Power-to-X Production in Colombia

Study of Fraunhofer ISE within the framework of the Colombian-German Dialogue on re-industrialization via renewable hydrogen

Christoph Hank, Lucas Edenhofer, Friedrich Mendler, Marius Holst, Christopher Hebling
Kickoff Meeting, 27th September 2023
www.ise.fraunhofer.de

Agenda

The Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany

The PtX Supply Chain

The Study for PtX Production in Colombia

- Overview and project goal, key results
- Work packages

The Fraunhofer Institute for Solar Energy Systems ISE

Performing research for the energy transition for over forty years

The Institute in Numbers

Institute Directors:

Prof. Dr. Hans-Martin Henning
Prof. Dr. Andreas Bett

Employees: ca. 1,400

Budget 2021:

Operation	€104.4 million
Investment	€12.3 million
Total	€116.7 million

Founded in 1981

Fraunhofer ISE

The Fraunhofer Institute for Solar Energy Systems ISE

Performing research for the energy transition for over forty years

Photovoltaics

Energy Efficient Buildings

Solar Thermal Power Plants and Industrial Processes

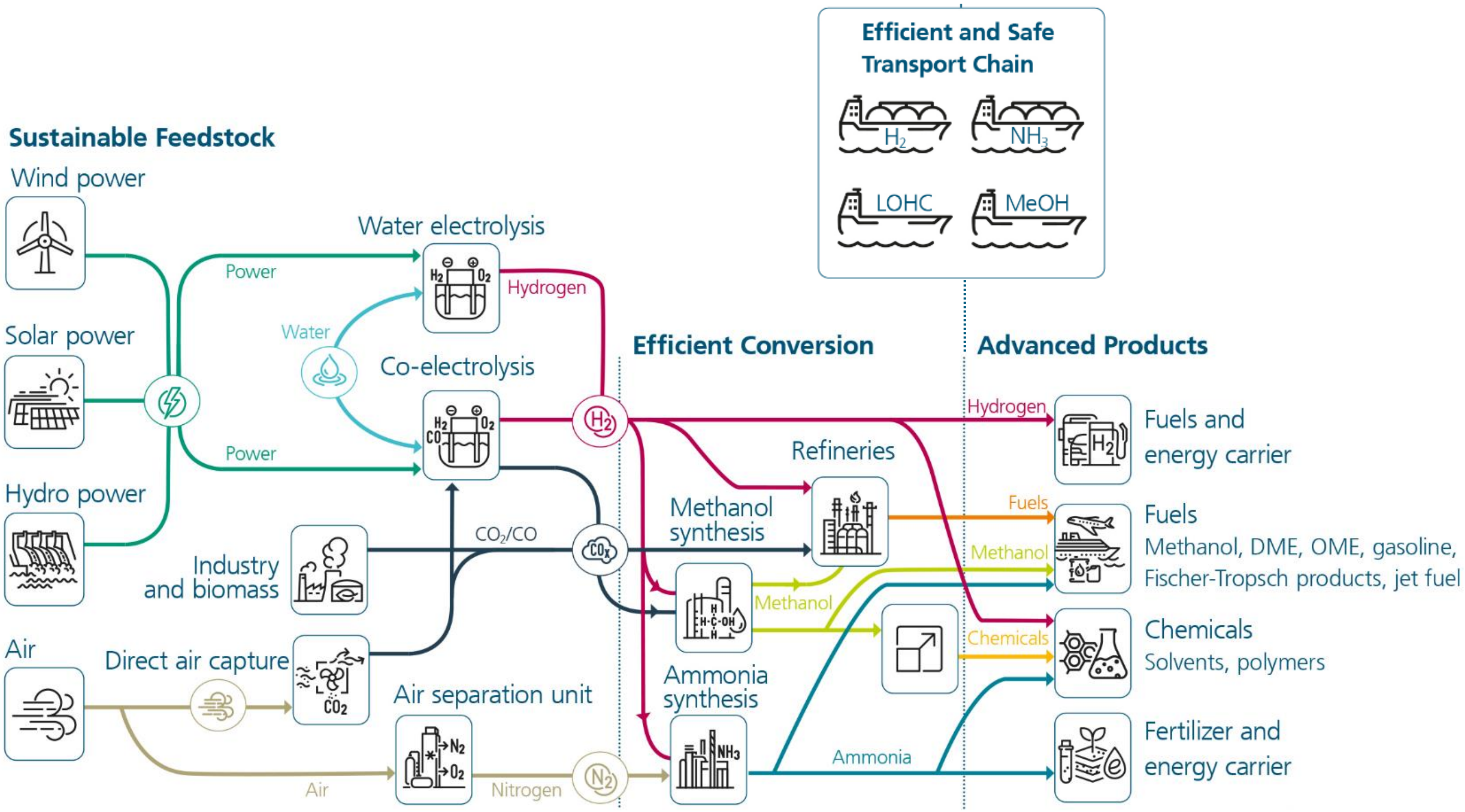
Power Electronics, Grids und Intelligent Systems

