Facilitating a sustainable future

LAND USE IN THE CONTEXT OF POWER-TO-X

- Avoid (the apprehension) of land grabbing and land-use conflicts when planning a green hydrogen and PtX project
- Where there is competition for land, coexisting and synergetic uses must be sought
- Develop legal frameworks including permitting procedures as well as monitoring and enforcement mechanisms to minimise direct and indirect land use effects

International PtX Hub

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

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Developments and chances

The rapid development and scalability of green hydrogen and Power-to-X (PtX) technologies opens up opportunities for projects and value chains in countries rich in renewable energies. Some of these green hydrogen and PtX projects are likely to be located in countries where the legal framework for land use rights is less well developed. A clear legal framework for land use rights would facilitate the evaluation, assessment, development, implementation and financing of large-scale green hydrogen and PtX projects. To realise the full potential of green hydrogen and PtX, it is essential for all stakeholders to carefully examine the issues of land acquisition and land use. This is not only necessary from a legal perspective, appropriate and considerate land acquisition and use also contributes to the social licence to operate.

Land use along the green hydrogen and PtX value chain

Land is mostly needed as the starting point in the green hydrogen and PtX value chain: the generation of renewable energy. Generally, the higher the output in terms of green hydrogen or PtX products, the more land will be needed for realisation given that electrolysers and related technologies must be operated with green electricity. This electricity needs to be provided in addition to existing renewable capacities.

Though depending heavily on the exact location, Heinemann & Mendelevitch (2021) came up with a rough quantification of average required land for photovoltaic (PV) and wind farms:

- Onshore wind farms: 48 m^2/kW
- Ground-mounted PV: 20 m^2/kW

However, the area utilisation of onshore wind farms can be measured in different ways, for example depending on the possible use of the areas between the turbines. Project site areas of onshore wind can range from 8.4 m^2 to a max of 247 m^2 per MWh (Ritchie, 2022), depending on the number of wind turbines.

Next in the value chain, the electrolysis plant, depending on the exact technology used, would need about 0.048 to 0.095 m^2/kW (Heinemann & Mendelevitch, 2021). If the end product are synthetic hydrocarbons, carbon will be needed as input. Carbon sources could be organic residues or Direct Air Capture (DAC). The DAC plant alone would require 0.4 to 0.5 km^2 for the capture of 1 million tonnes of CO_2 and an additional 7.0 to 65.6 km^2 for the renewable energy source (7.0 km^2 for geothermal, 34.2 km^2 for solar PV, 65.6 km^2 for wind) (Lebling et al., 2022).

Table 1: Land use per various renewable energy and PtX plants

Land needed for	Size of required land
Onshore wind	48 m^2/kW
	8.4 m^2 to a max of 247 m^2 per MWh
Ground mounted PV	20 m^2/kW
Electrolysis plant	0.048 to 0.095 m^2/kW
DAC plant	0.4 to 0.5 km^2 for the capture of 1 million tonnes of CO_2 plus 7.0 to 65.6 km^2 for the renewable energy source (7.0 km^2 for geothermal, 34.2 km^2 for solar PV, 65.6 km^2 for wind)

Source: Based on Heinemann & Mendelevitch (2021), Lebling et al. (2022) and Ritchie (2022)

The figures above show a huge range of size of required land, as it mostly depends on the location and on the number of wind turbines or PV panels used. Nevertheless, the numbers confirm that a large area of land is needed for renewable energy production as input for green hydrogen and PtX projects. However, it must be mentioned that the stated land requirement is far lower than it would be for biofuels. Additional land is needed for PtX plants (Fischer-Tropsch, Haber-Bosch, methanisation) and infrastructure such as roads, pipelines and, if not already in place, ports or desalination plants. However, these figures are rather small compared to the land for renewable energy.

Adding up all these requirements on land, one quickly reaches very large dimensions for green hydrogen and PtX projects. One of the largest green hydrogen projects, the Western Green Energy Hub in Australia, will be implemented on 15,000 km^2 with 25 million solar panels, 3,000 wind turbines and 3.5 million tonnes per year of green hydrogen or 20 million tonnes of green ammonia (Western Green Energy Hub, n.d.). The ‘Project Nour’ in Mauritania will be spread over an onshore and offshore area of 14,000 km^2 and will produce renewable electricity from solar and wind with an expected capacity of 10 GW for electrolysis to produce green hydrogen (Green Hydrogen Organisation, n.d.). For comparison – this would be about half the size of Belgium.

