HOW TO ACCELERATE TOWARDS 100% RENEWABLE ENERGY

Dii
Renewable energy
bridging continents

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Fraunhofer Institute for Solar Energy Systems ISE

11th annual Desert Energy Leadership Summit

11.11. 2021 W Dubai The Palm, UAE

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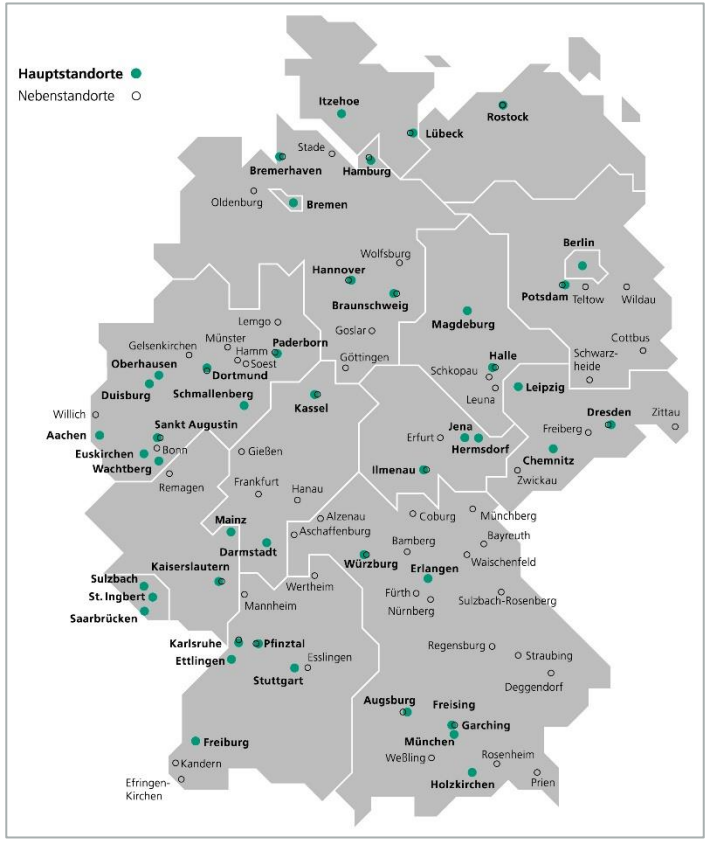
Fraunhofer-Gesellschaft for Applied Research in Germany

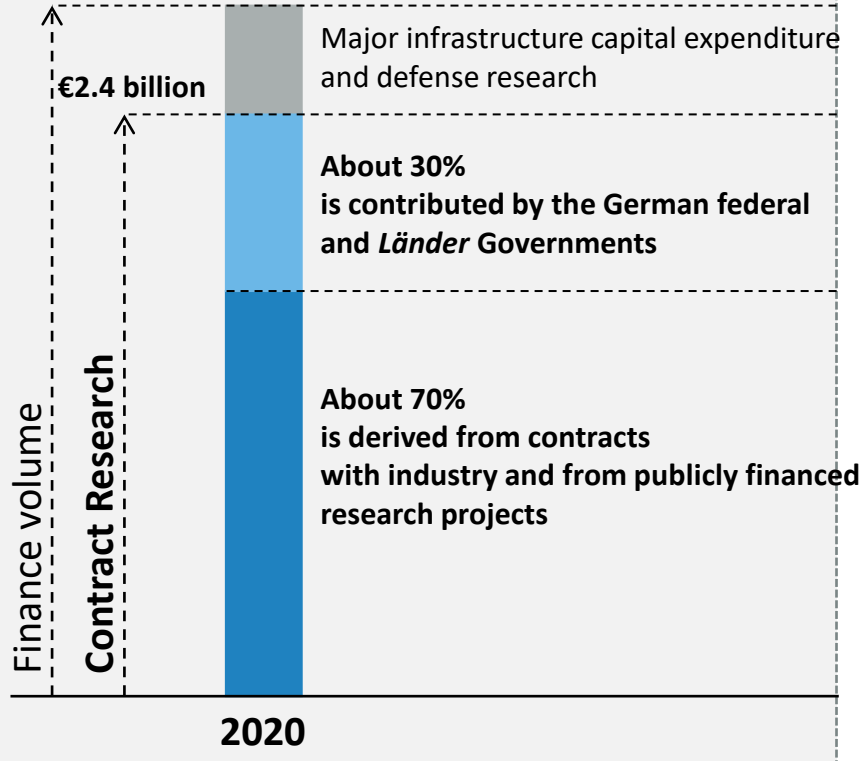
Key technologies and innovations that are vital for the future of the society

75 Fraunhofer Institutes and research institutions
(6/2021)

29,000 staff
(6/2021)



€ 2.8 billion research budget



Applied research is the foundation of our organization.
We partner with companies to transform original ideas into innovations.

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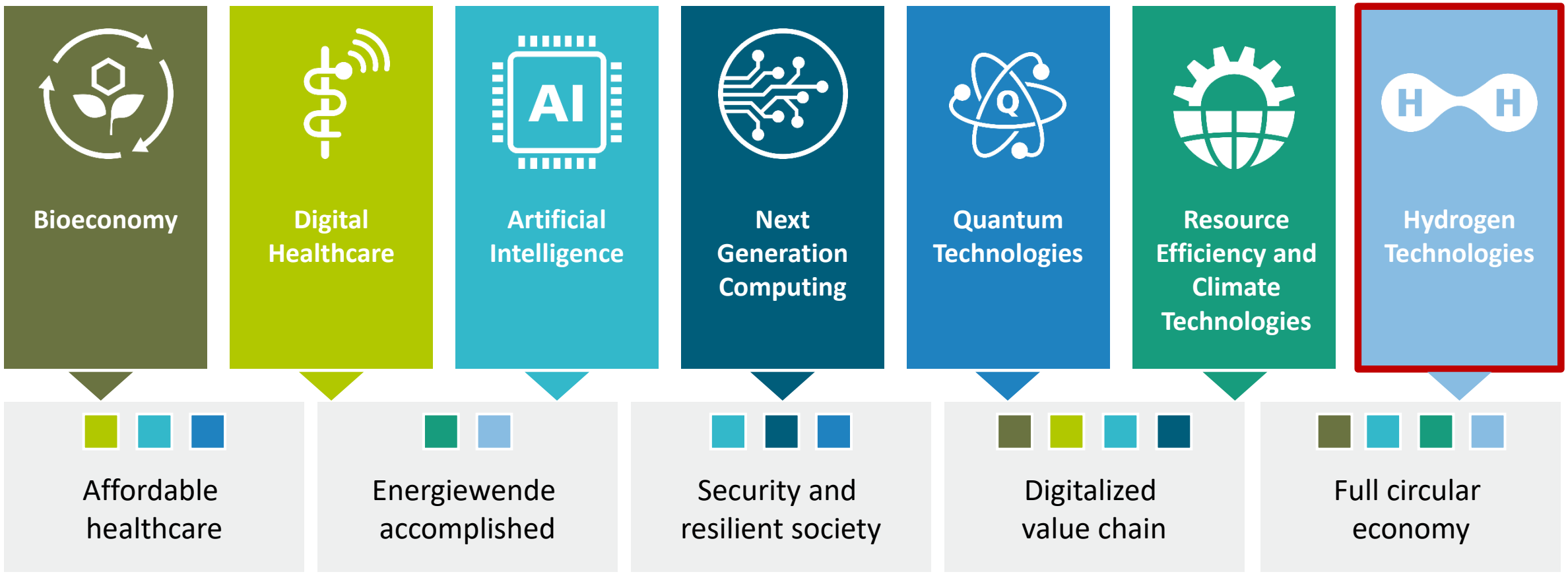
Fraunhofer Strategic Research Fields of Highest Priority



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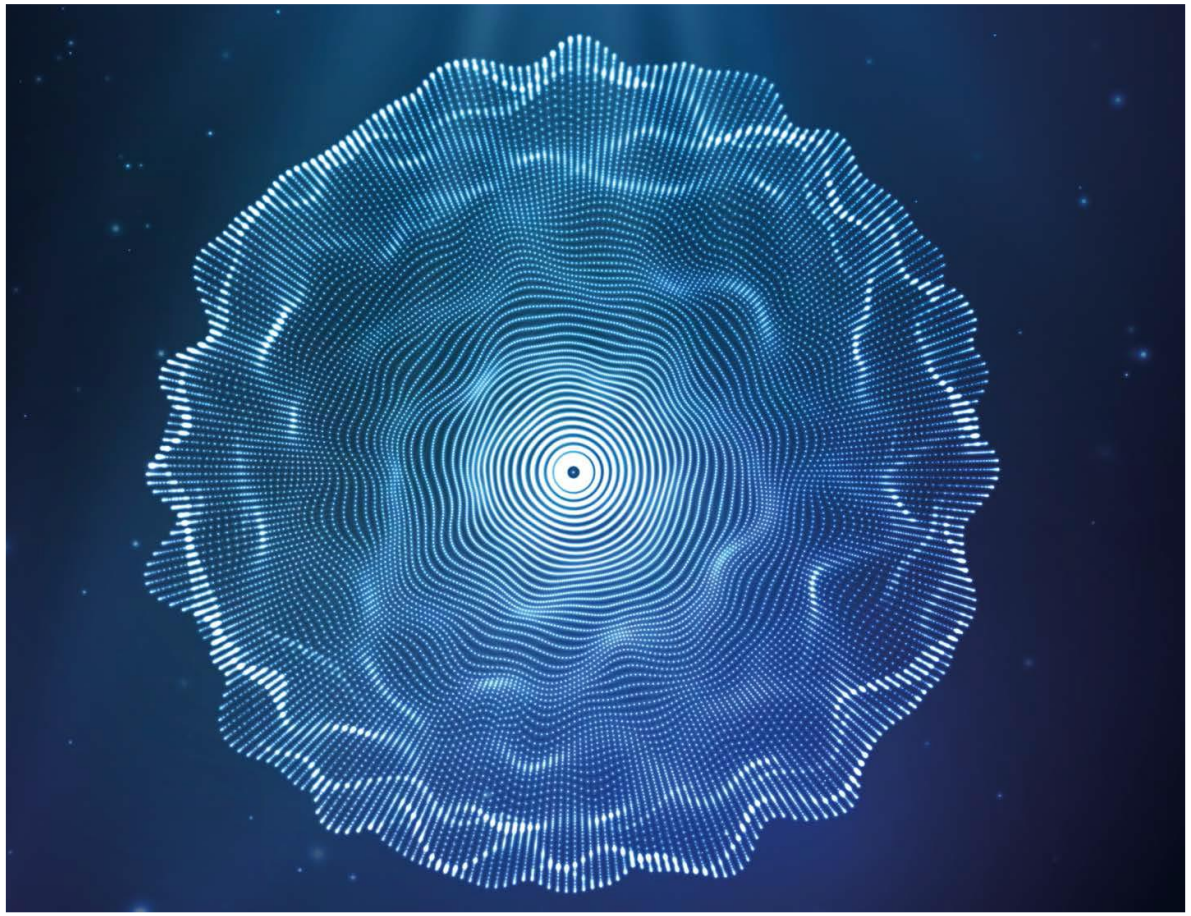
The Paradigm Shift

