Power-to-X Production in Colombia

Study of Fraunhofer ISE within the Framework of the
Colombian-German Dialogue on Re-industrialization via Renewable Hydrogen
Webinar 2: Technology & Finance

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Power-to-X Production in Colombia

Content

- Overview to the study
- Methodology applied
- Analysis of Renewables Potential and relevant Infrastructure in Colombia

Hydrogen Technologies at Fraunhofer Institute for Solar Energy Systems ISE

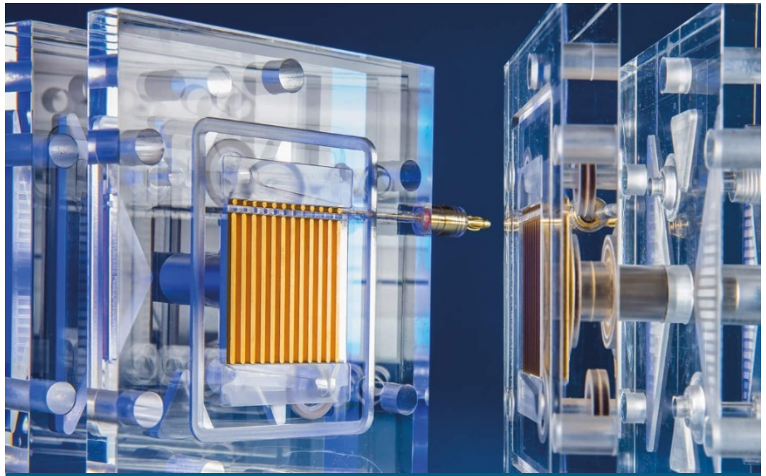
Defossilization of Transport, Chemicals and Process Heat

Fuel Cell Systems

Fuel cell cars at the solar hydrogen filling station; PEM fuel cell characterization, modelling, manufacturing, and development

Sustainable Synthesis Products

Development of catalysts and processes including life cycle assessment (LCA) and techno-economic assessment



Electrolysis and Power to Gas

Hydrogen production by water electrolysis; hydrogen injection; power to X simulations and techno-economic assessments

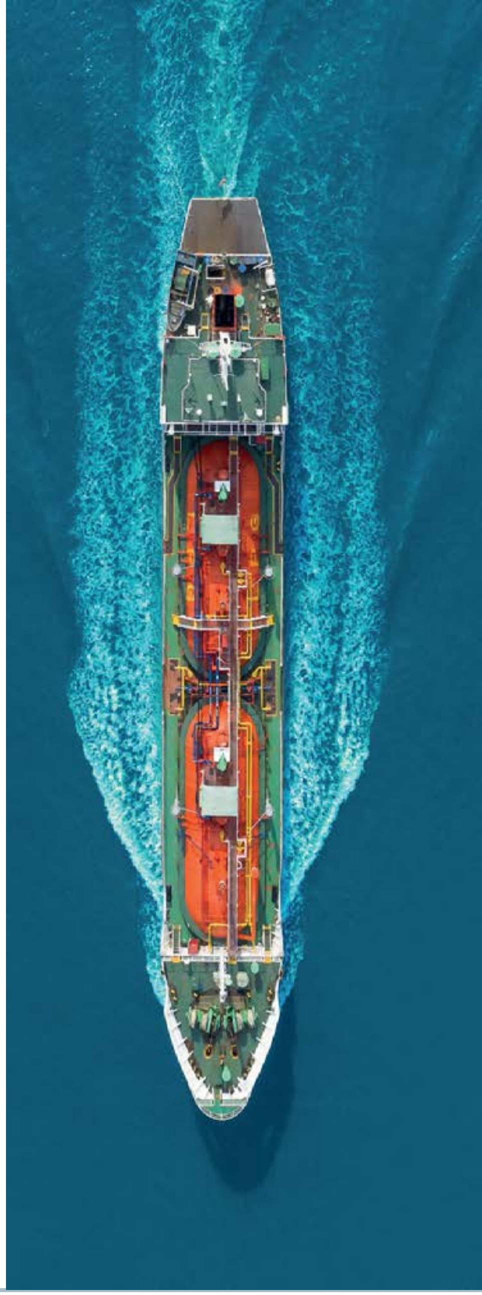
Power-to-X Study for the Colombian-German Dialogue

Project goal

A **techno-economic assessment** of production pathways **for green hydrogen, ammonia and methanol**, taking into account **the potential for renewable energies** as well as **local infrastructural conditions, synergies and the needs of local stakeholders**.

Key results

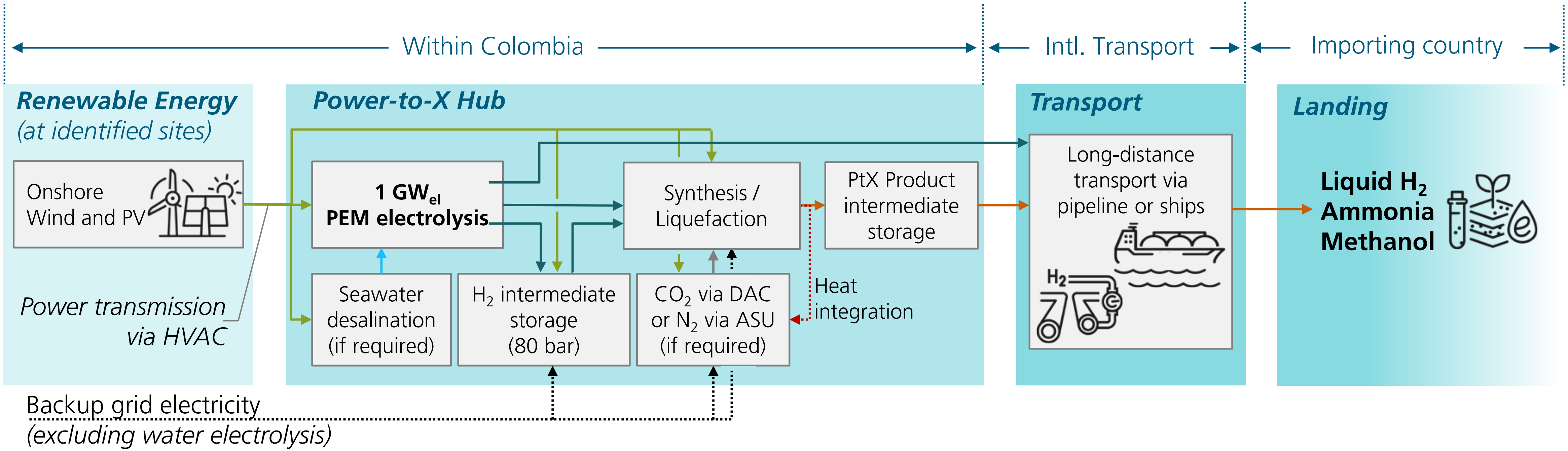
- Analysis of RE potential (onshore wind and PV) in Colombia and **identification of promising locations**.
- **Mapping of relevant infrastructure** for RE and Power-to-X (PtX).
- Identification of up to **three promising locations for implementation of large-scale PtX Hubs**.
- (I) Local generation and (II) supply **costs for PtX** incl. long distance transport; **necessary investments** (at pre-feasibility detail - Cost estimate "Class V")



Power-to-X Study for the Colombian-German Dialogue

Scope & System Layout

- Dynamic simulation, optimization and design of the overall PtX chain as a function of the renewable load profile (h resolved)
- Scale and timeline: 1 GW_{el} electrolysis for PtX production in 2030 & outlook for 2040
- Carbon supply via Direct Air Capture (DAC) and (where available) carbon point-source



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Methodology: GIS and Techno-Economic Optimization of PtX

Data Input

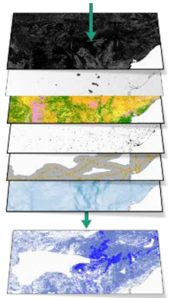
Location Parameters (capital costs, grid power costs)

Export destination

Location related boundaries (Desalination required, max. available land)

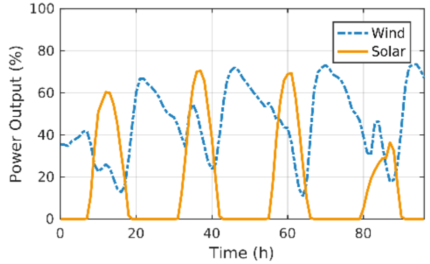
Internal Database for technical and economical parameters for system components (Efficiencies, Capex, Opex, etc.)

GIS analysis of countries to identify best suited regions taking land use, topology, population density, infrastructure, weather data into account



Preparing

Generation of **annual wind and solar** timeseries based on satellite data from the past 10 years (TMY) or user specific input timeseries



Automatic **Transport route analysis** based on real world shipping routes

System Optimization

Complete **PtX production and supply chains** (RE, electrolysis, H2-liquefaction/ synthesis, transport,…)

System optimization using **Genetic Algorithm (GA)** to solve complex problems

Dynamic, **non-linear modelling** of PtX production plants

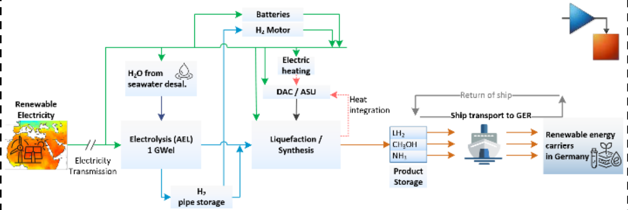
Considering of **operation management** taking component behaviors into account, e.g., limited part load operation of synthesis (continuously running process)

Strong simulation server for **parallel computing**

Optimization Algorithm
(mutation and crossover functions)

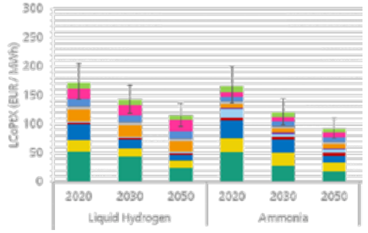
Handover of parameters

Results (EUR/kg)



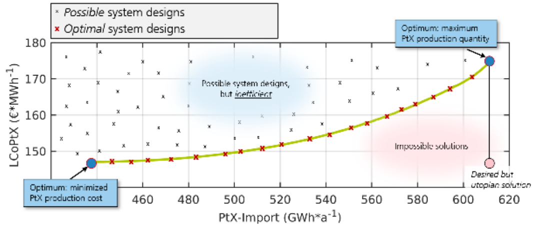
Result Output

Key performance indicators: levelized costs of product (EUR/MWh; EUR/kg), production quantity, total investment costs, overall system efficiency, full load hours, water consumption, energy flows, cost structure of product



Plant design in the cost optimum, e.g., optimized ratio of wind/ solar to electrolysis, intermediate hydrogen storage, etc.