Land use competition

There are several possible competing land uses: Next to agriculture, livestock farming, or forestry, also conservation areas (including rare and endemic species), tourism development areas (including natural landscapes and historical artefacts) and mining concessions can be named.

In general, most planned large-scale green hydrogen and PtX projects are likely to involve competition for space, as there are hardly any large areas that are of no value to anyone. Even if the selected land appears to be desolate, it will have some value for biodiversity or cultural use. Early stakeholder involvement is necessary to decide on the priorities for the land.

Identification of suitable land for green hydrogen and PtX

The identification of suitable land for green hydrogen and PtX areas can be broken down into the following steps (Pfennig et al., 2023):

1) High potential for renewable energy
Important criteria for the production of green hydrogen and PtX are the favourable conditions for the generation of renewable electricity. This relates primarily to wind energy (onshore and offshore) and PVs.

2) General criteria
This refers to the current land use: Proximity to built-up areas, population densities, taking over land that has been used for livestock farming, agriculture or forest. Special protected areas can also be part of the exclusion criteria.

3) Economic criteria
The economic criteria relate to the costs of purchasing or leasing the corresponding area.

4) Green hydrogen and PtX specific criteria
Water availability for the electrolysis is a decisive but often a challenging factor. Specific criteria for PtX include the availability of a carbon source. Distance criteria can also be applied: What is the distance to harbours, pipelines, cities, the national coastline, inland waterways, etc.

The process of selection therefore starts with broader areas that can be further narrowed down by using for example these criteria (Figure 1).

Selection process for identification of suitable land for green hydrogen and PtX

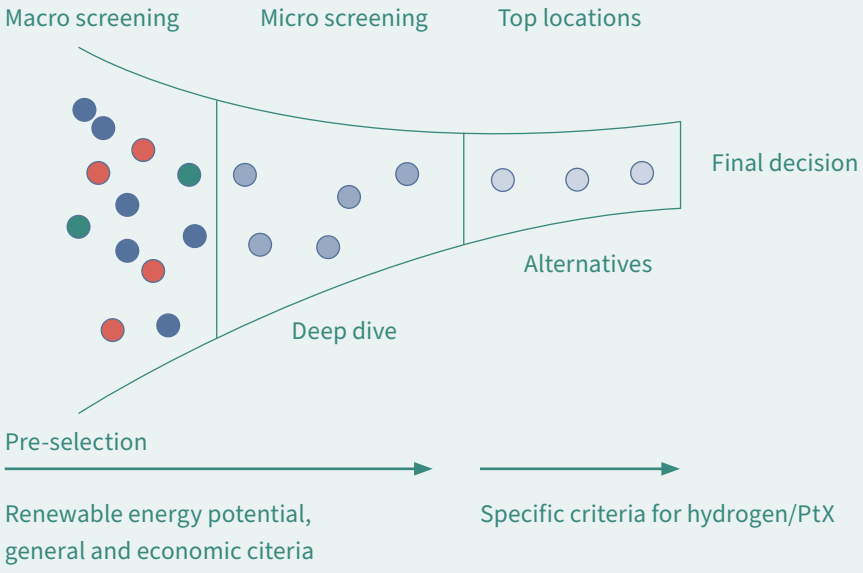

Figure 1: Based on Ramboll (2022)

However, these criteria are not always so easy to apply and are intertwined. When looking at areas with renewable energy potentials, for example for PV, these areas will be sunny locations. Sunny locations are often in arid regions, probably leading to a water challenge. When focusing on wind, windy areas are often at high altitude or at coasts. High altitude may also cause a challenge for water availability. Coastal regions are often of high environmental sensitivity or densely populated. If the land is undeveloped and unutilised, it does not mean that is has no value. It may be used for cultural purposes, or the land is home to a high level of biodiversity. Water availability as specific criteria for green hydrogen and PtX is critical for choosing the most suitable land, as there might be conflicting uses, for example with agricultural land (Government of Western Australia, 2022). In the case of hydrogen and PtX in particular, the interplay of these factors along the value chain is of great importance, from renewable energy to potential locations for local use or export (via pipelines or ship).