The fight against Climate Change…

- **Global commitment to the defossilization of the global energy system**

- **Net-Zero Emissions Race** with **Nationally Determined Contributions** (NDCs) are a cornerstone of the Paris Agreement:
  110 states in **„Net Zero-Emissions Race“**
  - in law
  - proposed legislation
  - in policy document
  - target under discussion



The Backbone of the Future Energy System: Renewable Energy

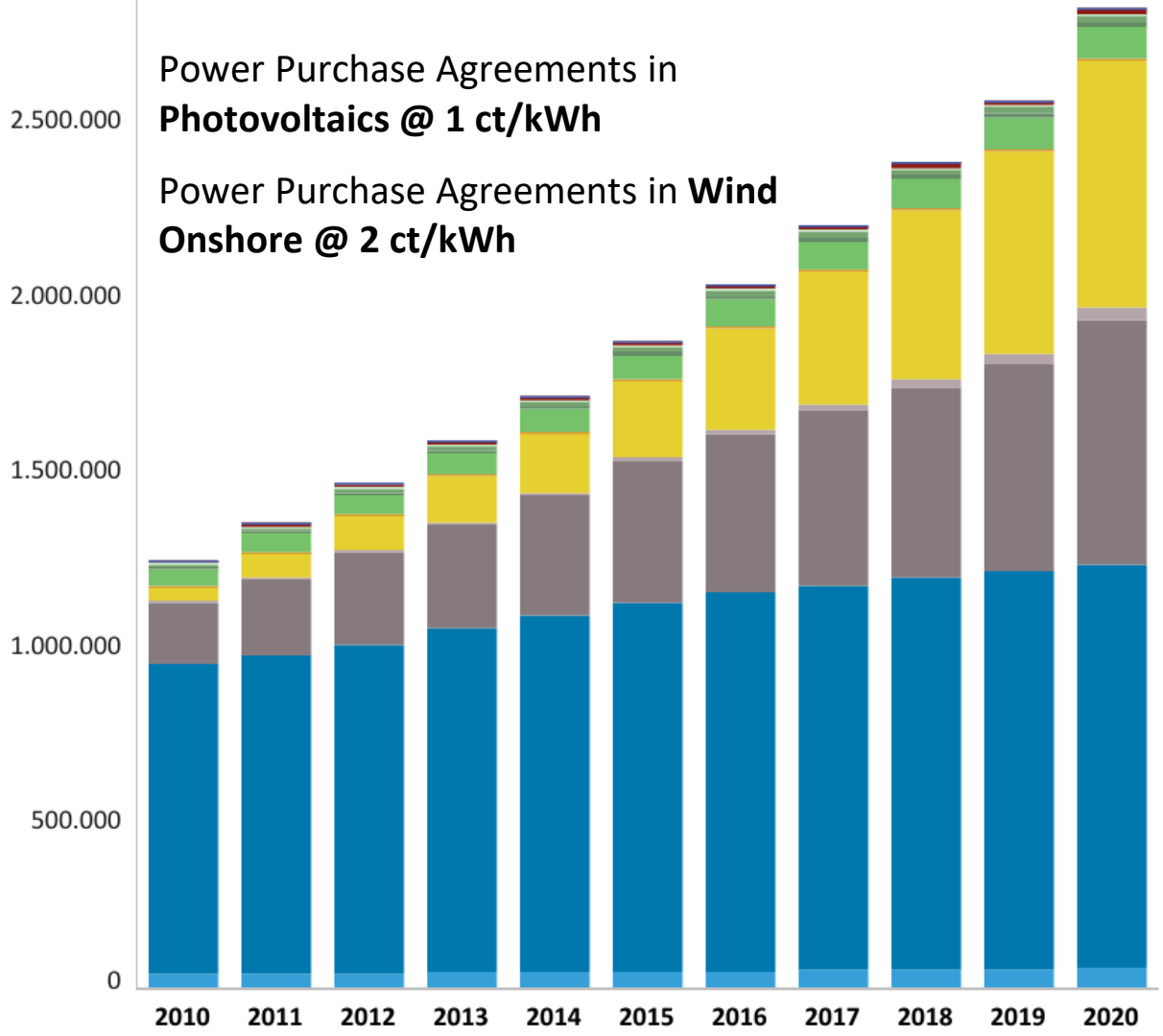
Global Wind and Photovoltaic Installations at 1.5 TW Total Capacity

Renewables in 2020:

2789 GW Global Renewable Generation Capacity:

- 756 GW Wind
- 707 GW Photovoltaics
- 1215 GW Hydro
- 111 GW Bioenergy

- **260 GW new renewable capacity in 2020**
- 80% of all new electricity capacity in renewables
- 91% of new renewables in Solar and Wind



Source: IRENA, 2020, http://resourceirena.irena.org/gateway/dashboard/

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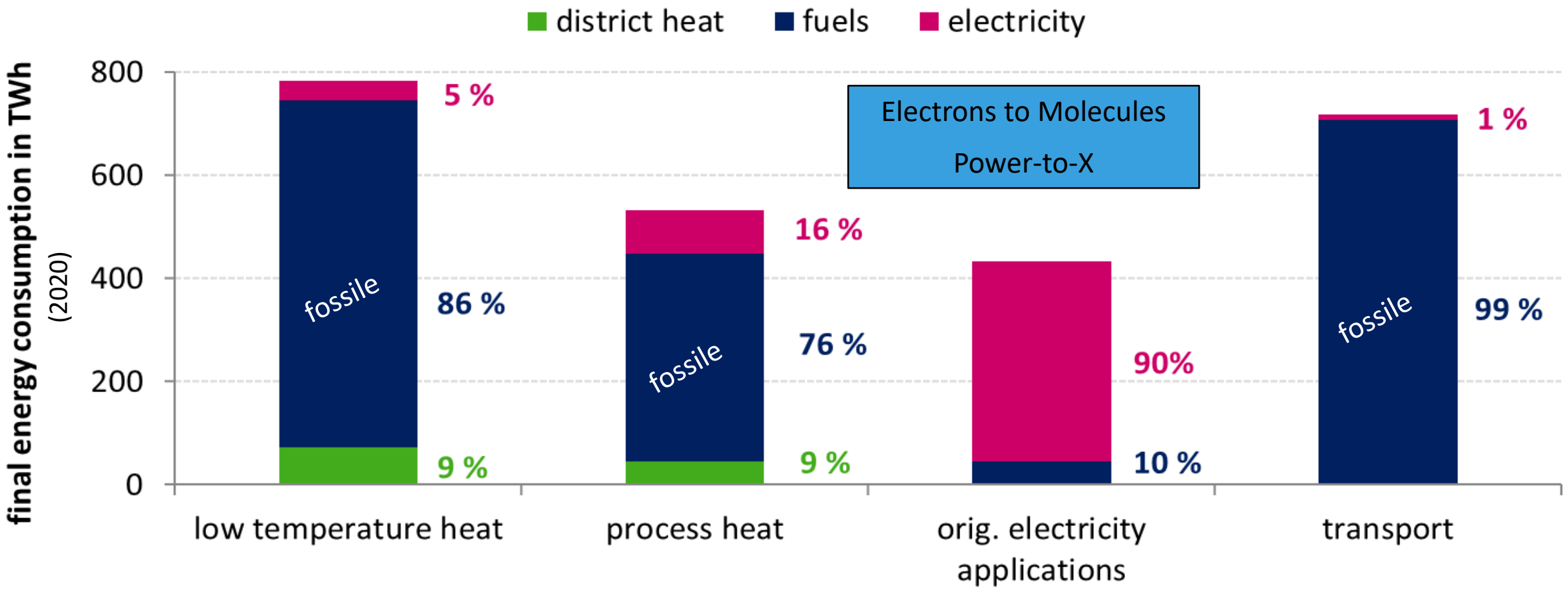
The Contribution of Hydrogen towards Climate Neutrality

»Sector Coupling« – The Next Phase of the Energy System Transformation



Datasource: „Zahlen und Fakten: Energiedaten", BMWi, 23.10.2020.

acatech DEUTSCHE AKADEMIE DER TECHNIKWISSENSCHAFTEN
UNION DER DEUTSCHEN AKADEMIEN DER WISSENSCHAFTEN
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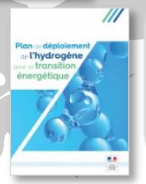
Drivers for a Global Hydrogen Economy

35 National Roadmaps, Strategy Papers, R&D Programms on Hydrogen

-Environment
(Paris Agreement)
-Economy, Industry, Export
-Flexible Energy System
-Air Quality

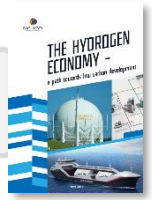
-Economy, Industry
-Import-Independence
-Air Quality
-Environment



-Industry
-CO2-Neutrality
-GHG-Reduction
-Flexible Energy System

-Environment (RED II)
-Industry
-Export
-Economy and Industry
-H2-Production
-Environment

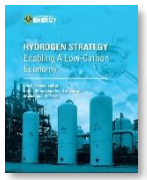
-Economy and
Industry



-Environment
Economic Growth

-Prosperity, Growth
-Industry
-Air Quality
-CO2-Reduction
-Supply Security
-Export

-Economy and Industry
-Self Sufficiency
-GHG-Reduction
-Air Quality



-Economic Growth
-Export
-Independence / Self
Sufficiency
-Environment
-Supply Security in isolate
areas