Pareto front of multi objective optimization



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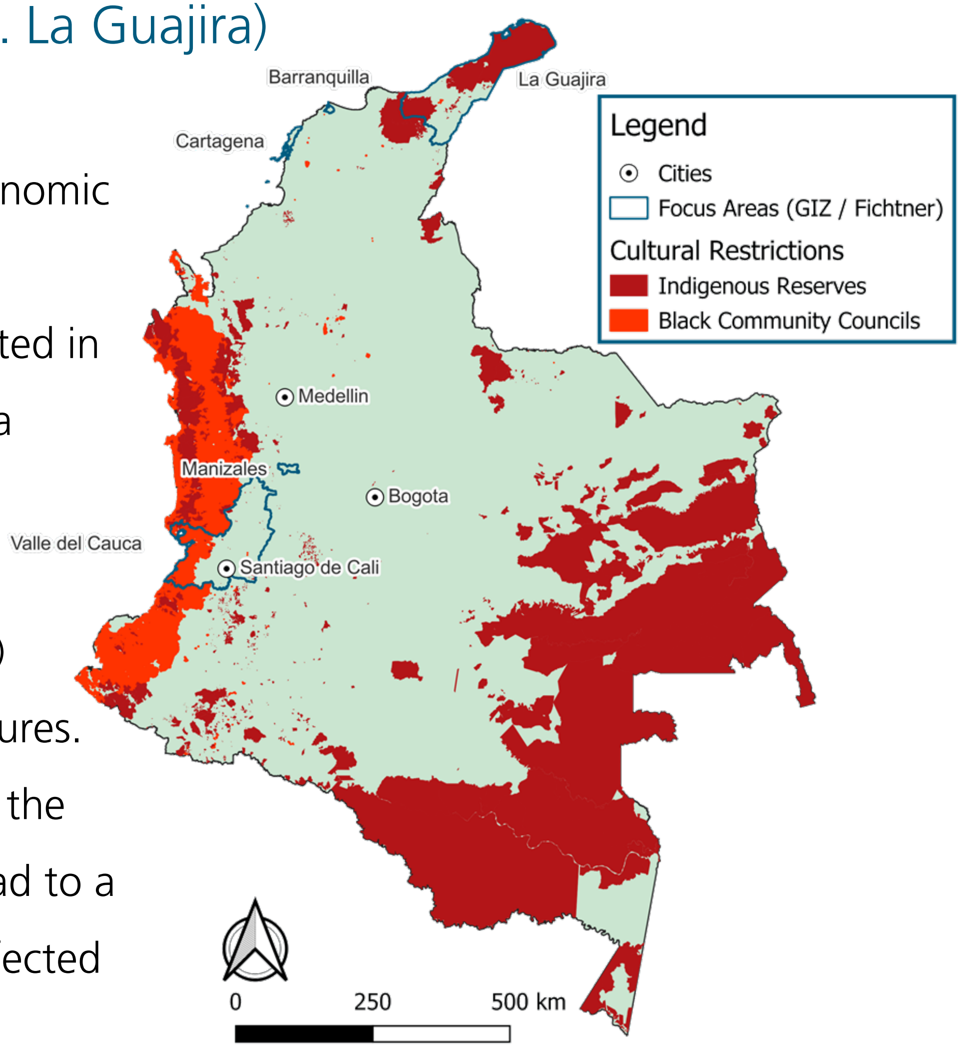
Power-to-X Study for the Colombian-German Dialogue

Handling of regions with ongoing public and cultural debates (e.g. La Guajira)

- The **study has a purely technical focus** - there is no analysis of the socio-economic implications of introducing large-scale hydrogen and RE technologies.
- **However**, a large number of potential and promising RE and PtX sites are located in **regions that are the focus of ongoing public and cultural debates** (e.g. La Guajira).
- **For this reason**, the Fh ISE study identifies promising PtX locations based on:
  - **(I)**: **Excluding specific regions** (i.e. La Guajira and others; marked in red) which are currently the subject of debate and lengthy RE planning procedures.
  - **(II)**: or taking into account the **nationwide potential** and assuming that the comprehensive involvement of local communities and stakeholders will lead to a thorough participation process and subsequently to the consent of the affected communities.



Analysis of RE potential

Methodology

- Identification of suitable production sites for onshore wind and ground-mounted photovoltaics
- Identification of suitable locations for hydrogen, ammonia and methanol production

1. Restriction areas

- Detailed compilation of restriction areas and setback distances
  - Settlements + infrastructures
  - Ecology and culture
  - Land use and other areas
- Compliance with legal framework and protection of cultural and natural heritage

2. Suitability criteria

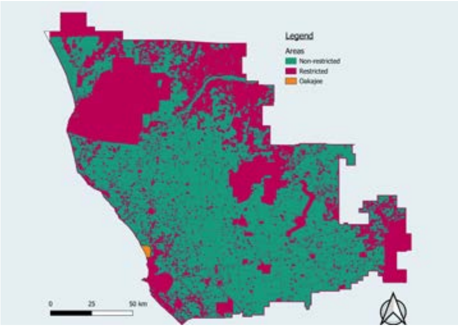
- Selection of suitability criteria reflecting solar and wind resources and other physical, technical and economic factors
- Weighting of the suitability criteria to evaluate site suitability

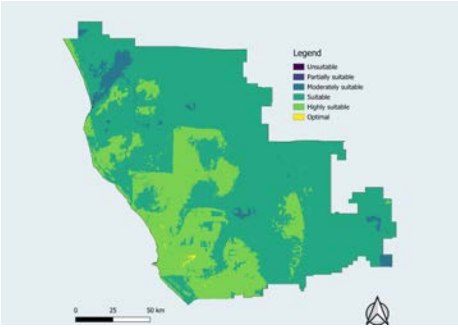
3. Overlay

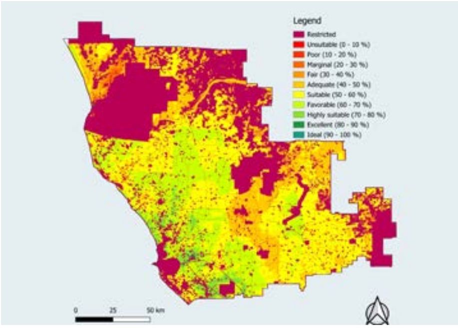
- Combination of restriction areas and setback distances with site suitability criteria
- Weighting of the suitability criteria to evaluate site suitability

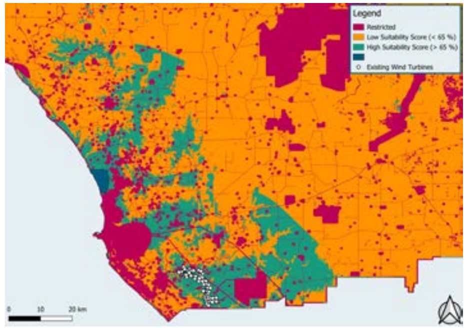
4. Result evaluation

- Site clustering of non-restricted areas with high suitability score
- Identification of suitable production sites to enable the envisioned PtX production volumes
- Consideration of further PtX-relevant criteria to select suitable locations for PtX production









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Restriction areas
Overview

Settlements and infrastructure

- Industrial areas
- Settlement areas
- Roads
- Railway lines
- Airports and airfields
- Navigational aids
- Transmission lines
- Existing wind turbines
- Existing PV parks
- Military areas

Ecology and culture

- Strict nature reserve
- Wilderness area
- National park
- Natural monument
- Habitat management area
- Protected landscape or seascape
- Protected natural resources
- Drinking water protection
- Ramsar wetlands
- High biodiversity (mammals, birds, …)
- Indigenous and cultural heritage

Land use, natural hazards and others

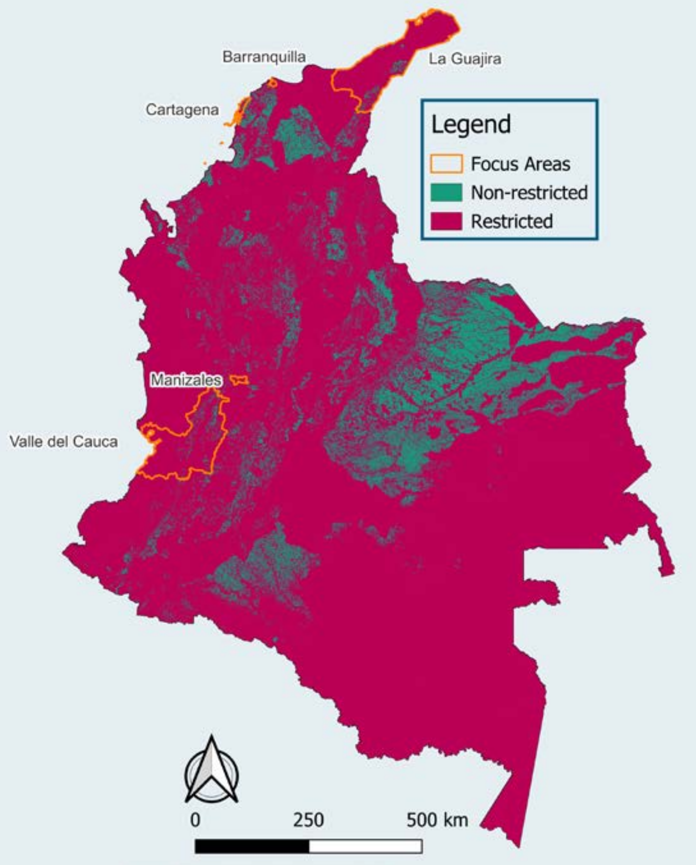
- Forests and dense vegetation
- Flooded vegetation
- Water bodies and rivers
- Crop land
- Peasant reserve zones
- Mining areas
- Floodplains
- Flood areas
- Active faults (earthquakes)
- Slope > 30°

