

Figure 8-4 BAT to prevent incidental wastewater discharges (Source: (63))

In case ammonia or methanol plants make use of cooling waters with discharge of hot waters, impacts of warm plumes onto the receiving water body shall be considered. The max temperature rise at the edge of the mixing zone shall be compliant with relevant limits, including as defined by the IFC in the general EHS guidelines and sectoral guidelines on the power sector.

8.4.2.1. Water Discharge Modeling

The increase in salinity or temperature, or the reduction in dissolved oxygen, in the water bodies receiving brine discharge from electrolysers or cooling systems shall be modeled with proper software tools. Selection of the most appropriate models depends on numerous factors, including:

- Complexity of shoreline topography
- Presence of streams within receiving bodies
- Possibility of water recirculation (for example, within bays with strong tidal streams), with pollutant accumulation
- Sensitivity of local ecosystems to average and/or peak pollutant concentrations
- Discharge geometry (along the shoreline, under water level, single or multiple discharge, etc.)
- Distance to discharge point at which the respect of a limit is requested (point of compliance).

As a technical reference for the selection of the most appropriate modelling, recommendations included on the website of the U.S. Environmental Protection Agency (EPA) can be considered. The EPA maintains and updates a specific page (currently available at https://www.epa.gov/ceam/surface-water-models-assess-exposures) with a list of commercial software and freeware tools, with recommendations for their use in different situations.

8.4.3. Waste and Sludges

As mentioned within the scoping section, generation of sludge or wastewater from (fresh) water purification for electrolysis currently seems not well-documented in the literature.

Quantity of sludge depends on the level of contaminants originally present in the raw water, and on the purity of water requested by the specific electrolysis process adopted. Based on the experience of the authors of this report in chloro-alkali facilities, the amount of produced sludge can be significant. Deeper investigation and monitoring of this aspect is recommended in future phases of developing a sectoral EHS guideline.

In addition, both ammonia and methanol production processes make use of catalysts, and spent catalysts are among the most typical hazardous waste of these productions. Treatment capacity of the spent catalyst within the host country of production facilities shall be ensured or the plant operator may be asked to arrange international waste transportation and ensure proper treatment.

8.5. Decommissioning

As already mentioned, some facilities are likely to be built in pristine or near-pristine areas where an industrial or urban development may not occur; as such, at the end of their operational life, there exists the risk of abandonment of the industrial facilities. Abandoned sites are common both in LAC and in Europe, and such events should be prevented. Figures 8-4 and 8-5 below show some typical examples of abandoned sites.

Figure 8-5 Hashima Island
Once densely populated after finding an underwater coal deposit, this site was abandoned when the coal ran out (Source: Google Creative Commons)

Figure 8-6 The abandoned whaling station at Leith Harbor on South Georgia in the south Atlantic (Source: (64))

It is a best practice to allocate reasonable financial reserves accumulated during operation, for plant decommissioning.

Decommissioning of facilities within the GH value chain should not generate additional major issues in terms of soil and underground water contamination. In fact:

- Hydrogen is gaseous and not toxic.
- Ammonia plants are not subject to significant soil contamination risk, as long as anhydrous ammonia is not converted into liquid or solid fertilizers. In soil, ammonia may either volatilize to the atmosphere, adsorb to particulate matter, or undergo microbial transformation to nitrate or nitrite anions. Volatilization of ammonia from moist soil surfaces is expected to be an important process given a Henry's Law constant of 1.61X10-5 atm-cu m/mole. In water, it is also lost from water by volatilization, based upon a Henry's Law constant of 1.61X10-5 atm-cu m/mole. Using this Henry's Law constant, volatilization half-lives for a model river and model lake are 1.4 and 12 days, respectively.
- With reference to methanol, biodegradation is expected to be the dominant process controlling the fate of methanol in the soil, groundwater, and surface water environments compared to other loss mechanisms, including volatilization and chemical degradation. Methanol biodegradation can occur under both aerobic (oxygen present) and anaerobic (oxygen absent) conditions. The half-life of methanol in groundwater is expected to be in the range of 1-10 days.

It should be highlighted that, as a consequence of the short half-life of ammonia and methanol in the environment, the concentration of such substances in groundwater is not included in most European and American national regulations on soil and groundwater pollution.

Nevertheless, continuous and long-term methanol leaks may modify redox characteristics of the soil with induced contamination of groundwater by metal ions: under such long-term leakages, metal ions normally contained in the terrain become soluble and free to migrate into water.

Decommissioning of electrolysers and related renewables plants will likely generate a large amount of electric and electronic waste, containing hazardous substances. Assessment of the type and amount of waste to be managed is currently not possible because it will depend on the specific technology used within each single project and on the development of the electrolyser technology.

Also, with respect to decommissioning, it is also almost impossible to foresee the future technologies that will be available for waste treatment, as decommissioning is something that will not occur for at least 25-30 years after installation.

8.6. Process safety management

Safety is a major concern in facilities where hydrogen, ammonia, or methanol is produced or stored. Accidental toxic release may affect areas well beyond the plant area and endanger the life of communities.

8.6.1. Framework Policies for process safety

LAC governments are developing new framework regulations related to safety, apparently in the absence of an overarching framework document shared among different countries aimed to align approaches. As already noted, at present, most countries are not signatories of the ILO convention and recommendation on the prevention of major incidents (44).

In preparing the sectoral guideline, it should be considered to include the recommendation for project developers to establish a high-level process safety policy based on the ILO Convention on the Prevention of Major Incidents, and to develop a safety management system and risk assessment based on the technical recommendations included within the ILO support documentation or in the U.S. EPA Risk Management Plan ("RMP") Policies, as well as in the European Seveso Directive, all of which shall be considered as reference for Good International Industry Practices ("GIIP").

The following paragraphs of this section highlight some unique aspects of projects within the GH value chain that should be considered during the preparation of such a policy.

8.6.2. Siting

The siting of hazardous facilities ensuring proper distance from inhabited areas, and land use control measures once the facility is in operation, are both crucial to ensure safety. Proper siting and land use control is also recommended within the relevant ILO acts, EU regulation, and some of the hydrogen strategies of LAC countries, as presented in Section 6, above.

In Europe, land use control is implemented within most national regulations by acts that rule that, once the facility is approved (normally by the regional/federal government or central national government), this automatically determines, when necessary, a modification of the municipal master plan, with limitations on land uses allowed within hazardous areas.

The definition of such land use limitations – superimposed on the existing master plan -- may generate inconsistencies within the overall master plan, cause friction in different administrations (at local, district/regional level, and central level), create confusion among investors (because of changes in land value due to the presence of the nearby plant and subsequent land use limitations), and potential opposition on the part of the population within or near the hazardous area.

To limit or avoid such situations, proper preliminary land use planning should be adopted, and local administrations should be encouraged to define locations suitable for installation of hazardous establishments within master plans, as suggested in Section 8.1.

Once limitations in land use are established, it is crucial to enforce the decision, throughout the life of the plant, avoiding both legal developments (i.e., development authorized or planned by public authorities) and informal or squatter developments.

Unfortunately, it is a well-known characteristic of human behavior (65) to become acquainted to risk after some time passes since the risk was first perceived. Thus, urban developments within areas potentially affected either by natural disasters or anthropogenic risks are not uncommon; after some time, the area is not affected by an actual incident. This should be avoided through the enforcement of planning decisions.

Purchase of land (or some rights over land use) by the plant owner or by a consortium of industrial operators of an area may be considered as one strategy to control land use in hazardous areas.

IAEA Hazardous and Buffer Zone Assessment Method

The implementation of policies related to land use control requires the definition of the extension of hazardous and buffer zones in the facility's surroundings.
In the phase of facility siting or land use planning, when a detailed project design is not yet developed, the definition of such extension shall be defined through simplified methods based on a very limited set of inputs.

In 1996, the International Atomic Energy Agency ("IAEA") released a comprehensive paper (66) dealing with risks to public health from fires, explosions, and release of toxic substances outside the boundaries of hazardous installations due to major accidents in fixed installations with off-site consequences. The paper also includes a simplified method for the assessment of the maximum distance of the effects of incidents. Simplified methods for assessments of the extension of effects of incidents are also suggested within other documents issued by the IAEA, American Petroleum Institute, the European Industrial Gases Association, the U.S. Environmental Protection Agency, and others, detailed and referred within Annex 2, and within the technical guidelines in place in the state of São Paulo, Brazil.

The 1996 IAEA document is briefly analyzed in this report. Despite the fact that it is a dated publication, it still has the following advantages:

- It is a very high-level document that does not require technical design data for preliminary assessment of the extension of the hazardous area. Thus, it is ideal when used in the phase of project and land use planning, before technical data become available i.e., in the SESA phase (when the siting of the facilities and/or the general plant layout still need to be defined) rather than in ESIA phase, when more detailed methods for risk assessment can be applied. Site modification becomes less manageable ss the project enters a more advanced phase.
- It is a method prepared by an international institution that can be consistently applied to a stationary punctual risk source (such as a hazardous substance storage area), pipelines, and transportation facilities. Thus, the method can be applied consistently to all parts of projects within the GH value chain (this aspect is discussed further in following paragraphs).

The method provides an assessment of the maximum hazardous distance from the risk source. For example, in the table below, distances are estimated for cases of potential interest, related to storage facilities of hydrogen, ammonia, and methanol (NB reported stored quantities are as expected in a big hydrogen plant with conversion into ammonia).

It should be highlighted that the method does not specifically address differences between different flammable gases. Thus, the results shown in the table below related to hydrogen are unchanged if LNG is considered instead.

When applicable, the results of the IAEA methods are compared in table below with the Distance of Reference calculated based on the regulation in place in the state of São Paulo, Brazil. In concept, the Distance of Reference of the state of São Paulo is linked to maximum distance of effects of the IAEA report.

Substance of storage modalities	**IAEA**	
	Quantity (t)	**Hazardous area (m)***
Ammonia, liquefied by pressure	200 - 1,000	1,000 – toxic release
Ammonia, liquefied by temperature	200 - 1,000	200 – toxic release
Ammonia, liquefied by pressure	1,000-5,000	1,000 – toxic release
Ammonia, liquefied by temperature	1,000-5,000	500 – toxic release
Ammonia, liquefied by pressure	5,000 - 10,000	3,000 – toxic release
Ammonia, liquefied by temperature	5,000 - 10,000	1,000 – toxic release
Substance of storage modalities	**CETESB P4.261 São Paulo**	
	Quantity (t)	**Hazardous area (m)***
Ammonia	100	495
Ammonia	200	706
Ammonia	500	1,041

(*) Distances calculated from the storage area (not form the facility fence)

Substance of storage modalities	**IAEA**	
	Quantity (t)	**Hazardous area (m)***
Hydrogen, liquefied by pressure	50 - 200	200 – fire & explosion
Hydrogen, liquefied by temperature	200 – 1,000	n.a. – fire & explosion
Hydrogen, liquefied by pressure	50 – 200	50 – fire & explosion
Hydrogen, liquefied by temperature	200 – 1,000	n.a. – fire & explosion
Substance of storage modalities	**CETESB P4.261 São Paulo**	
	Quantity (t)	**Hazardous area (m)***
Hydrogen	50	300
Hydrogen	100	378
Hydrogen	200	476
Hydrogen	500	647

(*) Distances calculated from the storage area (not form the facility fence)

Substance of storage modalities	IAEA	
	Quantity (t)	**Hazardous area (m)***
Methanol	200 – 1,000	50 – fire & explosion
Methanol	1,000 – 5,000	100 – fire & explosion
Substance of storage modalities	**CETESB P4.261 São Paulo**	
	Quantity (t)	**Hazardous area (m)***
Methanol	100	158
(*) Distances calculated from the storage area (not form the facility fence)		

Table 8-1 Ammonia, hydrogen, methanol safety distances from storage tanks calculated with the IAEA method (Source: Authors' example based on 1996 IAEA methodology)

All methods for assessment of the extension of the hazard area reviewed within the framework of this document, refer to potential damages to buildings and/or fatalities among human beings. Assessment of the ultimate effects to the environment is not considered. Broadly speaking, while this is a significant limitation on the proposed methods, it should be also considered that:

- Hydrogen cannot induce significant contamination or adverse environmental effects. Thus, the proposed methods are fully applicable to hydrogen without any concern related to potential non-addressed aspects.
- Significant release of ammonia may have acute effects (long-term effects are not predicted), but if anhydrous ammonia is of concern (without conversion into fertilizers), large-scale leakages on ammonia in aqueous solution are unlikely.
- Methanol leakages may potentially occur, any case normally without long-term effects.

In absence of methods elaborated by international organizations for assessment of the extension of hazard areas, taking into consideration ecological effects, Anthesis reviewed existing data on concentrations that can be considered an end point in case of leakages of methanol or ammonia into water.

Based on the European Chemical Agency's ("ECHA") official website[18],

> *The toxicity of ammonia to aquatic organisms is highly dependent on physicochemical factors, most notably pH because of its importance in chemical speciation. The acute toxicity of ammonia is also influenced to a lesser degree by temperature, carbon dioxide, dissolved oxygen, and salinity.*

18 ECHA official website https://echa.europa.eu/home (last access 07/01/2022).

The LC50 for fish after 96 h was determined to be 0.75 -3.4 mg/l of unionised ammonia (Thurston, 1983). The LC50 was noted to change with pH. The 96 h LC50 concentrations at pH 6.6, 7.2, 7.7 and 8.7 were 0.5, 1.06, 1.34 and 1.73 mg/l of NH3 (McCormick, 1984). All LC50 values obtained for fish are consistent with the classification; R50 very toxic to aquatic organisms.

The 96 h LC50 for Daphnia was 4.07 mg/L. Adverse effects on Daphnia were noted at 1.3 mg/L (Reinbold and Pescitelli, 1990). In a separate publication, the 48 h LC50 for Daphnia was 2.94 mg NH3N/L (Gersich and Hopkins, 1986).

The 48 h LC50 for algae was 2.94 mg NH3N/L (Tam and Wong, 1996). These LC50 values for algae and Daphnia would classify the test substance under 'toxic to aquatic organisms'.

With reference to methanol, ECHA (official website) states that:

a large amount of data on the toxicity of methanol is available for a broad spectrum of aquatic organisms (fish, invertebrates, and algae). The results from the most reliable and relevant available studies are listed below, limited to the short-term toxicity (96h test)

Fish
LC50 (96h) = 28100 mg/L (Pimephales promelas)
LC50 (96h) = 20100 mg/L (Oncorhynchus mykiss)
LC50 (96h) = 15400 mg/L (Lepomis macrochirus)
Daphnids
EC50 (48h) = 18000 mg/L (Daphnia magna)
EC50 (48h) > 10000 mg/L (Daphnia magna)
Green algae
EC50 (96h) ca. 22000 mg/L (Selenastrum capricornutum)
Microorganisms
EC 50: 19800 mg/L (activated sludge)
IC50: >1000 mg/L (activated sludge)
IC50: 880 mg/L (Nitrosamonas)

All the available data demonstrate consistently the very low acute toxicity of methanol to aquatic organisms.

8.6.3. Quantitative Risk Assessment and Tolerable Societal Risk

Once the project design is in an advanced phase, a detailed Quantitative Risk Assessment ("QRA") can be prepared, the outcomes of which should include a detailed analysis of:

- The forecasted frequency and magnitude of potential accidents
- The extension of potentially affected areas
- The forecasted number of injuries and fatalities within the population
- The overall risk assessment in terms of both individual and societal risk.

The literature offers many guidelines on how to prepare a QRA. Some guidelines are developed at a rather high level, and mainly address procedural aspects of a QRA. Others are rather detailed and provide the specific algorithms to be used in a QRA.

The use of a detailed, shared guideline may help define a consistent technical approach to safety in different projects, located in different countries. This approach appears reasonable, but it should be noted that different states (even within the same Brazilian confederation) adopt different reference scenarios and criteria of risk acceptability and based on what has been reported by the European Commission, such differences are grounded on historical and cultural differences among the states; therefore, a shared approach to safety is not advisable (as detailed in Section 6 above).

However, it is the opinion of Anthesis that a sectoral GH guideline may include references to some detailed provisions related to:

- Algorithms to be used for QRA preparation
- Release scenarios of reference for risk assessment
- Shared criteria of risk acceptability

to be used as a technical reference. The need to ensure actual compliance of each project to the reference methods and criteria can thus be assessed on a case-by-case basis.

