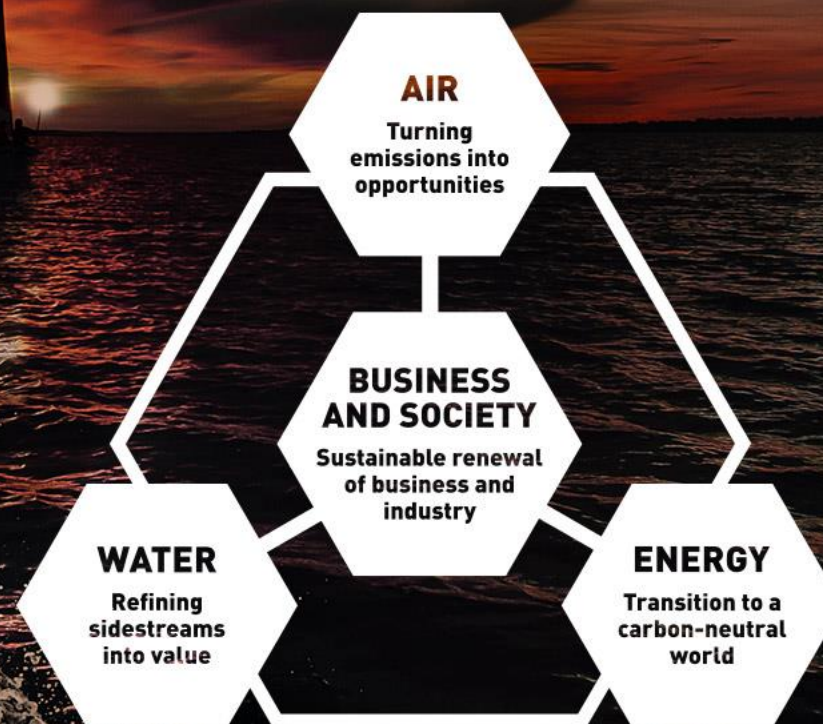


KesTech - Roundtable

SYSTEM EARTH



Petteri Laaksonen, D.Sc., Research Director

petteri.laaksonen@lut.fi



 LUT-yliopisto on

WORLD'S 9TH

University – SDG 13.

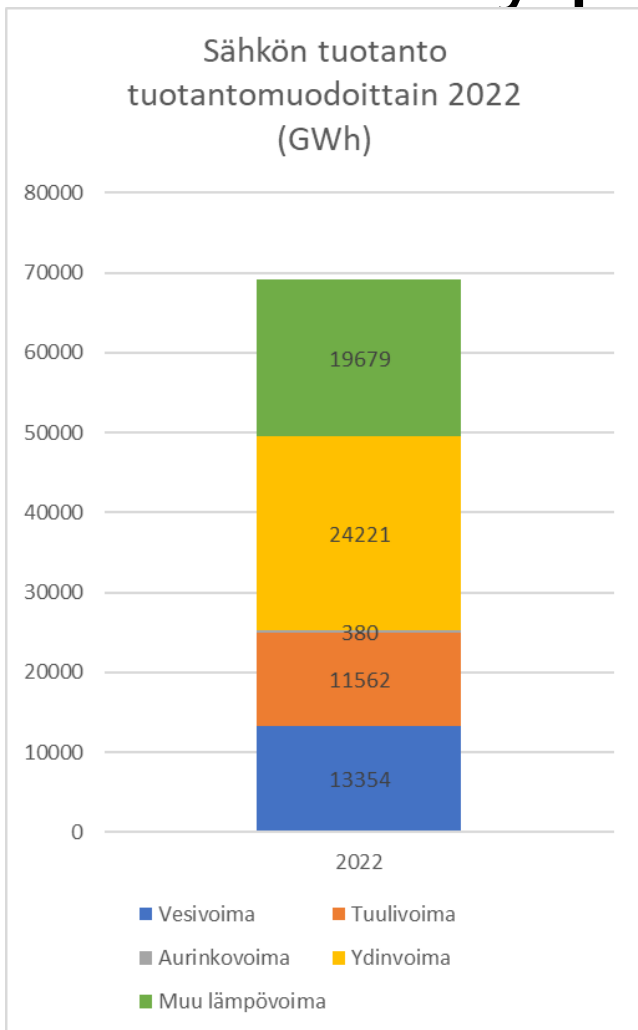
Times Higher Education Impact Rankings 2022 arvioi yliopistojen sosiaalista ja taloudellista vaikuttavuutta YK:n kestävän kehityksen tavoitteiden edistämisen kautta.