Hydrogen Technologies and Electrical Energy Storage
- Fuel Cell Systems
- Sustainable Synthesis Products
- Electrolysis and Power-to-Gas

Power-to-X Supply Chains at Fraunhofer ISE

Overview

- Production and Import of hydrogen and derivatives as a central element of a future sustainable energy system
- Focus of our ongoing analyses:
  - Liquid hydrogen (LH_2)
  - Ammonia (NH_3)
  - Methanol (MeOH)
  - efuels (e.g. DME, OME, aviation fuel)
  - Gaseous hydrogen (pipeline)



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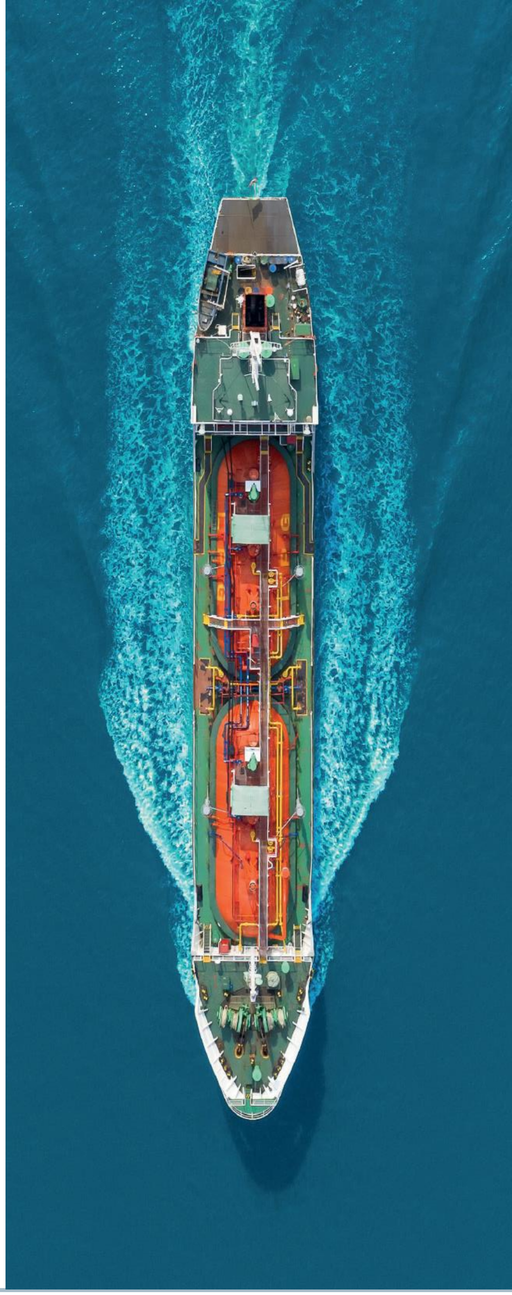
PtX Study for the Colombian-German Dialogue

Project goal

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

Key results

Local generation and (export) supply costs (incl. long distance transport) of liquid hydrogen, ammonia and methanol for selected sites, potential analysis for renewable electricity production (onshore wind and PV) power generation in Colombia, identification and mapping of relevant infrastructure.



Project Team and Work Packages

- **Project phase:** July 01, 2023 - March 31, 2024 (9 months)
- **Staff involved:**
  - Dr. Christoph Hank: Project management, synthesis pathways
  - Marius Holst: Simulation of PtX pathways, hydrogen production and conversion
  - Lucas Edenhofer: GIS Analysis of renewables potential analysis and overview of relevant infrastructures in Colombia
  - Prof. Dr. Christopher Hebling: Consulting for any hydrogen and power-to-X topics in Colombia, Germany and internationally
- **Work packages:**
  - WP1: RE potential analysis and overview of relevant infrastructures in Colombia
  - WP2: Technoeconomic simulations and optimizations for Power-to-X production and supply chains
  - WP3: Workshops and reporting