Sectoral guidelines could be based, for example, on safety guidelines prepared by the state of São Paulo that are comprehensive (it includes provisions for both punctual facilities and pipelines) and rather strict in terms of its criteria for societal risk tolerability (when compared to other regulations, as detailed in Section 6). It could also be based on similar guidelines prepared in the region that will become available in the near future.

It should be noted that the São Paulo guideline is directed to facility operators: in the event tolerable risk is exceeded, the guidelines prescribe that the plant operator shall adopt measures to reduce risk by limiting incident frequency or magnitude. However, as discussed in the previous paragraph, in the plant siting phase, authorities may limit societal risk through land use control. For example in the UK, *Planning Advice for Developments Near Hazardous Installations* ("PADHI") (67) establishes criteria related to land use permitting, which are aligned with those of São Paolo, in terms of final achieved safety level.

Criteria fix the activities and maximum advisable population density in areas that, based on outcomes of the QRA, may be affected by potential lethal effects with a certain frequency (probability per year). In short, based on the individual risk calculated within the QRA for a certain area, the criteria fix the maximum number of affected people that are allowed to stay within such an area, thus limiting societal risk.

Frequency of incidents with potential lethal consequence in the area	Allowed activities
< 1.00E-05	Working population allowed. Parking areas, warehouses, non-retail, buildings with fewer than 100 occupants, minor transportation links.
< 1.00E-06	General public allowed. At home and involved in normal activities – residential units less than 40 per hectares, hotels, motels up to 100 beds, major transport links, retail less than 5000 m2, gatherings of fewer than 100 people.
<3.00E-07	Vulnerable members of the public allowed (children, those with mobility difficulties, or those unable to recognize physical danger) – Hotel with more than 100 beds, more than 40 units per hectare, more than 100 people outdoors, hospitals 24 hr. care, < 0.25-hectare prisons.
None	Large activities with general public or vulnerable persons. Theme parks, stadiums, open air areas with more than 1,000 people, hospitals > 0.25-hectare, daycares larger than 1.4 hectare.

Table 8-2 Allowed activities based on the frequency of potentially fatal events, UK (Source: (67))

To conclude, for the siting and design of new projects it is recommended:

- To assess suitability of alternative sites in a preliminary phase of project development, through a SEA/SESA approach. In this phase, with the support of screening methods like IAEA, siting can be analyzed taking into consideration current land use of the area and any implications and limitations to land use that construction of the plant would require to ensure safety.
- In the phase of project design and ESIA preparation, to assess actual risk by means of a project specific QRA, with verification that actual risk is within the acceptable societal risk. If values are exceeded, the plant operator shall adopt additional safety measures to reduce the extension of the hazardous area or reduce probability of incidents.
- Within the QRA, especially for methanol plants, "environmental" risk shall also be assessed.

A final note regarding the glossary: in QRA analysis the risk for communities due to potential industrial incidents is normally referred to as "Societal Risk." The word "Societal" is never mentioned within ESPS, but in this document the use of the term "Societal" is recommended in order to ensure alignment with relevant literature in the field of QRA and to distinguish from the "Social Risk" that is a more comprehensive term.

8.6.4. Safety Issues Unique to the GH Value Chain

Specific issues related to hydrogen, even if not unique to the GH value chain, are:

- That hydrogen is colorless and odorless, and it burns without a visible flame. The odorizing of hydrogen in production facilities is not feasible. Sensors and alarms shall be installed within plants that are capable of providing early warning in case of leaks. Sensor design technology is evolving and operators shall ensure installation of state-of-the-art devices, applying best practice techniques. Personnel training is also a crucial point to be addressed according to best practices.
- In case of significant leak from systems under pressure, the jet of released hydrogen may undergo autoignition due to electrostatic charges originated by the jet itself. Control of electrostatic charges is crucial in hydrogen facilities.
- Hydrogen can embrittle metal alloys. The safety analysis of a plant shall consider the limitation in the material durability.

8.6.5. Technical Standards and Best Available Technology (BAT)

Technical standards related to hydrogen are rapidly developing at an international level, as R&D activities are in a rather active phase. A technical measure that is BAT now, may become obsolete and replaced by a new technique in an extremely short time (i.e., few months). In this context, it is impossible to define now or within an EHS guideline a set of BATs. Based on Anthesis' understanding, a reasonable approach would consist in ensuring:

- That the QRA and safety report of facilities include a detailed BAT Gap Analysis addressing all potential aspects of concern related to safety. The BAT Gap Analysis shall include verification that the most advanced safety and technical standards are applied.
- That the safety report, QRA, and BAT Gap Analysis are periodically updated, and that they will reflect progress achieved in the technical know-how of the whole GH sector.

8.6.6. Emergency Preparedness and Response

The safety management system in place in facilities within the GH value chain shall include an emergency plan composed of:

- An Internal emergency plan for measures to be implemented in the establishment. The internal emergency plan shall be created in consultation with personnel working inside the establishment, including relevant long-term subcontracted personnel.
- An External Emergency Plan for those measures to be implemented outside the establishment. For this purpose, the operator shall supply the necessary information to the competent authority, to enable the latter to draw up external emergency plans.

With reference to the latter point, a peculiarity of GH projects is that they may be developed in undeveloped rural areas as well as in small island states, where the availability of public resources for emergency management are limited and facility operators can expect to receive limited support in the event of major accidents. Thus, external emergency plans shall consider that facility operators may be required to operate in isolation during the emergency or rely on support of other industrial operators in the area, if any. Coordination between operators and the preparation of coordinated emergency plans is encouraged.

The public concerned should be given an early opportunity to give its opinion on external emergency plans when they are being established or substantially modified.

All persons likely to be affected by a major accident shall receive regularly and in the most appropriate form, without having to request it, clear and intelligible information on safety measures and requisite behavior in the event of a major accident. That information shall be supplied to all buildings and areas of public use, including schools and hospitals, and to all neighboring establishments potentially affected by consequences of an incident.

8.6.7. Hydrogen Transportation in Piping

Hydrogen distribution through a pipeline (either blended with natural gas or by dedicated separate network) may raise specific safety issues including:

- Hydrogen is colorless and odorless and thus leaks of pure hydrogen may remain undetected.
- Hydrogen can embrittle construction and structural materials, reducing their life.
- In large-scale piping, jets of hydrogen flowing from breaks may auto ignite due to electrotactic charges.

With reference to the first point, while in production facilities the installation of sensors is a reasonable solution for early warning about the presence of leaks, the installation of sensors all along the piping is not feasible. Thus, especially for hydrogen distribution systems, different odorizing measures are currently under development, none of which can be considered already consolidated. The delivery of hydrogen blended with natural gas is less problematic because odorizing technologies for natural gas are well-established.

As said, with reference to facilities, technical standards for handling hydrogen are experiencing quick development and, in this context, it is impossible to define now or within an EHS guideline a set of relevant BATs. Based on Anthesis' understanding, a reasonable approach would consist of:

- Ensuring that, for transmission lines, a QRA and safety report are prepared and updated periodically
- Ensuring that the safety report includes a detailed BAT Gap Analysis
- For the distribution system, preparing a BAT Gap Analysis, to be updated periodically.

The design of pipeline paths shall consider safety distances from existing buildings, applying the same methodologies normally adopted in the design of natural gas pipeline. No major modifications to the current approach to safety is envisioned. Some examples of safety distances calculated with the IAEA method are reported in the table below.

Delivering modalities	**Pipe diameter (m)**	**Hazardous area (m) and type of risk***
Hydrogen, liquefied by pressure	> 0.2	500 – jet fire
Hydrogen, gaseous	> 1 Transmission systems	50 – jet fire
Hydrogen, gaseous	02 < d < 1 Distribution systems	25 – jet fire

Table 8-3 Safety distances from pipes transporting gaseous/liquefied hydrogen (Source: Author's own elaboration calculated with the IAEA method)

Based on actual market trends, it could be assumed that GH distribution systems will be mainly controlled by the same companies currently involved in natural gas distribution, normally characterized by strong organizational structures, proper know-how about safety management, and existing training programs for workers.

Thus, with respect to the development of hydrogen distribution networks, the most challenging safety issue will likely be related to the need to raise awareness about specific characteristics of hydrogen among its final users, rather than among workers. Section 6 of this study highlighted that several national hydrogen strategies developed in LAC (for example, in Colombia) already recognize the need to engage the local population through awareness campaigns. Operators of distribution lines should be responsible not only to deliver training courses to workers, including contractors, but also to end users and public authorities.

8.6.8. Hydrogen Delivery by Truck/Train

Incidents during transportation may be originated by causes not directly linked to the quality of the transported good, for example, train derailment, collisions, road incidents, etc.

For safe transportation, it is therefore necessary to:

1. Reduce the number and probability of incidents
2. Reduce probability that a road/rail accident may develop in a loss of containment of the transported hazardous substance
3. Reduce probability of an accident during loading/unloading activities
4. Ensure proper management of emergencies.

With reference to point 2 above, safe vehicle design and maintenance can reduce the probability of loss of containment. Technically, transportation by truck or train shows the same issues as already seen for piping:

- Hydrogen is colorless and odorless
- Hydrogen can embrittle construction and structural materials.

As for production facilities and piping, relevant technical standards are under development; thus, the definition of minimal technical requirements or a standard of reference for vehicle design and maintenance is considered not possible at now.

The suggested approach consists of requiring companies in charge of truck design and management to prepare a BAT Gap Analysis of their products and services, to be periodically updated, taking into consideration ongoing development of safety standards.

Procedures shall be adopted:

- To plan the best transportation modalities, both at a strategic level (with assessment of transportation alternatives) and at a detailed one (with planning of the best routing of each single transport)
- To ensure the completion of periodic truck safety verification, truck testing, and maintenance, also ensuring proper technical capabilities and training of the personnel involved in these activities
- To ensure that training for truck drivers covers aspects related to safe driving, safe loading/unloading, and emergency management. Training should be tailored taking into consideration the different company backgrounds. While workers' training in production facilities is a rather straightforward activity, training of drivers and all contractors involved in the refueling chain is more problematic because workers are from different organizations and are used to working in a less structured environment compared to that of an industrial facility.

In transportation by train, procedures and training shall include details about:

- Modalities to select the routing of each train
- Allowed maneuvers for wagon handling and train formation
- Rule for train composition (maximum number of allowed wagons, presence of shield wagons, etc.)

- Allowable stops during transportation (either if the train is required to be forwarded directly from the origin to the destination pint, without intermediate stops in shunting yards)
- Maximum allowable speed
- Loading and unloading procedures
- Safe documentation and signaling
- Emergency management.

Completion of periodic truck/rail wagon safety verification and testing may imply the existence of national agencies with proper inspection and certification capabilities; when absent, the sectoral guideline may provide details to project sponsors on how to achieve proper safety levels through alternative methods, such as second and third party audits. Financing from project sponsors of national agencies aimed to control safety may be considered, with a proper management of the conflict of interest.

All nations of the region may be also encouraged to sign an agreement related to the transport of dangerous goods, as already done for countries that are signatories of the Mercosur Treaty.

Numerous technical and academic studies are available in the literature for the assessment of the hazardous area in the event of incidents during hydrogen (or ammonia) transportation, with a rather diversified set of results. For completeness of information and consistency in this study, safety distances for both liquefied hydrogen and ammonia calculated with the IAEA method are reported below.

Substance and storage modalities	Quantity (t)	Hazardous area (m) and type of risk*
Hydrogen, liquefied by pressure	10 - 50	100 – fire & explosion 200 – toxic release
Ammonia, liquefied by pressure	10 - 50	

Table 8-4 Safety distances from mobile tanks transporting liquified hydrogen and ammonia (Source: Authors' example based on 1996 IAEA methodology)

8.6.9. Ammonia and Methanol Shipping

Ammonia and methanol are currently shipped in large quantities across the globe. GH will further increase traffic of these substances and potential related impacts. However, no specific issues were detected that can be considered as unique to the GH value chain.

The existing IFC EHS Guideline for Ports, Harbors and Terminals (68) and that on Shipping (in particular, the section on dangerous substances) (69) can be considered a useful reference, and in the event it is updated, merged and tailored to include more practical provisions to be used in projects within the GH value chain.

Safety distances of ammonia tanks from storage facilities have already been reported above. Examples of safety distances from ammonia pipelines (that are supposed to be built in port areas for vessel loading/unloading), calculated with the IAEA, are reported in the table below.

Method	Pipe diameter (m)	Hazardous area (m) and type of risk*
IAEA guideline, Ammonia	0.1 - 0.2	1,000

Table 8-5 Safety distances from ammonia pipes calculated with IAEA method (Source: Authors' example based on 1996 IAEA methodology)

8.7. Security

No specific issues were identified related to the deployment of security forces and the GH value chain. However, concerns raised in Section 7 (risk of terroristic attack and thief control) imply the need for deployment of some security forces, that shall be proportionate to the scope, avoiding conflict with workers and local communities.

Application of international standards should provide appropriate and sufficient guidance. Aside from the well- known IFC Guideline, *Use of Security Forces: Assessing and Managing Risks and Impacts* (70), further provisions and guidelines of reference are included in the IDB guidelines for the implementation of the ESPS4 *(Guía para la norma de desempeño ambiental y social 4: Salud y seguridad de la comunidad,* 2021). Among other standards, the guidelines significantly mention standards developed by entities based in the region (i.e., the Comité Argentino de Presas, CAP, and Comitê Brasileiro de Barragens, CBDB).

With respect to cybersecurity measures, no specific issues were identified related to the GH value chain. However, considering that cyber-attacks may imply the loss of functionality of software tools used for control of "hazardous" facilities (i.e., Supervisory Control and Data Acquisition SCADA or Distributed Control Systems DCS), proper measures to limit risk of cyberattacks shall be ensured.

8.8. Biodiversity Conservation

Occupation of land for GH projects implies potential impacts on critical, natural and modified habitat and related ecosystem services and living natural resources.

As mentioned, the extension of land necessary for construction of an electrolyser is similar to what is necessary for other medium-sized industrial projects. Thus, the electrolyser itself is not considered a critical issue, in terms of land use, within the GH value chain. Existing guidelines on recommended measures for implementation of ESPS6 are applicable to electrolysers, without need for further notes. Main potential impacts to living resources and ecosystems are related to awater consumption and brine discharge, as commented upon in other sections of this report.

However, as already stressed in different sections of this report, GH projects are composed of different components (namely solar/wind farm(s), transmission line, hydrogen production plant, conversion facilities for ammonia/methanol production, shipping/transportation facilities, etc.), that may cumulatively have significant impact, in terms of land use/land cover fragmentation, especially in a region (LAC) characterized by vast areas of uniform land uses, ecosystems, and landscapes.

In 2016, UNEP published *The State of Biodiversity in Latin America and the Caribbean [103], while IUCN published the Red List of Ecosystems in South America* and some related papers, among which was *An ecosystem risk assessment of temperate and tropical forests of the Americas with an outlook on future conservation strategies* [104]. In these documents, most of the content is dedicated to forest conservation, sites that are probably not the most suitable for construction of GH projects (for geographic and technical reasons). but it is also stressed that the extensive grasslands, shrublands, and deserts, can be found on the Caribbean coast of Venezuela, northeastern Brazil, and inland areas between Brazil and Bolivia. Mid-latitude grasslands occupy areas in southern Brazil, Uruguay, and central and eastern Argentina. Tropical grasslands and savannahs are present in Central America, the Guyanas, Venezuela, Colombia, Brazil, Paraguay, and Argentina. Arid shrublands occupy the west of Argentina and Patagonia, and hyper-arid areas exist along the west coast of Peru and northern Chile, as well as in southern Bolivia and northwestern Argentina. Most of these ecosystems are threatened.

While it can be said that existing sectoral EHS guidelines related to wind farms and power transmission/ distribution lines formally cover all the necessary topics related to biodiversity conservation and these components of GH projects, it should be stressed again that the cumulative impacts of different components all together may generate impacts higher than the sum of the impacts of each component.
When developing GH projects, applicability of actions proposed by UNEP for biodiversity conservation in the region shall be considered, also taking into consideration that GH projects in some instances may even facilitate the implementation of some of them:

- *Mainstream biodiversity into business practices*
- *Build forest carbon conservation partnerships*
- *Share expertise on water payment schemes in the region*
- *Sustainably develop water resources in the region*
- *Link tourism to development planning in coastal nations*
- *Invest in raising public awareness of biodiversity values*
- *Strengthen the effectiveness of protected area networks and biological corridors*
- *Enhance implementation of biodiversity related conventions to build institutional capacity*
- *Enhance regulation and enforcement of environmental laws and policies*
- *Increase available resources for biodiversity*
- *Increase and promote multi-sectoral coordination, and South-South and Triangular cooperation*
- *Promote gathering appropriate data to measure progress toward the Aichi Biodiversity Targets in the region, using regional and national datasets.*

Aside from the high-level principles mentioned above, recommended procedures to control impacts on ecosystems and biodiversity are aligned with the procedures presented in the paragraph below, aimed to mitigate socioeconomic impacts of the land acquisition process.