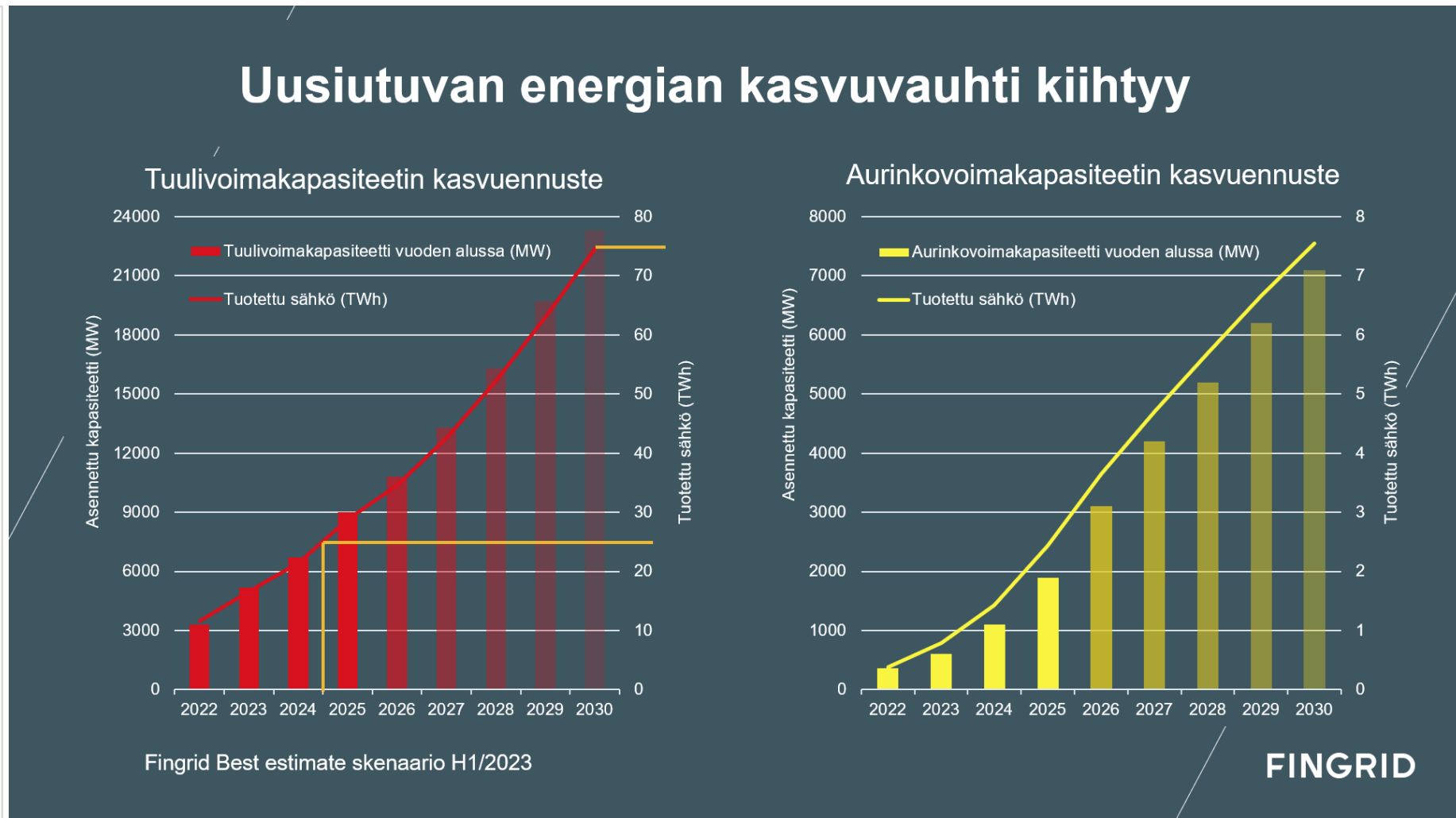


GREEN ELECTRIFICATION & P2X ECONOMY

Electricity production in Finland



Electricity production in 2022 69 TWh. Nuclear is the biggest source of electricity.

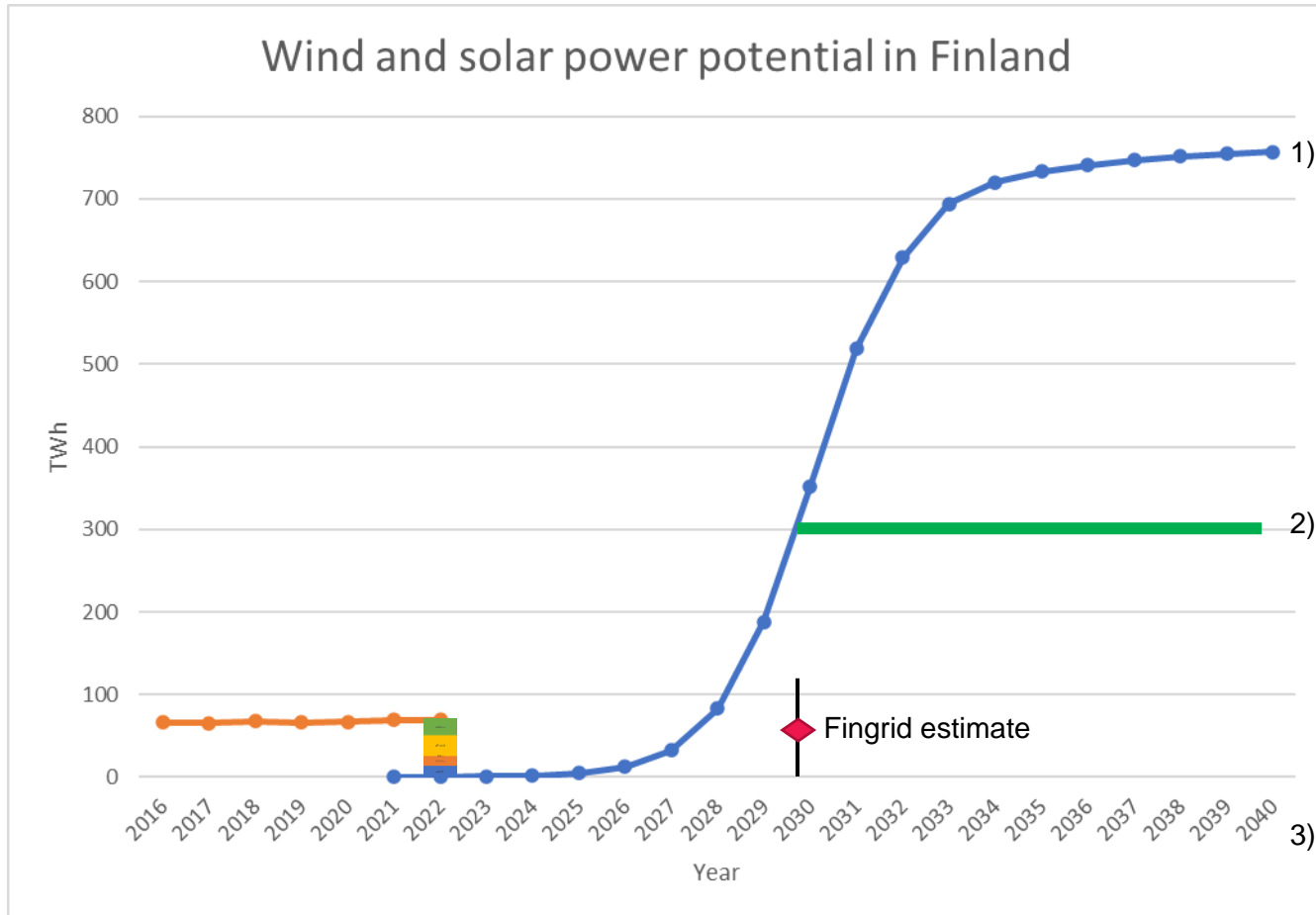


Wind power will pass nuclear 2024
In 2023 wind power exceeds existing production

Solar power will support the renewable production
will be approximately +10% in 2030