-Environment
-Economy and
Industry
-Efficiency
-Import

-Economic Growth
-Import (North Africa)
-European Green Deal
(GHG-Reduction,
Climate Neutrality)
-Supply Security

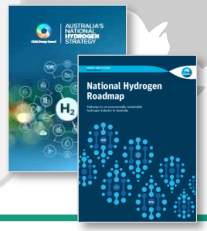
-Air Quality
-Supply Security
-GHG-Reduction
-Industry

North Africa
-Economic Growth
-Export (Europe)
-Social Stability

-Industry
-Export
-Green Mining

-Industry
-PGM-Processing

-Economic Growth
-Export
-Import-Independence
-Health
-CO2-Reduction
-Supply Security



https://de.wikipedia.org/wiki/Datei:BlankMap-World_gray.svg

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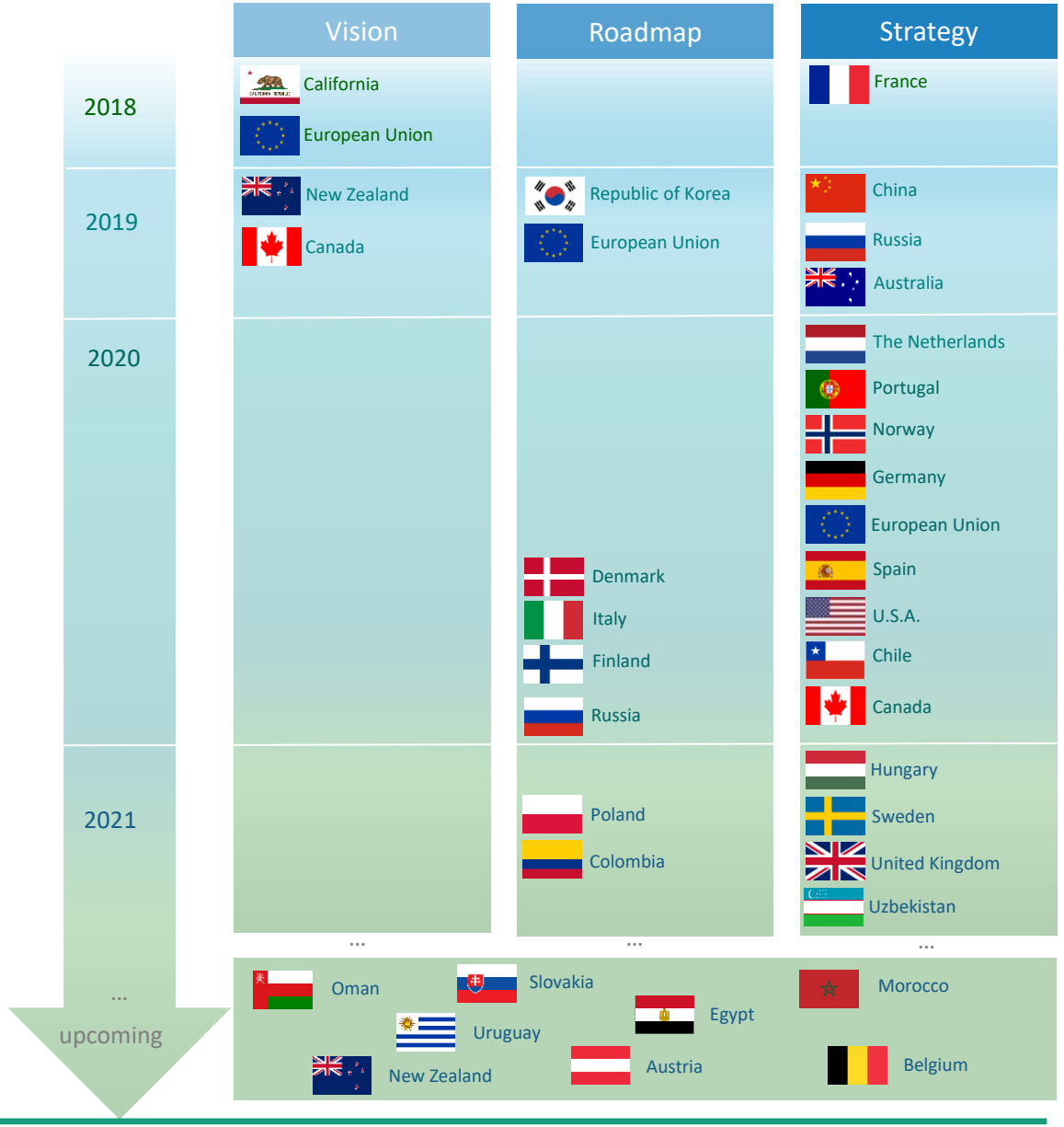
Drivers for a Global Hydrogen Economy

- States and private investors committed $ 300 bn globally for hydrogen programmes in
  - Production
  - Transport
  - Distribution
  - Applications

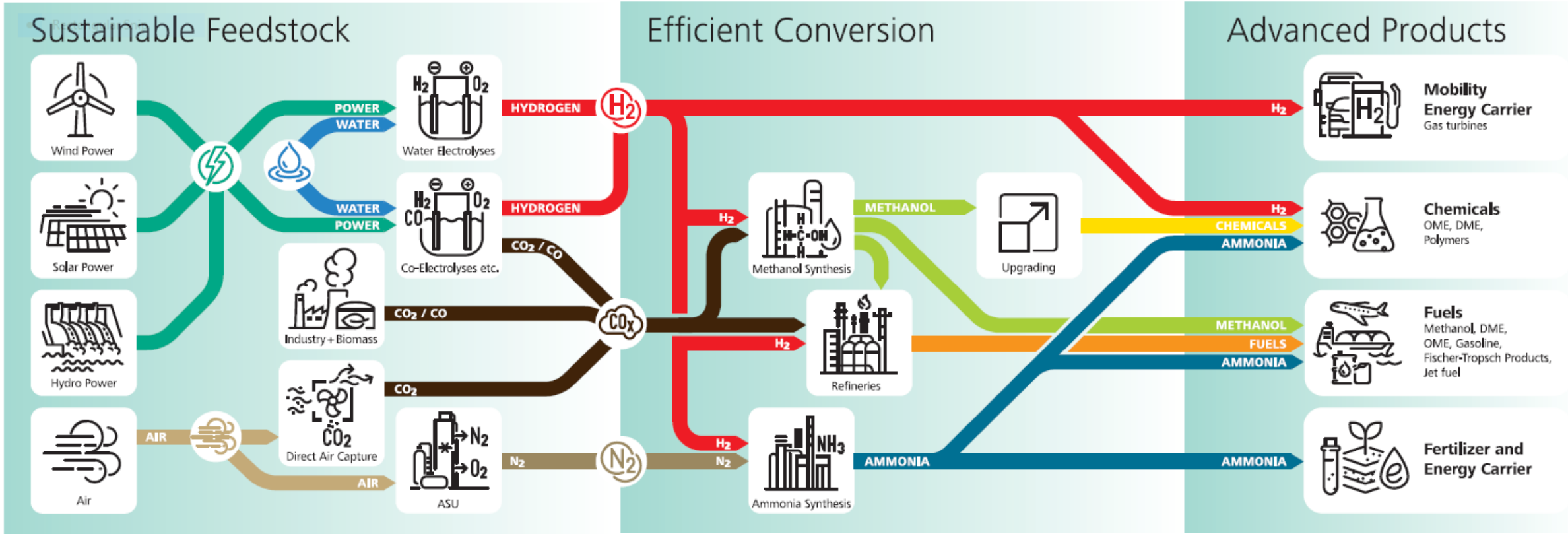
- Traceable
- Tradeable
- Transparent
- Trustworthy

} Guarantees of Origin (GO)



Sustainable Energy Carriers, Fuels and Base Molecules

The Promise: Power-to-X - H_2-based Molecules for Mobility, Industry & Chemistry



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Meta-Study Hydrogen for the National Hydrogen Council

- Meta-study included the most important **European and National System Studies**
  - Determination of the **demand ranges** for hydrogen and synthesis products
  - Elaboration of the **determinants** (assumptions that determine demand)
  - Identification of the **deficits in the studies**
  - **Evaluation and conclusion** (considering the time horizons for the important turnaround points and the corresponding need for action)