8.9. Social Aspects and Stakeholder Engagement

8.9.1. Land Acquisition and Land Use Fragmentation

Renewable energy production and the push to develop new, large-scale renewable farms – which is a key element in the world's efforts to tackle global problems related to climate change and carbon emissions, as well as representing a foundational brick of the GH value chain – poses a relevant challenge to regional planners and administrators with respect to managing landscape transformation and territorial fragmentation. Most negative effects associated with the development of large renewable farms -- i.e., land-use changes, land take, diminishing aesthetic values, and loss of habitat quality -- depend on the location and spatial pattern of the plants, the relative distance between them, the extension of secondary infrastructures, and their technical characteristics (71).

The fast pace at which the development of a GH value chain across the LAC region is projected may also represent an additional pressure factor, making it difficult for land planners to properly address these issues and incorporate them within zoning and land planning and management systems at national, regional, and/or local levels.

The following considerations shall be made in relation to efforts to minimize such negative impacts when developing guidelines for the development of GH projects in the LAC region:

- To mitigate the impacts of land acquisition and subsequent resettlement, several international standards exist, among which are IDB PS5, IFC PS5, and World Bank ESS5, the applicability of which must be established during the environmental and social risks and impacts identification process.
- Existing tools addressing land acquisition shall be tailored to consider regional needs and/or significant presence of indigenous communities in the area of influence of the project.
- The siting shall be analyzed through tools similar to SESA rather than ESIA, with the involvement of potentially affected communities, in order to (i) understand primary and secondary, direct and indirect, as well as cumulative impacts on local communities, with particular attention to disadvantaged groups e.g., women and young girls, minorities, indigenous peoples, etc. (ii) to avoid the development of local opposition, each one potentially capable of putting the project at risk.
- The preparation and approval of a preliminary development plan prior to the project disclosure should be considered.

8.9.2. Threats to Water Resources

Water is a natural resource, a commodity, as well as a perceived human entitlement.

The development of a GH value chain across the LAC region may pose significant pressure on countries' water resources and subsequently on the livelihood and quality of life of communities at a local level. Nonetheless, these challenges can be overcome by crafting guidelines and policies that address the water issue in GH production, through strategic planning and modeling of future developments, as well as by carefully implementing dedicated mitigation measures, both structural and non-structural, including the engagement of all interested stakeholders.

8.9.2.1. Development-induced Water Scarcity

While water scarcity can be caused by natural conditions, such as drought cycles, it can also be caused and/or worsened by over-abstraction, unsustainable land use, deforestation, intensified irrigation, and modification of ecosystems, leading to deterioration of the services they provide.

Furthermore, local inadequate access to safe freshwater contributes to the worsening of health conditions of affected communities due to the spread of waterborne diseases, and it has been widely linked to malnutrition, poverty, economic and political instability, and (potentially violent) conflicts between countries or groups within countries. In the worst-case scenario, water conflicts, especially if they turn violent, may trigger further spiraling negative impacts on human health: not only injuries and death, but also, among others: (i) damages or destruction of health-supporting infrastructures, including systems for freshwater provision; (ii) forced migration, with subsequent further reduction of access to freshwater; and (iii) diversion of human and financial resources, including resources to maintain and improve access to the water resource (72).

Impacts of water scarcity due to over-abstraction are particularly harsh on low-income and disadvantaged groups. An increasing number of poor rural and urban communities, rural producers, and rural laborers are viewing access or entitlement to water as a more critical problem than access to food, primary health care, and education. Water scarcity may even worsen poverty rates at a local level, especially if it negatively impacts water availability for agricultural uses, in particular where communities depend on subsistence agricultural practices: *"If irrigation has played a central role in poverty reduction in the past, the growing scarcity and competition for water and the overexploitation of groundwater resources are putting the poor in irrigated areas at great risk"* (73).

As already noted in previous sections of the present study, water demand for GH production is significant (although it varies, depending on the technologies deployed and the local context of reference), and clear linkages exist between the development of GH projects and water additionalities.
The development of a GH value chain in some areas/countries in the LAC region that are affected by water shortages and/or difficulties in water provision (a condition that may get worse due to the medium/long-term effects of climate change) may exacerbate competition for accessing available water resources among different stakeholders, with subsequent negative impacts on those whose voice is less easily heard.

8.9.2.2. Impacts of Desalination on Water Quality

Where possible, a potential solution to reduce the impact of GH production on the availability of freshwater resources may be resorting to desalination of saline or brackish water. However, brine discharge may lead to significant environmental impacts on receiving water bodies, which may subsequently affect water quality as well as changes in composition and distribution of biota. This is the aspect that may have the furthest-reaching social consequences with respect to water desalination for GH production in the LAC region, in relation to two respects:

1) The potential negative impacts on food provision of local communities that depend on fishing activities for their protein intake
2) The potential negative impacts on livelihood of local communities that depend on fishing activities for their income.

Concerning the first point, as the latest FAO report (74) on the state of world fisheries highlights, fish proteins are essential in the diet of some densely populated countries where the total protein intake is low, particularly in Small Island Developing States ("SIDS")[19] , among which are a few LAC countries in the Caribbean sub-region, including – from the sample countries of this study – Trinidad and Tobago. *"For these populations, fish often represents an affordable source of animal protein that may not only be cheaper than other animal protein sources but preferred and part of local and traditional recipes". In some SIDS "… fish contributed 50 percent or more of total animal protein intake"* (74).

As noted also within the FAO report, the outlook above is extremely high-level, and subject not only to great intercountry variations, but also within each country: *"… Differences in income levels represent another important factor underlying differences in fish consumption, as do the availability and price of substitutable proteins. Other determinants include climate, market penetration, regional demographic characteristics, as well as the density and quality of transportation and distribution infrastructure"* (74).

The contribution that fish resources give to daily protein intake of communities also across the LAC region – in particular, in small Caribbean Island nations as well as in countries like Peru and Guyana on the mainland –, can be quite significant, and changes in availability and quality of the resource could cause significant impacts at the local level.

Regarding the second point -- impacts on livelihood of communities that are dependent on fishing activities for their income -- the same 2020 FAO report notes how fish trade and aquaculture shall be regarded as a significant driver *"of economic growth and a contributor to global food security. Exports of fish and fish products are essential to the economies of many countries and regions"*. Underlying these global flows of products and money, small-scale fisheries ("SSF") contribute to more than half of the world´s fish catch, *"…providing food and livelihoods to coastal villages, mainly in developing countries"* (75).

19 The full list of SIDS is available at https://www.un.org/ohrlls/content/list-sids (last access 02/12/2021)

If at the regional level, the LAC region emerges as a solid net fish exporter, and the continent is characterized by consistent interregional trade flows[20] (76), zooming into the sector, we see that almost one-third of the total marine catch in the region is represented by SSF. The importance of SSF in LAC is therefore widely acknowledged in terms of income, livelihood, and food security for more than two million people. As Mirella de Oliveira Leis and colleagues note in their 2019 paper, *Overview of Small-Scale Fisheries in Latin America and the Caribbean* (76), "Small-scale fisheries in the region are deeply linked to the history and culture of local fishing communities and have a strong influence on the regional economy through the generation of employment, income, and livelihoods".

Climate change, increasing pollution, and competition of illegal, unreported, and unregulated fishing activities, are all sources of existing pressure on SSF. It is important to plan appropriate and proportionate mitigation measures so that large-scale desalination activities do not add further pressure on water quality and the marine biota (both on stocks and species distribution) of coastal areas, with subsequent adverse impacts to SSF in the LAC region.

8.9.2.3. Final Recommendations

The following aspects can be considered when developing guidelines for development of GH projects in the LAC region:

- Several international standards exist, among which are IDB and IFC PSs 3 and 6, respectively, and World Bank ESS3 and 6, the applicability of which must be established during the environmental and social risks and impacts identification process. Such standards shall be referred to and used in synergy with other available and relevant regulations at the international and national level to encourage stakeholder engagement and incorporate valuable contributions of local communities on shared management of water resources.
- Sustainability of freshwater consumption for GH production depends on the environment of reference. Impact assessments should always consider the shared (current and potential) use of the water resource, as analyzed in Section 8.3.
- In relation to desalination, no specific measures are required for relatively small plants (up to hundreds MW). Existing tools for impact assessments are suitable in such cases.
- Regarding bigger developments, the preparation of a preliminary development plan (and related SESA) may be considered, which shall take into account the specific characteristics (biophysical, chemical, socioeconomic, and cultural) of marine ecosystems in coastal areas and carefully assess the presence and relevance of SSF for local communities. Impacts that variations in stock availability and health, as well as in species' distribution, may have on the livelihood and food security of local communities shall be included within the assessment and properly followed up with mitigation measures.
- In establishing guidelines for safe management of shared water resources, it is recommended to include dedicated provisions on targeted assessment to be carried out at both local and regional levels, always including dedicated requirements for gender mainstreaming in evaluation, monitoring, and decision-making, as well as in subsequent project design.

20 In 2018, interregional trade flows of fish and fish products represented on average 51% of total imports for the LAC region in terms of value (74).

- Furthermore, in those areas characterized by significant water stress and/or restricted access to the water resource (including drinking water and sanitation), more stringent parameters and requirements should be adopted to safeguard local communities and, in particular, vulnerable groups, including women. Their early and effective involvement in project planning will enable capitalizing on local knowledge and practices to achieve more efficient and equitable access to the water resource.
- Careful design of guidelines and of subsequent plans/programs/projects will also unlock potentially beneficial impacts of the development of a GH value chain in the region, including improving access to basic and improved services linked to drinking water and sanitation.

8.9.3. Labor Issues

As IDB ESPS2 clearly states, *"the pursuit of economic growth through employment creation and income generation should be accompanied by protection of the fundamental rights of workers. […] Failure to establish and foster a sound worker-employer relationship can undermine worker commitment and retention and can jeopardize a project. Conversely, through a constructive worker-employer relationship, and by treating workers fairly and providing them with safe and healthy working conditions, Borrowers may create tangible benefits, such as enhancement of the efficiency and productivity of their projects".*

All LAC countries have ratified the eight fundamental ILO conventions[21], the only exceptions being Brazil concerning Convention n.87 on Freedom of Association and Protection of the Right to Organize, and the Caribbean Island state of Saint Lucia concerning Convention n.138 on Minimum Age.

With respect to the development of a GH value chain in the LAC region, potentially adverse risks and impacts on workers may be anticipated in relationship to:

- Labor conditions and practices, considering that GH-related developments, especially when of sizable dimensions, may involve large numbers of workers as well as several contracting companies, for long periods of time
- OHS aspects, which may become prominent in case projects, are located in remote and under-served areas where access to basic services such as medical care may be extremely limited (if not absent without the implementation of additional measures), and the provision of essential goods and services can be very difficult and therefore requiring careful planning
- Forced labor and modern slavery are both significant phenomena in the LAC region, although the region reports the lowest figures compared to other regions of the world (see the table below).

21 The overview is available on ILO's official website, at the following address https://ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:10011:::NO:10001:P10011_DISPLAY_BY,P10011_CONVENTION_TYPE_CODE:3,F (last access 14/12/2021).

Region	Unit	Total forced labor	Modern slavery
World	Number (thousands)	24,850	40,293
	Prevalence (per thousand)	3.4	5.4
Africa	Number (thousands)	3,420	9,240
	Prevalence (per thousand)	2.8	7.6
Americas	Number (thousands)	1,280	1,950
	Prevalence (per thousand)	1.3	1.9
Arab States	Number (thousands)	350	520
	Prevalence (per thousand)	2.2	3.3
Asia and the Pacific	Number (thousands)	16,550	24,990
	Prevalence (per thousand)	4.0	6.1
Europe and Central Asia	Number (thousands)	3,250	3,590
	Prevalence (per thousand)	3.6	3.9

Table 8-6 Forced labor and modern slavery in world's regions (Source: (77))

The figures above are the latest available and come from the ILO 2017 report, *Global estimates of modern slavery: Forced labour and forced marriage* (77). The document reports data for LAC, together with the USA and Canada. Global estimates indicate that there were over 1.9 million victims of modern slavery in the Americas on any given day in 2016. This translates into a prevalence of 1.9 out of every 1,000 persons. Although forced labor is not affecting the hydrogen sector specifically, dedicated provisions addressing this aspect within future guidelines should be included, in particular with respect to unskilled labor. Potential areas of risk include the massive earth moving and civil works necessary for construction of roads, port/harbor facilities, and large ammonia plants (rather than the prevailing electromechanical construction works necessary for hydrogen electrolysers).

- Child labor is also a phenomenon that remains significant in the region. In fact, according to the latest ILO-UNICEF report published in 2021 (78), LAC countries have 8.2 million children between the ages of 5-17 (6% of the regional total) who are engaged in child labor. Most of these children are male adolescents; 33% of child laborers are girls. According to the report, child labor is present in both rural and urban areas, although it mostly affects the agricultural sector (about 48.7%). As for the previous point, although the hydrogen sector may not be specifically affected by the phenomenon of child labor, dedicated provisions should be considered in drafting future guidelines for the development of the GH value chain in the region, especially addressing activities entailing highest OHS risks, such as earth moving activities and civil works.

To avoid and/or mitigate such impacts, the following measures should be included within future guidelines for development of GH projects in the LAC region:

- Several international standards exist, the applicability of which must be (i) clearly stated at the level of guidelines as well as in relation to SESAs drafting and/or (ii) established on a case-by-case basis during the environmental and social risks and impacts identification process for specific projects. Among them, those concerning labor and working conditions of workers, are IFC PS2 (and the relevant handbook (79)), IDB ESPS2, and WB ESS2, which also cover in their scope those workers who are engaged by third parties and primary supply workers.
- Depending on the degree and magnitude of risks initially identified in relation to a specific project, a labor assessment may be explicitly requested from borrowers. This may be carried out at different levels, depending on the initial assessment of project risks in relation to labor practices.
- Borrowers as well as contractors should be requested to implement specific labor management procedures (or "LMP") to identify the main labor requirements and labor-related risks of the project and determine resources necessary to properly manage them according to international standards. Risk assessment should cover Tier 1 suppliers as well. The LMP should be understood as a living document to be developed early in project preparation and reviewed and updated throughout the whole project life cycle.
- For large developments, especially if located in remote areas, robust provisions to ensure workforce health and safety should be required and implemented accordingly, ensuring provision of essential goods and services, such as appropriate accommodation and food, proper sanitation facilities, and recreational spaces, etc.. The plan should also include adequate arrangements to provide for health services in case of injuries, which shall take into account the possibility that needed hospital infrastructure may be far away and difficult to reach. The 2009 guidance note (80) by IFC and the EBRD on *Workers' accommodation: Processes and standards can be used as reference.*
- Response measures in case of accidents should be reflected in projects' emergency and response plans and adequate funds should be allocated.
- Other labor-related issues (such as the need to establish a worker grievance mechanism, freedom to join workers' associations, etc.) are considered well-addressed by existing standards and there is no need to add specific provisions related to the GH value chain.
- Since risks of forced labor and/or child labor are often further down a supply chain where there is less visibility over working practices, it should be kept in mind that, in order to effectively conduct due diligence and understand where such risks reside, entities and companies should progressively improve their understanding and oversight of all tiers of their supply chains, through supply chain mapping and screening, by implementing pre-contractual due diligence processes, or by conducting dedicated human rights due diligence. Useful guidance in this respect is provided by documents such as the Good Practice Note for the private sector on how to manage risks associated with modern slavery by Ergon Associates, and Ethical Trading Initiative (81) or, for child labor, within ILO's *Checkpoints for Companies – Eliminating and Preventing Child Labour* (82).

