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 3: Infrastructure

Christoph Hank, Marius Holst, Lucas Edenhofer, Christopher Hebling
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Power-to-X Production in Colombia

Content

- Overview & methodology
- Sites and scenarios selected
- Technical and economic design of the PtX chains
- Selected techno-economic results (La Guajira & Cartagena)

Overview & Methodology

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")

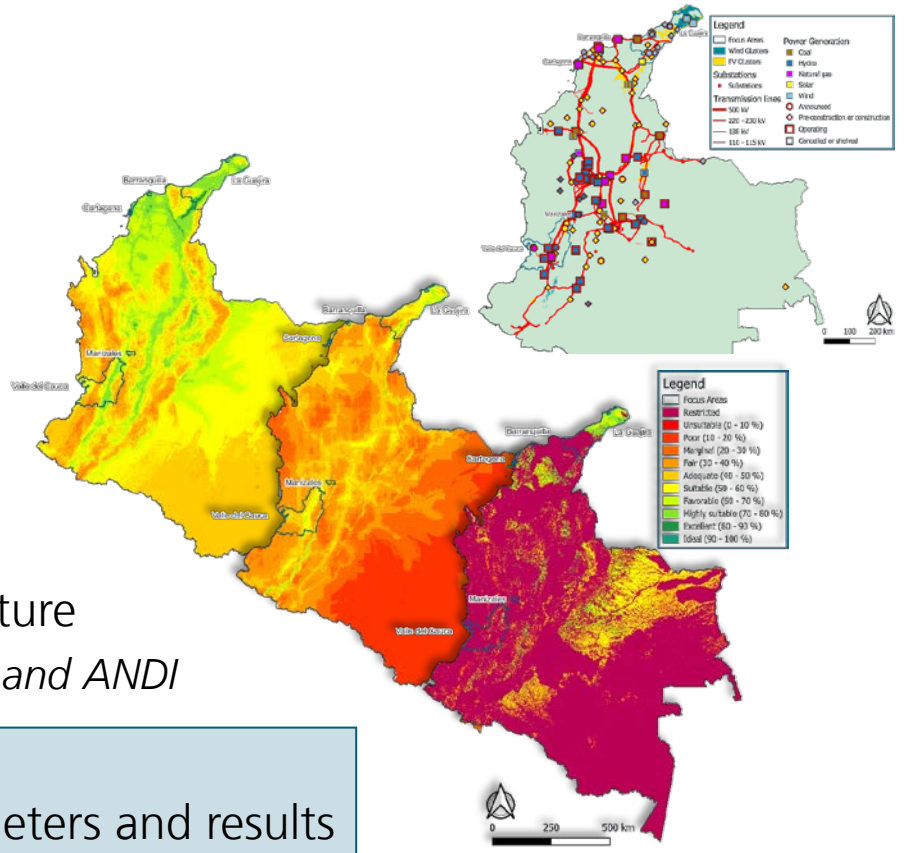
Power-to-X Study for the Colombian-German Dialogue

Our work presented in three webinars:

Webinar 1: 27th September 2023
Kickoff - Project scope - Goal

Webinar 2: 21st November 2023
RE potential - RE site clustering - Relevant Infrastructure

→ *Talk and slides made available by WEC and ANDI*



Webinar 3: Today
Selection of PtX locations - Techno-economic parameters and results

→ ***Today***: *Preliminary results for two of the selected locations (La Guajira & Cartagena)*

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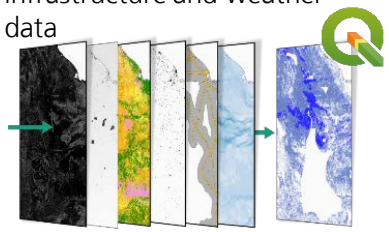
Methodology: GIS and Techno-Economic Optimization of PtX

Location Analysis and Data Preparation → System Simulation & Optimization → Results Analysis

GIS analysis to determine the most suitable regions, taking into account land use, topology, population density, infrastructure and weather data



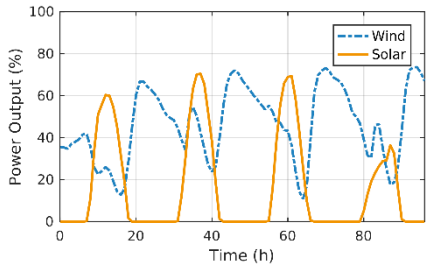
Internal data library for techno-economic parameters of PtX components

Location parameters (e.g. capital costs, grid electricity costs)

Export harbours (e.g. infrastructure, size, handled goods)

Additional requirements (seawater desalination, land availability)

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



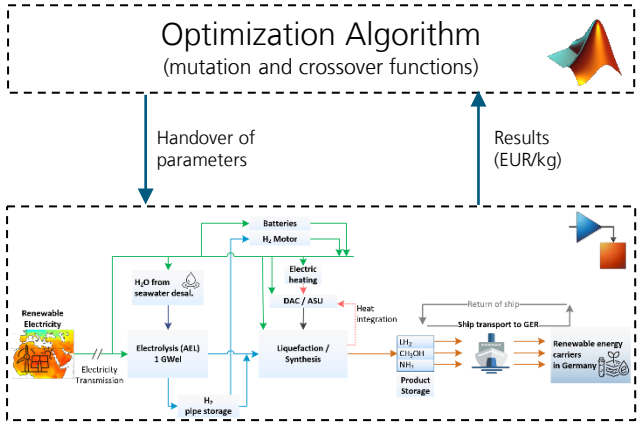
Automatic **Transport route analysis** based on real world shipping routes:

Dynamic and **hourly-resolved simulation of the PtX production and supply chains:** RE, electrolysis, H2 liquefaction/synthesis, transport, reforming/re-electrification, onshore onward transport).