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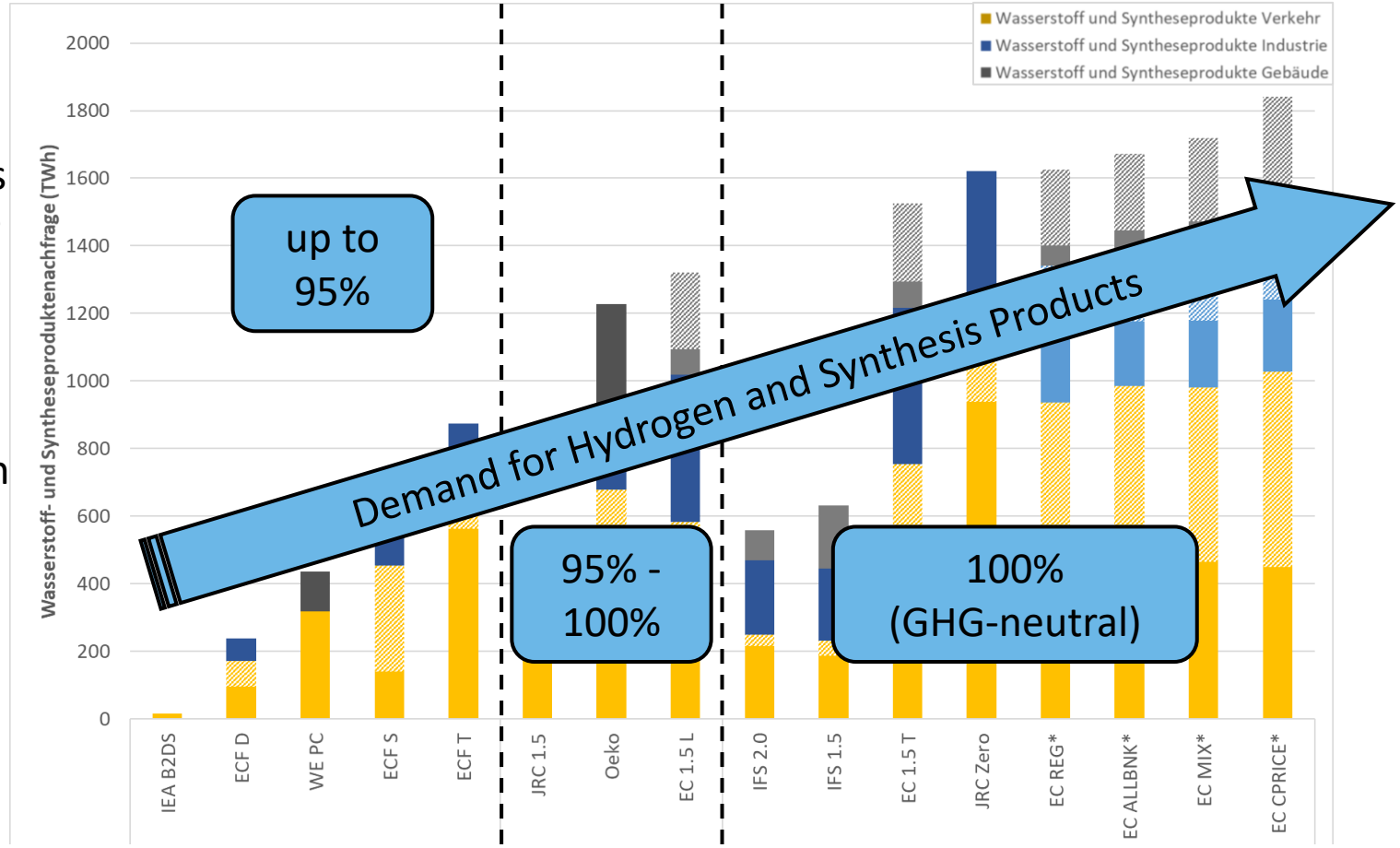
Martin Wietschel et.al.: Metastudie Wasserstoff - Auswertung von Energiesystemstudien, http://publica.fraunhofer.de/documents/N-635372.html

Meta-Study Hydrogen for Europe

Ambitious GHG Emission Reduction Targets lead to Higher Demand for Hydrogen and Synthesis Products

- Only **GHG emission targets of 90%** and higher until 2050 were considered
- **Ambitious GHG emission** reduction targets result in a clear tendency towards a **higher demand for hydrogen and synthesis products**
- **Climate neutrality in 2050** is only achievable with large amounts of hydrogen and synthesis products
  - Europe: 1500 TWh H2 and derivatives

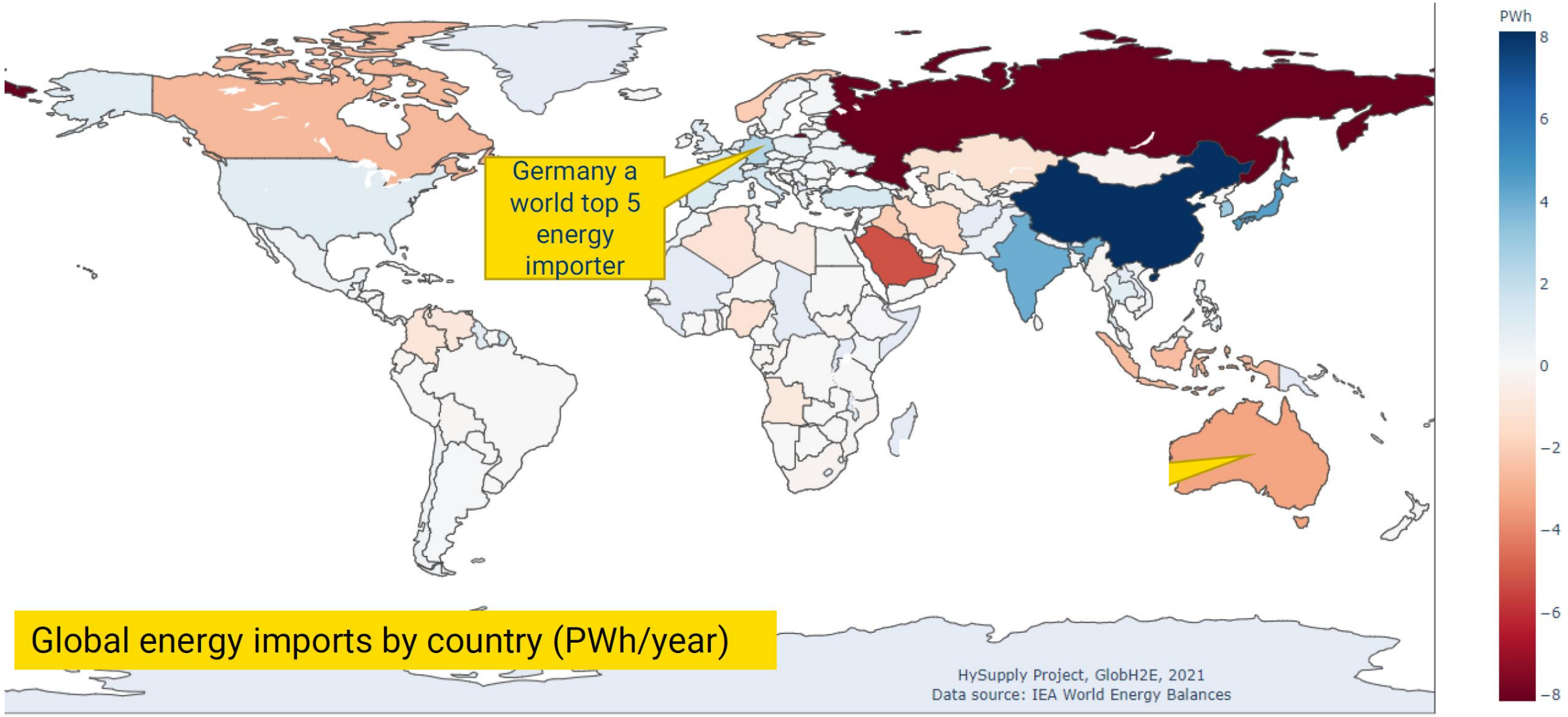
European Demand for Hydrogen and Synthesis Products in 2050



[1] Metastudie Wasserstoff

[1] Metastudie Wasserstoff – Auswertung von Energiesystemstudien, Studie im Auftrag des Nationalen Wasserstoffrats 06/2021
[2] Assumption: 4000 full-load hours of electrolyzer operation and 70% efficiency rate (1 GW electrolyzer capacity ~ 2,8 TWh hydrogen)

Current Global Energy Trade



Source: **HySupply - Australian Update** *Achema World Forum for Process Industries 2020*

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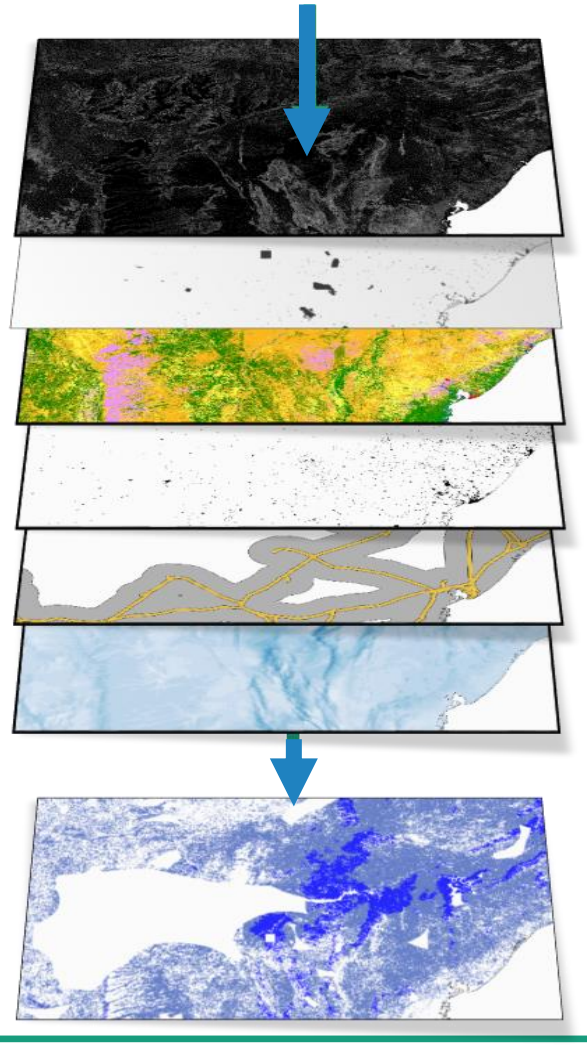
Methodology for Holistic Techno-economic Assessments at Fraunhofer ISE