 LUT University

POTENTIAL OF GREEN ELECTRICITY PRODUCTION

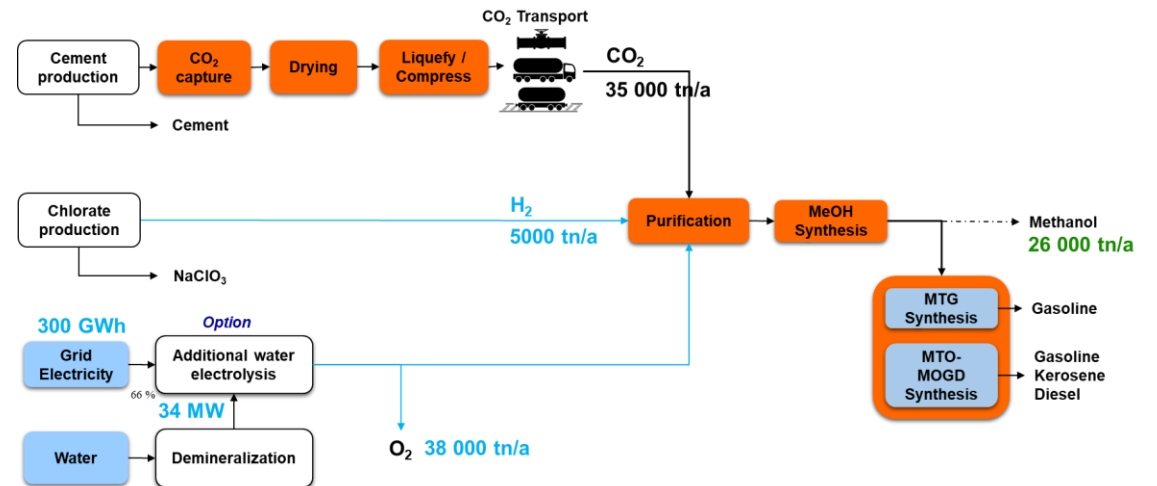


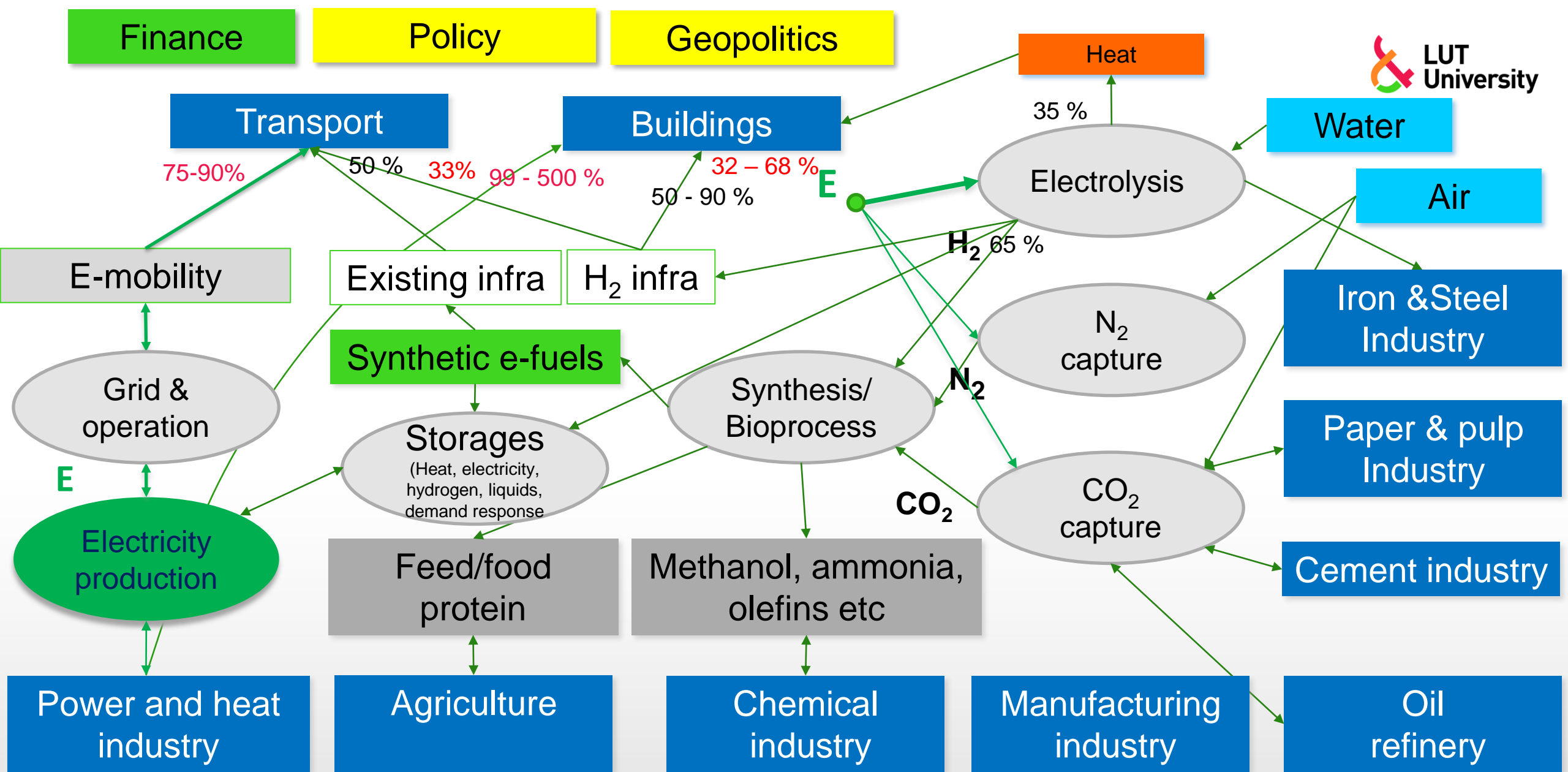
Investments in energy production approximately 400 BEUR

- 1) Based on Actual Grid Connection Request in Finland. Source: Energy transmission infrastructure as enabler of hydrogen economy and clean energy system. Fingrid and Gasgrid Finland's joint project, 15 March 2022. Updated 10.1.2023, Mikko Heikkilä, Fingrid 200 GW+.
- 2) Fingrid estimates 300 TWh wind production to Finnish system (Mikko Heikkilä, Bryssels, 9/2022)
- 3) Timeline not real estimate, just referential.