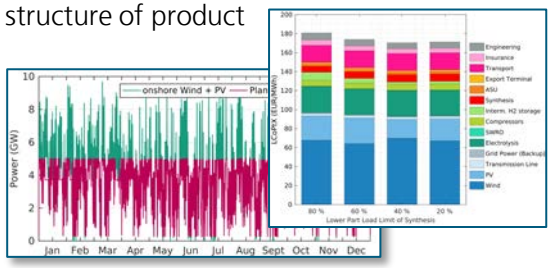
Holistic **system optimization** with the help of a genetic algorithm to minimize costs.

Dynamic, non-linear modelling of large-scale Power-to-X hubs.

Advanced operation management for consideration of e.g. limited part load operation of the syntheses processes.

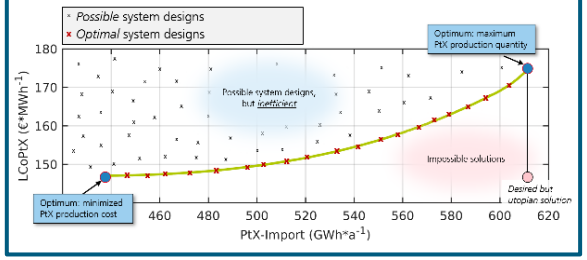


Key performance indicators: levelized costs of product (EUR/MWh; EUR/kg), production quantity, total investment costs, overall system efficiency, full load hours, water consumption, energy flows, cost structure of product



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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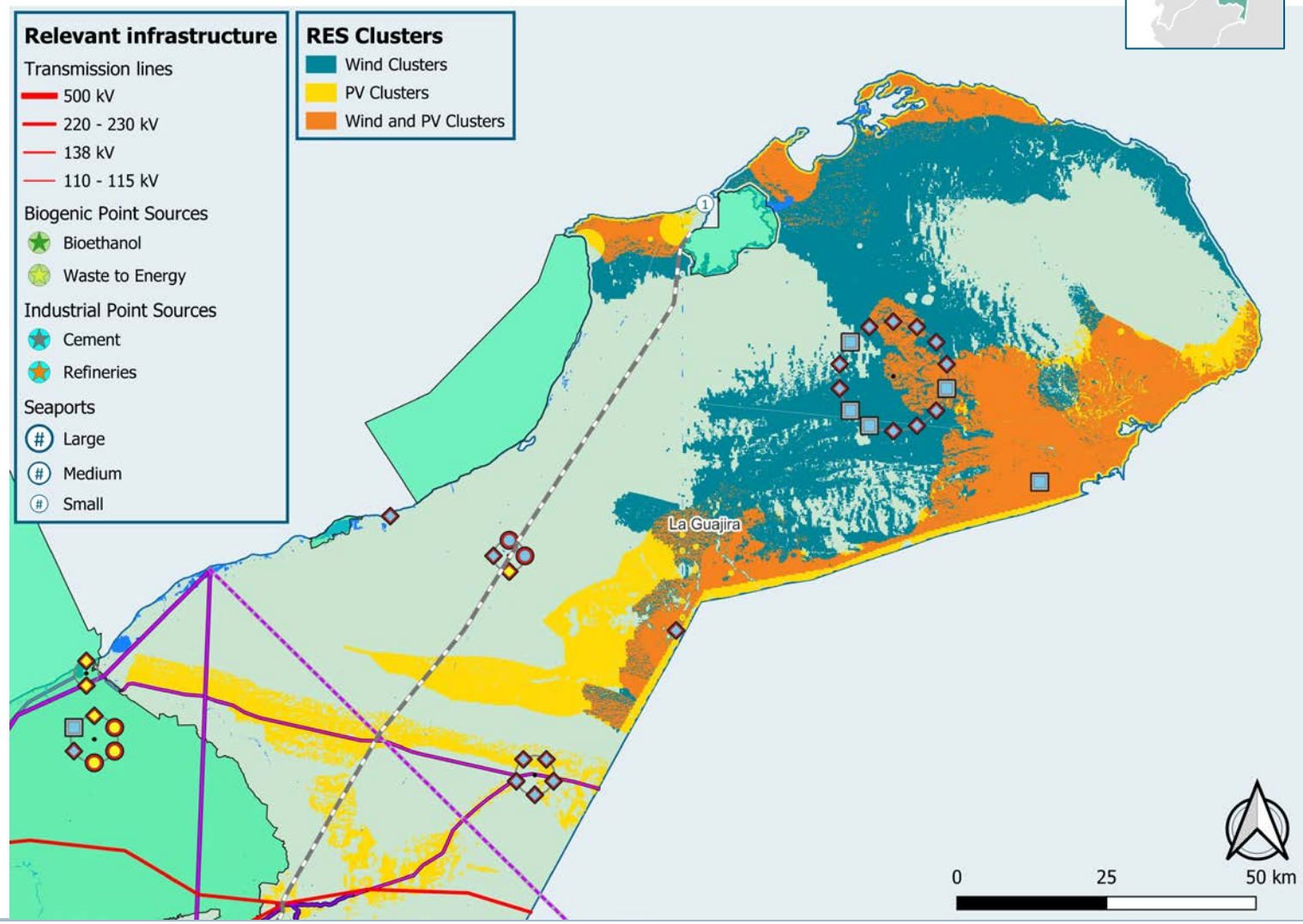
Sites and scenarios selected

Site selection

La Guajira

Suitability for RE and PtX:

- **Outstanding large-scale wind and photovoltaic clusters**
- **Sufficient free space near the port to enable a PtX hub** for ammonia, methanol and liquid hydrogen
- **Water scarcity** results in the use of seawater desalination as primary water source (access to non-protected coast; overdimensioning could enhance the local water supply situation)
- Significant expansion of the Port of Bolivar (1) is required to enable future ship transport of PtX products
- **RE and PtX facilities located within indigenous reserves** call for a mutually acceptable solution in regard to implementation and participation
- **Limited transmission line** and gas pipeline availability
- No local carbon point sources or PtX product offtakers available



The map features solely photovoltaic and wind initiatives that exceed 100 MW for better clarity of presentation.
The exact location of many photovoltaic and wind initiatives could not be identified.