Techno-Economic Optimization of PtX Supply Chains at Fraunhofer ISE

General Methodology

Data Input

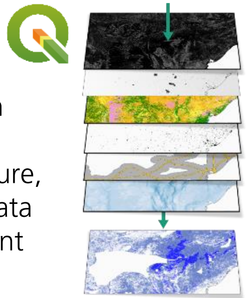
Location Parameters (capital costs, grid power costs)

Export destination

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

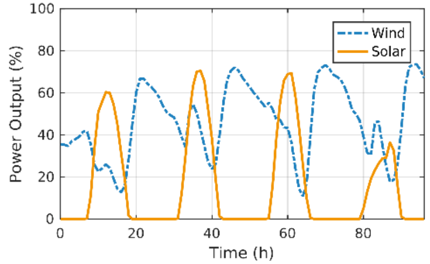
Internal Database for technical and economical parameters for system components (Efficiencies, Capex, Opex, etc.)

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

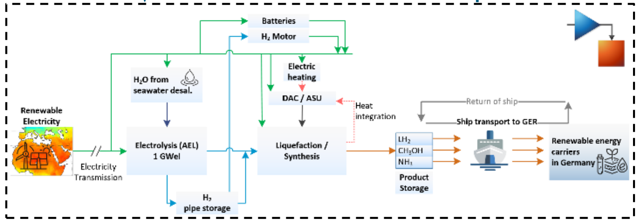
Considering of **operation management** taking component behaviors into account, e.g., limited part load operation of synthesis (continuously running process)

Strong simulation server for **parallel computing**

Optimization Algorithm
(mutation and crossover functions)

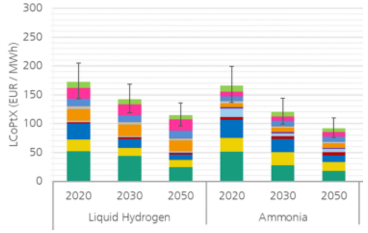
Handover of parameters

Results (EUR/kg)



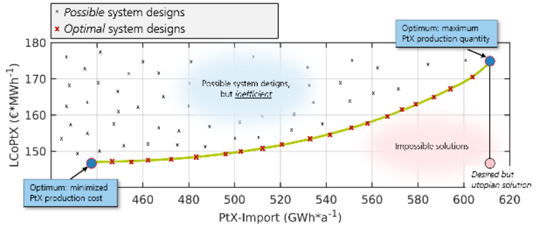
Result Output

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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Thank you for your kind attention

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Hydrogen and PtX Technologies

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PtX Colombia - Work Packages

WP 1: RE potential analysis and overview of relevant infrastructures in Colombia

WP goal

1. Classification of renewable energy potentials in Colombia and identification of two suitable locations
   - Suitable RE-related evaluation criteria will be selected, weighted, and matched with appropriate GIS data sets
   - Available solar and wind data sets will be compared and assessed based on their suitability
   - Site selection for renewable energy production (onshore wind and ground-mounted photovoltaics) is conducted via a weighted multi-criteria overlay analysis
   - Renewable energy site suitability maps are generated for focus-regions
2. Identification of two suitable locations and potentials for large-scale PtX production within or nearby pre-selected focus-regions
   - Suitable PtX-related evaluation criteria will be selected, weighted, and matched with appropriate GIS data sets
   - The results from the renewable energy section serve as an input for the Power-to-X section
   - Site selection for PtX production is conducted via a weighted multi-criteria overlay analysis
   - PtX site suitability maps is generated for the focus-regions

PtX Colombia - Work Packages

WP 1: RE potential analysis and overview of relevant infrastructures in Colombia

Onshore wind

Wind resource

- Wind speed
- Wind power density
- Seasonal variability

Technical and physical suitability

- Slope
- Elevation

Economic suitability

- Transmission lines
- Main roads

Land use and location

- Settlements and infrastructures
- Ecologically sensitive areas
- Natural hazards

Ground-mounted photovoltaics

Solar resource

- Solar irradiation
- Sunshine duration
- Seasonal variability
- Temperature
- Relative humidity

Technical and physical suitability

- Slope
- Aspect

Economic suitability

- Transmission lines
- Main roads

Land use and location

- Settlements and infrastructures
- Ecologically sensitive areas
- Natural hazards