P2X

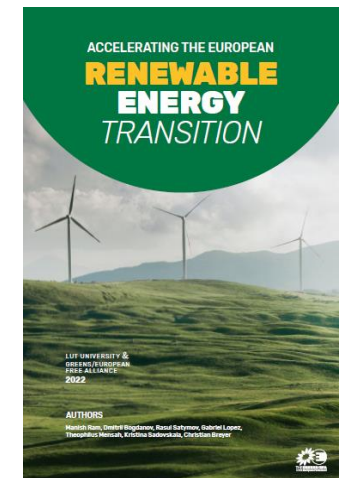
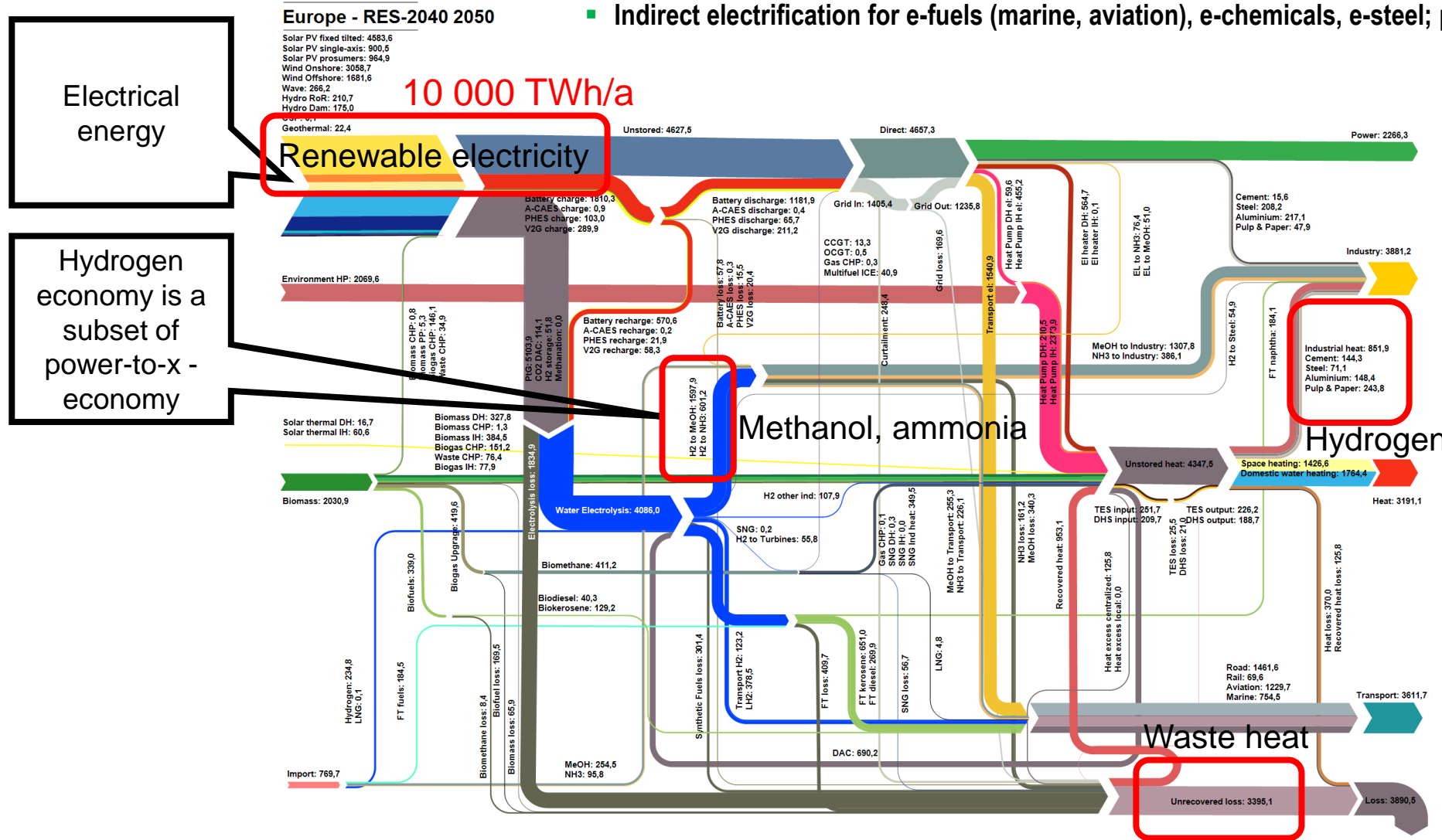
From electricity & hydrogen to products





Energy system transition in Europe

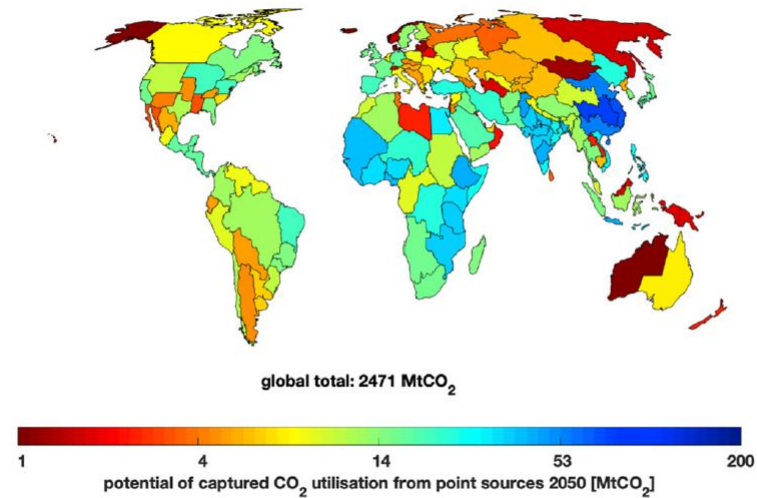
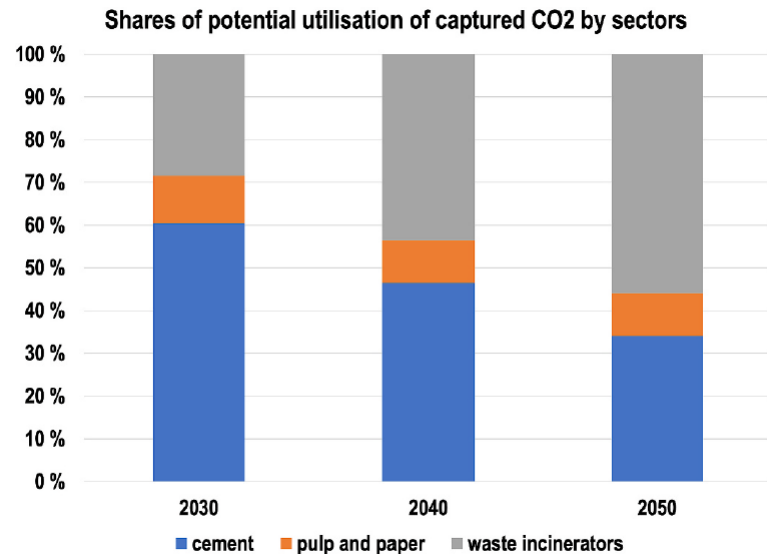
- Zero CO₂ emission low-cost energy system is based on electricity
- Core characteristic of energy in future: **Power-to-X Economy**
 - Primary energy supply from renewable electricity: mainly solar PV and wind power
 - Direct electrification wherever possible: electric vehicles, heat pumps, desalination, etc.
 - Indirect electrification for e-fuels (marine, aviation), e-chemicals, e-steel; power-to-hydrogen-to-X