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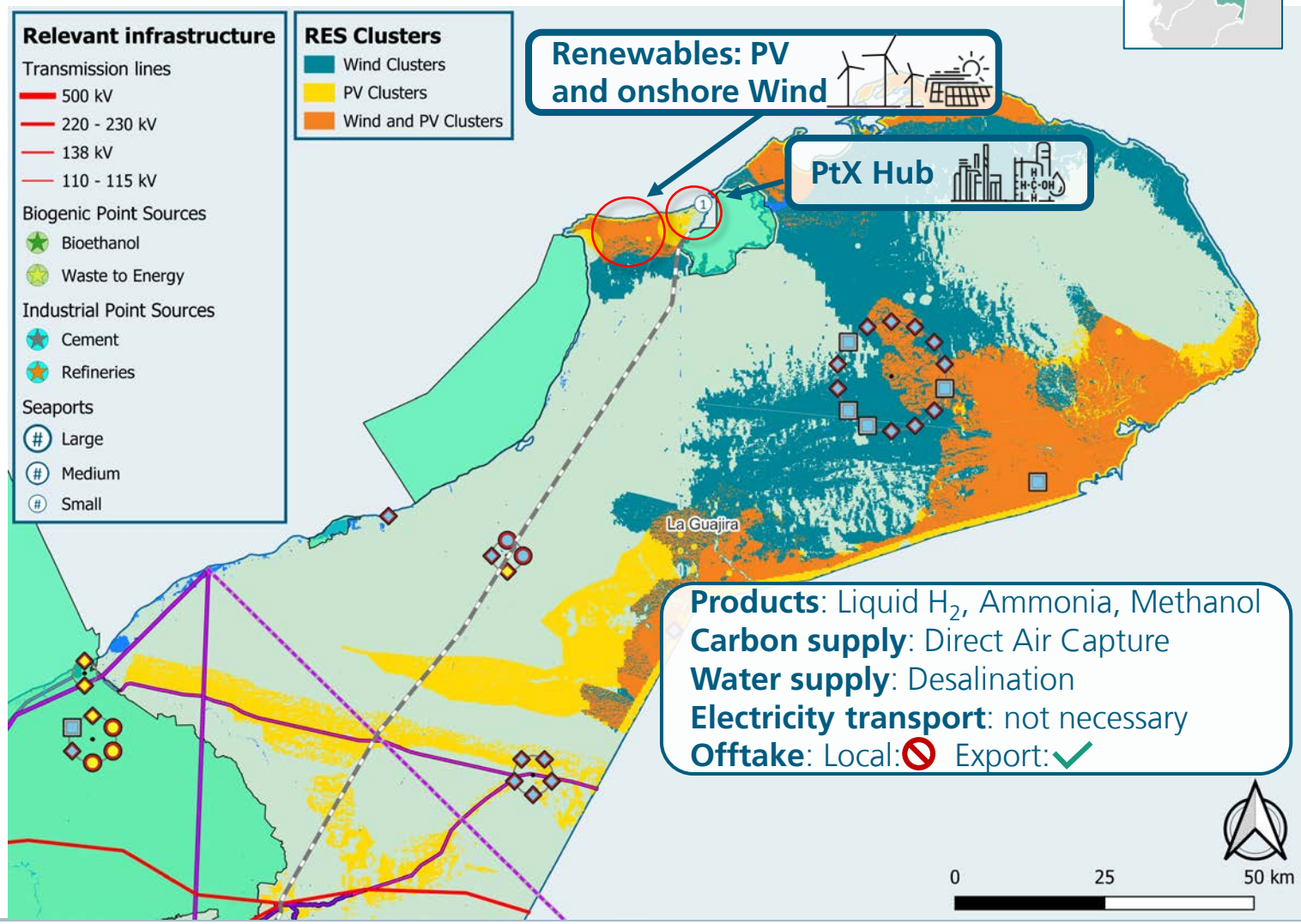
Site selection

La Guajira

Selected PtX Scenario:

- **Supply of renewable electricity via**
  - Large hybrid RE cluster located on land area west of Puerto Bolívar
- **Direct connection** between RE and PtX hub (offgrid)
- **PtX hub** location in the area of Puerto Bolívar
- **Target products**: Liquid H_2, Ammonia, Methanol
- **Carbon supply** via
  - Direct-Air-Capture
- Cost calculated for
  - Local cost of gaseous H_2 produced
  - Supply cost: incl. long-distance ship transport of LH_2, NH_3, MeOH



The map features solely photovoltaic and wind initiatives that exceed 100 MW for better clarity of presentation.
The exact location of many photovoltaic and wind initiatives could not be identified.