PtX Colombia - Work Packages

WP 1: RE potential analysis and overview of relevant infrastructures in Colombia

Renewable energy

- Onshore wind potential
- Ground-mounted PV potential

Power grid

- Transmission lines
- Substations

Water

- Fresh water sources
- Coast proximity
- Desalination plants
- Wastewater treatment plants

Carbon source

- Biogenic point sources
- Industrial point sources
- Direct air capture

Industry

- Industrial areas
- Potential PtX offtakers
- Potential oxygen offtakers
- Waste heat sources

Storage

- Salt caverns for H_2
- Aquifers for H_2
- Depleted gas fields for H_2
- Geological storage for CO_2

Transport

- Ports
- Fuel bunkers
- Inland waterways
- Railways
- Pipelines

Land use

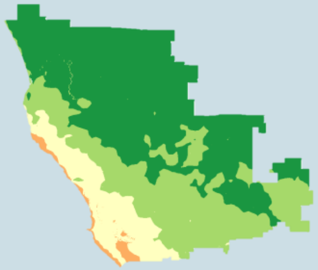
- Settlements and infrastructures
- Ecologically sensitive areas
- Topography
- Natural hazards

PtX Colombia - Work Packages

WP 1: RE potential analysis and overview of relevant infrastructures in Colombia

Criteria selection and reclassification

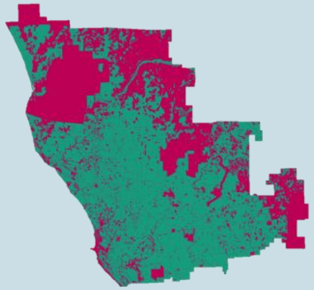
- Solar irradiation
- Sunshine duration
- Seasonal variability
- Ambient temerature
- Relative humidity
- Slope
- Aspect
- Distance transmission lines
- Distance main roads



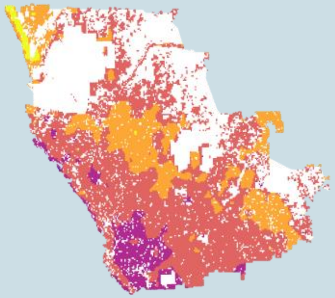
AHP and weighting

Restriction areas

- Settlements and infrastructures
- Ecologically sensitive areas
- Other restriction areas



Overlay analysis



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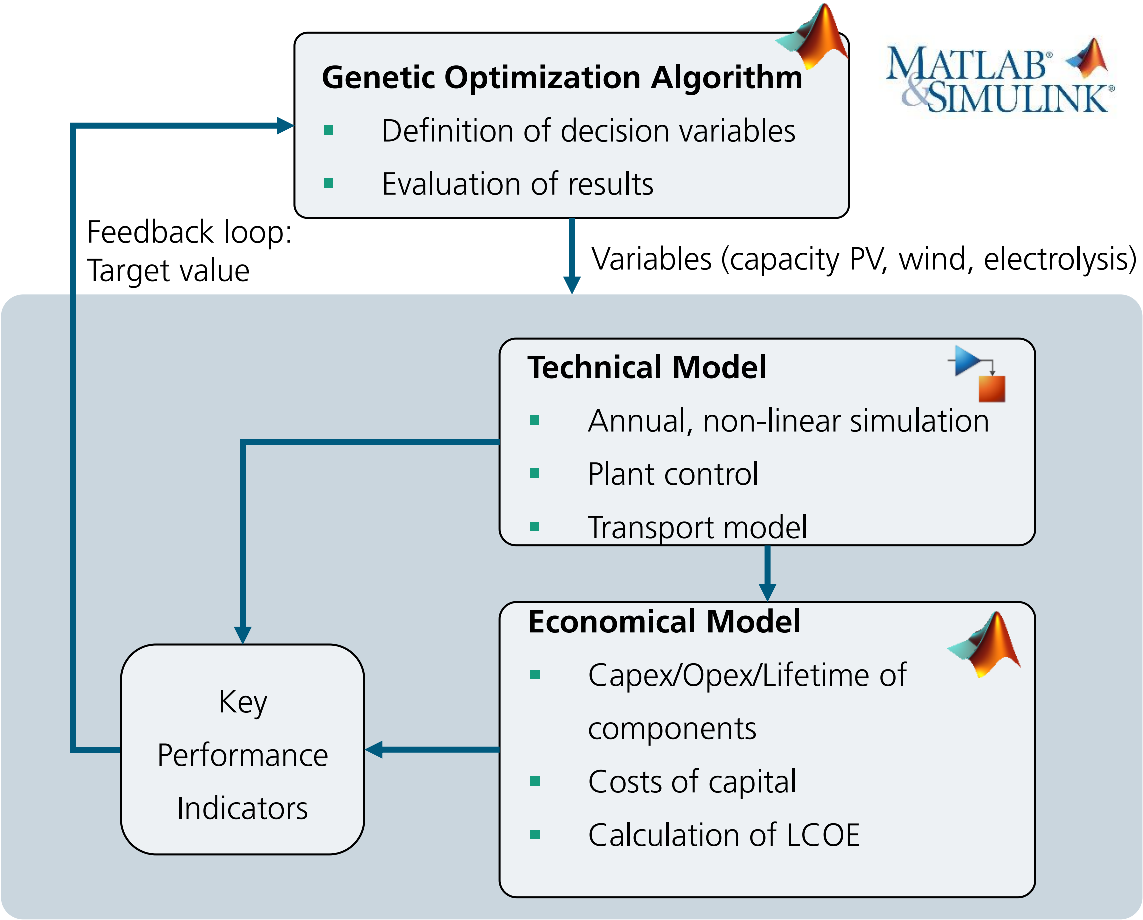
PtX Colombia - Work Packages