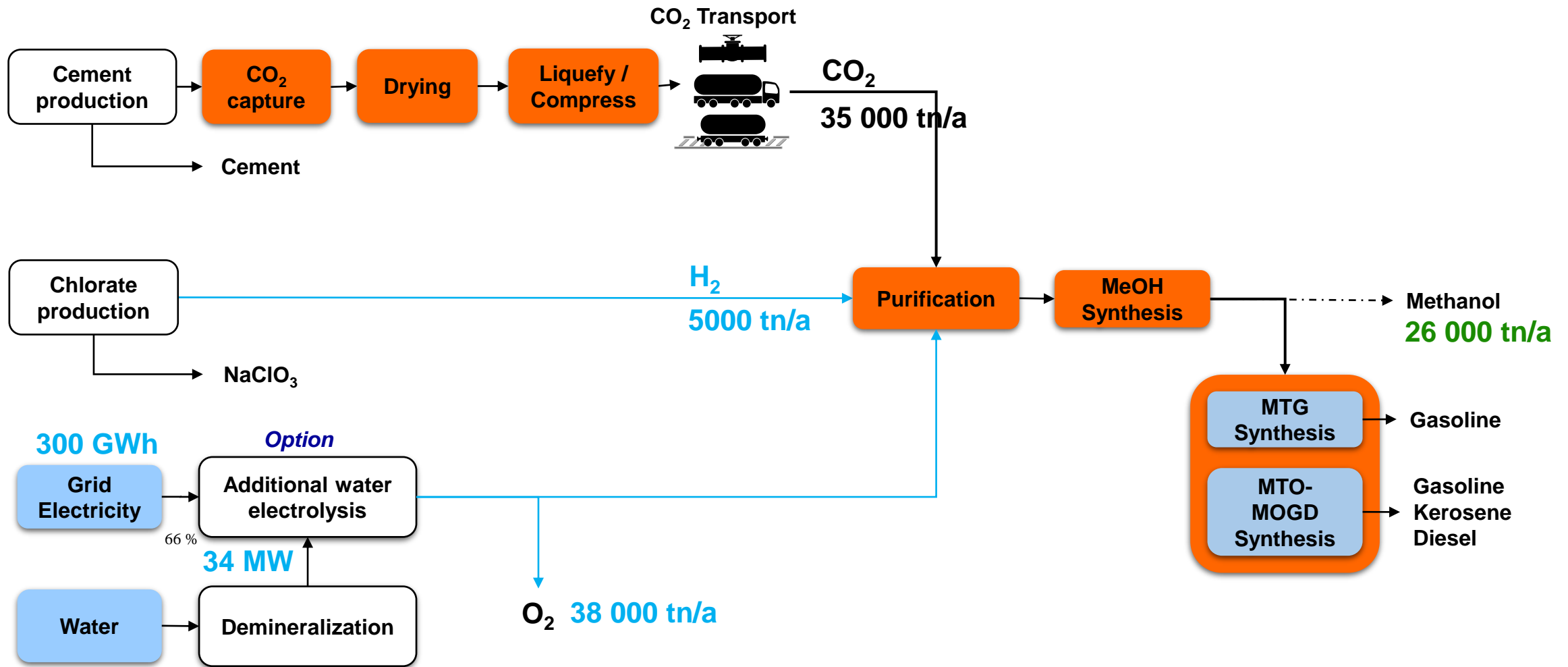
Greens/EFA, 2022

GLOBAL DEMAND FOR CO₂

In 2030, the total potential of captured CO₂ from point sources that could be utilised is 2112 Mt annually (T. Galimova et al.(2022))



Production of Carbon Neutral Fuels - P2X



St1 P2Methanol Production

St1 is planning a synthetic methanol pilot plant in Lappeenranta, Finland

RELEASE 04.10.22

The energy company St1 is planning the first synthetic methanol plant in Finland next to the Finnsementti factory at the Ihalainen industrial site in Lappeenranta. The Ministry of Economic Affairs and Employment has granted a funding of EUR 35.4 million to St1's Power-to-Methanol Lappeenranta project, which aims to produce renewable synthetic methanol to replace fossil fuels used in maritime and road transport. St1's goal in the commercial-scale pilot project is to develop a replicable and scalable synthetic methanol production concept.