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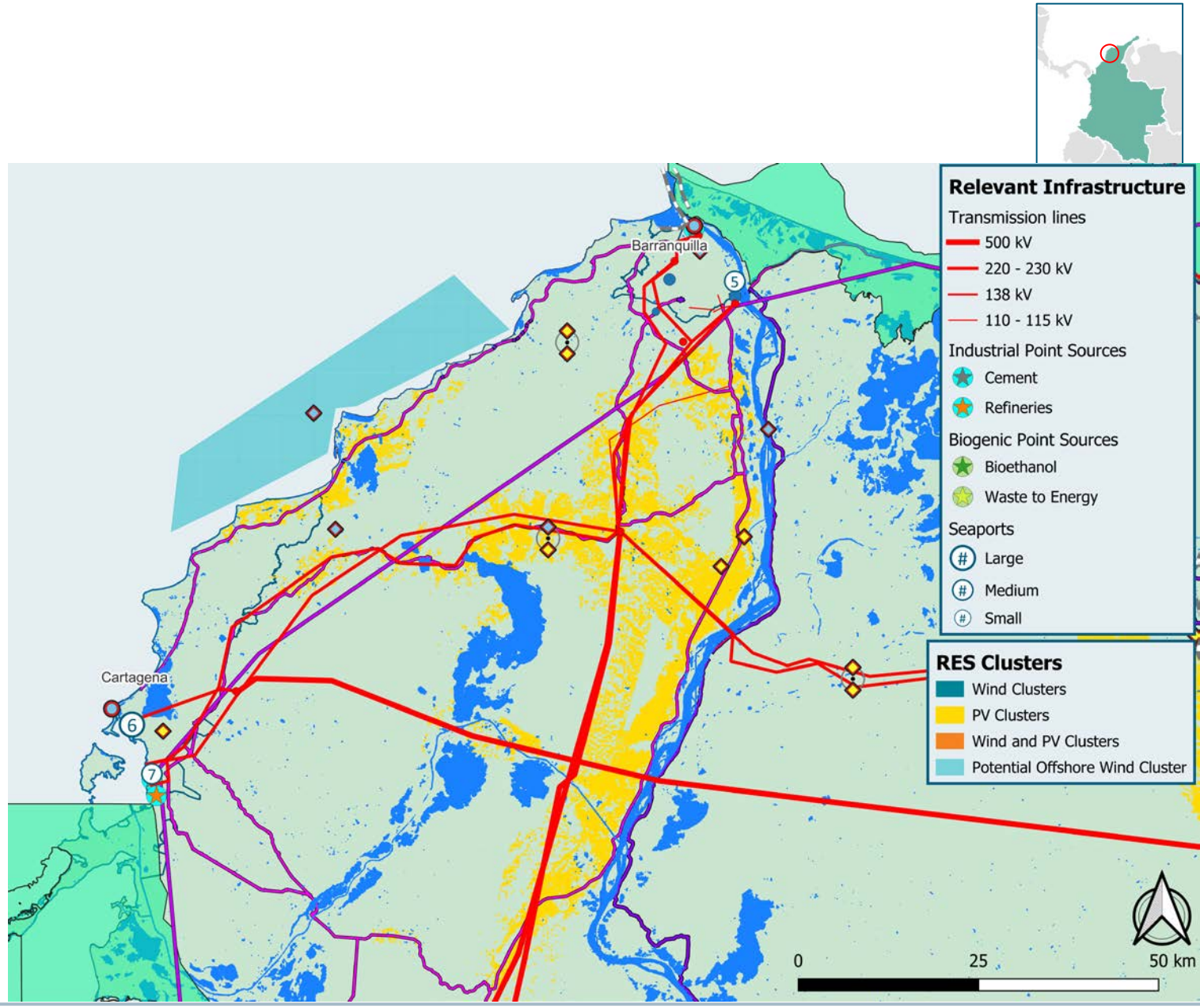
Site selection

Cartagena and Barranquilla

Suitability for RE and PtX:

- ⊕ **Large-scale** photovoltaic clusters available
- ⊕ **Decent port infrastructures** in Cartagena (6) and Barranquilla (5) including existing methanol and ammonia terminals
- ⊕ Both ports are planning to become hydrogen export facilitites; partly represented in National Development Plan
- ⊕ **Excellent transmission line** and NG pipeline **availability**
- ⊕ Several potential industrial point sources available within refinery and cement complexes in Cartagena and Baranquilla
- ⊕ Several potential local offtakers in Cartagena with refinery, cement and fertilizer plants (ammonia, urea, nitric acid)
- ⊕ Decent water availability from various sources
- ⊖ No onshore wind cluster rendered as suitable (some areas with high wind speeds, but restricted due to natural and marine protection areas)
- ⊖ No railway connection or biogenic point source
- ✓ Extensive areas available for potential offshore wind power generation (fixed and floating) - however, these must first be tendered, developed and financed in the coming years.