- Consideration of areas that are incompatible for legal, ecological, social or physical reasons
- Compilation of restriction areas will be affected by data availability and the specified spatial and temporal boundaries

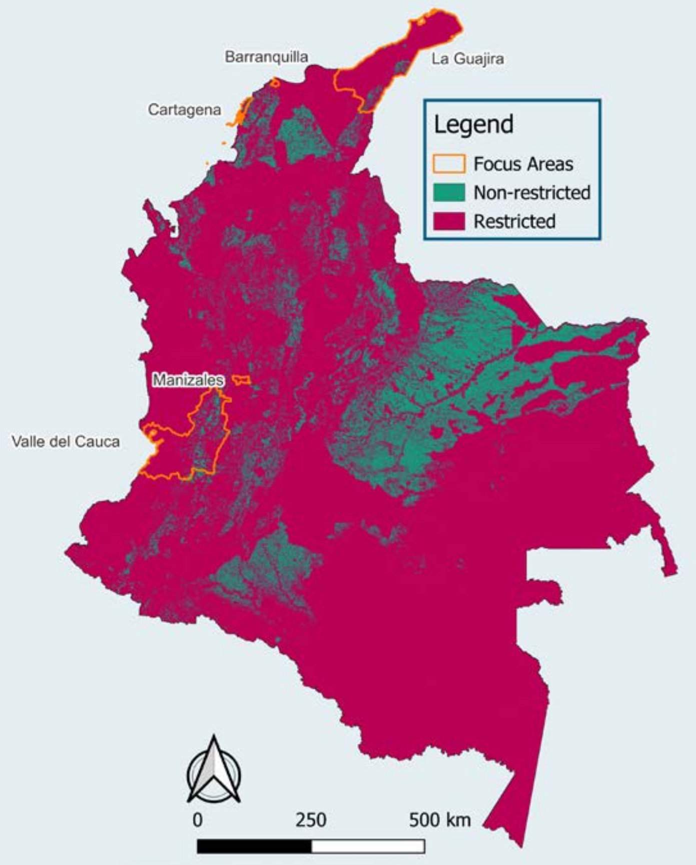
Restriction areas

Ground-mounted photovoltaics and onshore wind

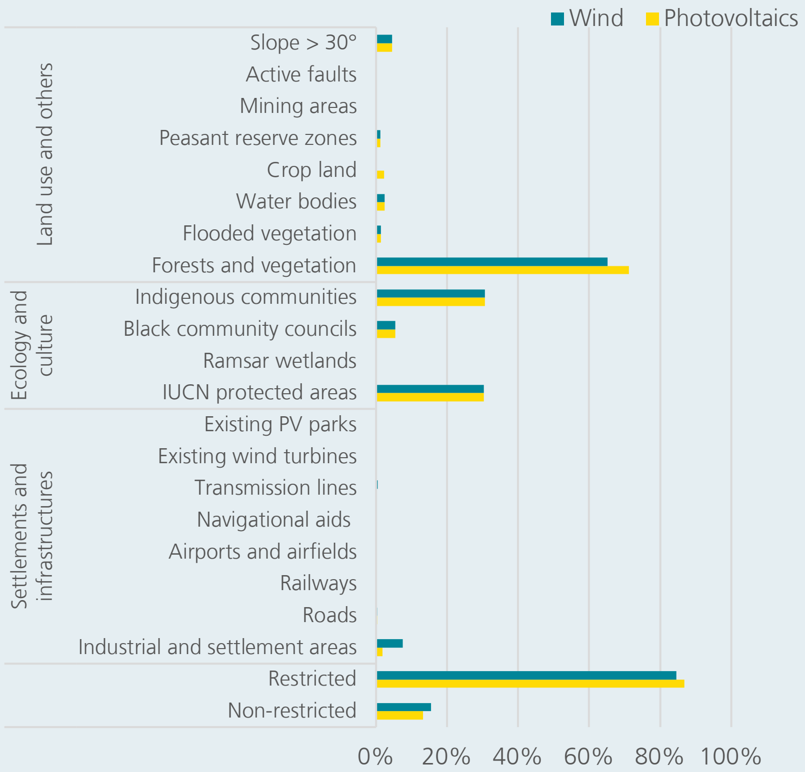
Ground-mounted photovoltaics



Onshore wind

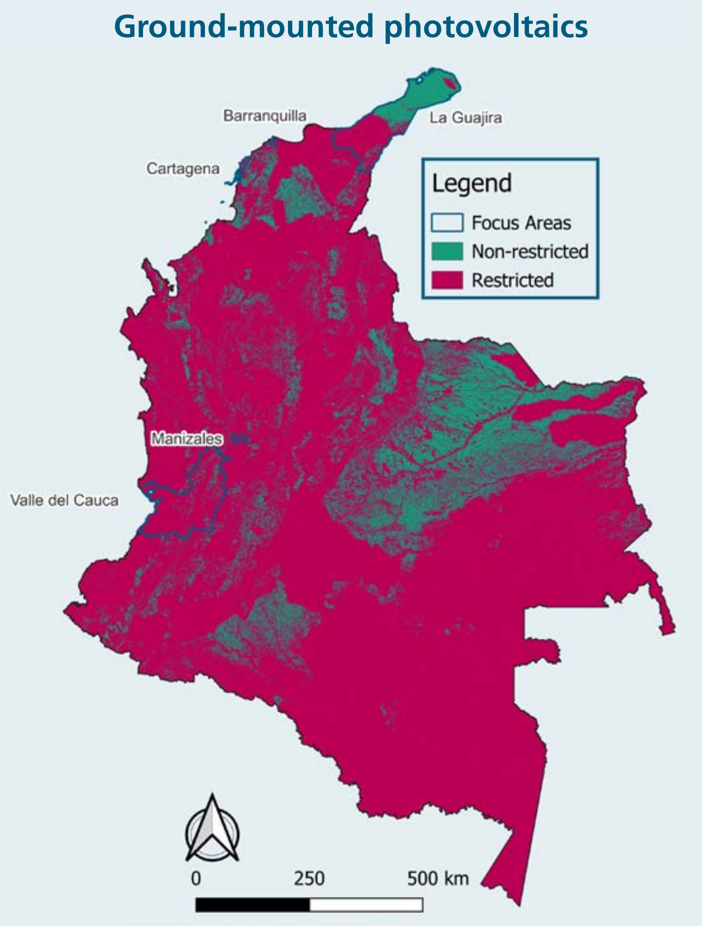


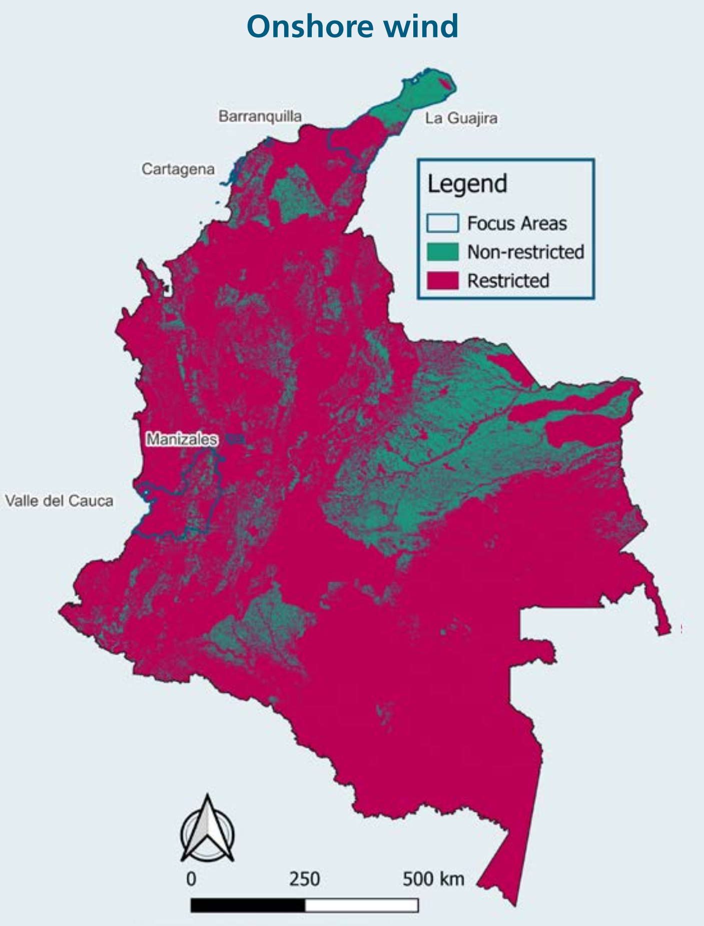
Restriction area allocation



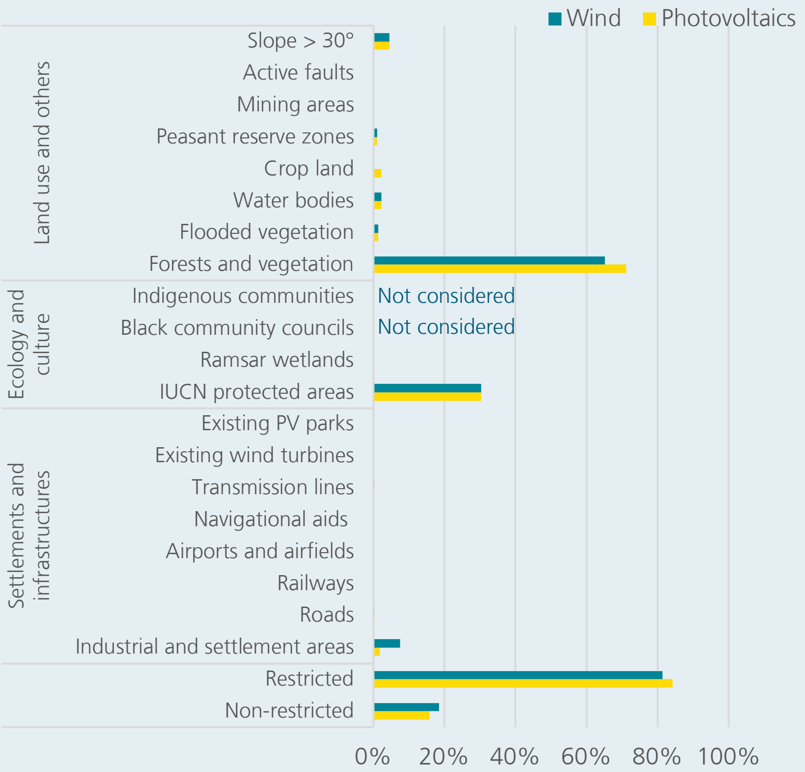
Restriction areas

Ground-mounted photovoltaics and onshore wind – Without cultural restrictions





Restriction area allocation



Suitability criteria

Overview

Ground-mounted photovoltaics

- Direct normal irradiance
- Seasonal variability