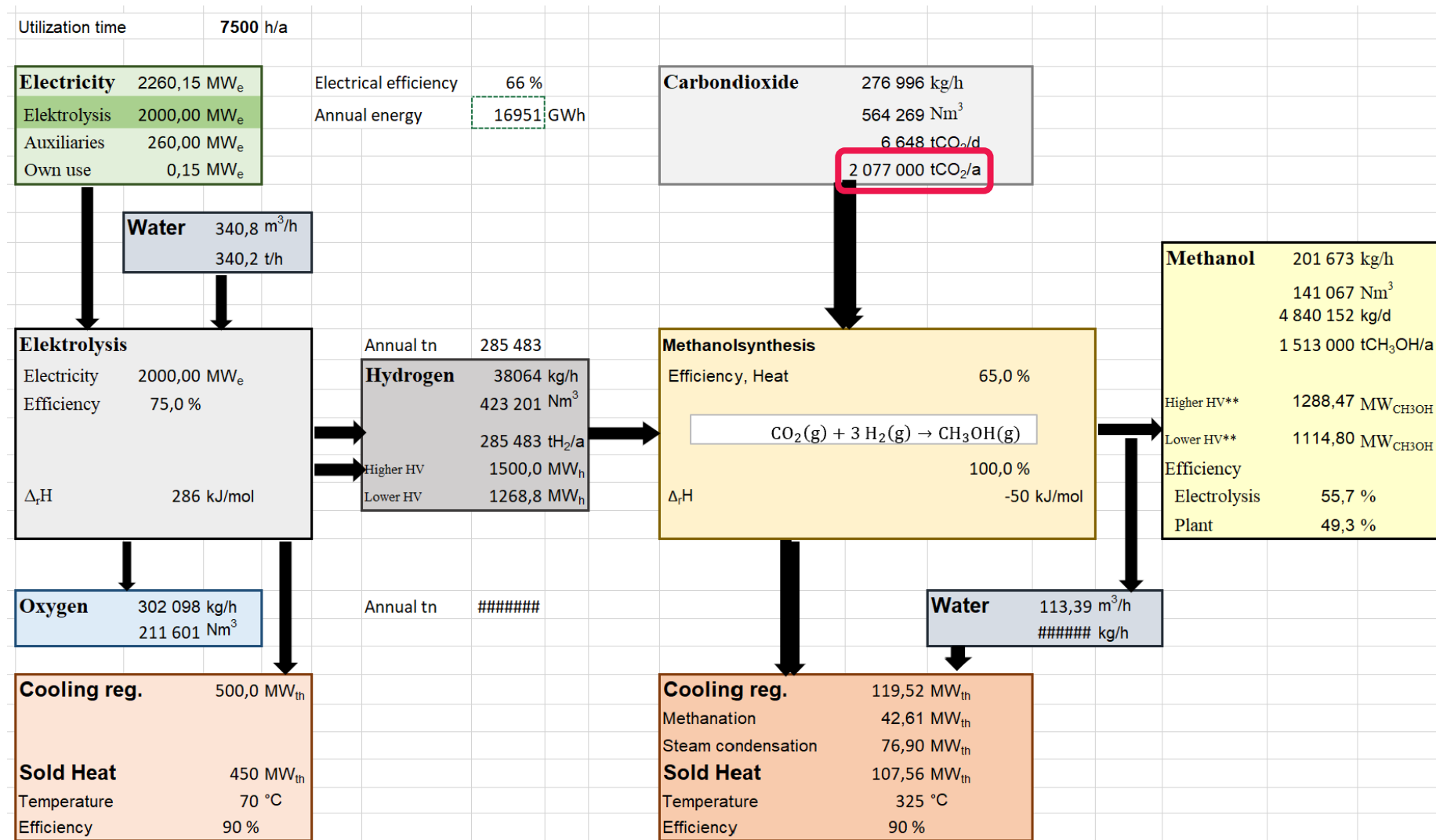


Finnsementti factory



CASE LARGE PULP MILL – METHANOL PRODUCTION

- Annual biobased CO2 emissions 2,1 Mt (2017)
- Chemical scrubbing (amine, 40 - 140 C)
 - CO2 capture efficiency 98%
 - CO2 capture purity >99%
- Electrolyser 2 GW
- Annual electricity 17 TWh
- Green Methanol production 1,5 Mt/a
- Value á 1000 EUR/tn
- ➔ 1,5 Mrd EUR/a





SOUTH - EAST FINLAND HYDROGEN VALLEY

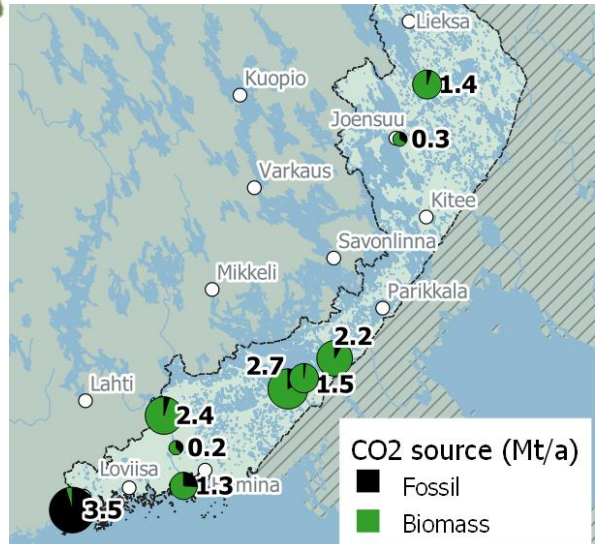
Petteri Laaksonen

Research Director, School of Energy Systems, LUT University

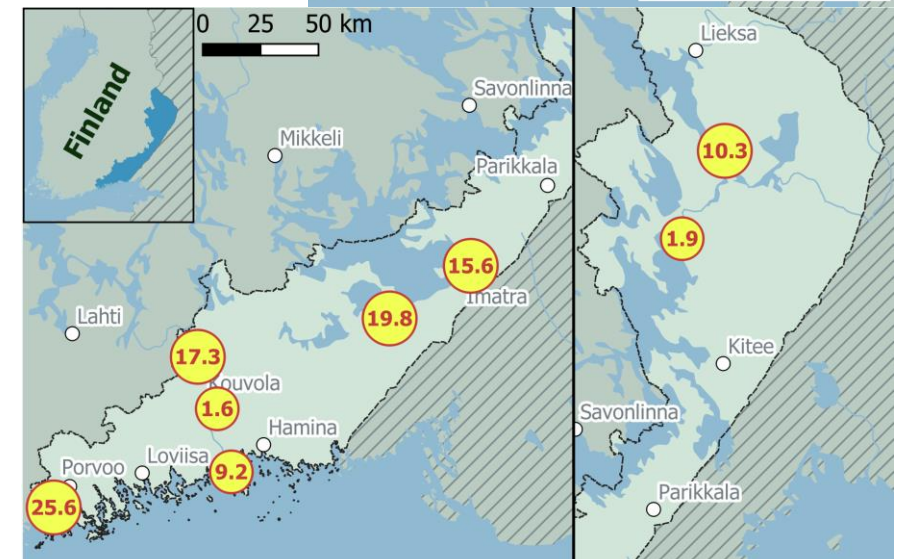


BIOGENIC CO₂ SOURCES

➤ Mainly biobased emissions (10.8 Mt/a), located in the southern part of the area



Scenario	Base			
	(All)	(All)	Pulp and paper	(All)
CO ₂ emission facility type	(All)	(All)	Pulp and paper	(All)
CO ₂ type	Total	Biogenic	Biogenic	Biogenic
Portion of CO ₂ utilized	100 %	100 %	100 %	20 %
CO ₂ utilized (Mt)	15.5	10.8	9.5	2.2
Methanol production (Mt)	11.3	7.8	6.9	1.6
Hydrogen demand (Mt)	2.1	1.5	1.3	0.3
Electrolyser electricity demand (TWh)	112	78	69	16

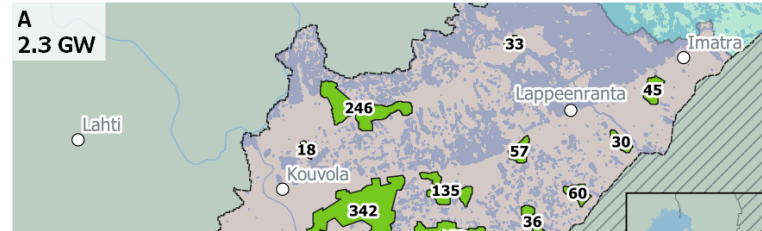


Indicative power-to-X electricity demand (TWh)
 100% CO₂ conversion to methanol
 Fossil+biogenic sources included (>100 kt/a units)

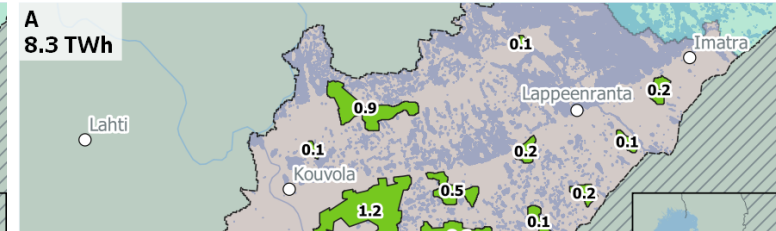
WINDPOWER POTENTIAL

- Scenario approximately 50 % will be built
- Mainly located in the northern part of the area
- Energy transfer volume of 78 TWh between north and south is huge