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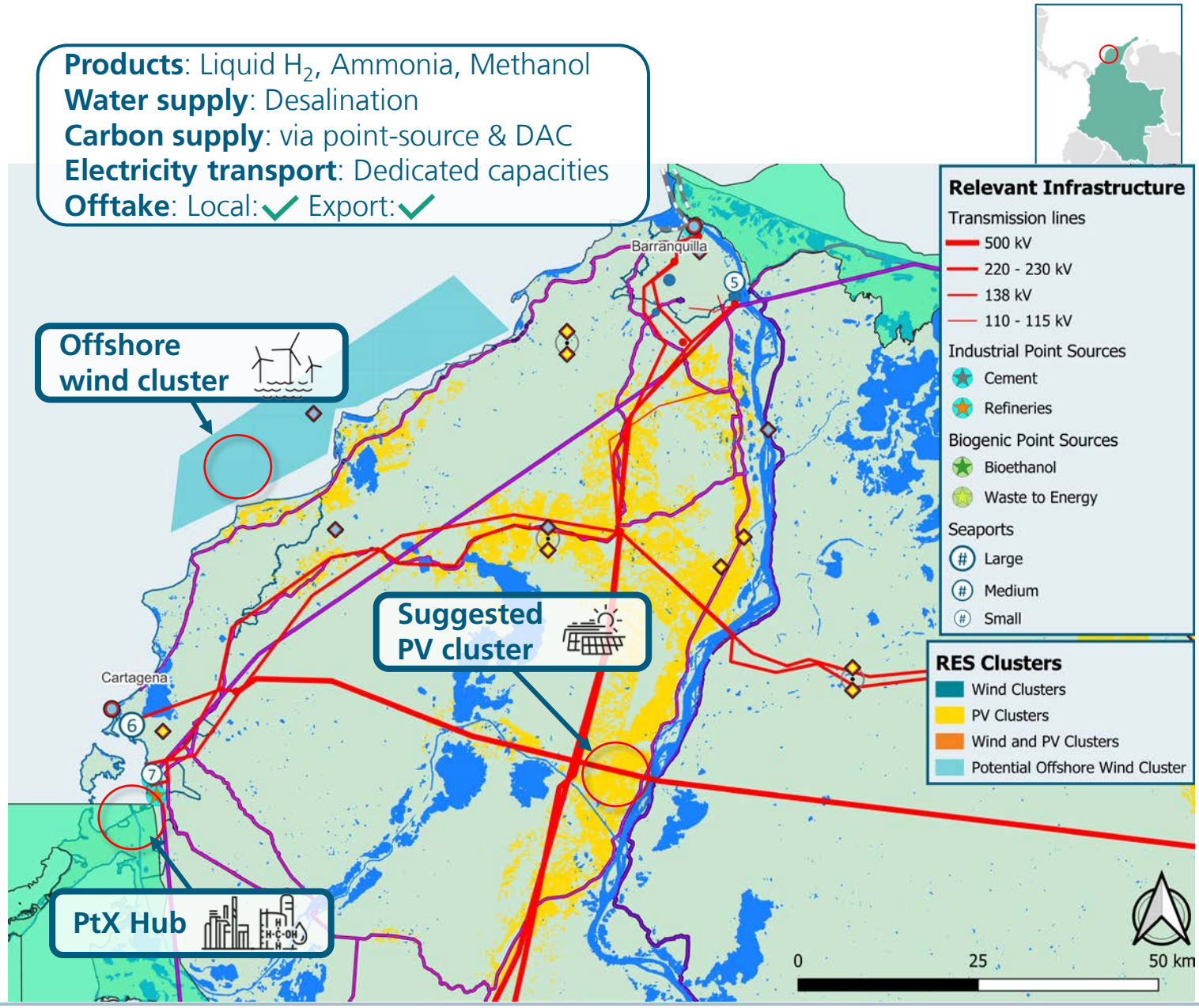
Site selection

Cartagena and Barranquilla

Products: Liquid H_2, Ammonia, Methanol
Water supply: Desalination
Carbon supply: via point-source & DAC
Electricity transport: Dedicated capacities
Offtake: Local: ✓ Export: ✓

Selected PtX Scenario:

- Supply of renewable electricity via
  - PV cluster: east of Cartagena
  - Offshore wind: north of Cartagena; non-floating; area as identified by Minenergia offshore report
- Surplus renewable electricity: free feed-in to grid
- Transport of electricity to PtX hub via dedicated grid capacities (considered in costs)
- PtX hub location in the area of Puerto Bahia or within petrochemical complex in the Mamoral/Casablanca zone
- Target products: Liquid H_2, Ammonia, Methanol
- Carbon supply via
  - Point-source: e.g. Cement facility of Cementos Argos with sufficient direct CO2 emissions (2.1 Mt CO2/a)
  - Direct-Air-Capture
- Water supply via desalination of seawater; no protected coastal regions nearby
- Cost calculated for
  - Local cost: Gaseous H_2, liquid H_2, Ammonia, Methanol
  - Supply cost: incl. long-distance ship transport



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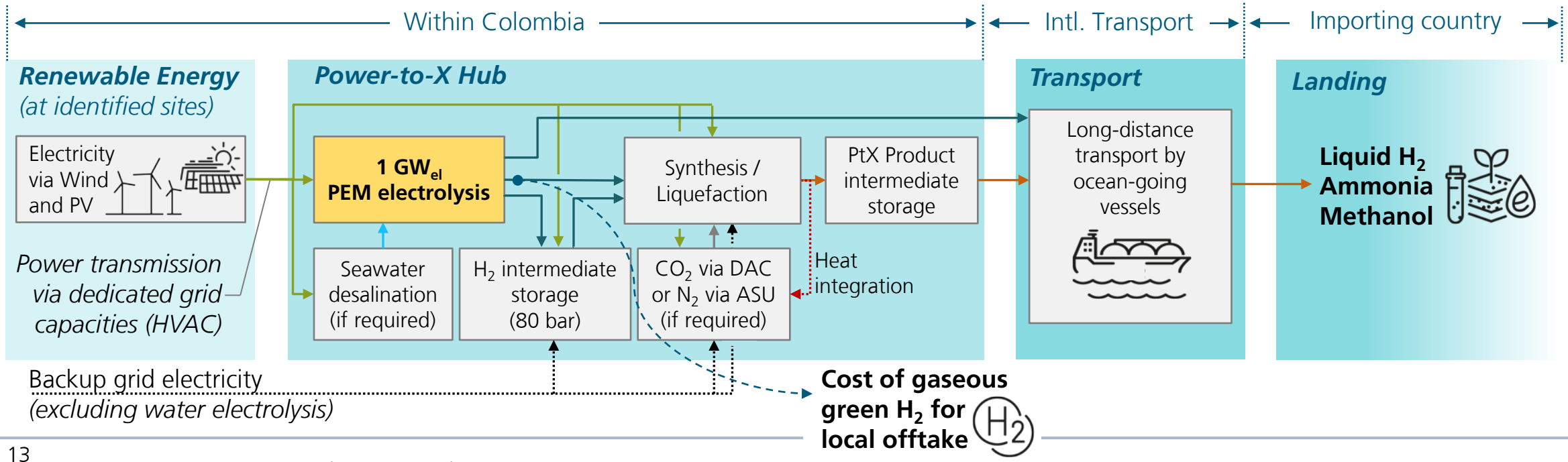
Technical and economic design of the Power-to-X chains