- Average ambient temperature
- Slope
- Aspect
- Distance to HV-transmission lines
- Distance to main roads

Onshore wind

- Wind power density
- Seasonal variability
- Slope
- Elevation
- Distance to HV-transmission lines
- Distance to main roads

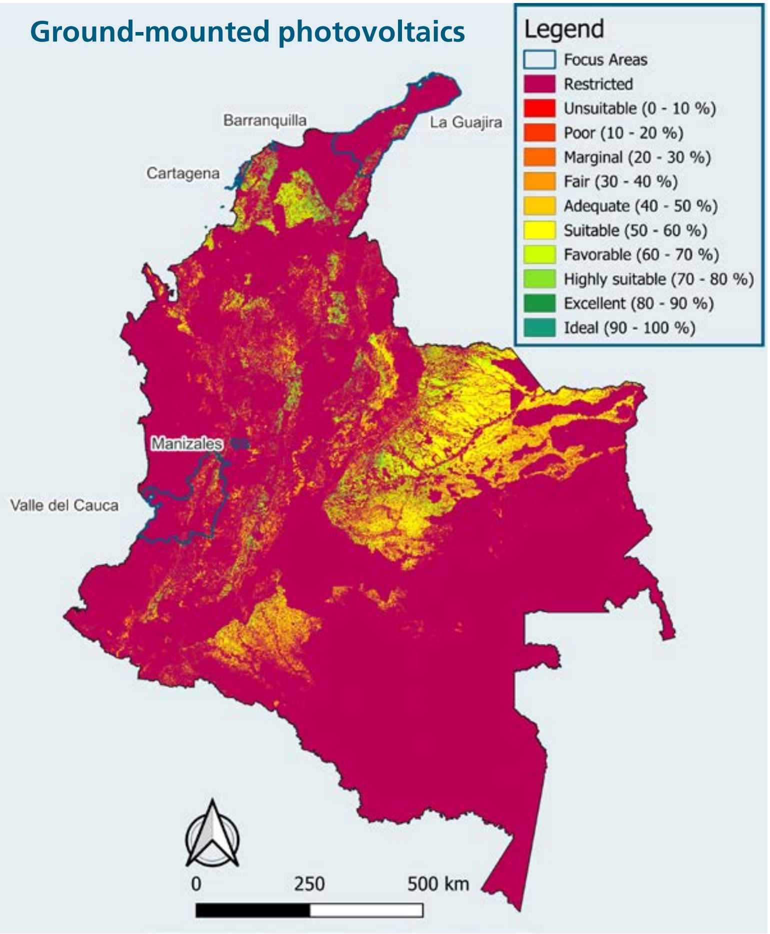
Power to X

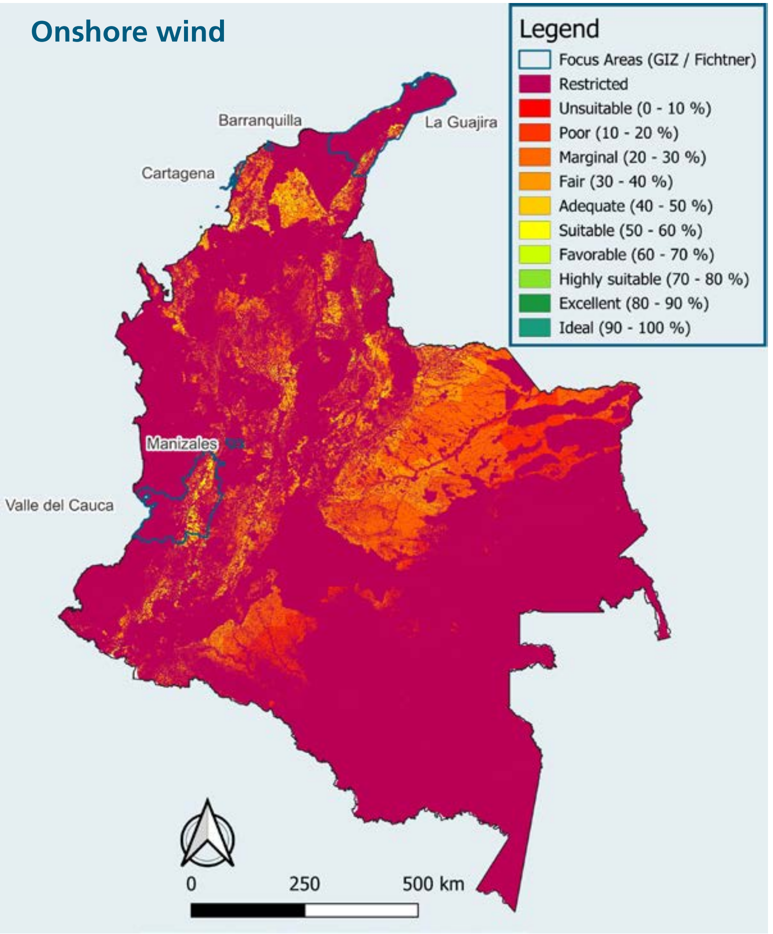
- Photovoltaics potential
- Wind potential
- HV-transmission lines
- Freshwater sources and unprotected coast
- Biogenic and industrial CO_2 point sources
- Potential underground H_2 storage
- Large seaports
- Railways
- Existing natural gas or future H_2 pipelines

- Consideration of criteria that influence the economic competitiveness and feasibility of projects
- Compilation of suitability criteria will be affected by data availability and the specified spatial and temporal boundaries