WP 2: Technoeconomic simulations and optimizations for Power-to-X production and supply chains

H_2ProSim – Model structure

- MATLAB
  - Upper level for calling simulation model and functions
  - Cost calculation with economic model (calculation of hydrogen costs)
  - Assessment of system parameters (e.g., efficiency, power curtailed power, full load hours, etc.)
  - Genetic Optimization Algorithm
- Simulink
  - Technical models of system components (e.g.: electrolysis, compression, Storage)
  - System control
  - Evaluation of simulation (annual simulation)



PtX Colombia - Work Packages

WP 2: Technoeconomic simulations and optimizations for Power-to-X production and supply chains

H_2ProSim – Cost model

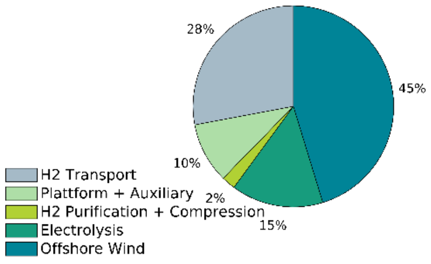
- Cost data from our database <u>or customers specific data input</u>
- Calculation of hydrogen production cost based on annuity methodology:
  - Capex, Opex and technical lifetime of individual component
  - Cost of capital (WACC)

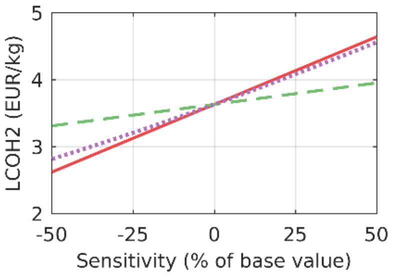
$$LCOH_{2,i} = \frac{CAPEX_i * \frac{WACC(1+WACC)^{n_i}}{(1+WACC)^{n_i}-1} + OPEX_i}{m_{H2}}$$

Project specific WACC:
Dept-equity-ratio; costs of dept/equity; tax rate; expected inflation rate

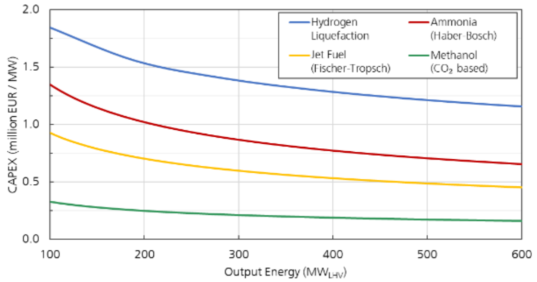
- Cost breakdown to identify main cost drivers
- Sensitivity analysis to identify effect of change in cost

Example of cost breakdown and sensitivity analysis

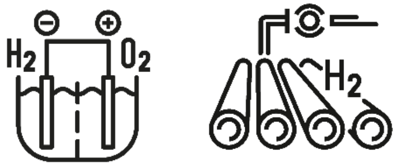




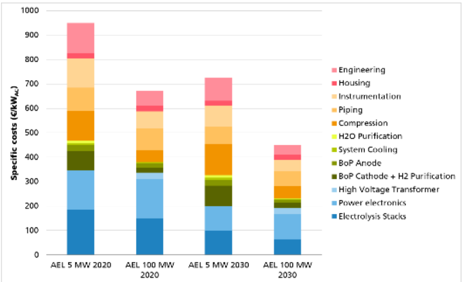
Literature



Expert information



Cost database



Own cost models

Budget quotes

PtX Colombia - Work Packages

WP 3: Workshops and reporting

WP goals

- Webinars:
  Coordinated perspective on hydrogen in Colombia in consideration of harmonized needs of local stakeholders as input for the technoeconomic assessments conducted in this project