8.9.4. Labor Influx

As social expert Daniel Owen put it during the 38th Annual Conference of the International Association for Impact Assessment that was held in Dubai in May 2018, *"… Projects also stimulate speculative influx, including those seeking employment or enterprises hoping to sell goods and services to the temporary project workforce, as well as 'associates' who often follow the first two groups to exploit opportunities for criminal or illicit behavior (e.g., prostitution and crime)".*

Although project-related labor influx is usually described as being "temporary and transient", in the case of large developments such as those connected to GH production, duration and magnitude may be longer and more fixed, with several years required for construction works of large infrastructure) and hundreds of external workers needed, especially in remote and low-populated areas, where specialized and skilled labor may not be available. Furthermore, this specific environmental factor may also bear a high degree of unpredictability about its significance as it is often subject to large fluctuations over time, making it more difficult to regulate and be overseen by local authorities, project managers, and practitioners who may be called in to conduct impact assessments of future developments.

Labor influx may generate a cascade of potentially negative impacts, greater in magnitude the more remote the area and smaller the community in which they happen. Among them[22], shall be mentioned:

- Induced pressure on land, natural resources, and availability and price of goods and services at the local level as the influx of newcomers in the area will likely increase demand for food, fuel, housing, and land. Such pressure may exert greatest impact on the most vulnerable in the location, as well as on those communities whose livelihoods are highly or even exclusively resource-based, in particular those depending on subsistence agriculture.
- In connection with the above, a great influx of labor from outside may stretch beyond capacity the local level's social infrastructure due to increased demand in housing services, schools, and health care, as well as generating additional pressure on waste management, sanitation, water, power, and transportation services.
- Influx of labor may cause communities to experience significant boosts to the local economy associated with the start of projects, followed by sharp declines once construction works have concluded.
- External worker influx may pose threats to the health and safety of local communities, provoking higher rates of violence, injuries, alcohol and drug consumption, and communicable diseases (including sexually transmitted diseases) in the local population.
- Conflicts between local community members and workers from outside the community may arise with respect to employment opportunities, wages, and demand and pressure on natural resources.
- Finally, a large influx of external male workers may lead to an increase of gender-based violence.

22 In January 2017 the World Bank commissioned a study on social impacts of labor influx (Plexus Energy for the World Bank, 2017. *Labor Influx: Select Portfolio review and Case Study Situation Analysis*, available at http://www.plexusenergy.net/wp-content/uploads/2019/03/labor_influx_review_summary.pdf last access 02/12/2021) from which, alongside an extensive literature review on the matter, have been selected the most relevant social impacts reported above.

Considering all above-mentioned potential impacts related to labor influx for GH development projects, the following considerations are offered to avoid and/or minimize them:

- Several international standards exist, among which are IDB PS4, IFC PS4, and World Bank ESS4, addressing *"adverse impacts on the health and safety of the project-affected people during the project life cycle from both routine and non-routine circumstances"* (IDB, 2021), the applicability of which must be established during the environmental and social risks and impacts identification process. Such standards shall be referred to and used in synergy with other available and relevant regulations at international and national levels to encourage stakeholder engagement and incorporate valuable contributions of local communities.
- Labor influx risk screening shall be always required and requested to be conducted as early as possible by project proponents, alongside a comprehensive baseline at local level, including the availability of relevant skills and competencies at local level.
- The preparation of a preliminary development plan (and related SESA) may be considered, especially for bigger developments, which shall consider regional and local needs for capacity building, with particular attention paid to the empowerment of the area's disadvantaged and/or indigenous communities.
- A prevention and mitigation plan is recommended, which takes into account regional needs related to work and employment and involves local communities at an early stage of planning. Targeted training programs in synergy with regional/national/local authorities in the early stages of project development shall be considered.

8.9.5. Sourcing of Critical Raw Materials

As previously noted in the present study, the development of a GH value chain is highly dependent on the supply of several raw materials and metals, including those of the platinum group and iridium. These are well-known in the literature as well as in the global public discourse, due to rising concerns about their environmental and social impacts.

The figure below shows the percentage of iridium demand (with respect to current production) to achieve a production of 8,100 PJ of green hydrogen production (equivalent to ca. 300 GW). The figure has been taken from a recent study conducted by Wieclawska and Gavrilova (83).

Amount of iridium required annually for various applications, ton/year

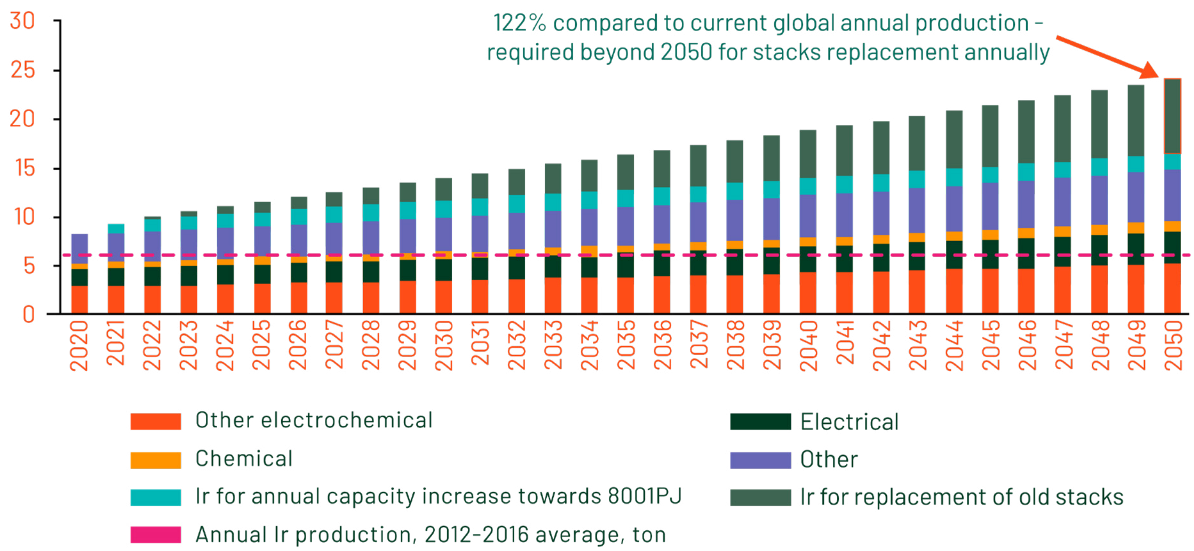


Figure 8-6 Iridium demand trend
(Source: (83))

Green hydrogen production may limit the future additional use of lithium (as hydrogen is considered a competitor energy carrier with respect to lithium batteries), but in any case, green hydrogen production will increase the need for lithium, as batteries are often utilized in the power supply system for green hydrogen production.

In fact, as low-carbon technologies advance (including those linked to GH production), heightened extraction rates increase stress placed on communities and ecosystems in extractive locations. As Lèbre and her colleagues highlight, *"84% of platinum resources and 70% of cobalt resources are located in high-risk contexts"* (84). The demand for these "energy transition metals" (or "ETMs") is projected to increase in the next decades as countries make a transition toward a low-carbon economy. Unless new technological advancements and/or increasing recycling rates come more prominently into the picture, the mining industry will play a major role in their provision.

As noted within the 2018 study, *Green Conflict Minerals: The Fuels of Conflict in the Transition to a Low-carbon Economy,* commissioned by the International Institute for Sustainable Development, *"Significant reserves of all of these identified minerals are found in states perceived to be both fragile and corrupt […] For the minerals required to make the transition to a low-carbon economy, there are real risks of grievances, tensions and conflicts emerging or continuing around their extraction"* (Church & Crawford, 2018) (85).

The unsustainable extraction and trade of mineral resources can fuel tensions and conflicts *"particularly when they happen in a context defined by weak governance, multidimensional poverty, human rights violations and youth unemployment". Where governments and elites rely on resource rents, states can become "more accountable to mining companies than their citizens, eroding the social contract between the state and its population, weakening the government's legitimacy and increasing political instability"* (85).

Sourcing and trade of so-called "conflict minerals"[23] is often linked to land disputes and conflicts over access to resources (often bursting into violence at mine sites) as well as displacement of local communities and subsequent disruption of local livelihoods. These adverse social impacts can have further reaching negative consequences, such as the rise of armed groups and violent extremism in areas at risk of recruitment and radicalization (86).

More specifically, LAC is a limited producer of iridium, platinum, tantalum, cobalt, and nickel, but a primary producer of lithium, and conflicts between mining activities and local populations, including indigenous peoples, are well-known, as shown in the case study below (grey box).

SANTIAGO, Sept 13 (Reuters) - Indigenous communities living around Chile's Atacama salt flat have asked authorities to suspend lithium miner SQM's (SQMA.SN) operating permits or sharply reduce its operations until it submits an environmental compliance plan acceptable to regulators, according to a filing viewed by Reuters.

Chile's SMA environmental regulator in 2016 charged SQM with overdrawing lithium-rich brine from the Salar de Atacama salt flat, prompting the company to develop a $25 million plan to bring its operations back into compliance. Authorities approved that plan in 2019 but reversed their decision in 2020, leaving the company to start again from scratch on a potentially tougher plan.

That ongoing process has left the fragile environment of the desert salt flat in limbo and unprotected as SQM continues to operate, according to a letter from the Atacama Indigenous Council (CPA) submitted to regulators last week.

In the filing, the indigenous council said the ecosystem was in "constant danger" and called for the "temporary suspension" of SQM's environmental approvals or, where appropriate, "to reduce the extraction of brine and freshwater from the Salar de Atacama."

"Our request is urgent and... based on the state of environmental vulnerability of the Salar de Atacama," council president Manuel Salvatierra said in the letter.

SQM, the world's No. 2 lithium producer, told Reuters in a statement that it was moving forward with a new compliance plan and incorporating changes requested by the regulator to a draft document it submitted in October 2020.

"This is a normal part of the process, so we are working on the observations, which we hope to present this month," the company said.

The Atacama region, home to SQM and top competitor Albemarle, supplies nearly one-quarter of the globe's lithium, a key ingredient in the batteries that power cellphones and electric vehicles.

23 The European Commission defines conflict minerals: *"In politically unstable areas, the minerals trade can be used to finance armed groups, fuel forced labor and other human rights abuses, and support corruption and money laundering."* Definition available at https://ec.europa.eu/trade/policy/in-focus/conflict-minerals-regulation/regulation-explained/index_en.htm (last access 14/12/2021).

Automakers, indigenous communities and activists, however, have increasingly raised concerns in recent years about the environmental impact of lithium production in Chile.

SQM, which is ramping up production in Chile to meet fast-rising demand, last year announced a plan to slash its use of water and brine at its Atacama operations.

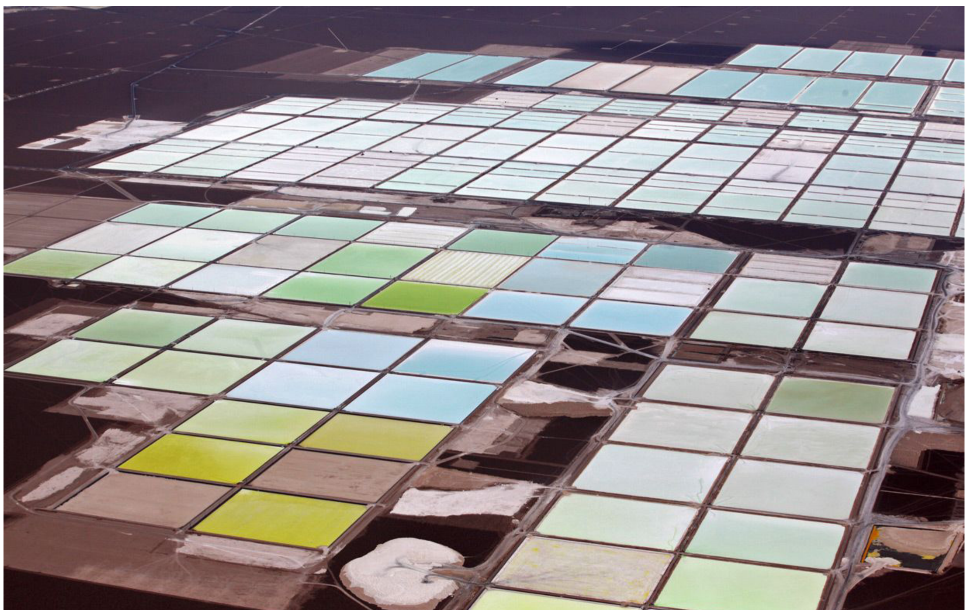


Figure 8-7 Aerial view of brine pools and processing areas of the SQM Soquimich lithium mine, Atacama Desert, Chile (Source: Reuters, 2020)

Therefore, also in connection with the development of a GH value chain in the LAC region, how these materials are sourced is critical in determining whether the GH supply chain will exacerbate, both in the short- and longer term, local tensions and grievances in those countries with strategic reserves, or instead support peaceful and sustainable development through the generation of employment and income linked to responsible mining and trade.

To avoid and/or mitigate such impacts, the following measures shall be included within future guidelines for development of GH projects in the LAC region:

- Several international standards exist, among them:
  - o Concerning labor and working conditions, IFC PS2, IDB ESPS2, as well as WB ESS2, which also cover in their scope any workforce engaged by third parties and primary supply workers.
  - o Concerning the responsible use of resources aimed at avoiding and/or minimizing to the furthest possible extent adverse impacts on human health and the environment that can in turn generate negative social impacts as described above, IFC PS3, IDB ESPS3, and WB ESS3 address the sourcing of raw materials.

- Regarding conflict minerals, relevant documents include:
  o The European Parliament and Council Regulation 2017/821 on Conflict Minerals[24] that outlines supply chain due diligence obligations for importers of these critical materials from conflict-affected and high-risk areas.
  o The 2016 OECD *Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas* (87), which was developed to support companies in their efforts to respect human rights and avoid contributing to conflict through their mineral sourcing practices, as well as *"to cultivate transparent mineral supply chains and sustainable corporate engagement in the mineral sector with a view to enabling countries to benefit from their mineral resources and preventing the extraction and trade of minerals from becoming a source of conflict, human rights abuses, and insecurity"* (87).
- The risk identification phase shall include a BAT gap analysis with the assessment of the selected technology for electrolysers and catalysts for ammonia and methanol production, ensuring minimal use of critical materials.
- When use of significant quantities of critical materials cannot be avoided, provisions to assess potential risks in supply chains should be made, via the implementation of human rights diligence processes, and to provide for consistent risk assessment and management plans. Such plans should always provide for mitigation measures, including the establishment and/or strengthening of supply chain management processes, incorporating ad hoc internal controls, information flows, and monitoring and reporting processes. In this respect, relevant guidance can be found in the 2020 Sedex *Guide to risk assessment in supply chains* (88).
- Whenever possible and to the furthest possible extent, all provisions outlined above shall be extended to the entire supply chain, including Tier 2 and 3 suppliers.

8.9.6. Indigenous Communities

There is no single definition of "indigenous peoples"[25]. Data on the presence of indigenous communities within the LAC region vary greatly, depending on the source, methodology, changes in national censuses, number of countries covered, and years examined. Below is a figure taken from the US Congressional Research Service Report, *Indigenous Peoples in Latin America: Statistical Information* (released in August 2021), on indigenous populations and percentage of general population of Latin America, drawn from different sources.

24 Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32017R0821 (last access 14/12/2021).
25 The relevant UN Declaration on the Rights of Indigenous Peoples (UNDRIP) does not provide a definition of the term "indigenous peoples," but it uses the one that was formulated in the 1983 Study of the Problem of Discrimination Against Indigenous Populations: *Indigenous communities, peoples and nations are those which, having a historical continuity with pre-invasion and pre-colonial societies that developed on their territories, consider themselves distinct from other sectors of the societies now prevailing in those territories, or parts of them.* Article 1 of the ILO convention C169 - Indigenous and Tribal Peoples Convention (1989) reports a different definition.

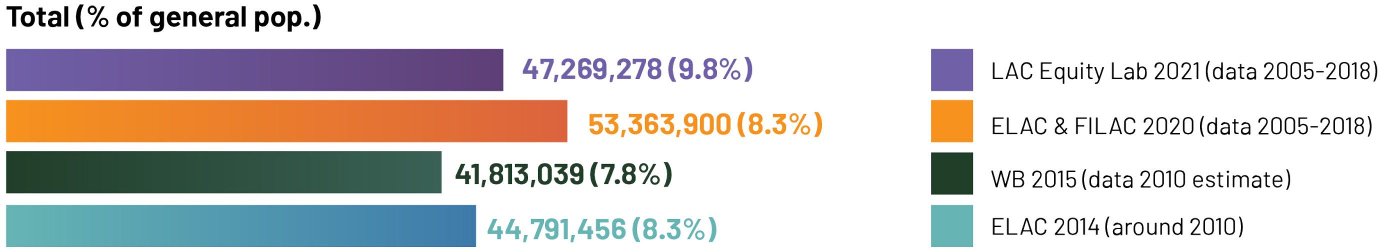


Figure 8-8 Indigenous population and percentage of general population of Latin America (Source: US Congressional Research Service, 2021)

On this subject, the World Bank further commented in its 2015 report: *"… Official data on indigenous people are not conclusive, as many technical and sociological difficulties persist in census data collection. Other sources based on estimates and unofficial data refer to 50 million indigenous inhabitants in Latin America, about 10 percent of the total population,"* although it finally resolved to use official censuses as a baseline for the report (89).