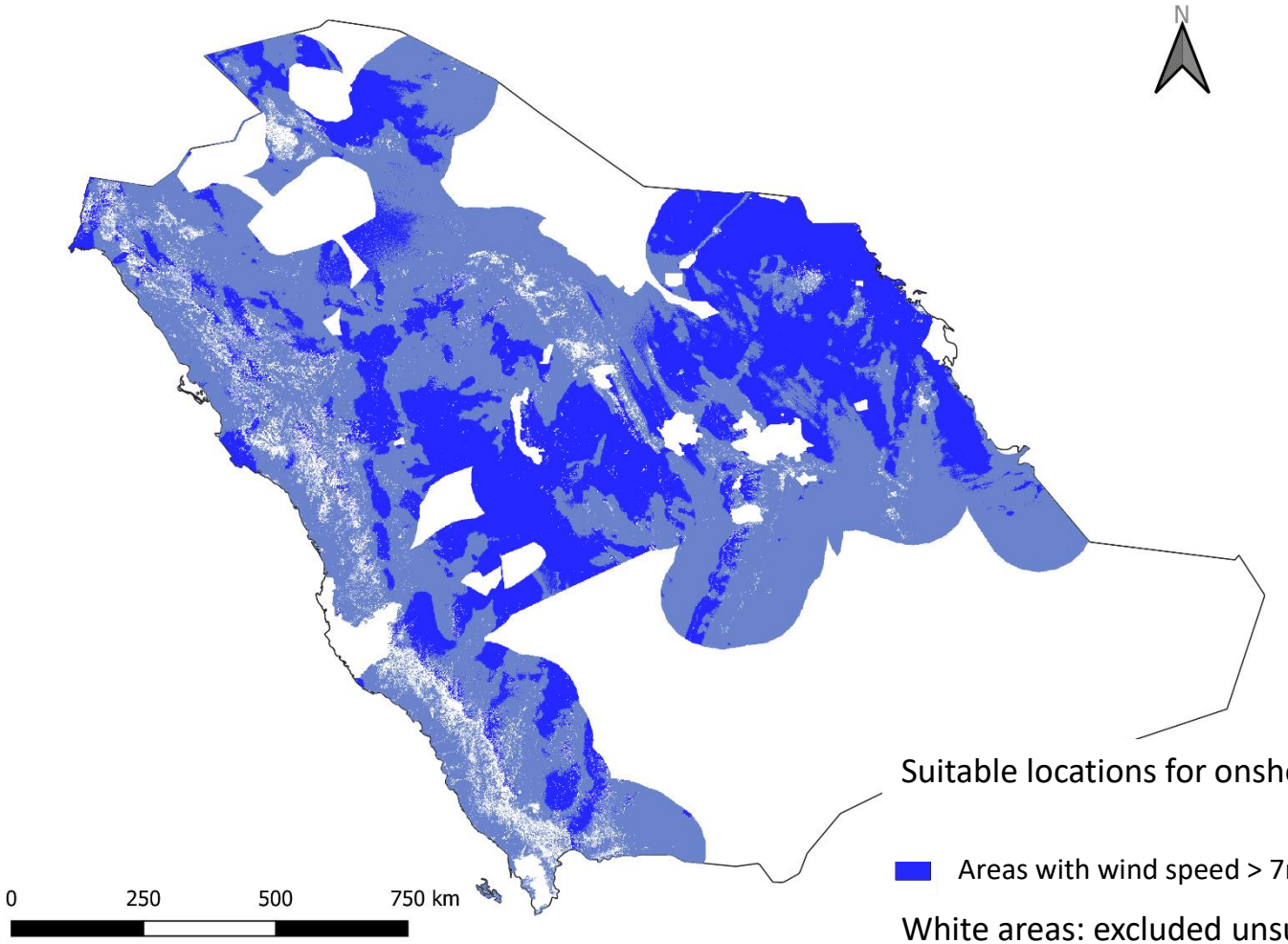
Identification of Locations for Power-to-X Technologies Based on Geographic Information System GIS

- Preliminary analysis to identify **suitable areas** without **geographic or technical restrictions** for the expansion of **onshore wind turbines** and **PV ground-mounted systems**
- **Unsuitable areas** are being geographically identified (nature reserves, farmland, urban areas, water areas, military zones,…)
- The overlay analysis reveals **suitable areas** and sites **for renewable energy** and **PtX technologies** in the studied country.
- An additional **superimposition with weather data** shows locations with high economical potentials for **Wind and PV power plants**
- **Further criteria** like harbours, water supply, etc



Production cost and long-distance import of Power-to-X: Case Study

GIS analysis: Wind potential of Saudi Arabia



Suitable locations for onshore wind power generation

Areas with wind speed > 7m/s @ 100m

White areas: excluded unsuitable land areas (terrain slope, nature reserves, military restricted zones, urban areas, ...)

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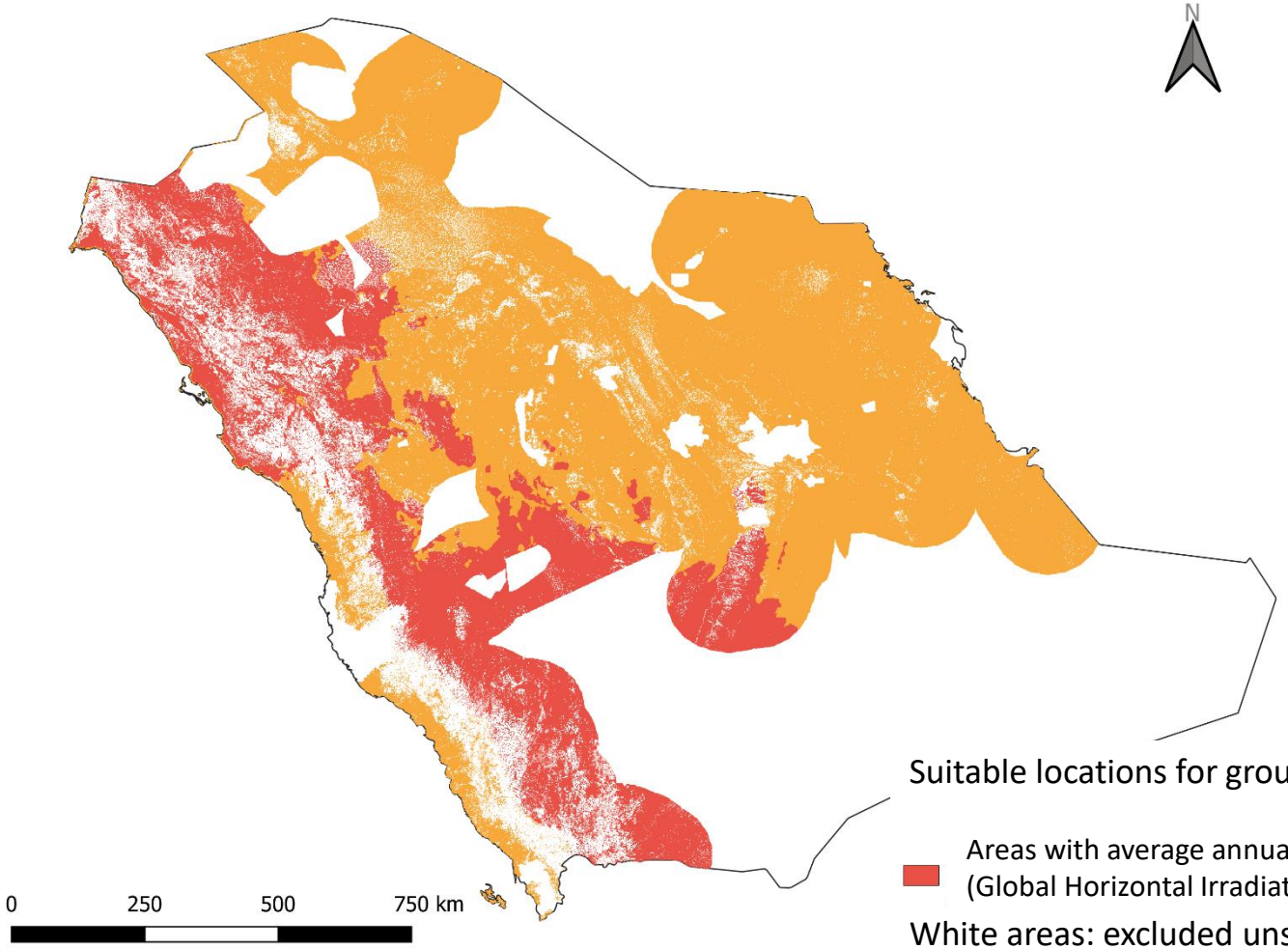
Production cost and long-distance import of Power-to-X: Case Study

GIS analysis: Solar Potential of Saudi Arabia



Suitable locations for ground-mounted PV systems

Areas with average annual irradiance
(Global Horizontal Irradiation > 2300 kWh/m²)

White areas: excluded unsuitable land areas (terrain slope, nature reserves, military restricted zones, urban areas, ...)

GHI = Global Horizontal Irradiance is the sum of direct, diffuse and reflected radiation

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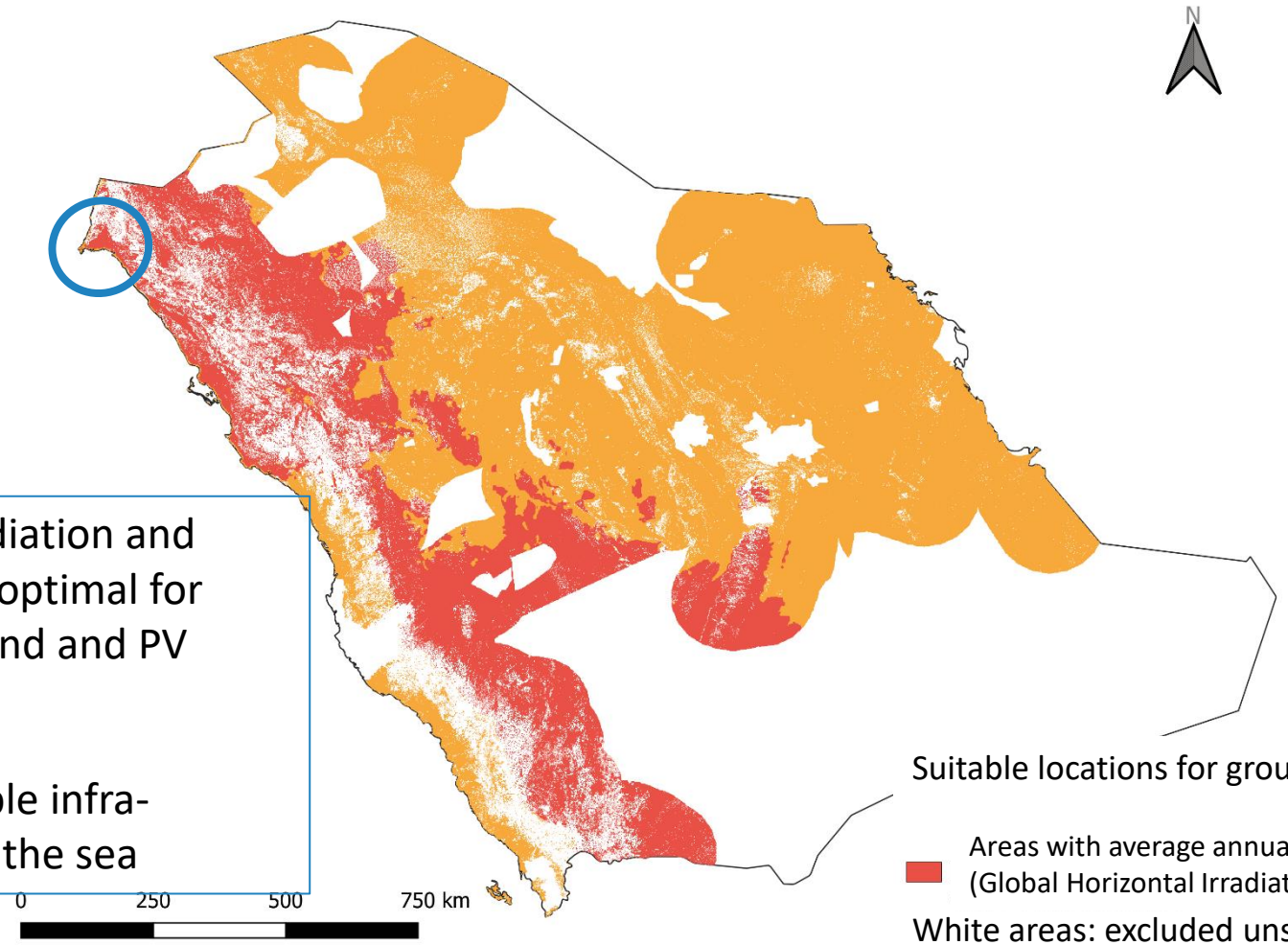
Production cost and long-distance import of Power-to-X: Case Study