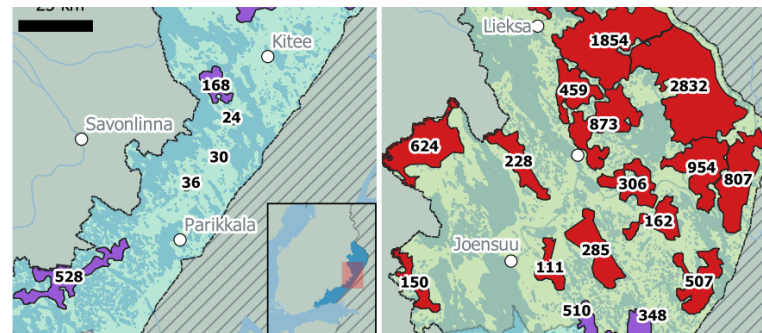
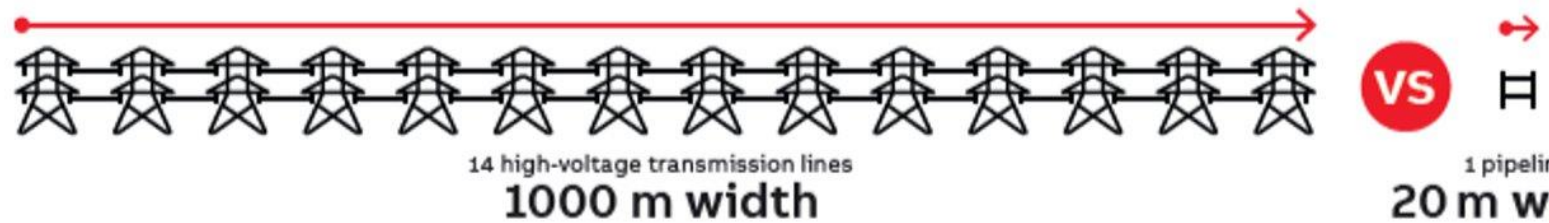
TOTAL 17 GW



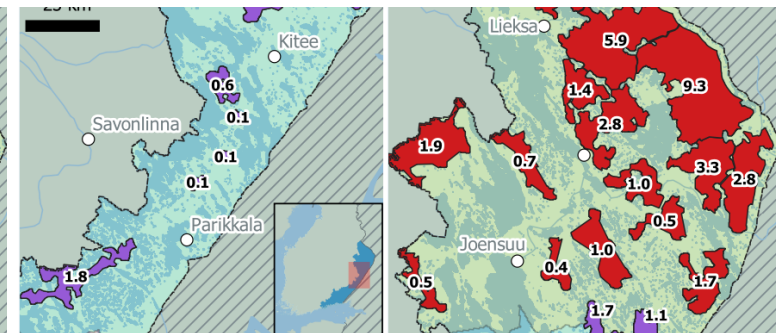
TOTAL 57 TWh



Moving 42GW of energy using power grid vs. hydrogen gas through a pipeline



Wind power potential (MW)
800x800 m turbine placement, 50% realized
6 MW turbine size, 150m hub height



Wind power potential (TWh)
800x800 m turbine placement, 50% realized
6 MW turbine size, 150m hub height



NORDIC COUNTRIES ELECTRICITY SUPERPOWERS



NORDIC ELECTRICITY SUPERPOWERS

- Total renewable electricity potential in **Finland exceeds 1000 TWh, representing 10% of the electricity demand in EU.**
- Combined with Sweden and Norway, the potential could be 3500 – 4500 TWh, **covering 35- 45%% of the European electricity demand** of 10 000 TWh
- **New P2X investments will be located neat the electricity production.** Investments in synthesis of methanol, ammonia and other P2X products exceed investments in electricity generation.
- **Total investments exceed 1000 BUEUR** in Nordic countries.

Thank you!

Petteri Laaksonen, D.Sc., Research Director

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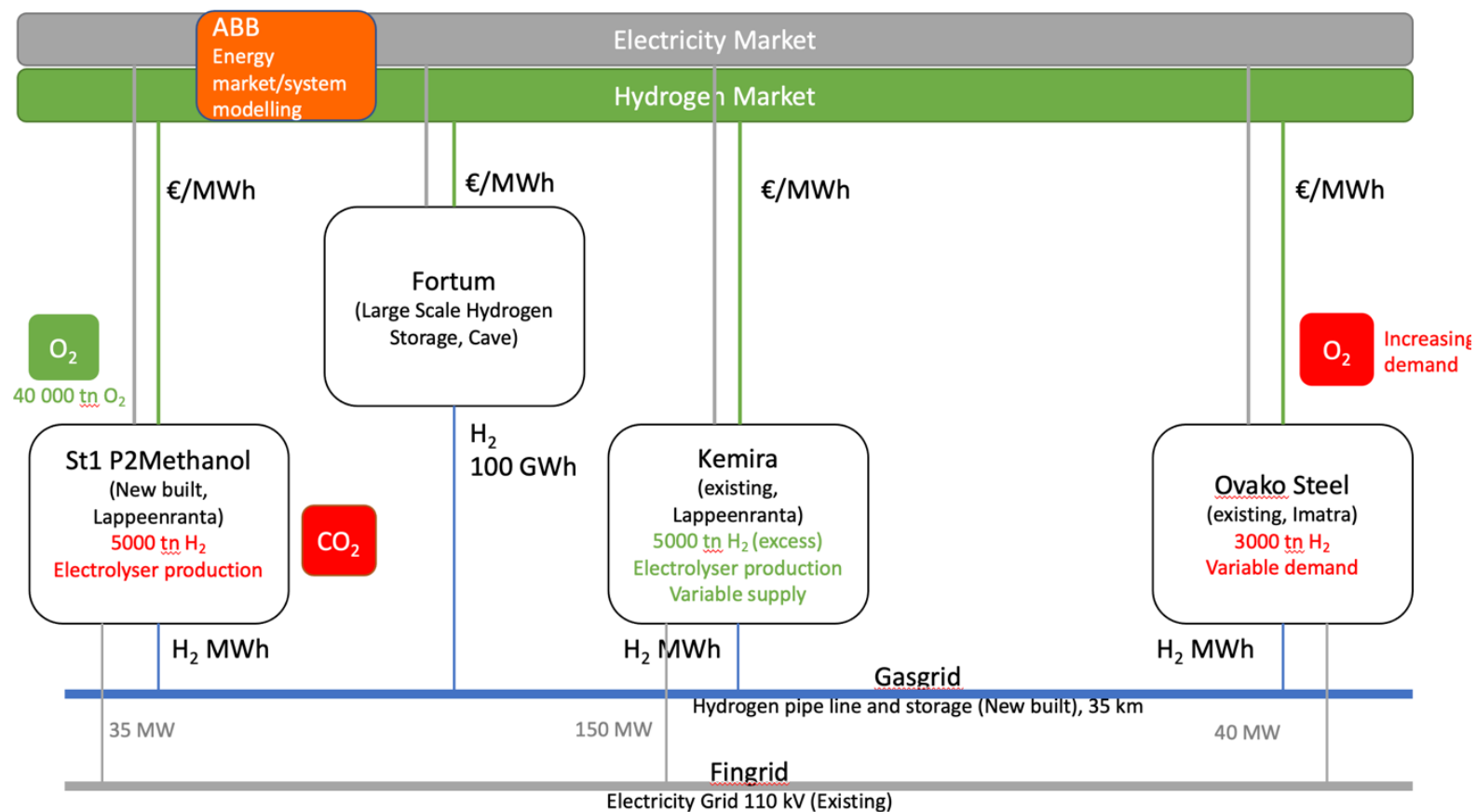
Renewable Energy in Finland