Regardless of variations, it can be stated that according to most recent official statistics, the percentage of people formally recognized as "indigenous" in Latin America ranges between 8.3% (ECLAC & FILAC) (90) and 9.8% (LAC Equity Lab, 2021). Shares vary greatly among countries, however. Using the ECLAC and FILAC 2020 study as reference (which reports data collected from 2015 to 2018) for the Latin America subregion, the highest share of general population recognized as indigenous peoples belongs to Guatemala (6,491,199 individuals, or 43.6%) and Bolivia (4,176,647 individuals, or 41.5%), while the smallest share has been recorded in El Salvador (13,310 individuals, or 0.2%).

For what concerns the Caribbean subregion, it was not possible to find studies reporting data for all countries that was homogeneous according to the year of reference and methodology. Therefore, this study reports the latest available figures from official censuses carried out at national level, such as the 2010 census in Panama[26]. For Trinidad and Tobago, the latest census was conducted in 2011[27] and has been used as a reference source.

For each of the sample countries of this study, both the percentage of indigenous people as a share of the total population and the absolute amount are reported in the table below.

26 As reported by the NGO International Work Group for Indigenous Affairs ("IWGIA") in https://www.iwgia.org/en/panama.html (last access 02/12/2021).
27 Data available at https://cso.gov.tt/census/2011-census-data/ (last access 02/12/2021).

Country	Indigenous Population (%)	Indigenous Population (Total)	Source
Argentina	2.4%	955’032	ECLAC & FILAC 2020
Brazil	0.5%	896’917	ECLAC & FILAC 2020
Chile	12,4%	2’175’873	ECLAC & FILAC 2020
Colombia	4,4%	1’905’617	ECLAC & FILAC 2020
Costa Rica	2,4%	104’143	ECLAC & FILAC 2020
Panama	12%	417’559	2010 national census
Uruguay	2,4%	76’452	ECLAC & FILAC 2020
Trinidad and Tobago	0.11%	1’384	2011 national census

Figure 8-9 Indigenous communities in the sample countries (Source: Authors’ elaboration from various sources)

Also in this case, numbers vary greatly from country to country, with Chile reporting the highest share and total amount of indigenous peoples within its territory (2,175,873, or 12.4% of general population) and the smallest proportions recorded in Brazil (by percentage, 0.5%) and Trinidad and Tobago and Uruguay (in absolute numbers, 1,384 and 76,452, respectively).

The latest UN Department of Economic and Social Affairs (“DESA”) Report (91) on the state of indigenous communities is decisive in highlighting the disproportionate impact that infrastructure projects and industrial developments may have on indigenous communities: *“As the pressures on the Earth’s resources intensify, indigenous peoples bear disproportionate costs from resource-intensive and resource-extractive industries and activities such as mining, oil and gas development, large dams and other infrastructure projects, logging and plantations, bio-prospecting, industrial fishing and farming, and also eco-tourism and imposed conservation projects. These pressures also accelerate some unsustainable economic activities undertaken by indigenous peoples themselves, notably where indigenous rights have not been respected, thus leaving communities with insufficient land and resources”* (91).

Concerning the development of a GH value chain across various LAC countries, it is important to identify the development of GH production plants and annexed infrastructure, including that for transportation as well as transformation plants, that bear potentially high negative risks and impacts for indigenous communities in the LAC region, especially for female members, as further detailed in Section 8.9 below.

At the same time, the development of a GH value chain within the LAC region, if carefully designed, planned, and implemented, may represent a precious chance to grant needed attention to human rights and human potential of indigenous communities and to ensure that development policies recognize their unique potential for contribution and capacity. Furthermore, thoughtfully crafted guidelines may support policymakers and project developers in understanding and incorporating within their work a concept of development in ways that support and engage with indigenous communities, including them as relevant stakeholders in common enterprises and their culture and knowledge, as well as the UN Sustainable Development Goals, with respect to both addressing issues of discrimination and marginalization, as well as recognizing the fundamental contribution indigenous peoples can make to sustainable development[28].

28 On the relationship between indigenous peoples and the UN Sustainable Development Goals https://www.un.org/development/desa/indigenouspeoples/focus-areas/post-2015-agenda/the-sustainable-development-goals-sdgs-and-indigenous.html (last access 02/12/2021).

To avoid and/or mitigate such impacts, the following measures shall be included within future guidelines for development of GH projects in the LAC region:

- Provisions of ESPS7 shall be reviewed and tailored for the scope. Complementary standards, such as IFC PS7 and World Bank ESS7, can be considered for comparison and cross-checking.
- In addition to the sociocultural assessment requested by ESPS7, the preparation of a preliminary development plan (and related SESA) may be considered, especially for bigger developments, which shall consider regional needs for capacity building, and which shall be tailored to empower indigenous communities in the area, including special attention dedicated to women.
- Particular attention and emphasis shall be devoted to stakeholder engagement at all stages of development efforts, starting at a very early stage and handled with a culturally sensitive approach, grounded in specific local contexts and with due respect to their cultures, ways of life, traditions, and customary laws. This will likely require significant efforts in identifying target populations and in understanding their specificities in terms of culture, beliefs, and values.
- In case of land acquisition, fragmentation, and resettlement, please refer to the previous sub-paragraph.

8.9.7. Cultural Heritage

According to the United Nations Educational, Scientific, and Cultural Organization ("UNESCO"), heritage is *"the cultural legacy which we receive from the past, which we live in the present and which we will pass on to future generations".*

With the 1972 Convention concerning the Protection of the World Cultural and Natural Heritage[29], UNESCO established that heritage is *"important for culture and the future because it constitutes the cultural potential of contemporary societies, contributes to the continuous revaluation of cultures and identities and is an important vehicle for the transmission of experiences, skills, and knowledge between generations. Furthermore, "it has the potential to promote access to and enjoyment of cultural diversity. It can also enrich social capital and create a sense of individual and collective belonging, which helps to maintain social and territorial cohesion"*. Finally, cultural heritage can be economically significant for the tourism sector and represent a relevant source of income at local, regional, and national levels.

With respect to indigenous peoples, UNESCO also recognizes[30] how they hold a rich diversity of living heritage, including practices, representations, expressions, knowledge, and skills that are vital not only in affirming their identity, but also how, in the practice and transmission of this heritage, they contribute to the ongoing vitality, strength and well-being of their communities.

29 Integrally available at https://whc.unesco.org/en/conventiontext/ (last access 02/12/2021).
30 See the 2003 UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage, available at https://ich.unesco.org/en/convention (last access 02/12/2021).

According to the UN Action Plan for the World Heritage in the LAC Region 2014-2024 (92), 32 LAC countries have ratified the World Heritage Convention and 129 properties are inscribed on the World Heritage List: 90 cultural properties, 36 natural properties, and three mixed properties, which are recognized for their "outstanding universal value." It is acknowledged that the LAC region *"possesses a rich and diverse cultural and natural heritage as well as diverse social, political, and economic conditions. […] It can also be said of the diversity of institutional situations concerning heritage policies of each country"* (92).

The International Council on Monuments and Sites ("ICOMOS"), among others, acknowledges how cultural heritage can be significantly impacted by human activities and among the development-related risks lists: (i) changes in land use, including loss of landscapes; (ii) inappropriate land use in sensitive heritage areas; (iii) environmental impacts (e.g., air, water, and soil pollution, deforestation, and land erosion); (iv) large development projects such as dams, mining, and other forestry operations, and transport infrastructure; and (v) accelerated physical abuse of heritage places due to large people influxes (ICOMOS, 2000) (60).

All the activities listed above may be applicable to projects aimed at developing a GH value chain in the LAC region, and special attention shall be placed on those instances in which a plan, program, or a specific project may impact cultural heritage, of both tangible and/or intangible value.

The following recommendations apply regarding the drafting of guidelines for the development of a GH value chain in the LAC region:

- Provisions of ESPS8 shall be reviewed and tailored for the scope. Complementary standards, such as IFC PS8 and World Bank ESS8, can be considered for comparison and cross-checking.
- Heritage impact studies shall be incorporated within the preparation of preliminary development plans (and related SESA) at regional and national scales at the earliest possible stage, and with the involvement of locally affected communities, with specific attention dedicated to intangible cultural assets as well as indigenous peoples' cultural heritage.

8.9.8. Stakeholder Consultations in a Diverse Context

As already extensively noted in previous sections of the present report, in particular in connection with SEA regulations worldwide and within the LAC region, GH development projects may require the arrangement of extensive consultation processes due to their nature and their likely scale (e.g., in terms of spatial impacts, duration, magnitude, etc.) and impacts. Such consultation processes may involve extremely heterogenous communities for language, culture, values, and interests, as well as unequal access to opportunities, and to subsequently incorporate outcomes into project design.

Stakeholder engagement requires significant efforts in terms of time and resources to yield effective outcomes that will be useful for project success. Not dedicating enough time and effort to consulting all interested parties during a project, and in doing so at the right time in order to be able to include their inputs within the project itself, may result in project delays and financial losses and, consequently, project failure.

The challenge of carrying out effective stakeholder engagement activities in contexts characterized by high diversity is recognized in the literature (among others, Lückmann & Färber, 2016; Zegarac & Spencer-Oatey, 2013; Aaltonen et al., 2010), especially in relation to business development and project management in international contexts.

This will be particularly relevant in cases of transboundary impacts and/or impacts that may interest different regions within a single country or across two or more countries, like during the development of linear infrastructure for GH transportation, posing significant challenges to the organization and positive outcomes of consultation processes. Such cases though may not be any different than other large infrastructure projects in the oil and gas or mining sector.

The main challenges that could emerge in relation to intercultural dimensions of stakeholder engagement activities, as described by Lückmann and Färber (2016), are, among others: (i) fear and lack of trust *"due to the choice of communication method, physical distance, fear of losing their jobs, power or influence"*; (ii) lack of participation and commitment by stakeholder groups, which could result in fear-based oppositions that may hinder project success if not addressed in a timely and appropriate manner; (iii) lack of communication, as well as knowledge and information-sharing, which may be worsened by the fact that the existing means of communication may not be user-friendly nor sensitive to intercultural differences; and (iv) lack of transparency regarding objectives, tasks, roles, and expectations.

IDB standards include ESPS9 related to gender equality and ESPS10, which is specifically dedicated to stakeholder engagement and information disclosure: the standards provide a robust framework of reference and set of provisions.

The following recommendations shall also be considered:

- Several international standards exist, among which are IDB ESPS10 and World Bank ESS10, with the scope of offering support in establishing *"a systematic approach to stakeholder engagement that will help the Borrower identify stakeholders, especially project-affected people, and build and maintain a constructive relationship with them"* (IDB, 2021). Such standards shall be referred to and used in synergy with other available and relevant regulations at international and national levels to encourage stakeholder engagement and incorporate valuable contributions of local communities.
- Specifically, as the World Bank notes in its Guidance Note on Stakeholder Engagement, *"women, children, youth, and the elderly or other groups may need to be considered as stakeholder groups of their own, and separate consultation formats may be needed to capture suggestions and concerns."*
- The preparation of a preliminary development plan (and related SESA) may be considered, particularly (but not solely) in relation to bigger developments that may produce transboundary impacts, with a strong emphasis on early involvement of all affected and interested parties, regardless of group size, and with the support of social specialists and cultural mediators as appropriate.
- Dedicated project follow-up evaluation and monitoring activities are recommended, including on inputs collected during consultation processes and, in particular, those from disadvantaged and minority groups e.g., women, elderly, indigenous peoples, etc.

Contents of ESPS9 are analyzed at greater length in Section 8.10 of this report.

One last note shall be dedicated to grievance mechanisms ("GMs"), which represent an essential element of stakeholder engagement for any development project, including those related to the establishment of a GH value chain. Many international standards and guidelines, including IDB ESPSs and IFC PSs, as well as dedicated guidelines (among others, see for example: IDB, 2019(94) and World Bank 2008 (95)), have provisions on GM, and shall be mentioned within future sectoral guidelines for reference. Regardless of the established practice of implementing GMs, it shall be emphasized once more:

- The importance of tailoring a GM to the circumstances to which it applies. Involving project-affected peoples ("PAPs") in the design of the GM can be helpful to achieve this.
- The relevance of including safe and viable mechanisms for all local community members (including women, as well as indigenous peoples and other disadvantaged groups) to address their grievances, concerns, and questions regardless of their capacity to access the Internet, for example, or to take the time and have the means to reach a given post to file a grievance, etc.
- The importance of setting up the GM in the earliest phases of the project.

8.9.9. Positive Social Impacts of GH Projects

Potential positive impacts of well-managed GH projects may include, among others:

- Opportunities for capacity-building for general population and workers
- Improved access to electricity in remote and/or underserved areas, i.e., increased energy resilience
- Development of basic services in remote and/or underserved areas.

Careful scoping and planning of project activities and the effective involvement of all relevant stakeholders may allow project proponents to unlock the positive potential of GH development projects. This will be particularly effective in cases where development plans, programs, and policies are accompanied by SESAs and allow for the adoption of a structural and multilayered approach to the development of a GH value chain.

With respect to improving access to electricity and/or other basic services in remote and/or underserved areas:

- Ensure that siting of dedicated renewables considers regional/area strategic energy plans
- Consider the possibility of delivering part of the power production to the territory as compensation, and/or identify potential synergies between GH initiatives and public works for electrification and improvement of power supply quality.
- Ensure that the project size and its siting consider local needs, both currently and considering the long-term strategic development of the area, as well as in consultation with local communities.

In all cases and as a final note, it shall be highlighted that the acceptance of large development projects such as those encompassed in the development of a GH value chain in the LAC region may greatly benefit from the specific attention given to identify and unlock their positive potential for the communities with which they will interact, as well as from sufficient time and energy devoted to appropriate communication of specific objectives, the roadmap to achieve them, and, finally, the results obtained on the ground.

8.10. Gender Equality in the GH Value Chain

ESPS9 recognizes that gender equality has intrinsic value. This ESPS pays close attention to how gender inequalities interact with other inequalities, such as socioeconomic, ethnic, racial, disability, and other factors, and how this intersectionality may exacerbate barriers to accessing project benefits, limit the ability to deal with negative project impacts, and create other vulnerabilities. The ESPS recognizes that diverse sexual orientations and gender identities may have the effect of excluding people, making them more vulnerable to negative project impacts, which often bars them from taking advantage of opportunities available to other community members. The ESPS also recognizes that, worldwide and in LAC, most of the unpaid care work falls on women. Unpaid care work is one of the main barriers preventing women from getting into, remaining, and progressing in the labor force. This presents a major barrier to gender equality and women's economic empowerment.

Thus, it shall be highlighted that ESPS9 includes considerations on both gender identity, which is a concept that includes men and non-binary people, and sexual identity, which includes LGTBIQ+. There are strong links among ESPS9, ESPS2, and ESPS4, such as those related to the Code of Labor Conduct, or exposure to diseases.

Most of these aspects are in common to all projects and industrial sectors financed by the Bank. Below are some considerations that are more specific or significant for projects within the GH value chain.

8.10.1. Land Use Fragmentation and Land Take

The issue of land use fragmentation and land take affects the female population the most: *"Women are more harshly affected by land tenure insecurity due to direct and indirect discriminatory laws and practices at the national, community and family level"* (UN OHCHR, 2017).

This disproportion in impacts of land acquisition processes happens within a framework of rooted disadvantage in all dimensions of land rights: i.e., ownership, management, transfer, and economic rights, in particular, those associated with agricultural land. As FAO notes in its 2018 information brief, *The Gender Gap in Land Rights* (93), the gender gap in land rights, globally, less than 15% of all landholders are women; the average is 18% in Latin America and the Caribbean. Furthermore, women constitute a significantly smaller share of all landowners (ranging from less than 20% in Honduras to slightly over 50% in Malawi) and own a smaller share of all agricultural land than men. Women landowners are also less likely than men to have a legal document proving ownership of their plots or to have their names on land ownership documents (93).