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

General Layout of the PtX systems

- **Dynamic simulation, optimization and design** of the overall PtX chains (1 GW Electrolysis as fixed parameter)
- Based on **hourly resolved renewable load profiles** (based on satellite data)
- No use of existing hydropower - solely consideration of **dedicated (newly installed) wind and PV parks**



Annuity Methodology for determination of LCOPtX
Depreciation over technical component lifetime
WACC assumed: 8 %

Technology Parameters

Overview of selected components

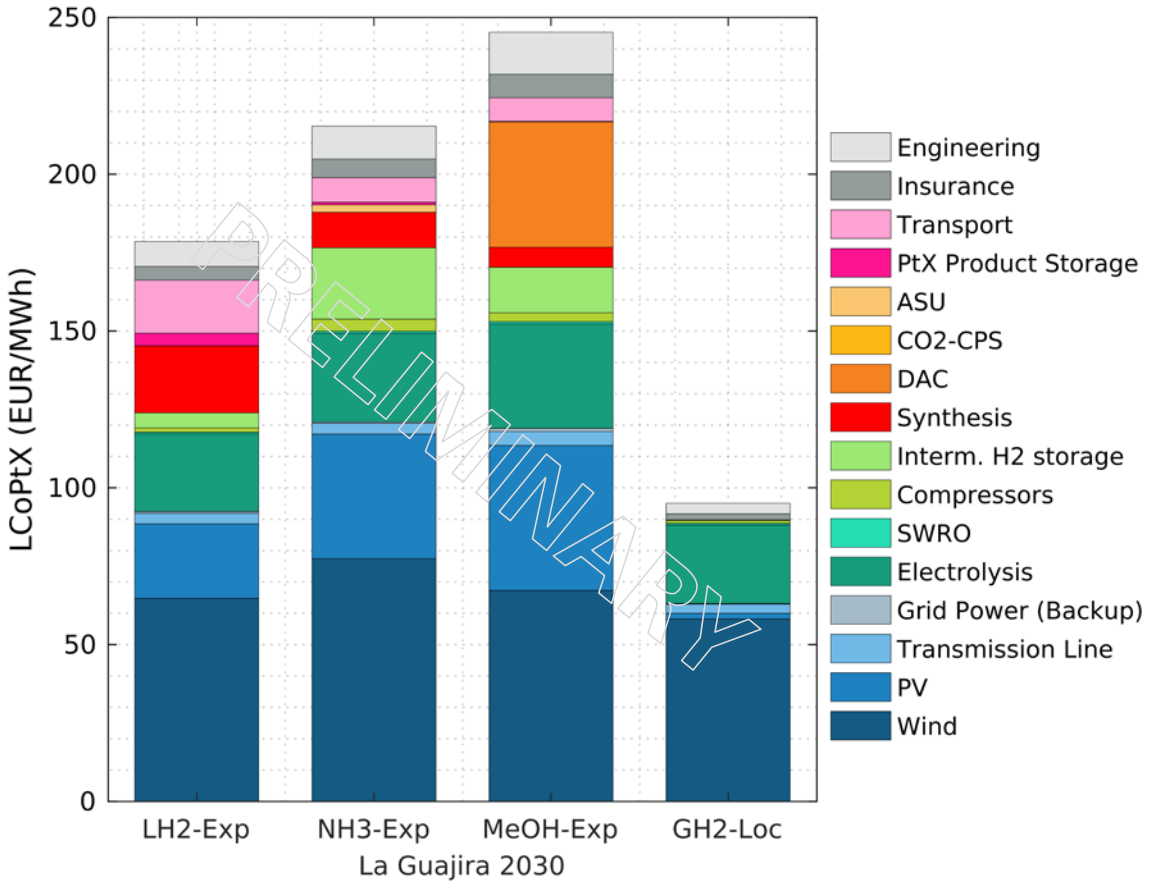
	Type	CAPEX	OPEX (fix)	Lifetime [years]	Operational Parameters	Energy Demand	Min. Part Load [% of RC*]	Feed/Losses
Wind	Onshore	2030: 1300 EUR/kW 2040: 1040 EUR/kW	0.015 EUR/kWh	25	-	-	-	-
	Offshore	2030: 2000 EUR/kW 2040: 1600 EUR/kW	0.030 EUR/kWh	25	-	-	-	-
PV	Fixed tilt	2030: 600 EUR/kW 2040: 450 EUR/kW	13 EUR/kW/a	30	-	-	-	-
Desalination	Seawater reverse osmosis	1640 EUR/(m3/d)	128 EUR/(m3/d)/a	30	-	3.6 kWh_{el}/Nm^3	-	-
Electrolysis	PEM water electrolysis	2030: 750 EUR/kW_{AC} 2040: 500 EUR/kW	15 EUR/kW_{AC}/a	System 30 Stacks: 2030: 70k h 2040: 85k h	H2,out at 30 bar	52.0 kWhel/kg H2	10 %	-
H2 Intermediate Storage	Pressure storage (tubular cylinders)	330 EUR/kg gross	1% of CAPEX/a	30	Pressure range 10-80 bar	-	-	-
H2 Liquefaction	Cryogenic multi-stage	Size dependent cost function	4% of CAPEX/a	30		2030: 9.4 and 2040: 6.0 kWh_{el}/kg	2030: 25% 2040: 25%	1.65% losses as boil-off
Ammonia Synthesis	Haber-Bosch w/o syngas production	Size dependent cost function	4% of CAPEX/a	30	250 bar 550°C	0.0087 $kWh_{el}/kg\,NH_3$	2030: 80% 2040: 60%	Feed per kg NH3: 0.180 kg H2 0.833 kg N2
Methanol Synthesis	CO2 based	Size dependent cost function	4% of CAPEX/a	30	70 bar 255-270°C	0.18 kWh_{el}/kg MeOH	2030: 60% 2040: 40%	Feed per kg MeOH: 0.195 kg H2 1.426 kg CO2
CO2 Sourcing	DAC via low-temperature vacuum swing adsorption	2030: 1000 EUR/(t*a) 2040: 300 EUR/(t*a)	4% of CAPEX/a	20	Atmospheric pressure ~100°C	0.50 kWh_{el}/kg CO2 1.81 kWh_{th}/kg CO2 (heat integration from synthesis will enable further reduction)	-	-