GIS analysis: Selected location in Saudi Arabia

North west (NEOM)



- Very high solar radiation and wind speeds thus optimal for combination of wind and PV
- Directly at the sea
- < 100 km to suitable infra-structure towards the sea

Suitable locations for ground-mounted PV systems

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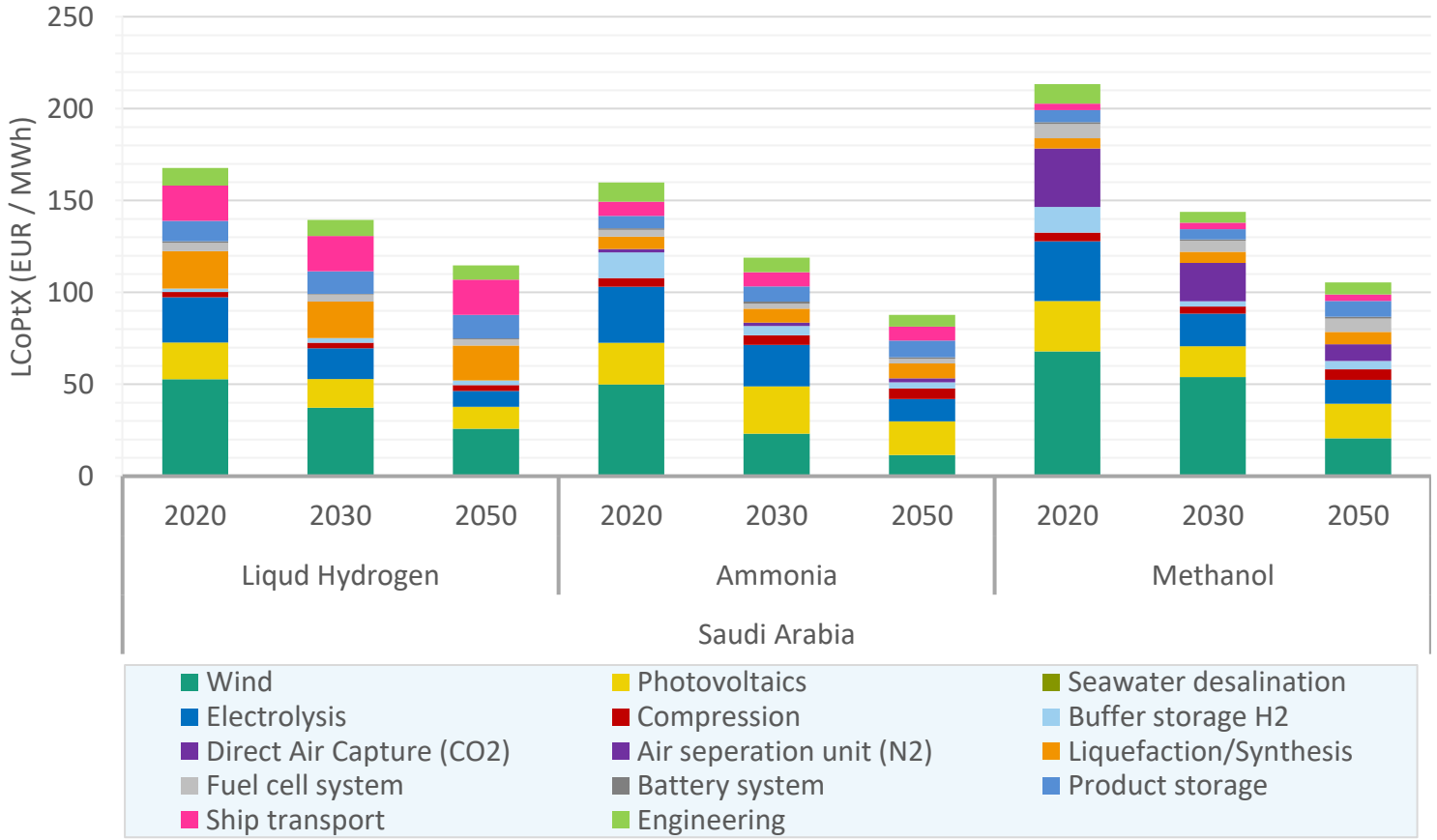
Production cost and long-distance import of Power-to-X: Case Study

Results: Saudi Arabia – North-West (Neom)

- Sizing of components and further results in the cost optimum in **2020** (Electrolysis 1 GW)

Component Sizing	LH_2	NH_3	MeOH
Wind (GW)	1.8	1.4	1.7
PV (GW)	2.0	1.8	2.0
H_2 Liquefaction / NH_3- / MeOH-Synthesis (tpd)	388	1,614	1,353
Battery (MWh)	53	42	60
LCoPtX (EUR/MWh)	168	160	213
LCoPtX (EUR/ton)	5,587	828	1,180
Exported Energy (TWh)	3.6	2.9	2.7
Full load hours electrolysis	5,755	5,192	5,005

WACC 10%
WACC 2%
(Base Case 5%)



All values shown apply to the optimal cost case (Paretofront lower left)

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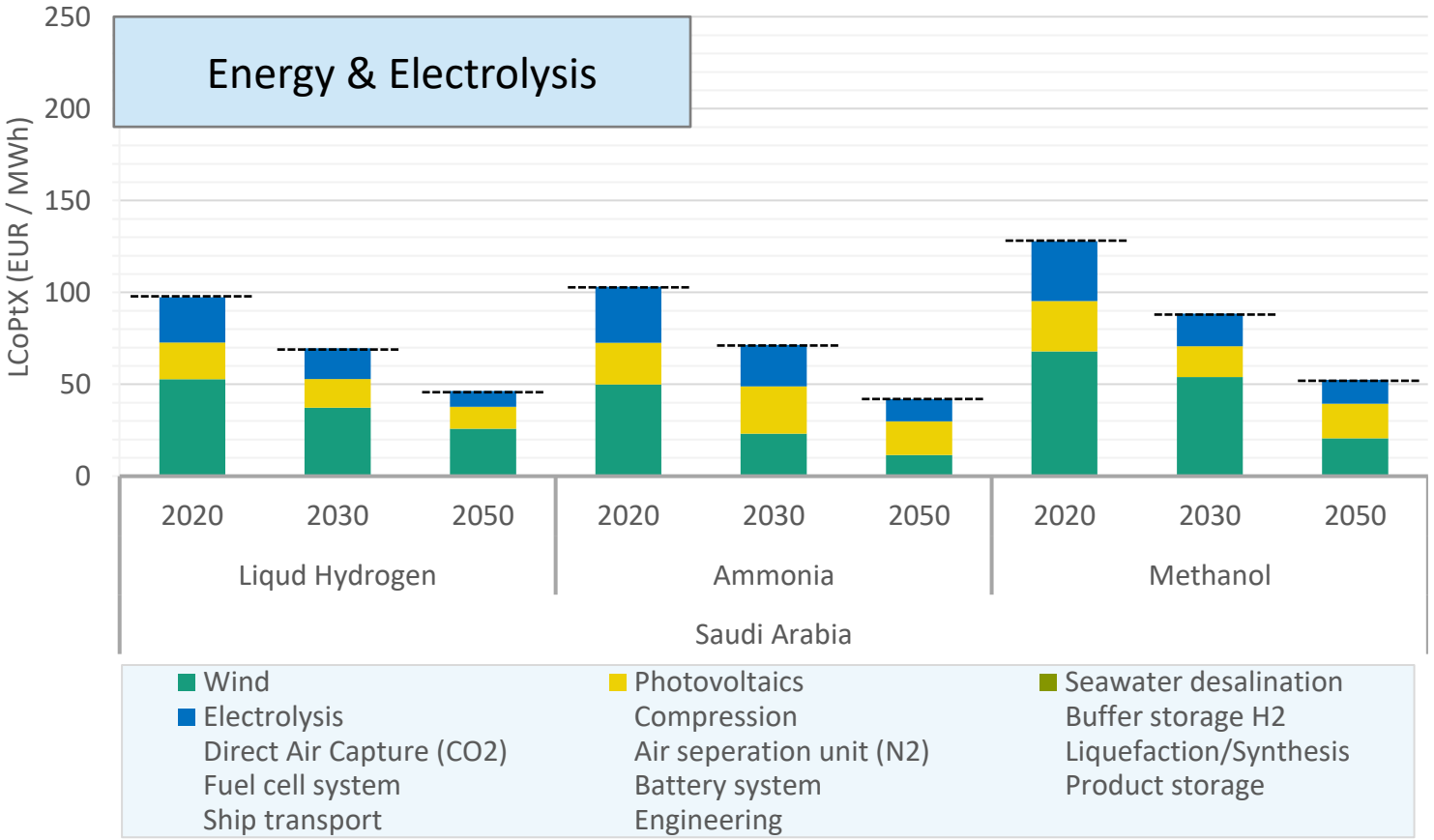