8.10.2. Access to Water

Women bear a disproportionate cost when it comes to lack of access to safe water for drinking, sanitation, and other purposes. Without safe access at home and/or in work and study places, it is disproportionately harder for women and girls to lead safe, productive, and healthy lives. The UN and other entities across the international landscape have long acknowledged this: *"Across low-income countries, women and girls have primary responsibility for management of household water supply, sanitation and health. Often, fulfilling these roles precludes any other occupation or participation in education, and their marginalization is compounded by the indignity and insecurity of having nowhere private to go to the toilet. Addressing the needs of females in relation to water, sanitation and hygiene is a key driver in achieving gender equity and locking the potential of half of global society".*

Furthermore, as the global NGO Water.org highlights (94):

- Women and girls around the world spend on average 200 million hours every day collecting water. This is all time that cannot be dedicated to other activities, such as working, caring for family members, or attending school.
- Women and girls living without a toilet spend, on average, 266 million hours every day finding a place to use the bathroom.
- Access to improved sanitation leads to a reduction in assault and violence on women and girls.
- Improved access to water and sanitation, as well as to other hygiene practices, leads to improved health for women and girls. It reduces disease, undernutrition, injury from water collection, and stress.

The situation with respect to access to safe drinking water and sanitation facilities, although not specific to women, offers a high-level global outlook on the topic (see figures below)

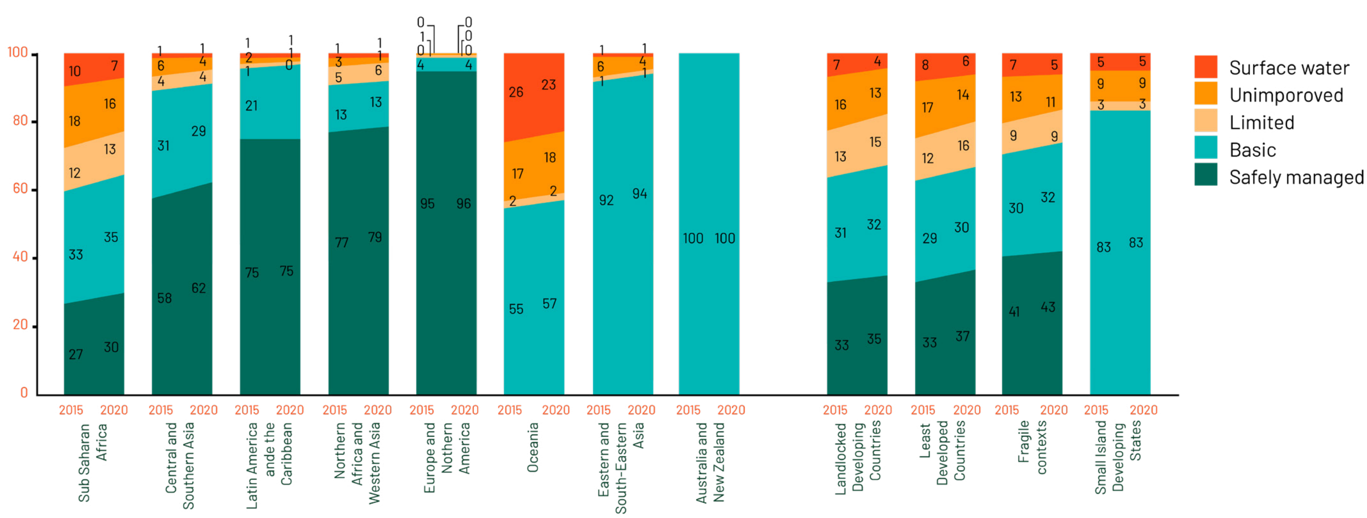
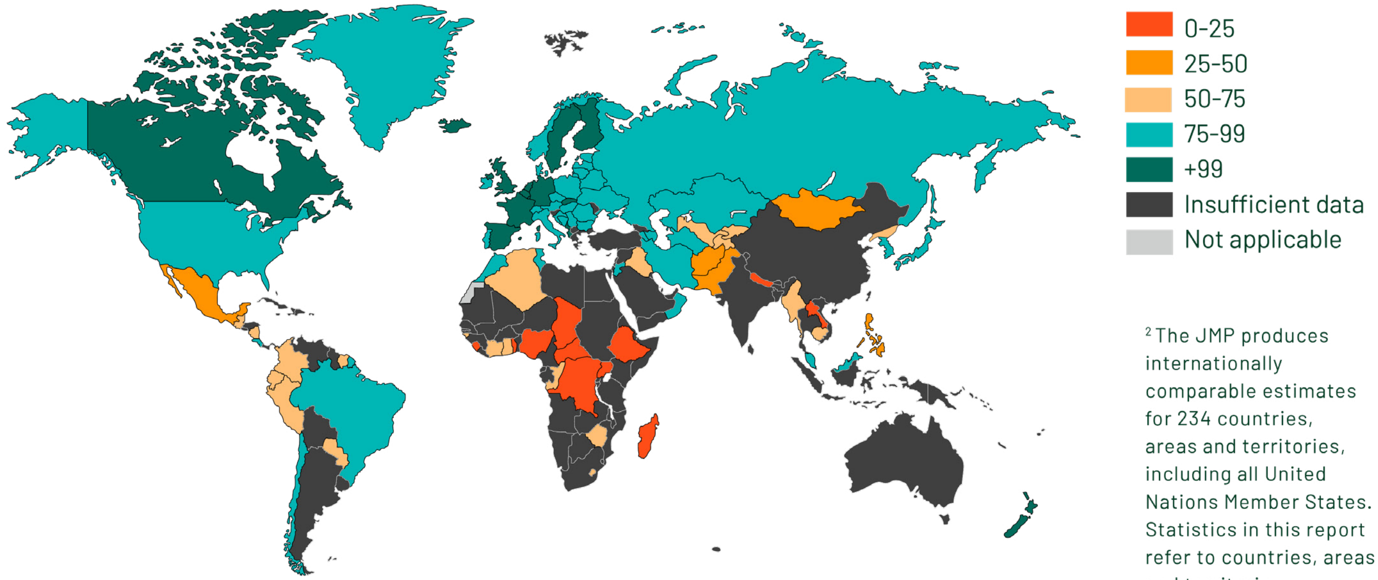


Figure 8-10 Regional drinking water coverage, 2015-2020 (%) (Source: (95))



[2] The JMP produces internationally comparable estimates for 234 countries, areas and territories, including all United Nations Member States. Statistics in this report refer to countries, areas and territories.

Figure 8-11 Proportion of population using safely managed drinking water services, 2020 (%) (Source: (95))

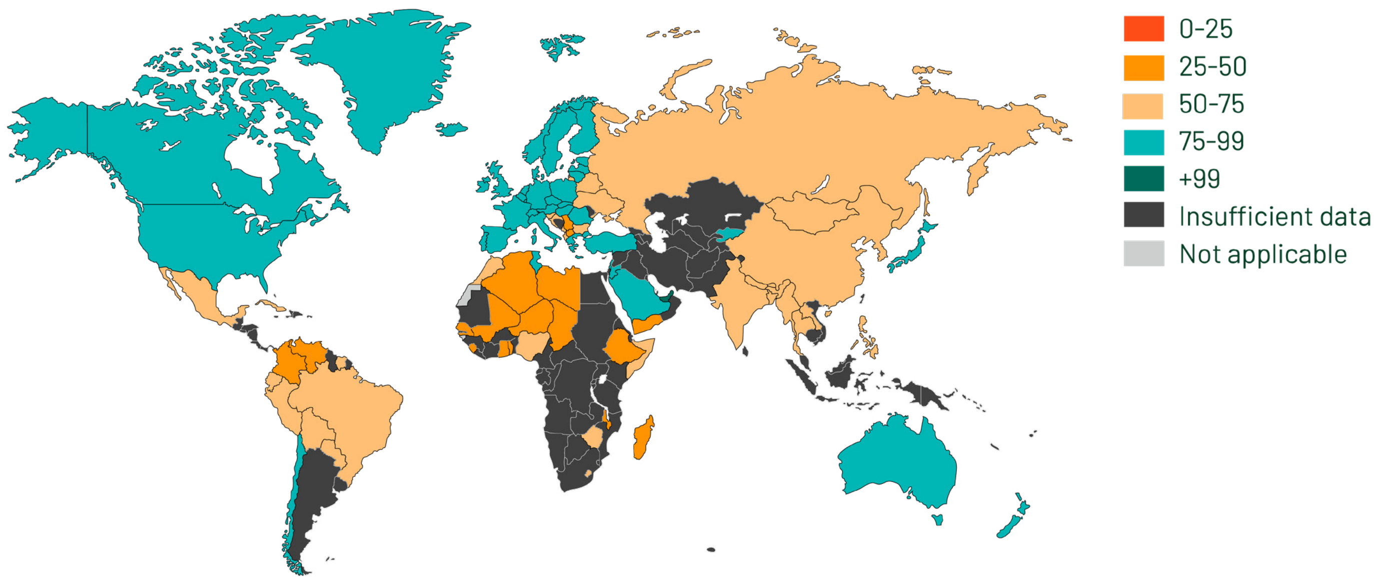


Figure 8-12 Regional sanitation coverage, 2015-2020 (%) (Source: (95))

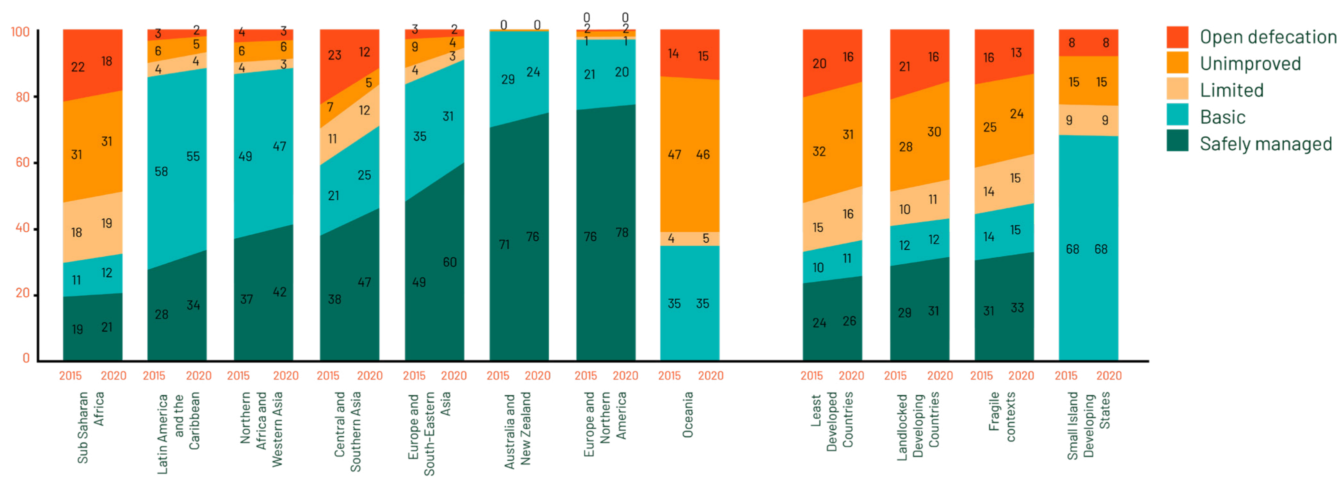


Figure 8-13 Proportion of population using safely managed sanitation services, 2020 (%) (Source: (95))

The overview provided by the above figures comes from the latest report (95) produced by the UN-Water Integrated Monitoring Initiative on SDG 6 ("IMI-SDG6"), which brings together the United Nations organizations that are formally mandated to compile country data on the SDG 6 global indicators.

It offers a look at the status of drinking water and sanitation coverage, as well as on population coverage in relation to both aspects, at a global level but allowing also for a regional perspective. In this respect, a few considerations related to the LAC region include:

- A significant lack of information affects a few countries within the region. Among these is Argentina, a country within our study sample.
- Access to drinking water in 2020 was considered well-managed in 75% of the region (no variation has been recorded since 2015), and at "basic" levels (i.e., access to safe water in adequate quantities for drinking that do not compromise health or dignity) in 22% of instances (it was 21% in 2015). On the other end of the spectrum, the remaining share of the regional population (about 2%) has unimproved access to safe drinking water or drinks untreated surface water.
- Access to safe sanitation facilities in 2020 was considered well-managed for 47% of the regional population (in 2015 it was 38%) and basic for 25% of the population (in 2015 it was 21%). For 17% of the LAC population, access to sanitation facilities was considered limited or unimproved, and more worryingly, for 12% was open defecation (although the region recorded a significant improvement since 2015, when 23% of the regional population resorted to open defecation).

The above outlook, although partial and high-level, still allows for an acceptable degree of confidence in assuming that – when access to safe drinking water and sanitation is already unimproved all the way to basic, particularly in rural and/or underserved areas –female populations will likely bear the highest costs of limited and/or reduced access to water resources, with consequences that may be farther reaching than what would be safe to assume in this context.

8.10.3. Gender Risks Related to Workers' Influx

An increase in labor influx may generate a cascade of potentially negative impacts, greater in magnitude the more remote the area and smaller the community in which they happen. Among them[31], with specific regard to risks and impacts on women in relation to GH projects:

- Induced pressure on land, natural resources, and availability and price of goods and services at the local level due to the influx of newcomers. Such pressure *"may impact greatest on the most vulnerable in the location and exacerbate the economic vulnerability of marginal groups,"* including women, as well as on those communities whose livelihoods are highly or even exclusively resource-based, especially those depending on subsistence agriculture.
- External workers' influx may pose significant threats to the health and safety of local communities, and more harshly on disadvantaged groups, including women, due to higher rates of violence (including gender-based violence) and communicable diseases (including sexually transmitted ones).
- The large influx of external male workers may lead to an increase of gender-based violence against women and young girls, particularly in socioeconomic settings where there is an existing gender differentiation in terms of power and norms.

Considering all above-mentioned potential impacts related to labor influx linked to GH development projects, the following considerations shall be taken to ensure proper assessment and management of adverse impacts on the local female population (besides all provisions already included in Section 8.8.4, above):

- IDB PS9 shall always be considered in both drafting guidelines for GH-related project developments in the region as well as more project-specific terms of reference.
- Targeted training programs on gender-related issues is recommended for the external workforce.

8.10.4. Threats to Indigenous Women

It has been internationally acknowledged that indigenous women face significant challenges to the full enjoyment of their human rights. As the United Nations Office of the Special Adviser on Gender Issues and Advancement of Women ("OSAGI") and the Secretariat of the United Nations Permanent Forum on Indigenous Issues ("UNPFII") note: *"indigenous women experience multiple forms of discrimination, often lack access to education, health care and ancestral lands, face disproportionately high rates of poverty and are subjected to violence, such as domestic violence and sexual abuse, including in the contexts of trafficking and armed conflict. […] Indigenous women's roles have eroded due the compounding factors of loss of natural resources and depletion of the ecosystems, their transformation into cash economies, changes in local, social and decision-making structures, and their lack of political status within States"* (OSAGI&UNPFII) (98). Furthermore, the difficult situation often faced by indigenous women is caused by multiple oppressions: as indigenous persons, as women, and as members of poorer classes of society.

31 In January 2017, the World Bank commissioned a study on social impacts of labor influx (Plexus Energy for the World Bank, 2017. *Labor Influx: Select Portfolio review and Case Study Situation Analysis*, available at http://www.plexusenergy.net/wp-content/uploads/2019/03/labor_influx_review_summary.pdf last access 02/12/2021) from which, alongside an extensive literature review on the matter, have been selected the most relevant social impacts reported above.

Regarding development of a GH value chain across LAC countries, it is critical to identify the development of GH production plants and annexed infrastructure, including that for transportation as well as transformation plants, as bearing potentially high negative risks and impacts for indigenous communities in the LAC region, and especially for female members.

8.10.5. Equal Participation

Equal participation in GH-related developments, if not carefully and properly managed, may trigger potential adverse impacts on women and girls, in particular:

- The absence or underrepresentation of female voices and views in stakeholder engagement activities
- The absence or underrepresentation of female students in capacity-building programs.