* RC= Rated Capacity

Selected Results

Levelized Costs of PtX products in the cost optimum – La Guajira (2030)

- **Wind and PV** have the highest share in total costs: around 40-50 % of final costs are related to the power supply
  - Availability of both technologies key for low cost PtX
- **Electrolysis** as the second largest contributor to total cost
  - Reduction of Capex and efficiency improvements with high influence on cost reduction potential
- Limited part load capability of **synthesis** process increase demand for H_2 buffer and RE overcapacity
  - LH_2 production benefits from larger operation window
  - Improvements of operation window reduces costs
- **CO_2 sourcing** for methanol production via DAC with significant contribution to total cost
  - Strong cost reduction for DAC from 2030 to 2040
- Gaseous hydrogen production (without transport, storage, etc.) as reference



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Selected Results

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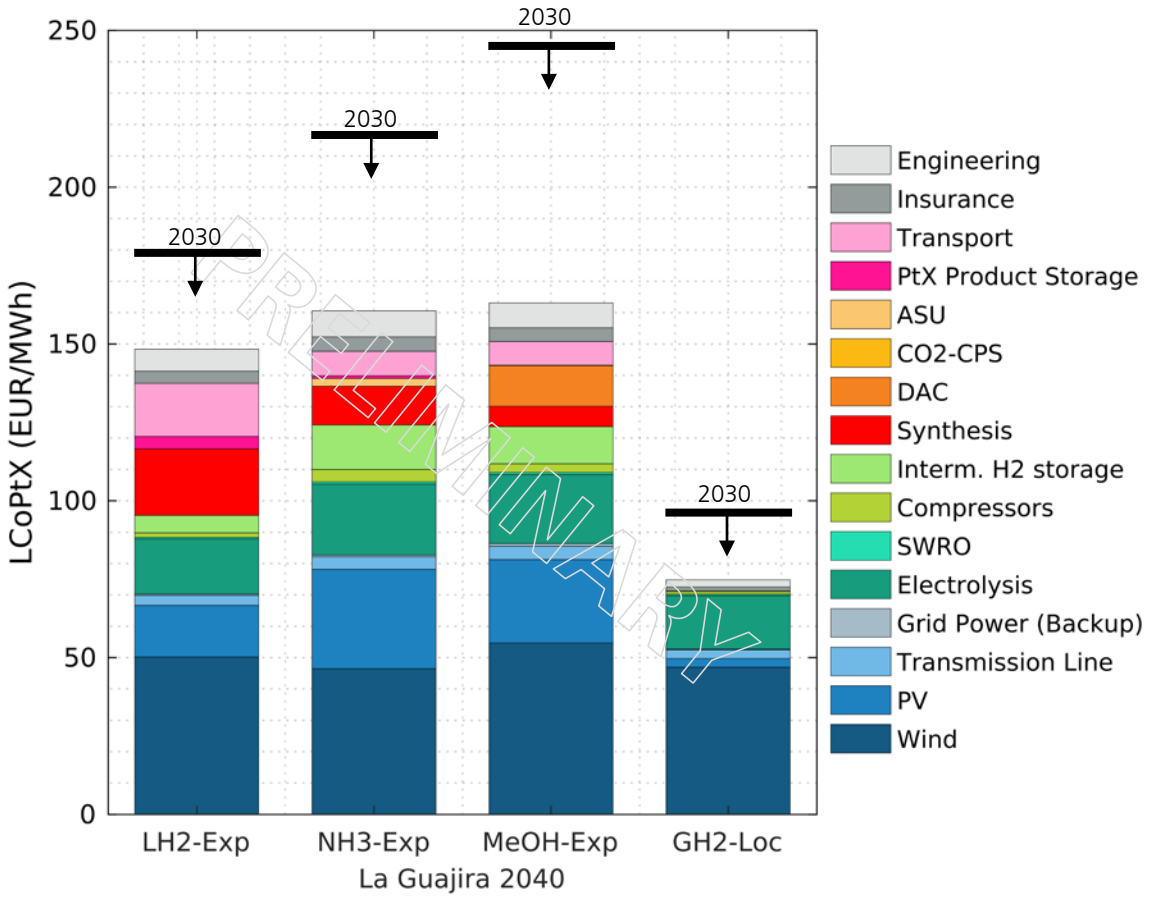
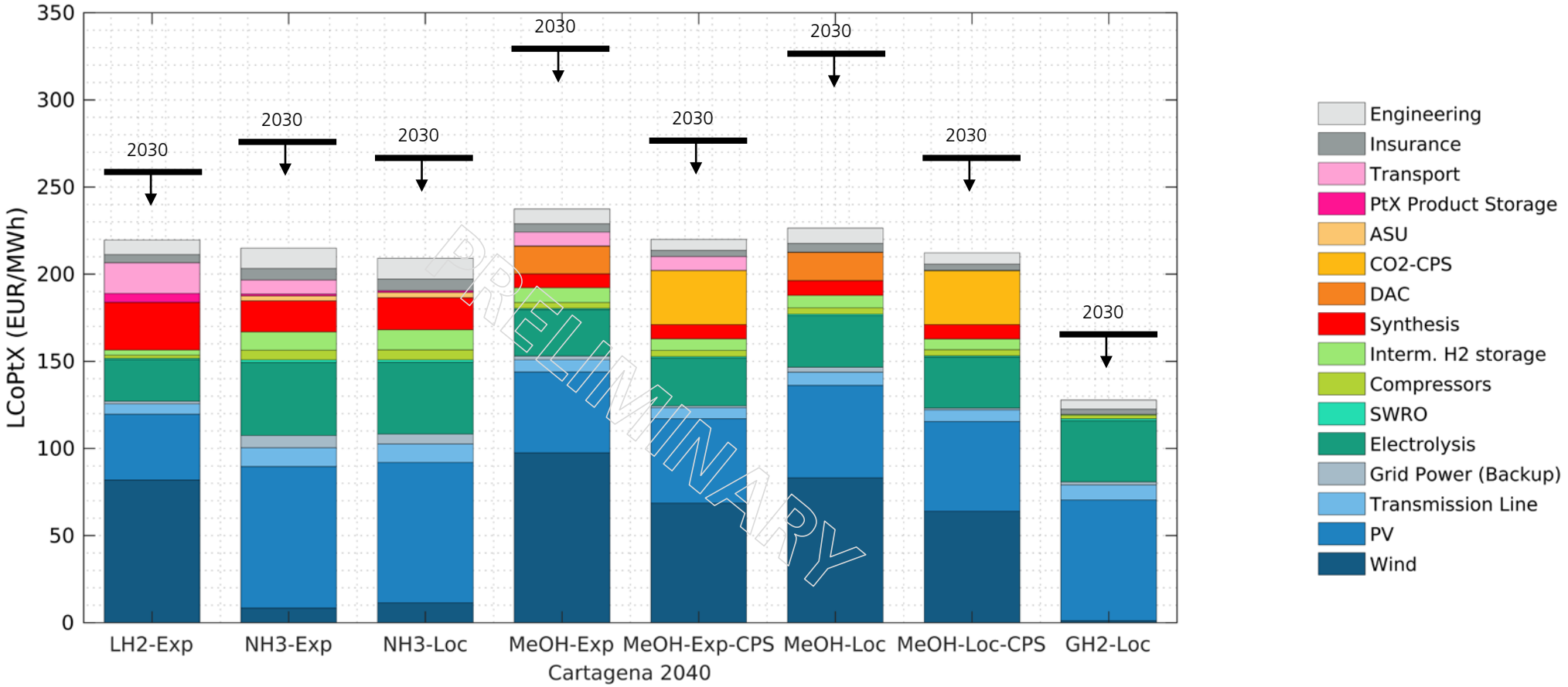