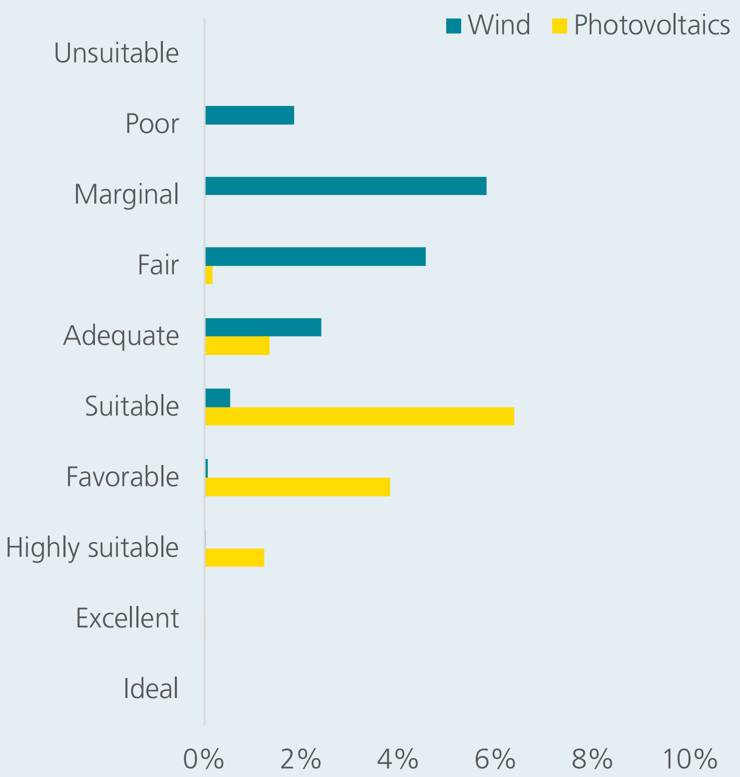
Site suitability

Ground-mounted photovoltaics and onshore wind





Site suitability allocation



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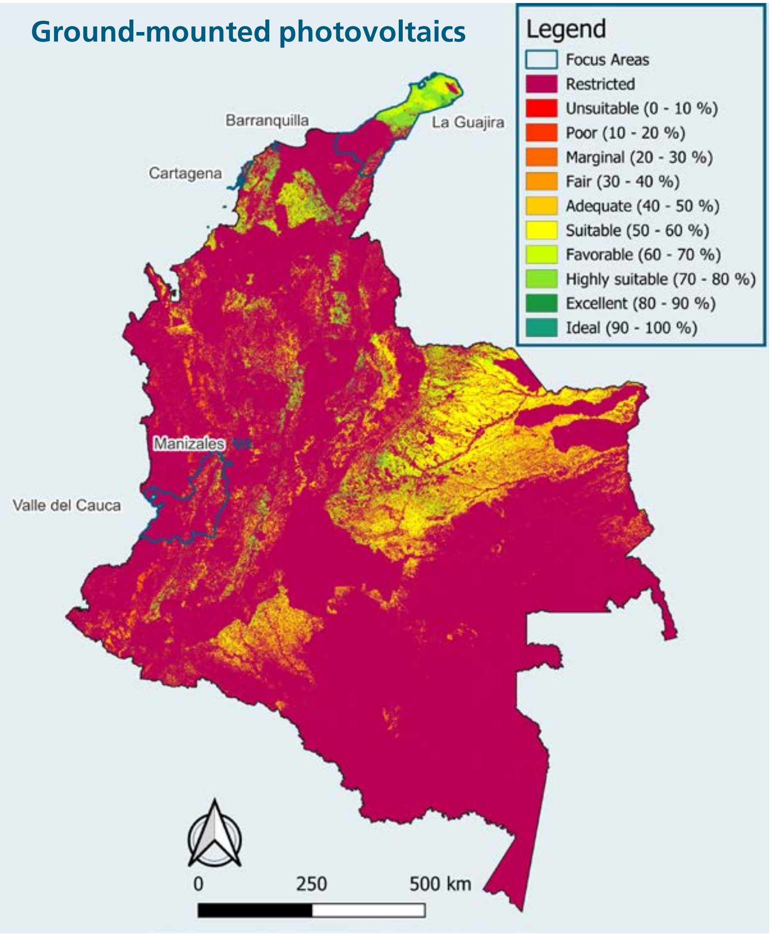
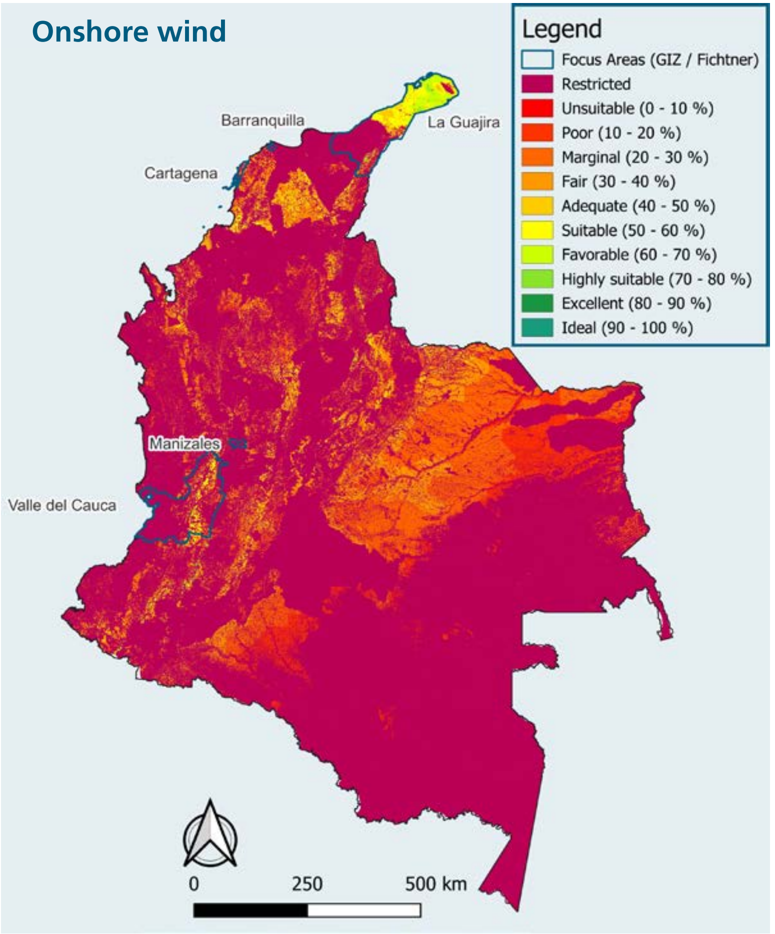
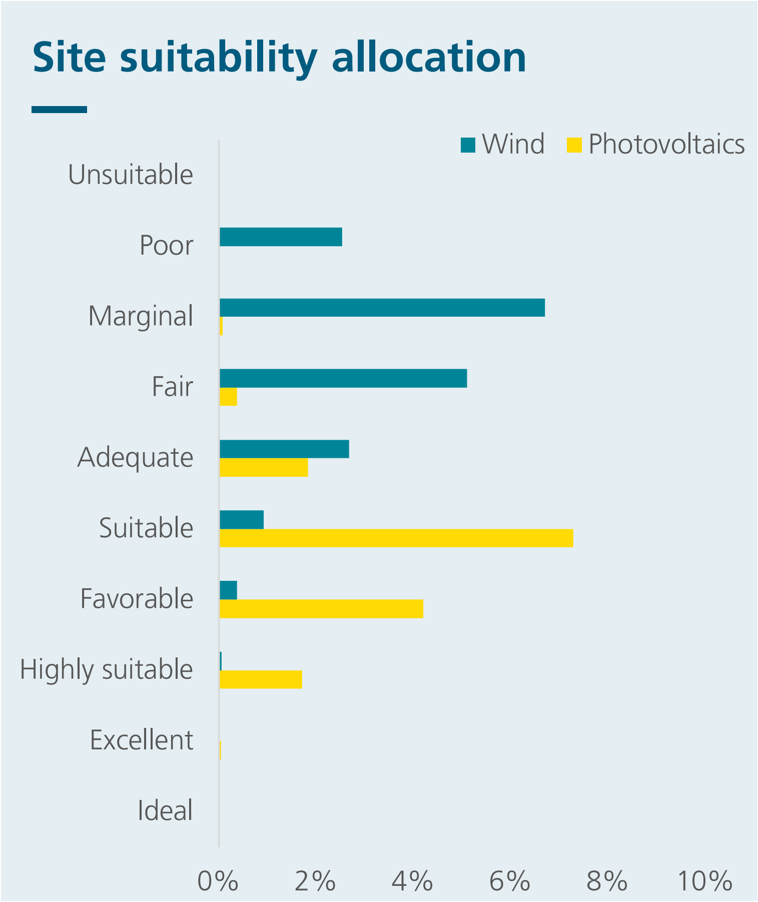
Site suitability

Ground-mounted photovoltaics and onshore wind – Without cultural restrictions





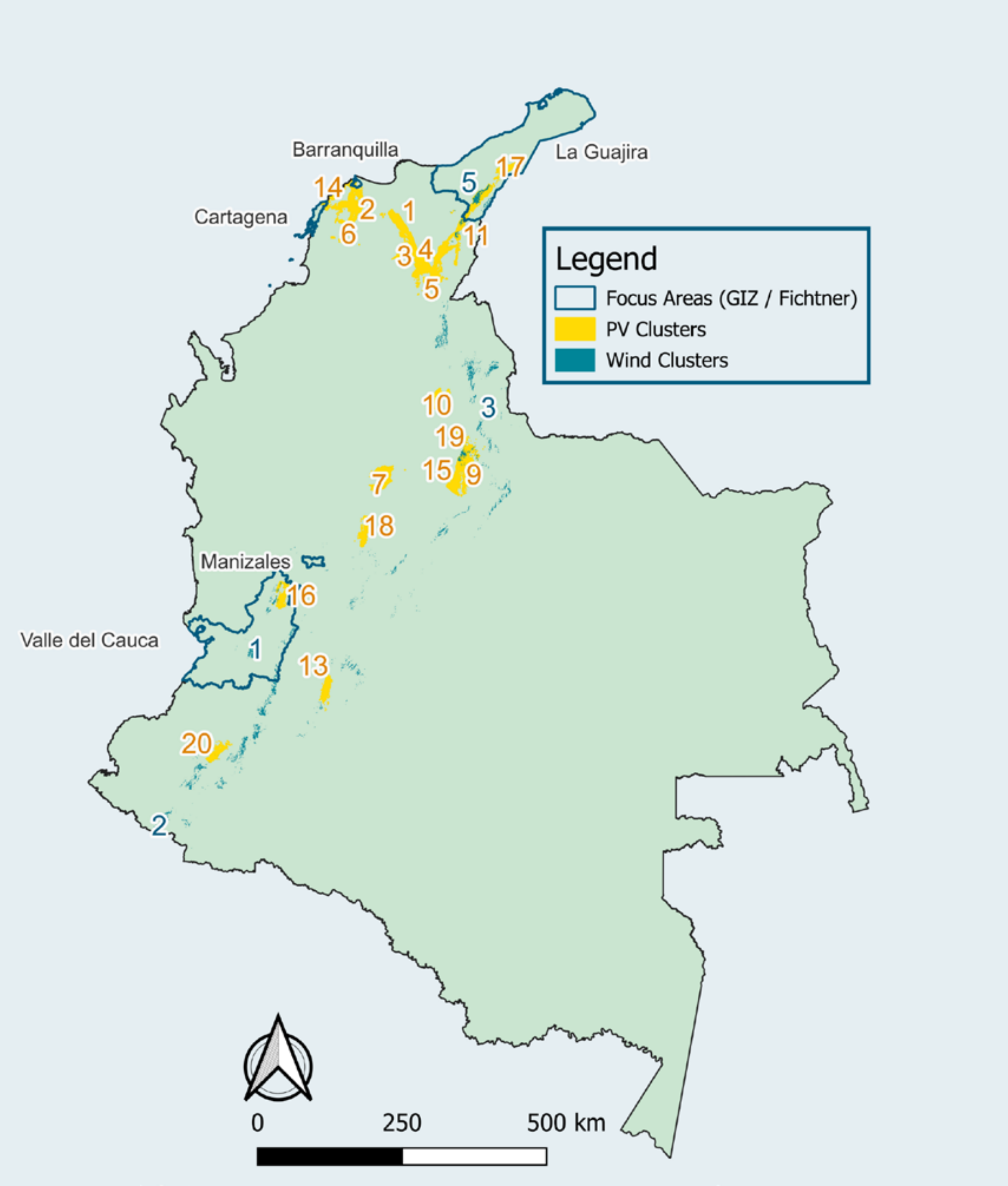


Site clustering

Photovoltaics and onshore wind

Clustering procedure

- Goal
  - Selection of large-scale contingous areas with high suitability score
  - 2.5 GW ground-mounted photovoltaics of 50 km²
  - 2.0 GW onshore wind of 150 km²
- Ground-mounted photovoltaics
  - Site suitability score above 75 %
  - 3443 km² available area
  - 69 Clusters of which 20 have more than 50 km²
- Onshore wind
  - Site suitability score above 60 %
  - 1108 km² available area
  - 7 Clusters of which 5 have more than 100 km²
  - Due to the insufficient suitable area, the wind clusters are distributed over a large area