Competitive advantages for Finland in P2X

- » Large and sparsely populated country
 - » Raw material availability
 - Bio based CO₂ raw material (20+ MtCO₂ annually), equals to 150 Mt MeOH & 15 BEUR/a revenue
 - Cheap electricity compared to rest of the Europe
 - Very big potential for new production (wind and solar) and fast to ramp-up
 - » Educated people, good education system
 - » Process industry heritage and skills
 - Steel
 - Chemical
 - Pulp and paper
 - » Robust infrastructure
 - » Good reputation within investors
 - » Fast permitting processes (some exceptions)
- 

SOUTH-EAST FINLAND HYDROGEN VALLEY EU-PROJECT



EU Large Hydrogen Valley

Finance for 20 MEUR, majority into industrial investments

P2X in Finland – some LUT research



- Carbon Negative Åland: Strategic Roadmap
<https://lutpub.lut.fi/handle/10024/163456>
- Bothnian Bay Hydrogen Valley – Research report
<https://lutpub.lut.fi/handle/10024/163667>
- South-East Finland Hydrogen Valley – Research report
<https://lutpub.lut.fi/handle/10024/164642>
- Feasibility Study for Industrial Pilot of Carbon-Neutral Fuel Production – P2X
<https://lutpub.lut.fi/handle/10024/162597>

P2X TECHNOLOGIES

- » Commercially available
- » Technology Readiness Level 9



Technology	Supplier	Technology type	Reference	
Electrolysis	Cummins	Alkaline, PEM	[21]	
	Green Hydrogen Systems	Alkaline	[22]	
	Hydrogen Pro	Alkaline	[23]	
	ITM Power	PEM	[24]	
	McPhy	Alkaline	[25]	
	NEL Hydrogen	Alkaline, PEM	[26]	
	Siemens	PEM	[27]	
	Sunfire	Alkaline, SOEC	[28]	
	CO ₂ capture	Air Liquide Engineering & Construction	Cryogenic	[29]
		Aker Carbon Capture	Amine	[30]
Carbon ReUse		Water	[31]	
GE Power		Amine, oxy-combustion	[32]	
Mitsubishi Heavy Industries		Amine	[33]	
Shell		Amine	[34]	
Toshiba Energy Systems & Solutions Corporation		Amine	[35]	
MeOH synthesis	Air Liquide Engineering & Construction	Syngas/CO ₂ to MeOH	[29]	
	BSE Engineering	n.a. ¹⁵	[36]	
	Carbon Recycle International	CO ₂ to MeOH	[37]	
	Johnson Matthey	Syngas to MeOH	[38]	
	Mitsubishi Gas Chemical	Syngas to MeOH	[39]	
	Fuel synthesis	Chemieanlagenbau Chemnitz	MTG	[40]
ExxonMobil		MTG	[41]	
Haldor Topsøe		MTG, syngas to gasoline	[42]	
Sunfire		Fischer-Tropsch	[28]	

P2X & Carbon Dioxide

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Global demand analysis for carbon dioxide as raw material from key industrial sources and direct air capture to produce renewable electricity-based fuels and chemicals

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ARTICLE INFO

ABSTRACT

Defossilization of the current fossil-fuel dominated global energy system is one of the key goals in the upcoming decades to mitigate climate change. Sharp reductions in the costs of solar photovoltaic, wind power, and battery technologies enables a rapid transition of the power and some segments of the transport sectors to sustainable energy resources. However, renewable electricity-based fuels and chemicals are required for the industrialization of hard-to-abate segments of transport and industry. The global demand for carbon dioxide as raw material for the production of e-fuels and e-chemicals using a global energy transition to 100% renewable energy is analyzed in this research. Carbon dioxide capture and utilization potentials from key industrial point sources, including cement plants, pulp and paper mills, and waste incinerators, are evaluated. According to this study's estimates, the demand for carbon dioxide increases from 0.6 Gt in 2019 to 6.1 Gtpa in 2050. Key industrial point sources can potentially supply 2.1 Gtpa of carbon dioxide and thus meet the majority of the demand in the 2030s. By 2050, however, direct air capture is expected to supply the majority of the demand, amounting to 3.8 Gtpa of carbon dioxide annually. Sustainable and unsustainable industrial point sources and direct air capture are vital technologies which may help the world to achieve sustainable climate goals.

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LUT School of Energy Systems
Energy Technology

Joonas Hyvärinen

TECHNO-ECONOMIC EVALUATION OF CARBON CAPTURE TECHNOLOGIES INTEGRATED TO FLEXIBLE RENEWABLE ENERGY SYSTEM

Hannu Karjunen

ANALYSIS AND DESIGN OF CARBON DIOXIDE UTILIZATION SYSTEMS AND INFRASTRUCTURES

1. Introduction

Climate change is one of the greatest threats that humanity is facing today. Scientists have been warning of many negative impacts such as rising sea levels, increased frequency of natural calamities, loss of biodiversity among others (Gardner et al., 2019). This in turn obligates the global community to limit the global average temperature rise to well below 1.5 °C above pre-industrial levels, which is likely to be reached between 2032 and 2096 (IPCC, 2018). This target has been declared as one of the top priorities, after which irreversible changes may be caused to the climate and the environment (Lemon et al., 2019). Nations around the world are confronting the challenging task of reaching zero greenhouse gas (GHG) emissions to enable achieving the ambitious 1.5 °C target.

Energy transition from fossil fuels to renewable energy (RE) based solutions has been gaining traction as increasingly more countries (The Guardian, 2021; cited (Ortiz-Martínez et al., 2016), and referenced (Görsz, 2020)) set their own sustainability and zero emission goals.

Renewable power resources for power generation have been steadily growing at United States (REN21, 2021) systems go (Lüger-Wal, 2020) annual growth.

The past rapid ramp up in capacity and clean energy demand were successful in meeting the world's increasing energy needs.

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LUT School of Business and Management

Examiners: D.Sc. (Tech.) Tero Tynjälä
M.Sc. (Tech.) Hannu Karjunen

Katja Kuparinen

TRANSFORMING THE CHEMICAL PULP INDUSTRY – FROM AN EMITTER TO A SOURCE OF NEGATIVE CO₂ EMISSIONS

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Feasibility Study for Industrial Pilot of Carbon-Neutral Fuel Production – P2X

Final report

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