Annuity Methodology for determination of LCOPtX
Depreciation over technical component lifetime
WACC assumed: 8 %

Selected Results

Levelized Costs of PtX products in the cost optimum – Cartagena (2040)



Annuity Methodology for determination of LCOPtX
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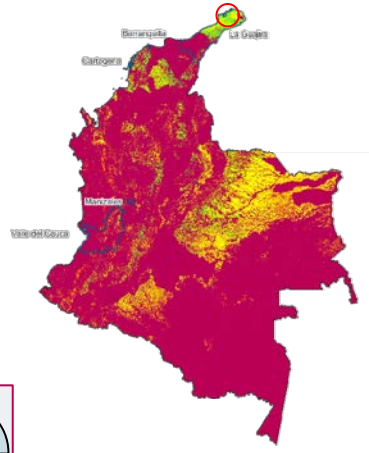
WACC assumed: 8 %

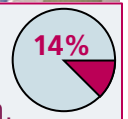
Selected Results

Capacities and necess

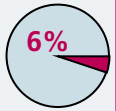
The example of a
2030 Green Ammonia
production in La Guajira



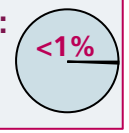
Electrolysis:
Installed cap.: 1 GW_{el}
CAPEX : EUR 0.75 bn.
Full load hours: 4800 h/yr (60% CF)



Haber-Bosch synthesis:
Installed cap.: 750 kt/yr
Output: 723 kt/yr
CAPEX : EUR 0.33 bn.



NH_3 intermediate storage:
Size: 30 000 m³
CAPEX : EUR 0.03 bn.



Renewable Energy

Onshore
Wind and PV

Power-to-X Hub

PEM Electrolysis
1GW_{el}

Haber-Bosch

NH_3 intermediate storage

Water supply via grid

H_2 intermediate storage (80 bar)

N_2 via ASU

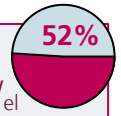
Transport

Long-distance transport via ships

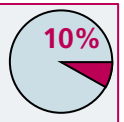
Green Ammonia

Supply cost: 215 EUR/MWh
1110 EUR/ton
Import of: 723 kt/yr
3.7 TWh/yr
Total Invest.: EUR 6.1 bn

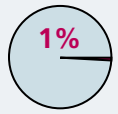
Wind and PV:
Installed cap. Wind / PV: 1.5 / 2.2 GW_{el}
CAPEX Wind+PV: EUR 3.2 bn.



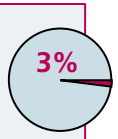
H_2 storage:
Size: 433 000 m³
CAPEX : EUR 0.9 bn.



Air Separation Unit:
Installed cap.: 648 kt/yr
CAPEX : EUR 0.8 bn.



Ship transport: LPG Carrier
Ship size: 84 000 m³
CAPEX : EUR 0.1 bn.
Distance: 8560 km



Contribution to total supply cost

Next finalizing steps

- Sensitivity analyses and sub-scenarios for all locations
- Summarizing report containing all technical and economic parameters and key performance indicators
- 6th March: Final Event, Bogóta
- 9th-11th April: 3rd International Hydrogen Congress, Bogóta

Thank you for your kind attention

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Christoph Hank, Marius Holst, Lucas Edenhofer
Hydrogen and PtX Technologies

christoph.hank@ise.fraunhofer.de
marius.holst@ise.fraunhofer.de
Fraunhofer Institute for Solar Energy Systems ISE
79110 Freiburg, Germany
www.ise.fraunhofer.de