It has been already noted above how important introducing and adequately structuring stakeholder consultations and engagement initiatives will be during the process of developing a GH value chain in the LAC region. In doing so, a potential adverse impact on the female population may be the risk of underrepresenting women (and, consequently, their needs, expectations, and issues) within stakeholder groups selected in the framework of a project.

Acknowledging women and girls as a societal group that faces gender-based challenges and discrimination means also recognizing the danger of having their voices underrepresented (if not absent) in stakeholder processes for complex projects such as those involved in the development efforts of a GH value chain in a region, that of Latin America and the Caribbean, where this value chain is largely not existent or only at the embryonic stage.

Equal participation also means attention to foster and safeguard women's and girls' participation in capacity- building and educational activities that may be triggered in relation to the development of a GH value chain, in particular, those linked to STEM disciplines and to future employment opportunities.

8.10.6. Final Recommendations

With respect to gender-related issues, in connection with each of the issues identified in the scoping phase (Section 7) and then further discussed within Section 8, the following recommendations have been formulated by Anthesis to mitigate potential gender-based risks and adverse impacts.

In connection to land acquisition processes and potential impacts of displacement and resettlement:

- IDB PS9 on gender equality shall be regarded as an essential reference to be implemented on a continuous basis throughout the development of guidelines, policies, plans, and programs as well as specific projects and the assessment of potential risks and impacts associated with their implementation.

- Nevertheless, gender-sensitive policies and legal frameworks (including their implementation) shall be promoted and safeguarded to the furthest possible extent possible, as they are fundamental for advancing women's land rights. In particular, a regulatory framework that guarantees rural women's equal rights to land (irrespective of their civil and marital status) and acknowledges and addresses the greater adverse impacts they may be subject to in case of land acquisition and resettlement triggered by GH projects shall be integrated within future guidelines.
- As data gathering for E&S assessment impacts both plans and programs and specific projects, and is an essential step within SESAs and ESIAs, a context-specific and gender-sensitive approach in data collection and interpretation shall be always requested and adopted. In fact, reliable and context-specific statistics on women's access and control over land are critical for providing an accurate picture, allowing for the improvement of formulation of guidelines and policies, and monitoring progress toward attainment of a more equitable access to land rights and therefore of a more effective mitigation of gender-related issues in connection with land acquisition processes.

To ensure that no adverse impacts are suffered by women in relation to potential labor issues:

- Mechanisms shall be supported to incentivize the hiring of women at all stages of project development and particularly to be employed in positions in the STEM fields. Such mechanisms shall include blind screening procedures during personnel selection
- All available best practices and tools shall be used to create a safe and comfortable working environment for women.

To ensure the proper assessment and management of adverse impacts linked to the presence of large numbers of external workers on the local female population, targeted training programs for the external workforce on gender-related issues are recommended.

Regarding access to safe water and sanitation, it shall be accepted the assumption that – when access to safe drinking water and sanitation is already unimproved all the way to basic, particularly in rural and/or underserved areas (see Section 8.8.2, above, for further details) – the female population will likely bear the highest costs of limited and/or reduced access to water resources, with consequences that may be farther reaching than what would be safe to assume in this context. Therefore, the development of a GH value chain in the region, which could potentially bear further water additionalities, shall be planned, and implemented taking this aspect into account, adopting all necessary available mitigation measures, including seeking and incorporating women's contributions throughout the whole project cycle.

For gender-related issues connected to indigenous communities that may be exacerbated by GH-related developments, it shall be recommended to:

- Ensure gender-mainstreaming in crafting future guidelines also on engagement with indigenous communities during project development, and support borrowers in doing the same in their endeavors, not only with respect to mitigating potential negative impacts, but also by adopting a positive and proactive approach in relation to capacity-building and inclusion in stakeholder engagement activities.

- A multi-layered approach shall be ensured in addressing gender-related issues of women within indigenous communities, which enables the comprehensive recognition and response of potential threats to the rights and well-being of indigenous women, ranging from multiple discriminations to violence, to poor sanitary facilities and lack of clean drinking water and other basic needs for sustaining healthy life.

Finally, on equal participation of both men and women in consultation and engagement activities of a GH-related project, the following recommendations are offered:

- Gender mainstreaming[32] shall be implemented and practiced in every stakeholder engagement activity, and contactors and subcontractors will be requested to do the same.
- Particular emphasis should be given to targeting women (alongside indigenous peoples and other disadvantaged groups) to foster their skill and knowledge development and involvement in STEM disciplines, capitalizing on the increasing momentum of GH for unlocking their potential across the region. Dedicated funding and training programs, targeted incentives for employers, partnerships with local and regional authorities, as well as consultation with organizations engaged in promoting gender equality and/or indigenous people's or other minorities' rights are just some of the efforts that can be made.
- Safe and dedicated spaces shall be created to open a dialogue with the female population, aimed at capturing their hopes and expectations, wishes, and fears.

8.11. BAT and Environmental and OHS KPIs

For ammonia and methanol facilities, both IFC EHS Guidelines and European Reference Documents on BAT prepared according to the Integrated Pollution Prevention and Control Directive are of reference. Most BAT applies only to plants that use fossil fuels, but others are also applicable to plants within the GH value chain. The latter ones have been already described within the sections dedicated to waste and wastewater management.

The table below summarizes identified KPIs applicable to plants within the GH value chain. Some targets refer to plants for ammonia/methanol production from fossil fuels and are not applicable to the GH value chain.

32 Gender mainstreaming means putting an effort into including both women and men in engagement activities, with due consideration for the traditional/cultural context to ensure that gender specific feedback is captured and incorporated into project design and management to mitigate such risks. This is essential to:

- properly manage adverse impacts that affect women and men differently
- identify gender-specific project risks associated with traditional/cultural roles and practices
- give access for women and men alike to raise grievances and provide feedback that may not otherwise be captured
- provide a platform for women and men to participate in decision making.

Facility	KPI	Indicated by
Ammonia	Energy efficiency (kWh/t NH3)	Reference Document on Best Available Techniques for the Manufacture of Large Volume Inorganic Chemicals - Ammonia, Acids and Fertilisers, August 2007 and Environmental, Health, and Safety Guidelines, Large Volume Inorganic Compounds Manufacturing and Coal TAR Distillation
	Emission into air, NH3 (mg/Nm3) Effluents: pHh, Temperature, TSS (mg/l), NH3 (mg/l and kg per t of NH3 produced)	Environmental, Health, and Safety Guidelines, Large Volume Inorganic Compounds Manufacturing and Coal TAR Distillation
Methanol	Emission into air, VOC (mg/Nm3)	Best Available Techniques (BAT) Reference Document for the Production of Large Volume Organic Chemicals – 2017 and Environmental, Health, and Safety Guidelines. Large Volume Petroleum-based Organic Chemicals Manufacturing
	Energy efficiency (kWh/t methanol) Effluents: pH, Temperature, BOD5, COD, Toxicity	Environmental, Health, and Safety Guidelines. Large Volume Petroleum-based Organic Chemicals Manufacturing

Table 8-7 Identified KPIs applicable to plants within the GH value chain (Source: Authors' own summary of reviewed codes and standards)

Environmental KPIs for electrolysers suggested within the framework of this study include the following ones. The performance and target ranges shall be further investigated in the phase of preparing the sectoral guideline.

- Platinum group metal utilized, and other critical material utilized [g/MW capacity]
- Energy efficiency [kWh/kg H2]
- Fresh raw water demand [liter/kg H2]
- Seawater demand [kWh/kg H2]
- Oxygen actually utilized (not dumped) [% of production]
- Produced wastewater and brine [liter/kg H2]
- Produced hazardous waste [kg/kg H2].

ACME Group Project in Port of Duqm, Oman, to produce green ammonia for export

Credit: https://www.pv-magazine-india.com/2022/03/07/scatec-joins-scaled-up-omani-green-ammonia-project/

09
Conclusions

This section presents some considerations relevant to the preparation of a GH sectoral guideline, taking into account the observations included in the previous sections.

9.1. General Considerations for a Sectoral Guideline

The initiatives potentially included in the GH value chain are very diverse and may include (non-exhaustive list):

- Greenfield integrated developments, potentially including renewables farms, transmission lines, electrolysers, conversion unit to ammonia/methanol, and shipping facilities
- Large- or medium-size brownfield developments in existing industrial areas, most often where GH (and eventually the by-product, oxygen) is utilized in existing units for power generation, or steel or ammonia/fertilizer production
- Medium-/small-size projects or distributed projects to produce hydrogen for mobility
- Projects that incude hydrogen transmission pipelines or distribution systems.

This diversification of projects potentially included in the GH value chain is much wider than the diversification among facilities within the field of application of existing IDB or IFC sectoral guidelines, e.g., facilities covered by guidelines on the refining sector, conventional fossil fuel power production, or bulk inorganic and fertilizer production (that also cover ammonia production).

Preparation of a single sectoral guideline that covers all different types of projects potentially within the GH value chain may be challenging.

The definition of the exact field of application of the guidelines is recommended.

A second general consideration is that the GH value chain include both project components:

- not already addressed within WB/IDB EHS international standards, nor within technical reference documents, such as the European Union BAT Reference Document, BREF. Significantly, the electrolyser, the core unit to produce hydrogen, is not yet covered by standards; and
- already addressed in WB/IDB EHS international standards and/or in technical reference documents: wind farms, transmission lines, ammonia units, port facilities, gas networks, and (partially) methanol units.

To avoid duplications, existing sectoral guidelines may be referenced within the EHS guideline on GH that shall also include integrations and coordination directives as necessary, without encompassing their full contents.

The feasibility of developing the GH sectoral guideline in the form of an overarching document should aim to:

- Provide indications on how to manage risks of large-scale (or even nationwide) projects in the phases of concept, siting, or preliminary planning, with a high level and holistic approach, in an early phase when the preparation of the ESIA for components is not yet feasible
- Set provisions for project components not already addressed in existing EHS guidelines, mainly the electrolyser
- Coordinate provisions related to different project components already addressed in existing EHS guidelines.

9.2. Risk Identification and Opportunities for Development

This study focused on the following main action items to produce a EHSS management study on the development of a GH value chain in the LAC region:

- An analysis of the main risks, impacts, and mitigation measures of activities related to green hydrogen production, transportation, storage, and transformation of associated energy carriers, including ammonia and methanol. Risks were identified based on: (i) a desktop review of scientific papers and other relevant publications; (ii) regular consultations involving IDB green hydrogen experts, as well as during an internal workshop involving Anthesis' specialists; and (iii) a EHSS due diligence exercise that benchmarked against the new IDB ESPF.
- A comparative analysis and synthesis of main international best practices on EHSS matters for hydrogen management.
- An analysis of gaps and interoperability between the new IDB ESPF and other existing standards and guidelines of reference in addressing key risks and impacts.

The relevant topics identified within the framework of this study, with reference to the IDB ESPS are summarized below in tabular format **(Table 9.1)**. In addition to the ESPSs, the topics also reference the following UN global sustainability goals:

- SDG 6 clean water
- SDG 7 affordable and clean energy
- SDG 8 decent work and economic growth
- SDG 9 industry, innovation, and infrastructure
- SDG 12 responsible consumption and production
- SDG 13 climate action.

GH may ensure significant economic and social development for the region. More specific opportunities that the sectoral guidelines may favor include:

- Capacity-building of entities and agencies in charge of safety. Financing from project sponsors of national agencies aimed to control safety may be considered, as long as conflict of interest is managed properly.
- Capacity-building of entities and agencies in charge of water management. Construction of desalination plants may envision the use of produced water for different final uses (GH production, potable uses, etc.). This may fit well in the current trend in LAC to move toward water management by means of the *mixed enterprise* model, a joint venture between public and private sectors (102).

9.3. Main Risks

Based on the outcomes of the analysis conducted here, it is the authors' opinion that some of the identified risks are so unique to the GH value chain or linked to it in the public perception, that mismanagement of actual incidents related to these types of risks in just one project may create confusion or actual opposition to the technology in full. It is therefore crucial to reduce these risks even below the level that would be acceptable as assessed by comparisons of the risks and the cost to control them.

These risks, indicated as Primary Risks in Table 9.1, include:

- Land use and land use fragmentation, which implies potential impacts addressed in ESPS 4 and 6 (biodiversity conservation, ecosystem services, and livelihood resources), ESPS 5, 7, and 9 (land acquisition and related potential impacts on the rights of indigenous people and gender issues).
- Water and wastewater/brine management, which implies potential impacts addressed in ESPS 4 and 6 (biodiversity conservation, ecosystem services, and livelihood resources); and
- Process and community safety (mainly with reference to ESPS 4).

Table 9.2 summarizes the main results of the study in relation to these three specific challenges. The phase of risk identification and management and stakeholder engagement (with reference to ESPS 1 and 10) provides the framework of reference for management of these risks.

ESPS 1 – Assessment and Management of Environmental and Social Risks and Impacts

ESPS Topic	Risk	Recommended mitigations
Identification of Risks and Impacts	Proper siting and preliminary risk identification, accounting for cumulative impacts of large-size projects shall be ensured. Land use and land use fragmentation shall be analyzed in detail. **PRIMARY RISK**	A SESA process (or a regional or sectoral EIA) is recommended in the phase of project planning and project siting.
	In the phase of risk identification, the risk of plant abandonment shall be analyzed. Proper decommissioning, ensuring the dismantlement of large-size industrial facilities and effective waste management, shall be considered an integral part of the management of environmental issues.	Allocation of resources for decommissioning is recommended during the operation phase.
Emergency Preparedness and Response	In case of GH projects located in undeveloped rural areas, as well as those in small island states, availability of public resources for emergency management may be limited and facility operators can expect to receive limited support in case of major accidents.	External emergency plans shall be designed, taking into consideration the limited external resources for emergency management.
Environmental and Social Management Framework specific to the operation Process and plans for mitigation of impacts and risks Organizational capacity to mitigate and manage risks and impacts Processes for monitoring and reporting.	A GH project may imply the construction of large-scale facilities and renewables farms. Management of related EHSS issues requires the adoption of a robust environmental and social management system and strong organizational capacity.	Application of relevant guidelines and mandatory regulations, also taking into consideration the obligations set forth by the relevant international agreements on safety of the handling and transportation of hazardous substances. There are no specific additional or unique recommendations for GH projects.

See ESPS 10 for Stakeholder Engagement, External Communications, and Grievance Mechanisms, Ongoing Reporting to Project-affected People and Other Relevant Stakeholders

ESPS 2 – Labor and Working Conditions

ESPS Topic	Risk	Recommended mitigations
Working Conditions and Management of Worker Relationship Protecting the Workforce	Significant influx of workers. The likely presence of migrant workers implies the need for careful management of labor issues.	Application of relevant guidelines. There are no specific additional or unique recommendations for GH projects.
Occupational Health and Safety	GH technology requires handling dangerous substances and careful management of OHS aspects. Despite the risks, a safe workplace can be ensured by applying best practice methods for safety management adopted in the industrial sector, without specific modifications made to the overall approach.	Application of relevant guidelines. There are no specific additional or unique recommendations for GH projects.
Workers Engaged by Third Parties Primary Supply Workers	Potential adverse impacts on human rights linked to the sourcing of conflict minerals and other critical raw materials to produce GH technologies.	Demand forcritical materials/metals shall be analyzed and limited. A BAT gap analysis of project design shall ensure that the most suitable techniques are applied to limit the use of critical materials/ metals. Provisions of existing relevant guidelines shall be applied, ensuring the control of the supply chain. There are no specific additional or unique recommendations for GH projects.

ESPS 3 – Resource Efficiency and Pollution Prevention

ESPS Topic	Risk	Recommended mitigations
Resource Efficiency	Energy efficiency of the system. Some projects envision the use of hydrogen or its derivates (ammonia, methanol) as fuel. The overall efficiency of these processes is extremely low, even below 20%. From an efficiency perspective, the production of electric energy by renewables to produce GH and to burn it in a power plant to produce electric energy anew, means significant loss. It should be considered if and at which level the development of the GH value chain shall also support decarbonization of the economy of a project's host country, ensuring the achievement of a minimal set of results in the jurisdiction. Based on still uncertain data, hydrogen released into the atmosphere by leakages may increase the lifetime of methane, increasing climate effects and depletion of the ozone layer.	The overall energy efficiency of the GH project shall be analyzed. The project design shall be coupled with a BAT gap analysis ensuring that the facility implements state-of-the-art measures for optimization of energy efficiency. Hydrogen leakages to the atmosphere shall be controlled. Utilization of oxygen produced as by-product shall be favored, to optimize overall efficiency of projects. GH projects shall not limit availability of renewable resources for domestic uses.
	Freshwater demand for the electrolyser. **PRIMARY RISK**	The sustainability of the freshwater demand shall be assessed. The project design shall be coupled with a BAT gap analysis ensuring that the facility implements the state-of-the-art measures for optimization of water management.