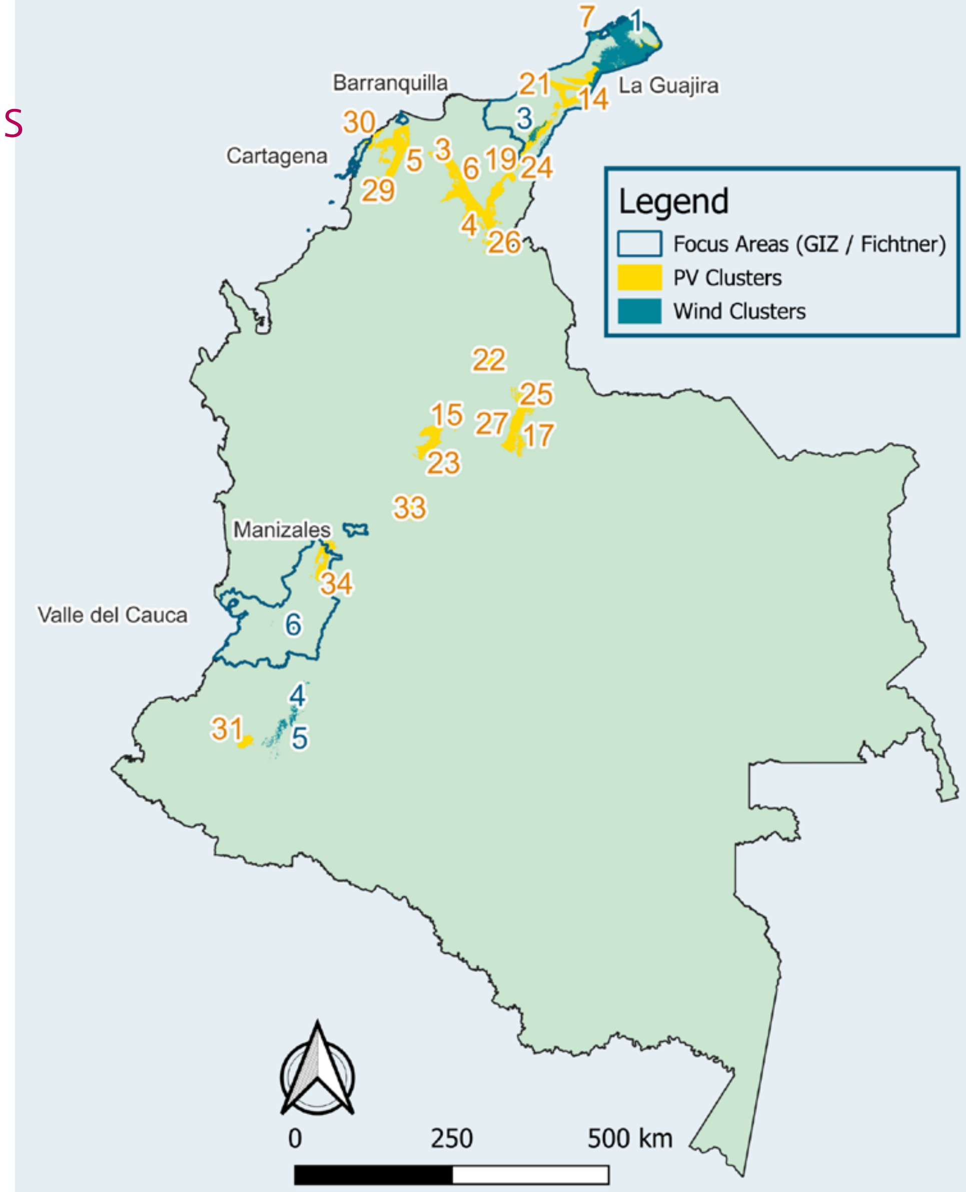
The clusters are numbered in descending order of size.
Wind Clusters are partially hidden behind PV clusters.

Site clustering

Photovoltaics and onshore wind – Without cultural restrictions

Clustering procedure

- Goal
  - Selection of large-scale contingous areas with high suitability score
  - 2.5 GW ground-mounted photovoltaics of 50 km²
  - 2.0 GW onshore wind of 150 km²
- Ground-mounted photovoltaics
  - Site suitability score above 75 %
  - 5560 km² available area
  - 111 Clusters of which 34 have more than 50 km²
- Onshore wind
  - Site suitability score above 60 %
  - 4933 km² available area
  - 33 Clusters of which 6 have more than 100 km²



The clusters are numbered in descending order of size.
Wind Clusters are partially hidden behind PV clusters.

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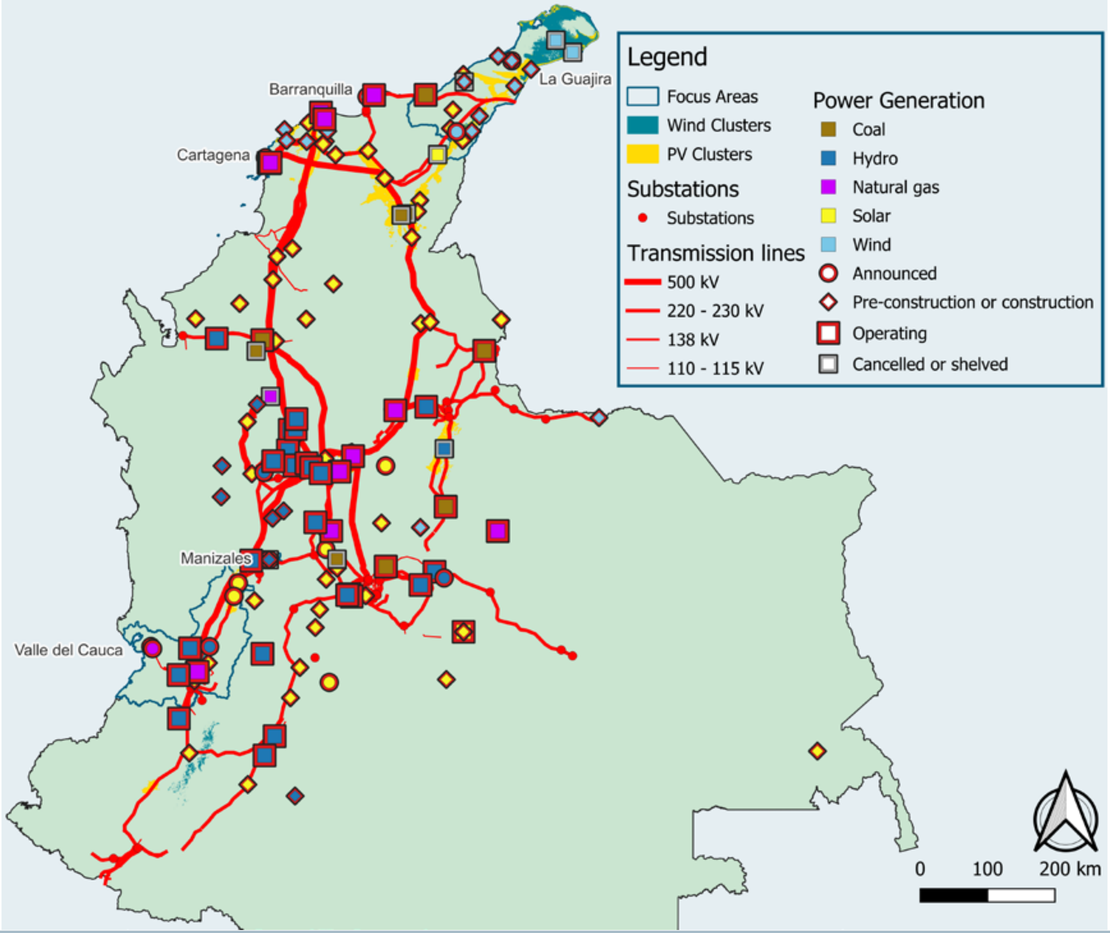
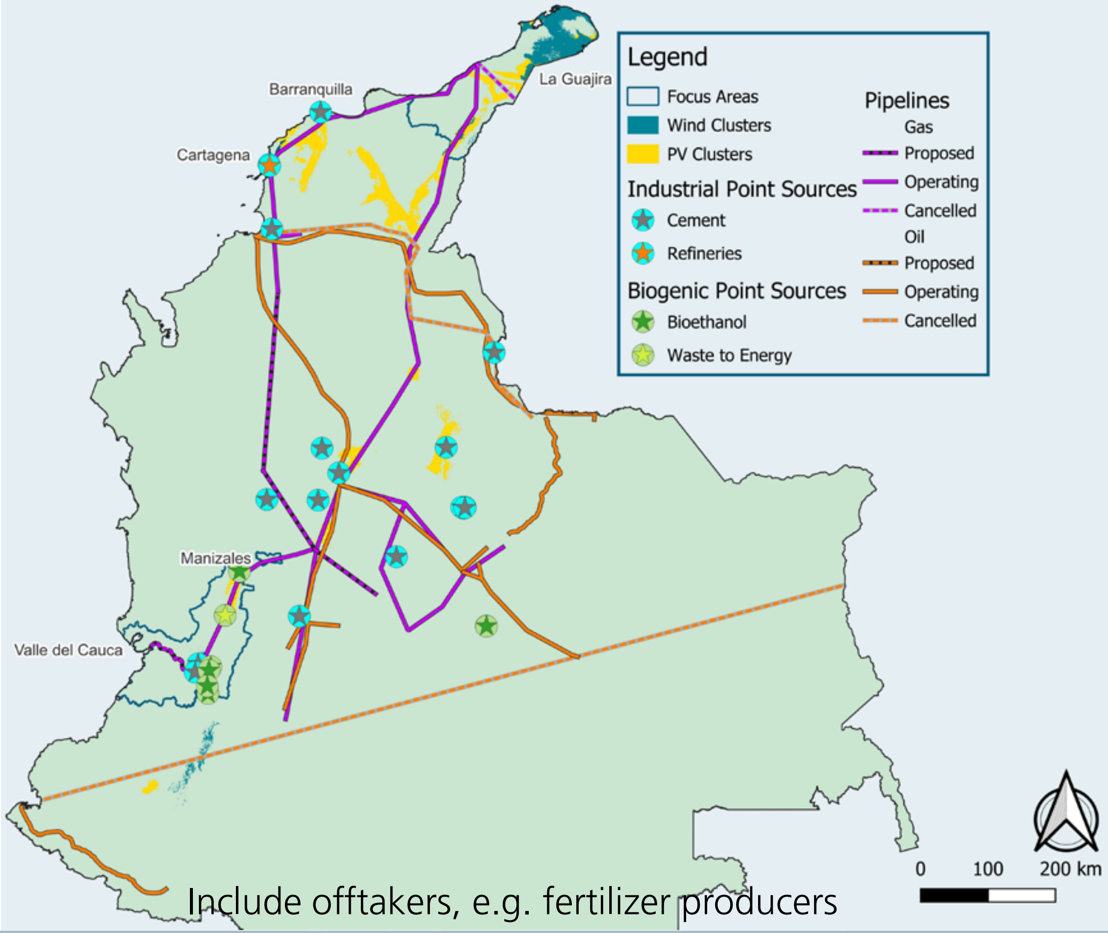
Power to X