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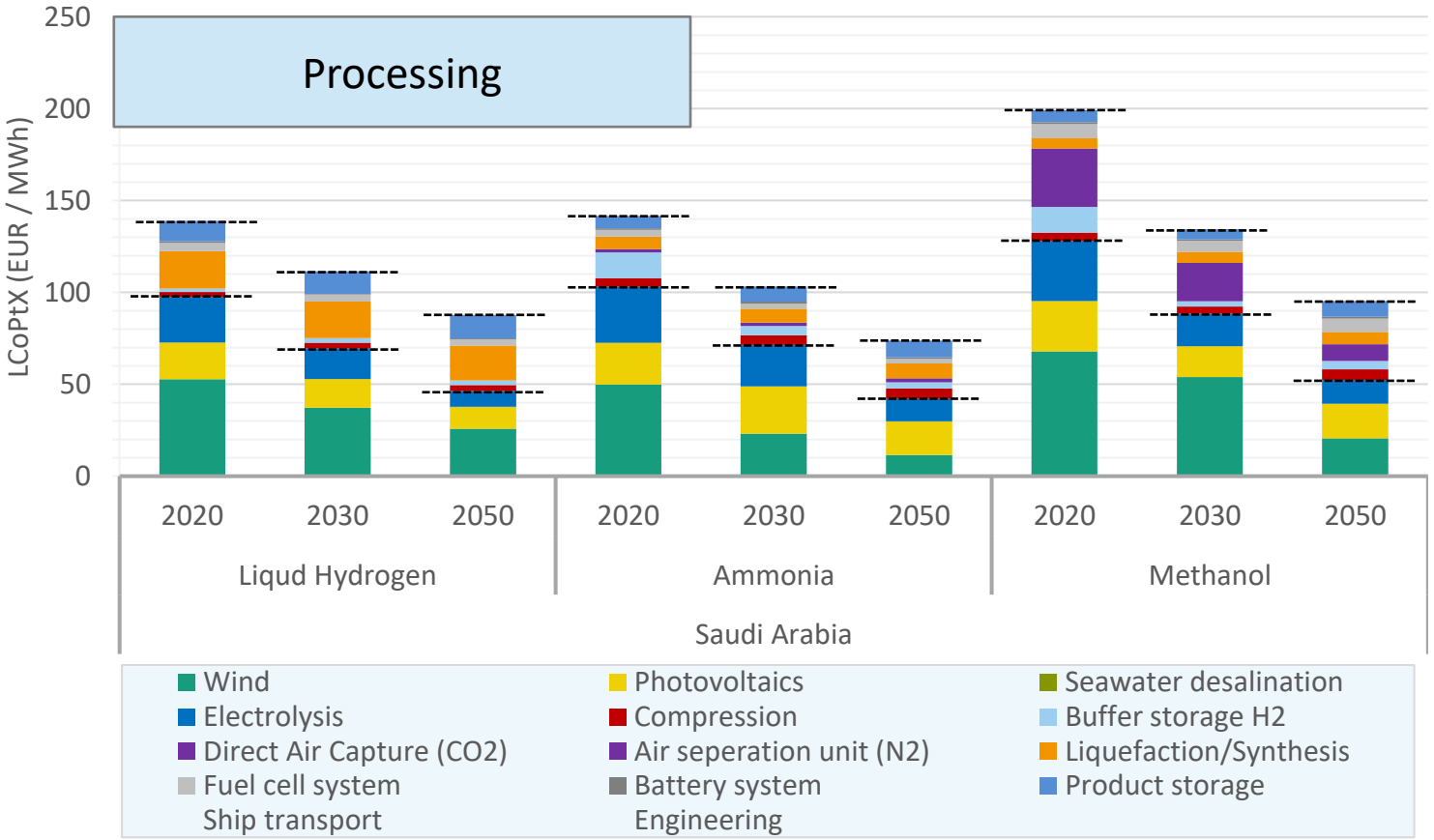

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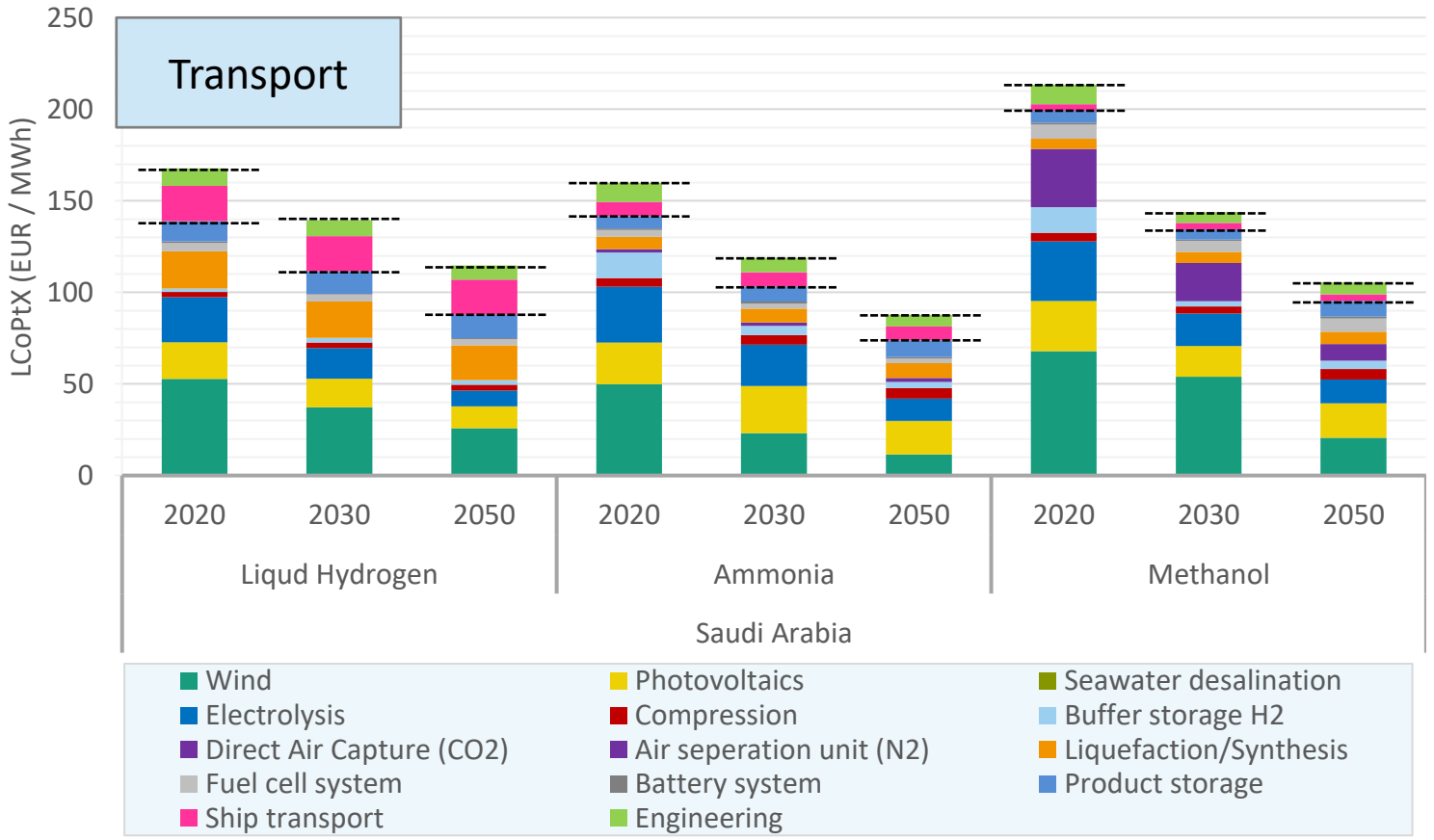

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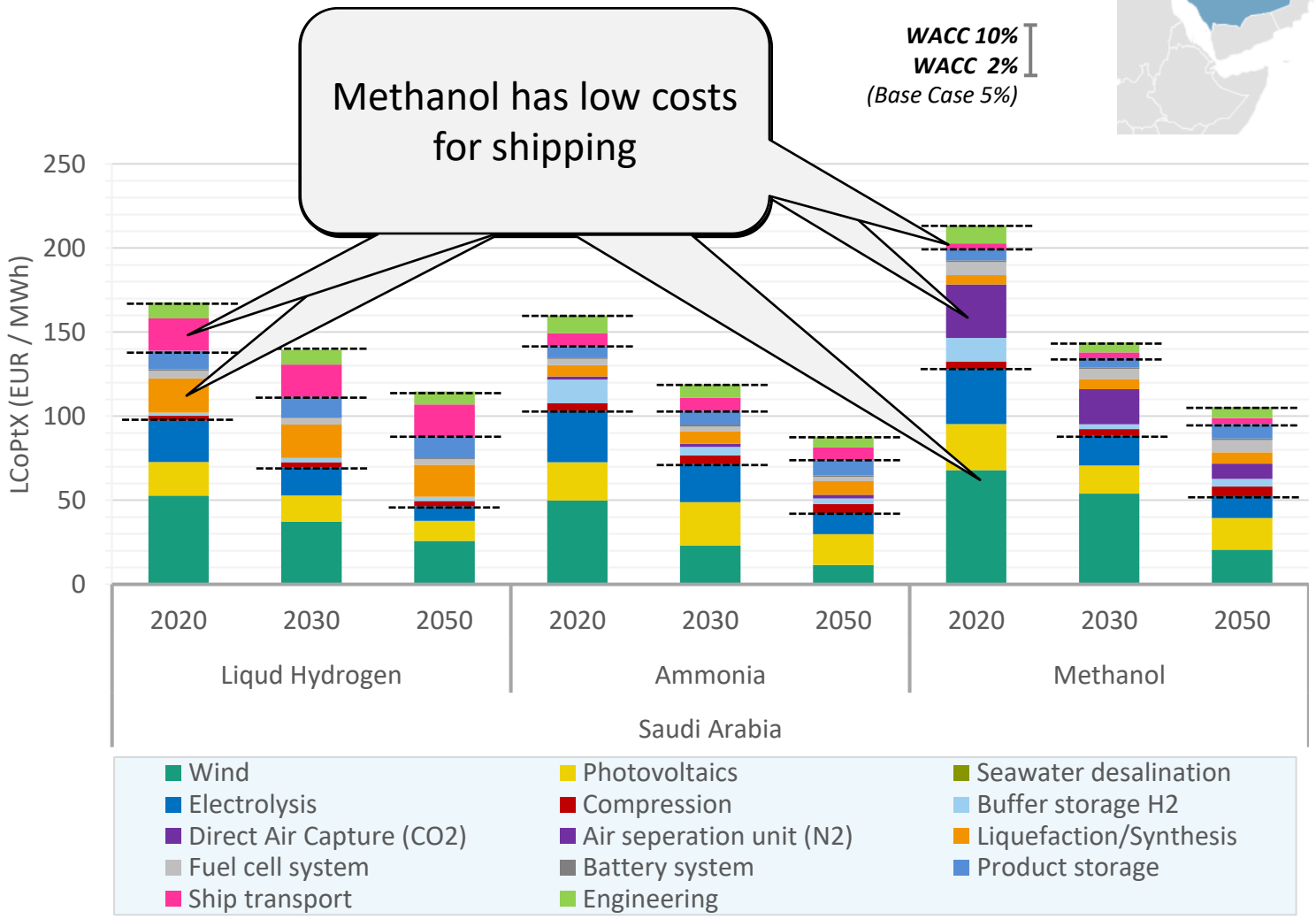