A starting point for identifying the most suitable location for green hydrogen and PtX is the Global PtX Atlas, developed by Fraunhofer IEE. This atlas shows comprehensive country analyses for selected economic areas worldwide and provides a differentiated view of potential production volumes and generation costs of various PtX fuels. The results are based on analyses that include high-resolution spatial data, long-term weather data, time-series-based and cost-optimised systems and the expansion planning of PtX technologies. An exemplary application for the African continent is shown in Figure 2.

The Global PtX Atlas shows a medium socio-economic potential for Namibia, but no PtX potential. However, Germany, the EU, Japan, and other countries have concluded agreements with Namibia to develop a PtX economy. This underlines that a global top-down analysis is helpful for an initial screening, but additional criteria, as described in the EESG framework (International PtX Hub, 2022), and in particular a bottom-up perspective should be taken into account when concretely identifying suitable sites and regions.

Power-to-X potentials for Africa as shown by the Global PtX Atlas

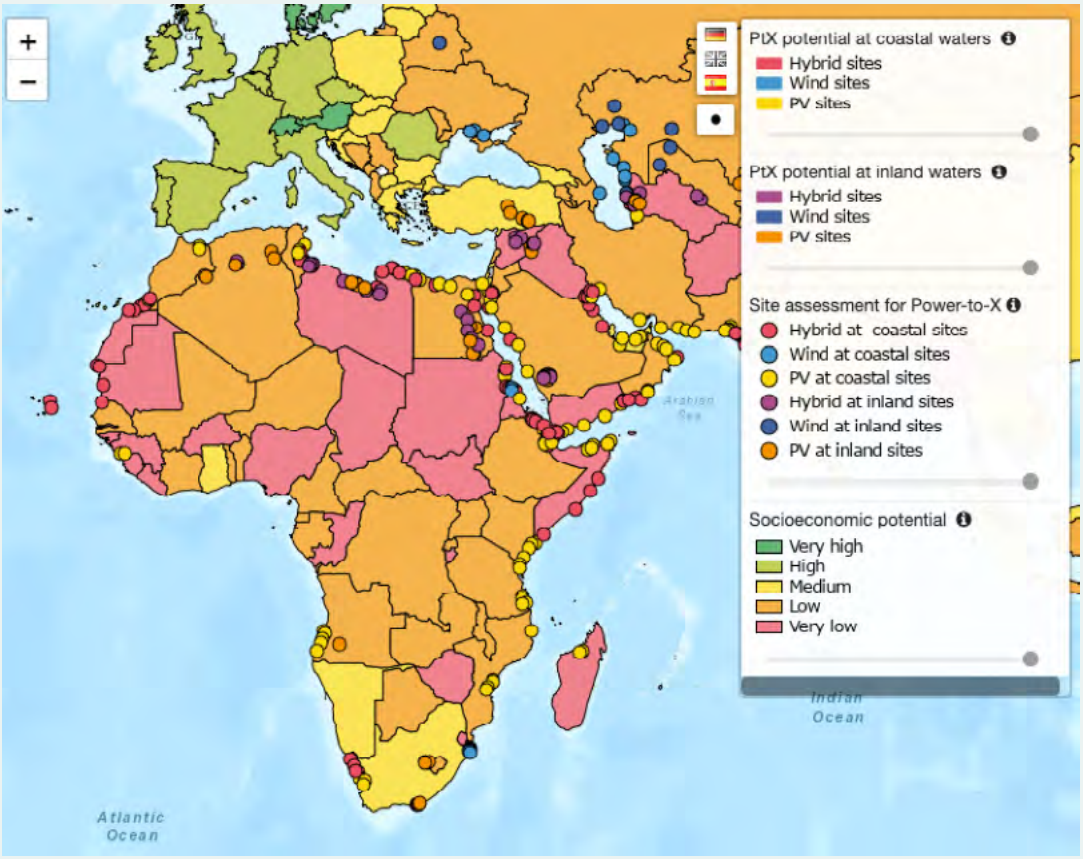

Figure 2: Global PtX Atlas by Frauenhofer IEE (https://maps.iee.fraunhofer.de/ptx-atlas/)

Realising opportunities

Several concerns regarding land use require sensitive action adapted to the local situation. Competition for land must be avoided and forced resettlement or illegal land grabbing must be ruled out. Plants for the generation of green electricity for green hydrogen must be environmentally compatible, which is why minimum requirements for the preservation of biodiversity are necessary in order to avoid ecological damage. Where there is competition for land, coexisting and synergetic uses must be sought. Traditional land, pasture and water use rights of local and indigenous communities must be recognised and respected. Table 2 shows an overview of concerns and options for reaction.