Power and industry infrastructure (Preliminary)

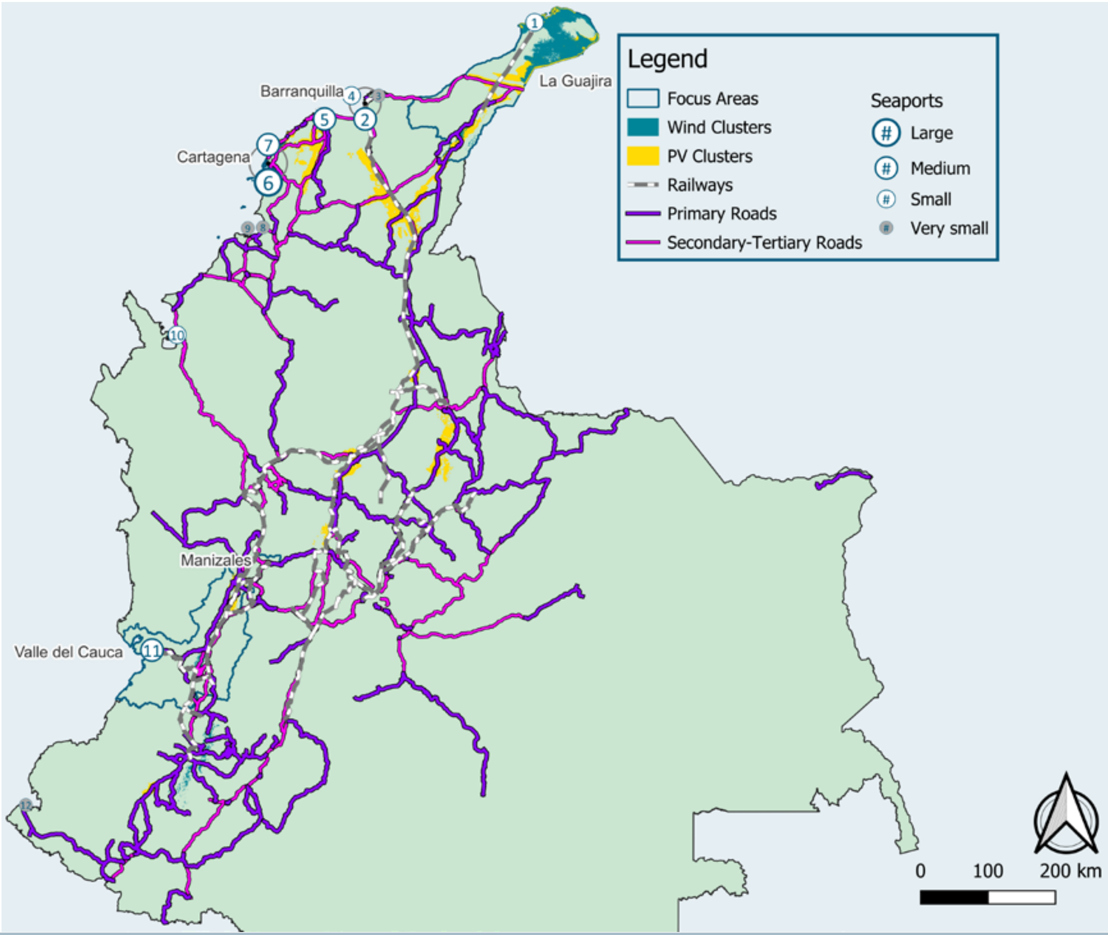


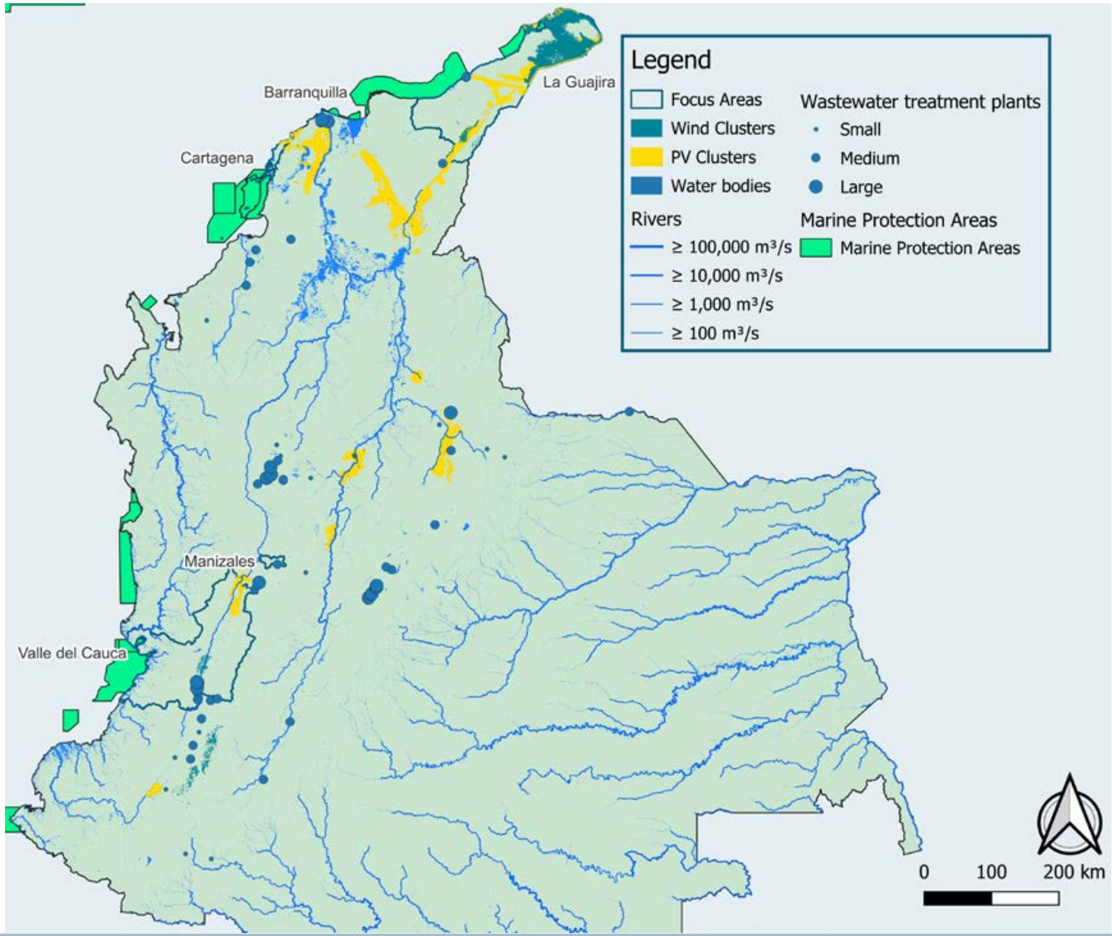


The map features solely photovoltaic and wind initiatives that exceed 100 MW for better clarity of presentation.

Power to X

Transport and water infrastructure (Preliminary)





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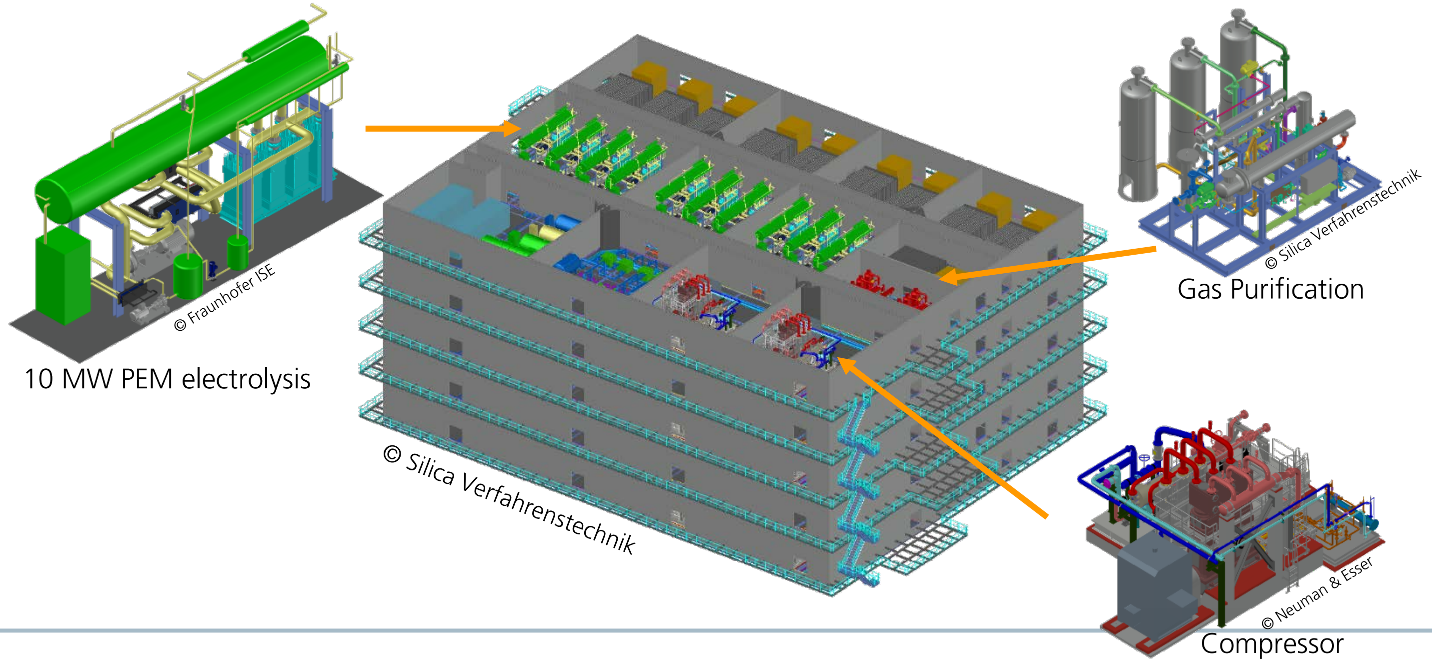
Examples of our Work