All values shown apply to the optimal cost case (Paretofront lower left)

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The Green Deal

Fit For 55 - A Policy Mix

- Legislative Package, July 14, 2021, by European Comm.
- Embracing adjustments and new regulations regarding Pricing, Targets, Rules and Support Measures

- Specific sub-targets for the consumption of renewable H2 for hard-to-decarbonize applications in:
  - the industry: 50% by 2030
  - Transport sector: 2,6% by 2030
- Extends the certification framework to all renewable fuels, including renewable hydrogen

New Arrangements	Existing Revision
CBAM - Carbon Border Adjustment Mechanism	**ETS** - Emissions Trading System
Social Climate Fund	**ETD** - Energy Taxation Directive
ReFuel-EU-Aviation Sustainable Air Fuel	**RED** - Renewable Energy Directive
Fuel-EU-Maritime Sustainable Marine Fuel	**DAFI** - Alternative Fuels Infrastructure
EU **Forest Strategy**	**EED** - Energy Efficiency Directive
	ESR - Sharing Energy Efforts
	Land-Use Change and Forestry
	ACER - Automotive Carbon Emissions Regulations

[1]

Source: European Commission Website. URL [1]: https://ses.jrc.ec.europa.eu/eirie/en/news-and-events/news/fit-55-major-step-towards-decarbonized-eu-2050

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Conclusions

- The Global trade of renewable energy based on hydrogen is beginning now
- We will only succeed in the transformation of the energy system towards a complete reduction of greenhouse gas emissions, if we understand the fundamentally new character of the new system
- Fossil energy has to be replaced completely - the inherent ability of storage must be substituted
- National and EU politics must develop clear pathes and targets for GHG neutrality and set-up an effective regulatory framework (taxes, levies, incentives, etc.) to achieve the targets
- We need a mix of state infrastructure and market elements controlled by the state
- The importance of both electric energy and molecular energy carrier is increasing

International research cooperations and energy partnerships are a prerequisite for faster progress, long term (trading) relationships and a secure investment environment

- **The electric light did not come from the continuous improvement of candles**

Oren Harari

Thank you for your attention

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Prof. Christopher Hebling, christopher.hebling@ise.fraunhofer.de

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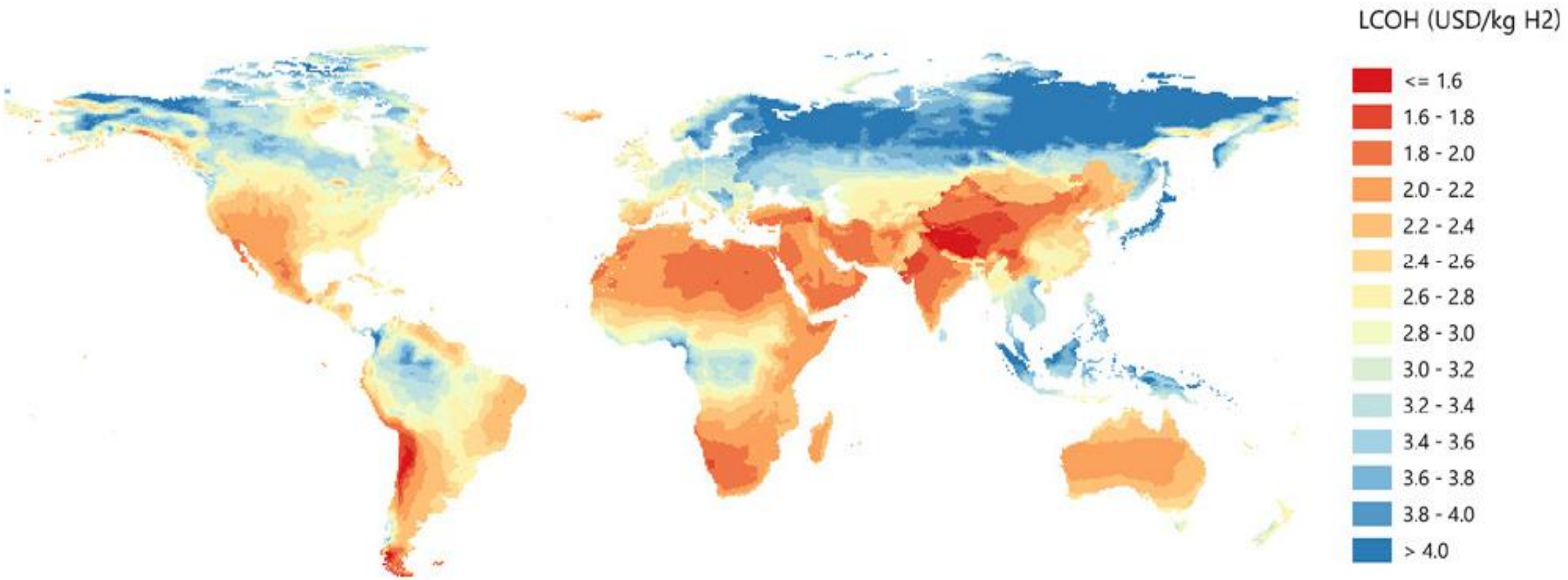
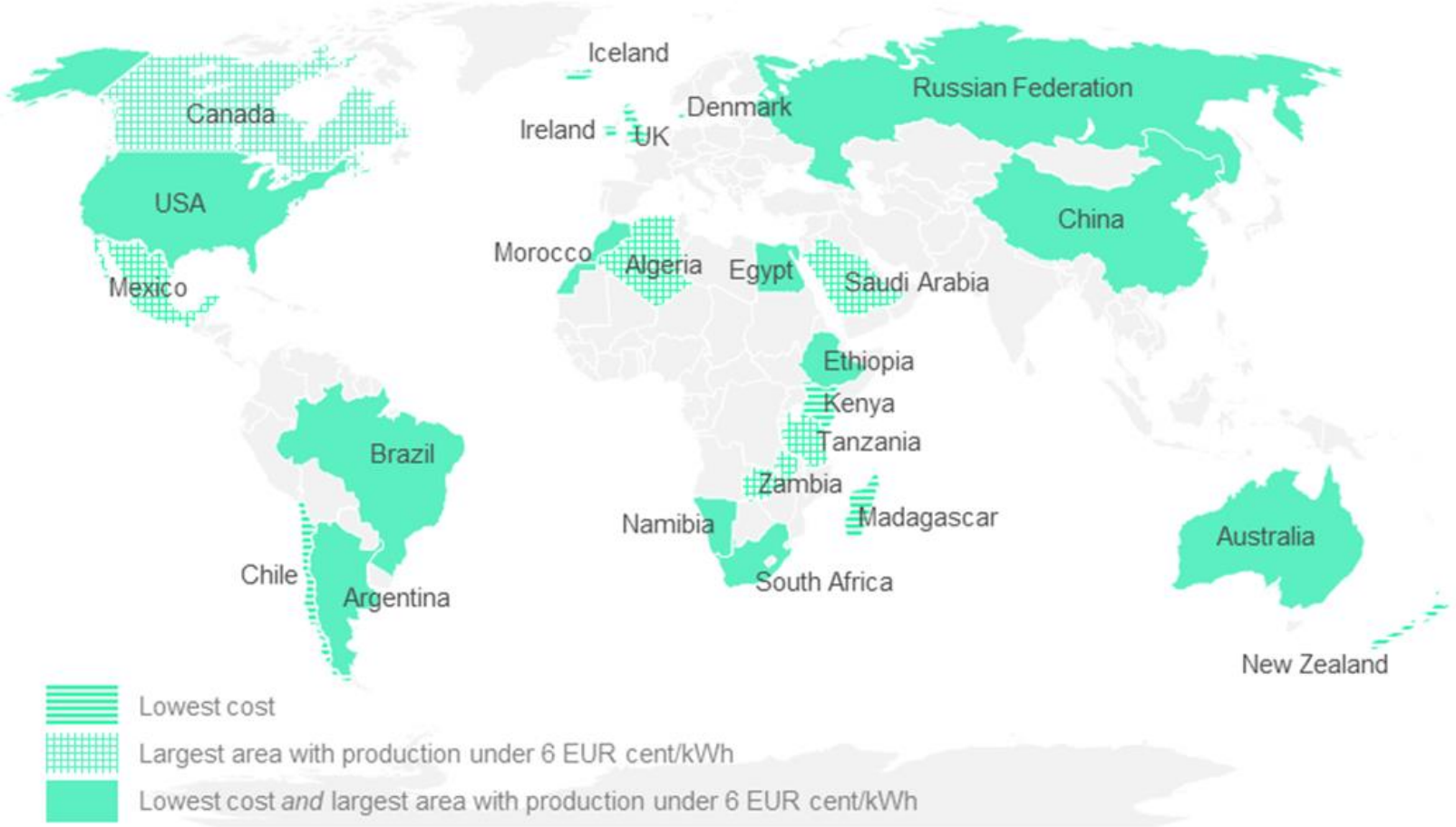
Global Hydrogen Generation Costs



IEA, The Future of Hydrogen, Seizing today's opportunities, Report prepared by the IEA for the G20, Japan, 2019

Identification of potential hydrogen supplier countries



Lowest costs and biggest production potential:

- Argentina, Chile, Brazil
- Australia
- China
- Egypt
- Morocco
- Namibia
- Russia
- South Africa
- United States

[1] Jensterle et al. 2019 (LUT-model)