- Reporting:
  Communication and documentation of project results

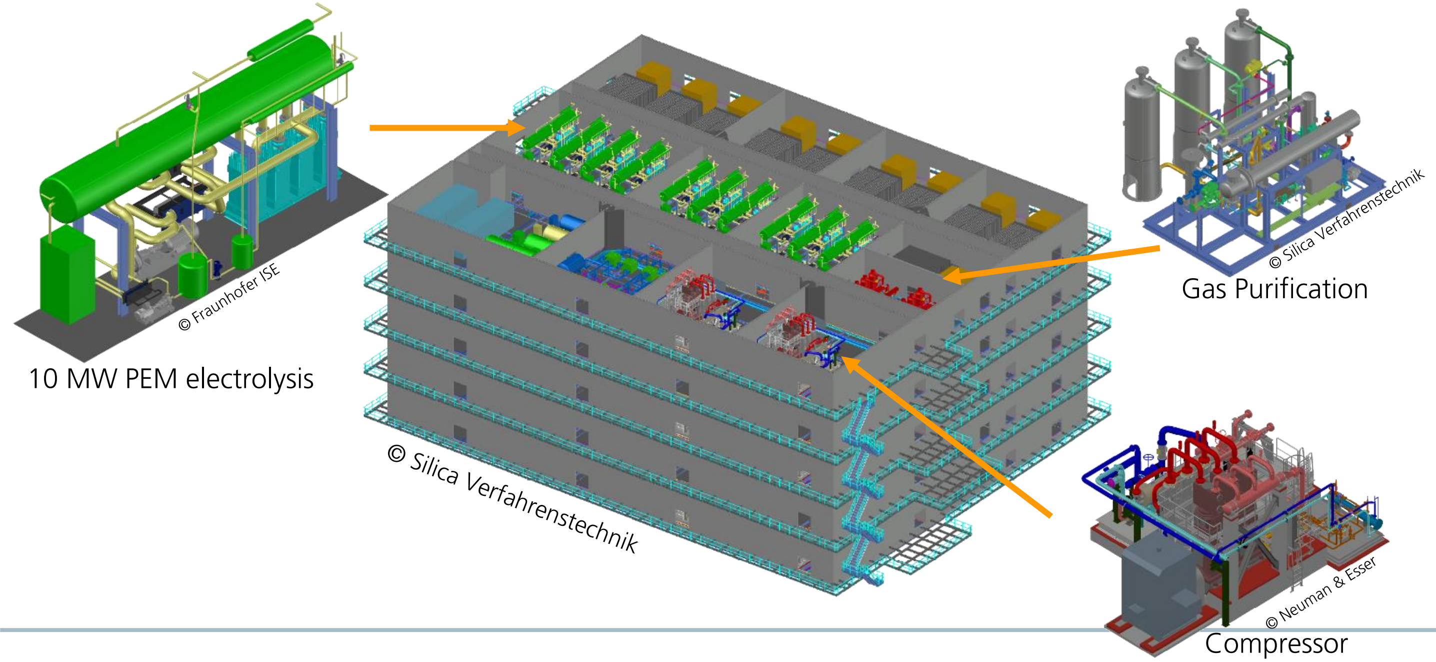
Scope, report and deliverables

- Participation in 3 Webinars + Final conference (COL)
- Project report (max. 25 p. excl. Appendix)
- A final presentation (*.pdf file)