Table 2: Overview of concerns and options

As a result of land use change, sustainability concerns arise		Options to allay the sustainability concerns of land use change
• Displacement of the (indigenous) population	⇒	• Respect human rights • Strict agreement on displacements as a no-go
• 'Land grabbing' – especially for projects in countries with insufficient land tenure regulations	⇒	• Involving local stakeholders right from the start • Application of sustainability criteria • Clear land tenure regulation, legal basis
• Land conflicts with other uses (agriculture, livestock, tourism, mining, etc.)	⇒	• Identification of renewable energy zones by the country • Dual use of land and creation of win-wins
• Effect on local and regional natural resources (prime soil, surface water, groundwater, habitat, etc.), environmental degradation	⇒	• Environmental impact assessments • Follow international environment standards • Application of (further) sustainability criteria
• Change in community character	⇒	• Involving local stakeholders right from the start • Agreement on benefits for local communities

Displacement of the population

Displacements and forced resettlements of the local (indigenous) population is one of the major concerns against huge infrastructure and energy projects. Proper land-use planning can avoid this in any case. Human rights need to be respected during the development and implementation of the green hydrogen and PtX project.

Land grabbing

Land grabbing or the impression of land grabbing can arise, especially, when projects are implemented in countries with insufficient land tenure regulation. To avoid this, projects can involve local stakeholders right from the start and apply respective sustainability criteria (e.g., access to jobs, co-benefits and financial participation). Existing regulations and laws must also be complied with. Countries where green hydrogen and PtX projects are to be implemented can prevent land grabbing by setting up clear land tenure regulation and provide a solid legal basis. Moreover, project developers can follow own standards, that in the best case go beyond local standards.

Land conflicts with other uses

By developing a national green hydrogen and PtX strategy, a comprehensive zoning for defining priority areas for large-scale renewable energy development for green hydrogen production should be considered (Villagrasa, 2022). This needs to involve a mapping of traditional land use, indigenous cultural heritage, and high-value biodiversity ecosystems.

A dual use of land on which wind and PV energy is generated can be considered. This could be an agrivoltaic system, for example, in which agriculture is practised under the PV panels. It is also possible to keep animals under high-mounted solar panels, which provide shade, especially in hot regions. Livestock farming, however, can be much more easily combined with wind parks, given the available space between the turbines (Waters-Bayer & Tadicha Wario, 2022). Such systems even allow for win-win situations, in which farmers may create additional income by leasing their land to investors or shading facilitates plant growth.

Effect on natural resources

Even if the identified land on which the green hydrogen or PtX project should be implemented, seems to be desert-like, there might be negative impacts on the environment. These impacts can include impacts on water resources, land and ecosystem degradation, soil degradation, or even contamination by chemicals used during the projects' processes. Also, marine areas (e.g., when offshore wind is used as renewable energy source) should be taken into account. There might be additional pollutants, for example from the desalination of seawater or ports (von Oertzen, 2021). Environmental permitting, monitoring of running projects as well as enforcement (e.g., penalties) belong to the tools that help to minimise the effects on natural resources. The projects themselves can draw up plans for compensatory measures or re-naturalisation if negative environmental impacts are expected.

Change in community character

A direct consequence of the land use change may be a change in the character of the local community. Huge green hydrogen and PtX projects require a large workforce, especially during the construction period. Depending on the size of the local community, the additional workforce can lead to a doubling or more of the local population. The integration of these temporary workers is a huge task and support by the project would be necessary. Next to the additional workforce, new and additional infrastructure will be necessary, which will also impact the community character. To avoid negative impacts on the community and on the project, it would be necessary to involve local stakeholders right from the start and to obtain an agreement on benefits for the local community. Sustainable urban development measures are needed that combine physical urban expansion with the promotion of education, economic development, social integration and environmental protection.