ESPS 3 – Resource Efficiency and Pollution Prevention

ESPS Topic	Risk	Recommended mitigations
Pollution Prevention	Brine discharge from the electrolyser fed by seawater. **PRIMARY RISK**	Effects of the brine discharge on ecosystems and ecosystem services shall be assessed.
	Wastewater discharge from ammonia and methanol plants.	Effects of wastewater discharge on ecosystems and ecosystem services shall be assessed. Existing EHS guidelines on discharge limits need to be integrated with provisions specifically related to GH projects.
	Waste and sludge. The generation of sludge or wastewater from (fresh) water purification for electrolysis is not well-documented in the literature. Spent catalysts from ammonia and methanol are among the most typical hazardous waste of these productions.	Availability of resources to manage waste and hazardous waste shall be assessed for each project. Existing EHS guidelines need to be integrated with provisions specifically related to GH projects.

ESPS 4 – Community Health, Safety, and Security

ESPS Topic	Risk	Recommended mitigations
Physical Safety of Infrastructure and Equipment	Process safety and land use control. **PRIMARY RISK**	Safety shall be considered in the plant siting phase, and buffer zones shall be established between projects and urban/commercial areas. Companies shall establish safety management systems and apply state- of-the-art methods for safety assessment.
	Transportation safety.	In case the application of guidelines also includes hydrogen transportation and gas distribution systems, the following aspects shall be addressed in the guideline: Implementation of strict procedures for design, testing, maintenance, and periodic verification of vehicles and infrastructure, and training of drivers and operators. These procedures shall be integrated with the national regulation, where necessary.
Ecosystem Services and Exposure to Diseases	With reference to Type 1 and 2 ecosystem services, the diminution or degradation of natural resources, with specific reference to sources of freshwater or fishing stocks, may result in health-related risks and impacts. Land use changes entailed by large- scale GH projects and related large-scale renewables farms may imply the loss of natural buffer areas that mitigate effects of natural hazards. Land use and land use fragmentation may also impact cultural ecosystem services. Impacts related to land use changes and potential degradation of resources are analyzed transversally in Section 8 transversally, with reference made to ESPS1, 3, 4, 5, 6, 7, and 8.	Application of relevant guidelines. Proper identification of risk (and design of mitigation measures, when necessary), in the siting (see comments to ESPS1).

Disaster and Climate Change Risk-related Aspects	GH projects may be negatively impacted by effects of climate change at local and regional levels, among others, because of climate change-induced water scarcity, sea level rise, and extreme events increasing in magnitude and frequency. GH projects are vulnerable to water stress and sea level rise. GH projects, if improperly designed and managed, may also play a role in exacerbating effects of such events, as a consequence of required water additionality, land use fragmentation, and potential deforestation and soil erosion in the case of the development of large renewables farms. GH export cannot impede achievement of decarbonization targets of the project's host country.	The risk to which facilities are exposed and the risk generated by projects themselves shall be properly identified and analyzed in the plant siting phase and again in the project design phase (see comments to the ESPS1) . Projects' contributions to achievement of national decarbonization targets shall be encouraged.
Use of Security Personnel	No specific issues, aside from the need to ensure proper security in facilities where hazardous substances are utilized.	Application of relevant guidelines. There are no specific additional or unique recommendations for GH projects.

ESPS 5 – Land Acquisition and Involuntary Resettlement

ESPS Topic	Risk	Recommended mitigations
General / Displacement Coordination among Government Agencies	Acquisition/occupation of large areas for large-scale projects and fragmentation of pristine territories. **PRIMARY RISK**	Potential impacts originated by land use and land use fragmentation on ecosystems and communities shall be assessed.

ESPS 6 – Biodiversity Conservation and Sustainable Management of Living Natural Resources

ESPS Topic	Risk	Recommended mitigations
Protection and Conservation of Biodiversity Management of Ecosystem Services	Land use and land fragmentation. Brine discharge in coastal areas. GH projects have different components (namely, solar/wind farm(s), transmission lines, hydrogen production plants, conversion facilities for ammonia/methanol production, shipping/transportation facilities, etc.), that may cumulatively have significant impact in terms of land use fragmentation, especially in a region (LAC) characterized by vast areas with uniform land use, ecosystems, and landscape.	Proper identification of risk (and design of mitigation measures, when necessary), in the siting phase (see comments to ESPS1). Land use, land use fragmentation, water demand and brine discharge shall be assessed also in terms of potential impacts to the livelihood resources of local communities.
Primary Suppliers	Potential adverse impacts on human ecosystems linked to the sourcing of conflict minerals and other critical raw materials.	The demand of critical materials/metals shall be analyzed. Demand for critical materials/metals shall be analyzed and limited. A BAT gap analysis of the project design shall ensure that the most suitable techniques are applied to limit use of critical materials/metals.

ESPS 7 – Indigenous Peoples

ESPS Topic	Risk	Recommended mitigations
General. Indigenous Rights and Avoidance of Adverse Impacts	Potential impacts generated by large-size projects in rural areas and land fragmentation. Land use, land use fragmentation, and water demand may impact indigenous people. The significance of the impacts mostly depends on the plant siting.	Land use, land use fragmentation, water demand, and brine discharge shall be assessed in terms of potential impacts to indigenous people.

ESPS 8 – Cultural Heritage

ESPS Topic	Risk	Recommended mitigations
Protection of Cultural Heritage in Project Design and Execution	No unique aspect. The significance of the impacts mostly depends on the plant siting.	Application of relevant guidelines. Proper identification of risk (and design of mitigation measures, when necessary), in the siting phase (see comments to ESPS1). There are no specific additional or unique recommendations for GH projects.
Project's Use of Cultural Heritage	No unique aspect.	Application of relevant guidelines. There are no specific additional or unique recommendations for GH projects.

ESPS 9 – Gender Equality

ESPS Topic	Risk	Recommended mitigations
Identification and Assessment of Sexual and Gender-Based Risks and Impacts Avoidance, Mitigation and/or Remediation of Impacts and Risks Managing Disproportionate Impacts in Situations of Involuntary Physical Resettlement or Economic Displacement Assessing and Managing Project-related Sexual and Gender-based Violence	Women, and more generally, any person, may be discriminated against or subject to abuse in the workplace, due to sexual identity and orientation.	Application of relevant guidelines. There are no specific additional or unique recommendations for GH projects.
	The issue of land fragmentation and land take may disproportionately affect the female population. If projects will induce additional water stress, women will likely bear a disproportionate cost. Overall impacts on indigenous people induced by water stress may specifically affect indigenous women.	Land use, land use fragmentation, water demand, and brine discharge shall be assessed also in terms of potential impacts to gender equality (see comments to ESPS1).
	A large influx of external male workers may lead to an increase of gender-based violence.	Application of relevant guidelines. There are no specific additional or unique recommendations for GH projects.
Equitable Participation of People of all Genders in Consultations	Underrepresentation of female voices in stakeholder engagement activities and female students in capacity-building programs.	Application of relevant guidelines. There are no specific additional or unique recommendations for GH projects

ESPS 10 – Stakeholder Engagement and Information Disclosure

ESPS Topic	Risk	Recommended mitigations
Engagement During Project Preparation Engagement During Project Implementation and External Reporting Grievance Mechanism Organizational Capacity and Commitment	Stakeholder engagement shall address numerous issues, including the most typical of the GH value chain: Land use and land use fragmentation Water use and brine discharge Process safety and transportation safety Risk associated with the use of hydrogen by end users.	Large-scale projects (or even nationwide projects) may require specific tools for engagement, starting in the early phase of project development. Delivering an awareness campaign and stakeholder engagement on hydrogen safety among end users, operators, authorities, and any further relevant stakeholder.

Table 9-1 List of identified risks
(Source: Authors' own summary)

Main Risks	Mitigations	International References	References to the IDB ESPS	Recommendations
Land use and land use fragmentation The fast pace at which the development of a GH value chain across the LAC region is projected may represent an additional pressure factor making it difficult for land planners to properly address issues linked to the development of large renewable farms and incorporate them within zoning and land planning and management systems at a national, regional, and/or local level.	**Risk management** For proper management of complex projects like those typical of GH production, an institutional and technical approach like the one applied in the Strategic Environmental and Social Impact Assessment (SESA) or the Regional/ Sectoral EIA may be necessary.	**International standards** • The UNECE SEA Protocol • The OECD Good Practice Guidance for Development Cooperation • The World Bank institution-centered SEA **Regulations** • EU SEA Directive 2001/42/EC • SPREP Guidelines for SEA in Pacific Islands and Territories (specifically for small Caribbean Island nations)	IDB Environmental and Social Policy Framework (ESPF) covers potential impacts of land acquisition (in ESPS 5), and secondary impacts on biodiversity (in ESPS 6), and related community safety considerations (in ESPS 4). ESPS 1 sets provisions for overall risk identification and management and establishes the requirement, when necessary, for an ESIA, a Strategic Environmental and Social Assessment (SESA), a Regional Environmental and Social Impact Assessment, and Disaster Risk Assessment. IDB guidelines on ESPS applications state again that where the project is likely to have sectoral or regional impacts, a sectoral or regional ESIA may be required.	Siting shall be analyzed through tools similar to SESA or Regional Sectoral ESIA rather than project ESIA, addressing: • Land use and land use fragmentation and related secondary impacts on biodiversity, indigenous people, vulnerable groups, and gender equality • The need for buffer zones between facilities and urban developments The preparation of a preliminary development plan prior to the project design shall be encouraged. Large-scale projects (or even nationwide projects) may require specific tools for stakeholder engagement, starting in the early phase of project development.
Water demand and Wastewater/ brine discharge **Water demand:** • The water additionality of GH projects is relevant in areas affected (currently or in the future) by water scarcity. • The typical water demand ranges between 18 kg and 24 kg of water per kilo of hydrogen. **On brine discharges:** • Brine discharge may cause (i) an increase in salinity and density, which may lead to higher water stratification due to concentrated brine; (ii) eutrophication due to phosphates' enrichment if polyphosphates are used and if organic cleaning solutions are added to the brine; (iii) discoloration due to high ferric concentration, also with high-suspended solids and turbidity, while discharging untreated	**Water management at country/ watershed scale** It is suggested to define a strategy for the preparation of SESA or regional EIA related to national GH strategies or single large-scale developments. The sustainability of the water demand can be assessed through tools applicable in all countries of the region. **Water management at local level** Specific attention shall focus on the shared use of the resource, at present and in the future, considering modifications in demography and climate. **Alternatives to freshwater** The alterative use of seawater shall always be considered and, generally, the use of seawater (that can be considered a non-limited resource) shall be preferred, also taking into account the limited economic impacts of desalination. Impacts of t brine	**Water management International Standards** • The 4th edition of the WHO Guidelines for Drinking-water Quality (2017) • Relevant provisions in the WBG General EHS Guidelines **Regulations** • EU BAT Reference Document ("BREF") on Common Wastewater Treatment Systems • IFC EHS guidelines on inorganic compounds **Brine discharge. Regulations** • USA: (i) Water Quality Control Plan for the Ocean Waters of • **Brine discharge. Regulations** • **USA:** (i) Water Quality Control Plan for the Ocean Waters of California; (ii) Clean Water Act; (iii) National Pollutant Discharge Elimination System	IDB ESPF addresses issues linked to water quality and pollution prevention and control within ESPS 3. ESPS 6 also offers provisions about risks and impacts on biodiversity and the delivery of ecosystem services to local communities, also in conjunction with ESPS4. IDB's publications *The Regulation of Public Utilities of the Future in Latin America and the Caribbean and Good Practice in Environment, Health, and Safety in Latin America and the Caribbean* provide both baseline considerations and recommendations for water management.	Water, brine, and wastewater management shall be analyzed, addressing: • Secondary impacts on biodiversity, ecosystem services, livelihood resources, and gender equality. • The project design shall be coupled with a BAT gap analysis, ensuring that the facility implements state-of-the-art measures for optimization of water management. • Potential impacts of desalination and brine discharge management can be minimized by treatment and recycling technologies, by limiting concentration values of brine at the discharge point, as well as by imposing concentration values within a prescribed mixing zone in the coastal waters via the outfall design.

Main Risks	Mitigations	International References	References to the IDB ESPS	Recommendations
backwash water; (iv) impact on the composition and distribution of biota.	discharges shall be analyzed.	Permit Program; (iv) National Environmental Policy Act. • **Saudi Arabia:** (i) Public Environmental Law (Royal Decree No. M/34 2001), (ii) Guidelines for concentrations in discharge and at the edge of the mixing zone, (iii) General Environmental Regulations and Rules for implementation – Appendix 2.1. • **Spain:** (i) Royal Decree 1302/1986 and successive modifications. In particular, Group 8 – Hydraulic engineering and water management projects; (ii) Law 21/2013. • **Chile:** Environmental norms established in Supreme Decree No. 90/00 • **Mexico:** Proy-NOM-013-CONAGUA/SEMARNAT-2015		
Process and community safety Safety is a major concern in facilities where hydrogen, ammonia, or methanol are produced or stored. Accidental toxic release may affect areas well beyond the plant area and endanger the life of communities. In LAC, governments are developing new framework regulations related to safety, apparently in absence of an overarching framework document shared among different countries aimed to align approaches. Most countries are not signatories of the ILO convention and recommendation on the prevention of major incidents. Risk associated with the use of hydrogen by end users.	**Siting** Safety shall be considered in the plant siting phase and buffer zones shall be established between the projects and urban/commercial areas. Companies shall establish safety management systems and apply state-of-the-art methods for safety assessment. **Safety Management System** A safety management system should be developed based on ILO standards and technically designed on the basis of the US EPA RMP or European Seveso Directive considered as a reference and GIIP. It shall include an external emergency plan for measures to be taken outside the establishment. Feasibility and impacts of land use limitations shall be assessed in the SEA/SESA phase.	**International standards** • **IAEA,** Manual for the classification and prioritization of risks due to major accidents in process and related industries (1996) • **IAEA,** Hydrogen as an energy carrier and its production by nuclear power (1999) • **European Industrial Gases Association's** report Determination of Safety Distances (2007) • **ILO** Conventions on the prevention of major incidents **Regulations** • **EU** Seveso Directive • **UK** HSE's land use planning methodology • **US EPA** Doc. 75/21 Rev 1, Methodology for Determination of Safety and Separation Distances (2021)	IDB ESPF includes specific provisions related to safe working conditions for personnel in ESPS 2 and on community health, safety, and security within ESPS 4. The guideline *Disaster and Climate Change Risk Assessment Methodology for IDB Projects* provides recommendations for QRA for natural disasters, including a definition of tolerable risk.	**Siting** • The following aspects shall be assessed in the siting phase: • Suitability of alternative sites with the support of screening methods for the definition of the extension of buffer zones. • Regarding external emergency plans, it shall consider that the facility operator may be required to operate in isolation during the emergency. **On QRA:** • The use of a detailed and shared guideline for QRA preparation may help define a consistent technical approach to safety in different projects located in different countries. A sectoral GH guideline may reference some detailed provisions related to • Algorithms to be used for QRA preparation

Main Risks	Mitigations	International References	References to the IDB ESPS	Recommendations
	Quantitative Risk Assessment (QRA) Once the design of the project is more advanced, a detailed QRA shall be prepared. **Hydrogen transportation** Implementation of strict procedures for design, testing, maintenance, and periodic verification of vehicles and infrastructure and training of drivers and operators, to integrate the national regulation, where necessary. **End users** Delivering an awareness campaign and stakeholder engagement on hydrogen safety among end users, operators, authorities, and any further relevant stakeholder.	• **US Environmental Protection Agency,** Risk Management Program Guidance for Offsite Consequence Analysis (2009) **LAC Regulations** • **ITS São Paulo,** Occupational Health and Safety Guidelines (2020)		• Release scenarios of reference for risk assessment • Shared criteria of risk acceptability • Provisions for QRA shall be aligned with existing provisions included in the Disaster and Climate Change Risk Assessment Methodology for IDB Projects • Within the QRA, especially for methanol plants, it may be appropriate to assess the "environmental" risk and identified concentrations of concern in the air, water, or soil.

Table 9-2 Summary of results on three main risks identified during the study (Source: Authors' own summary)

10
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