OffsH2ore: Offshore hydrogen production with Offshore Wind Energy

- Basic design of an offshore platform with 500 MW electrolysis capacity
- Electrical system development and analysis of island grid stability
- Development of a 500 bar H2 transport ship
- Techno economic analysis of the concept and alternative transport pathways (e.g. pipeline transport)



Project Partners

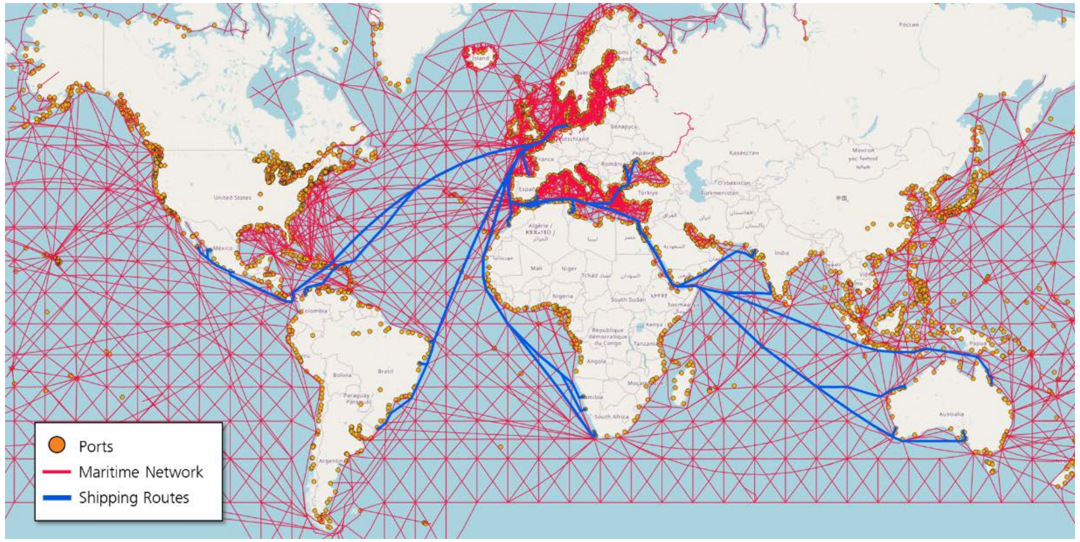
PNE pure new energy
Wystrach
Fraunhofer ISE
SILICA
KONGSTEIN

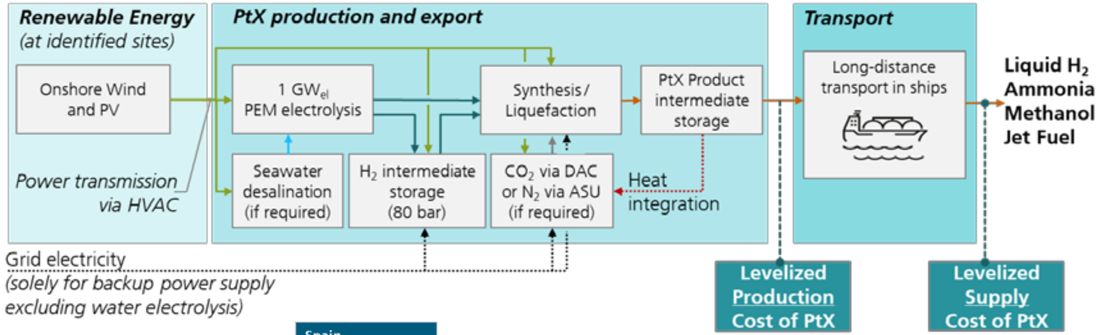
Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

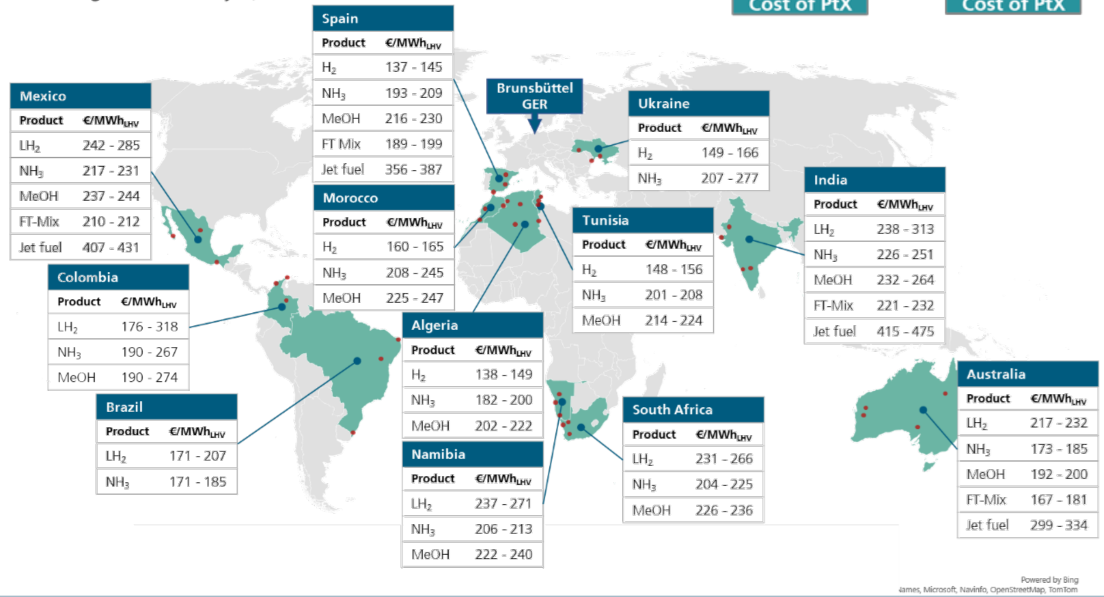
Examples of our Work

H2Global: Site specific analysis of PtX import to Europe

- GIS analysis to identify suitable regions for RE installation for multiple countries
- Annual simulations of the PtX production plants using site specific RE production profiles (satellite based)
- Time resolved ship transport model



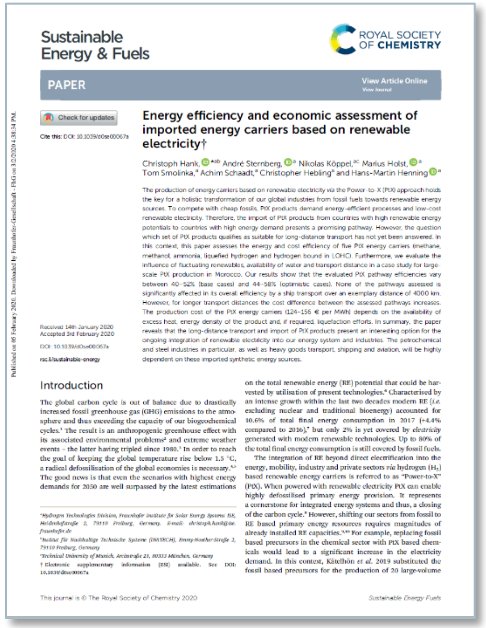


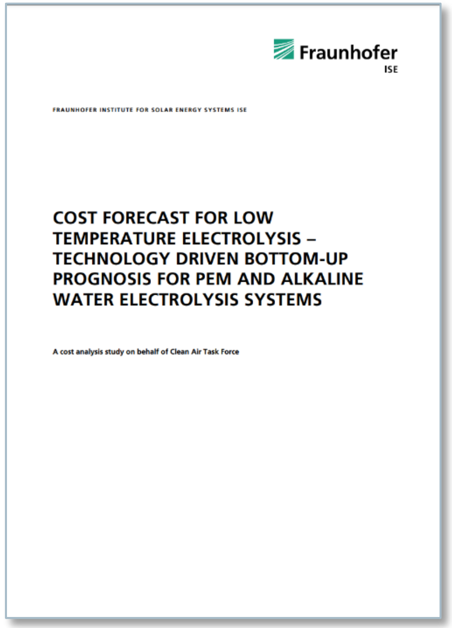


https://files.h2-global.de/H2G_Fraunhofer-ISE_Site-specific-comparative-analysis-for-suitable-Power-to-X-pathways-and-products-in-developing-and-emerging-countries.pdf

Recent Publications (Selection)

Click on publication to open





Coming soon:

- Hydrogen production costs across Europe
- Hydrogen refueling stations for heavy duty vehicles
- Evaluation of clustering algorithms for hydrogen ecosystems

Thank you for your kind attention

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Hydrogen and PtX Technologies

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