Ways forward

To ensure a sustainable land use during the whole value chain, a number of concerns must be taken into account. As shown above, there are several options how to address these. Project developers and host countries should use internationally recognised standards should be applied, especially when they are mandatory. Checklists and guidelines are available for some of them to facilitate the application. In the following, a selection of standards and guidelines relevant for green hydrogen and PtX projects are listed:

Biodiversity:

- The Convention on Biological Diversity (CBD) is the international legal instrument for the 'conversation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources' (Convention on Biological Diversity, n.d.)
- UN Sustainable Development Goals (SDGs) Goal No 15: 'Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss' (United Nations, n.d.)

Human Rights:

- IFC Performance Standard 5 (PS5): Land Acquisition and Involuntary Resettlement. PS5 advises companies to avoid involuntary resettlement wherever possible and to minimise its impact on those displaced through mitigation measures such as fair compensation and improvements to and living conditions (International Finance Corporation, 2012b).
- United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), Article 10: 'Indigenous peoples shall not be forcibly removed from their lands or territories. No relocation shall take place without the free, prior and informed consent of the indigenous peoples concerned and after agreement on just and fair compensation and, where possible, with the option of return.' (United Nations, 2007)
- ILO Convention No. 169, Article 16: '… the peoples concerned shall not be removed from the lands which they occupy.' (International Labour Organisation, 1989)

Guidelines and checklists:

- Green Hydrogen Contracting Guidance: Land Acquisition and Use (Green Hydrogen Organisation, 2022)
- IFC PS5 Guidance Note (International Finance Corporation, 2012a)
- Respecting the rights of indigenous peoples: a due diligence checklist for companies (The Danish Institute for Human Rights, 2019)
- Respecting Land and Forest Rights. A Guide for Companies (Interlaken Group, 2019)

Good practices:

- IFC Good Practice Handbook: Land acquisition and involuntary resettlement (International Finance Corporation, 2023)

Other initiatives:

- Green Hydrogen Standard, e.g. requirement 4B based on IFC PS5: GH2 accreditation and certification requires that project operators avoid involuntary resettlement wherever possible and to minimise its impact on those displaced through mitigation measures such as fair compensation and improvements to and living conditions'

Before embarking on major green hydrogen or PtX projects, countries should prepare accordingly and not just rely on compliance with project criteria that may not even be binding. As implementing huge green hydrogen and PtX projects is still in its infancy, no best practices can yet be formulated. However, Australia can serve as an example for a promising approach. As the country wants to become a relevant green hydrogen producer, states like Western Australia or Queensland have come up with guidelines and toolkits for investors, dealing with land tenure. Western Australia for example claims that project proponents wanting to progress their projects will need to consider the following:

1) the existing land tenure over the site being proposed,
2) the underlying interest holders of the land,
3) the various stakeholders with an interest in the site, and
4) the legislative framework for gaining short- and long-term access to the site.

The Australian Government has produced a guidance document to provide certainty and clarity for renewable green hydrogen project proponents as they seek to gain access to land and legal tenure for their projects (Government of Western Australia, 2022).

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This document is part of a series of six briefings which are intended to provide an initial overview of the relevant topics. To this end, expert interviews were conducted and a three-part discussion series was held in October and November 2023 to capture the key points of discussion within the various topics. We would like to thank all interviewees and participants in the online discussion for their time and effort.

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices:
Bonn and Eschborn, Germany

International PtX Hub
Potsdamer Platz 10
10785 Berlin, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15

E info@ptx-hub.org
I www.ptx-hub.org

Responsible:
Jan-Hendrik Scheyl (International PtX Hub)

Researcher:
Maike Venjakob (Wuppertal Institute for Climate, Environment and Energy)

Layout:
peppermint werbung berlin gmbh, Berlin

The International PtX Hub is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Affairs and Climate Action (BMWK). Financed by the International Climate Initiative (Internationale Klimaschutzinitiative, IKI), the International PtX Hub is a contribution to the German National Hydrogen Strategy of 2020 and represents one of the four pillars of the BMUV's PtX action programme initiated in 2019.

Berlin, February 2024

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