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

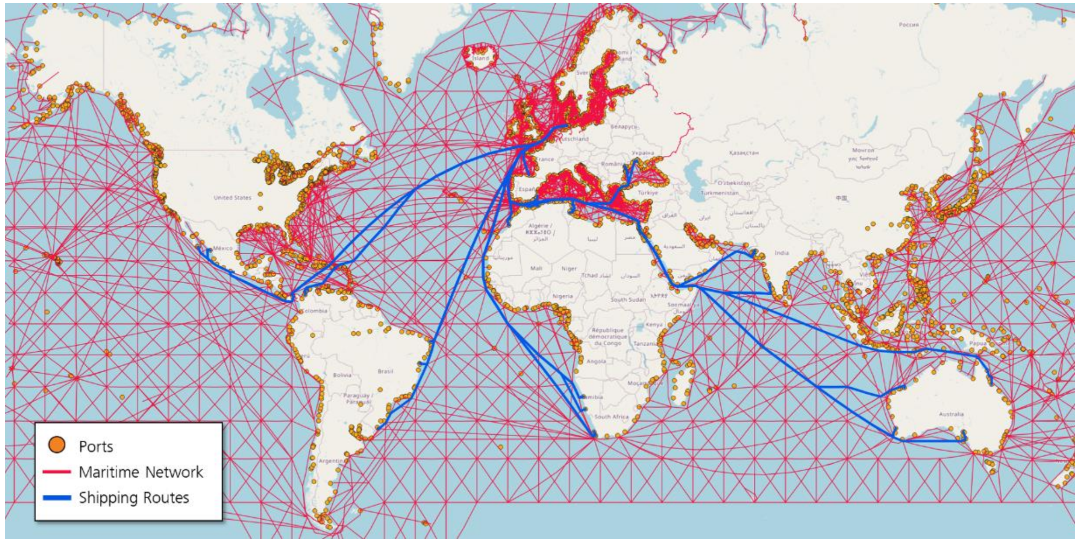
on the basis of a decision by the German Bundestag

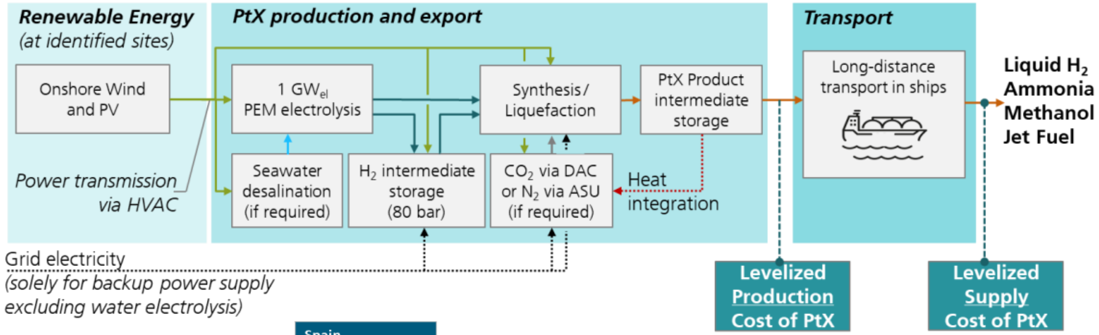
https://www.ise.fraunhofer.de/content/dam/ise/de/documents/presseinformationen/2023/Projekt-OffsH2ore-Abschlussbericht-2023_public.pdf

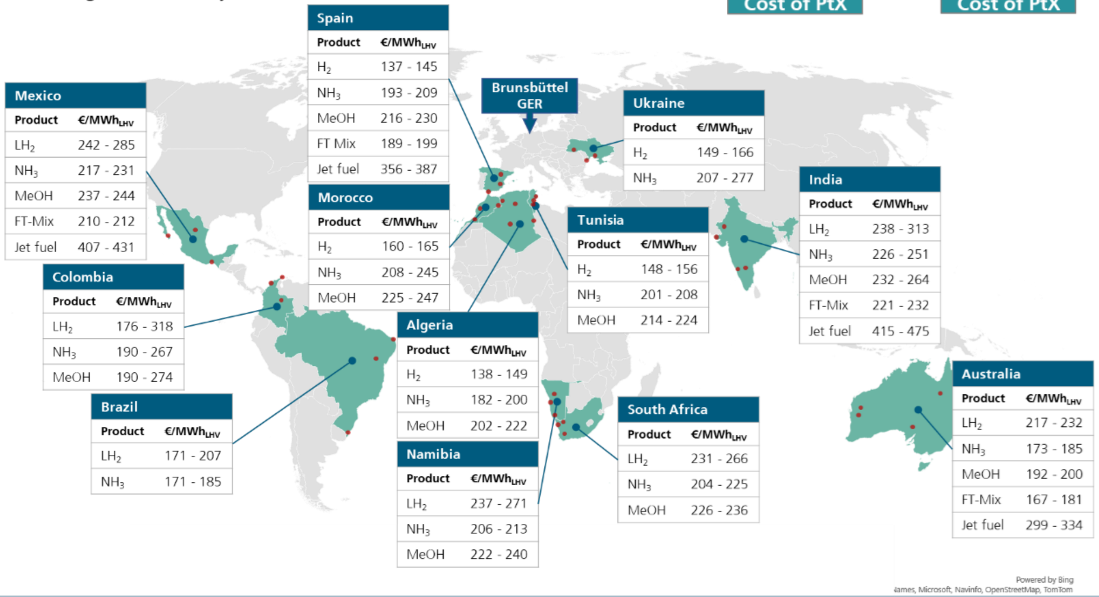
Examples of our Work

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



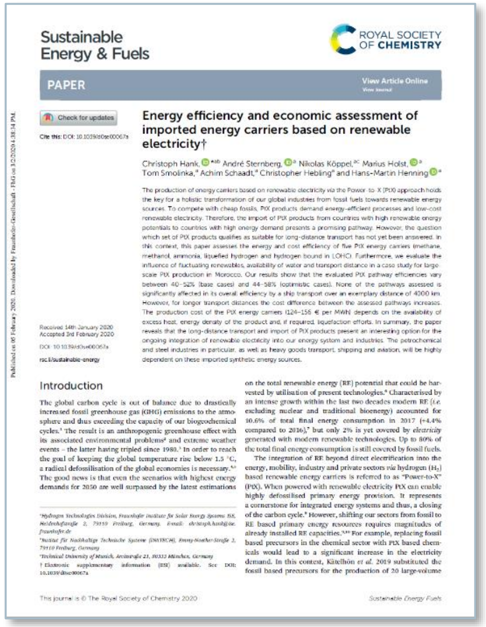


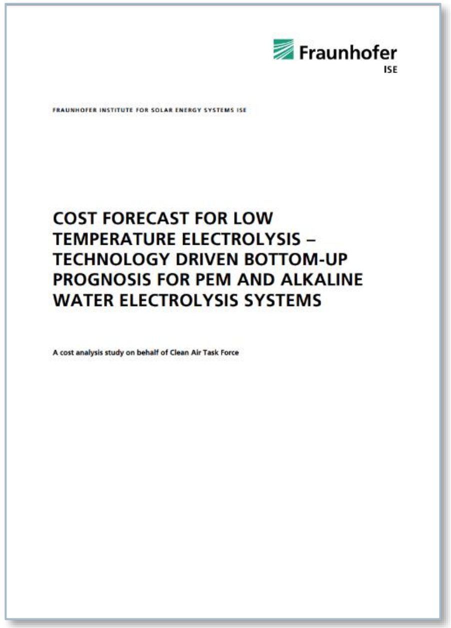


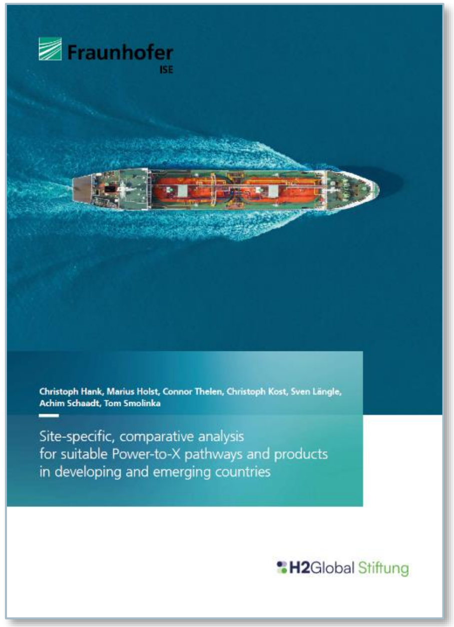
https://files.h2-global.de/H2G_Fraunhofer-ISE_Site-specific-comparative-analysis-for-suitable-Power-to-X-pathways-and-products-in-developing-and-emerging-countries.pdf

Recent Publications (Selection)

Click on publication to open


Sustainable Energy & Fuels
ROYAL SOCIETY OF CHEMISTRY
PAPER
View Article Online
Check for updates
Cite this: DOI: 10.1039/d0se00067a
Energy efficiency and economic assessment of imported energy carriers based on renewable electricity†
Christoph Hank, André Sternberg, Nikolas Köppel, Marius Holst, Tom Smolinka, Achim Schaadt, Christopher Hebling and Hans-Martin Henning
Introduction





Coming soon:

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