LUT University

SYSTEM EARTH

Science with a Purpose

PLANETARY RESOURCES

Regenerative use of natural resources

DIGITAL REVOLUTION

Utilising data and digital technology to benefit society

&

BUSINESS AND SOCIETY

Building resilient businesses, industry, and communities

ENERGY TRANSITION

Clean energy solutions for industry and society

LUT UNIVERSITY STRATEGY 2030

11.9.2025

Energiajärjestelmän murros ja sähköistyminen

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Great challenge: How to achieve net-zero greenhouse gas emissions

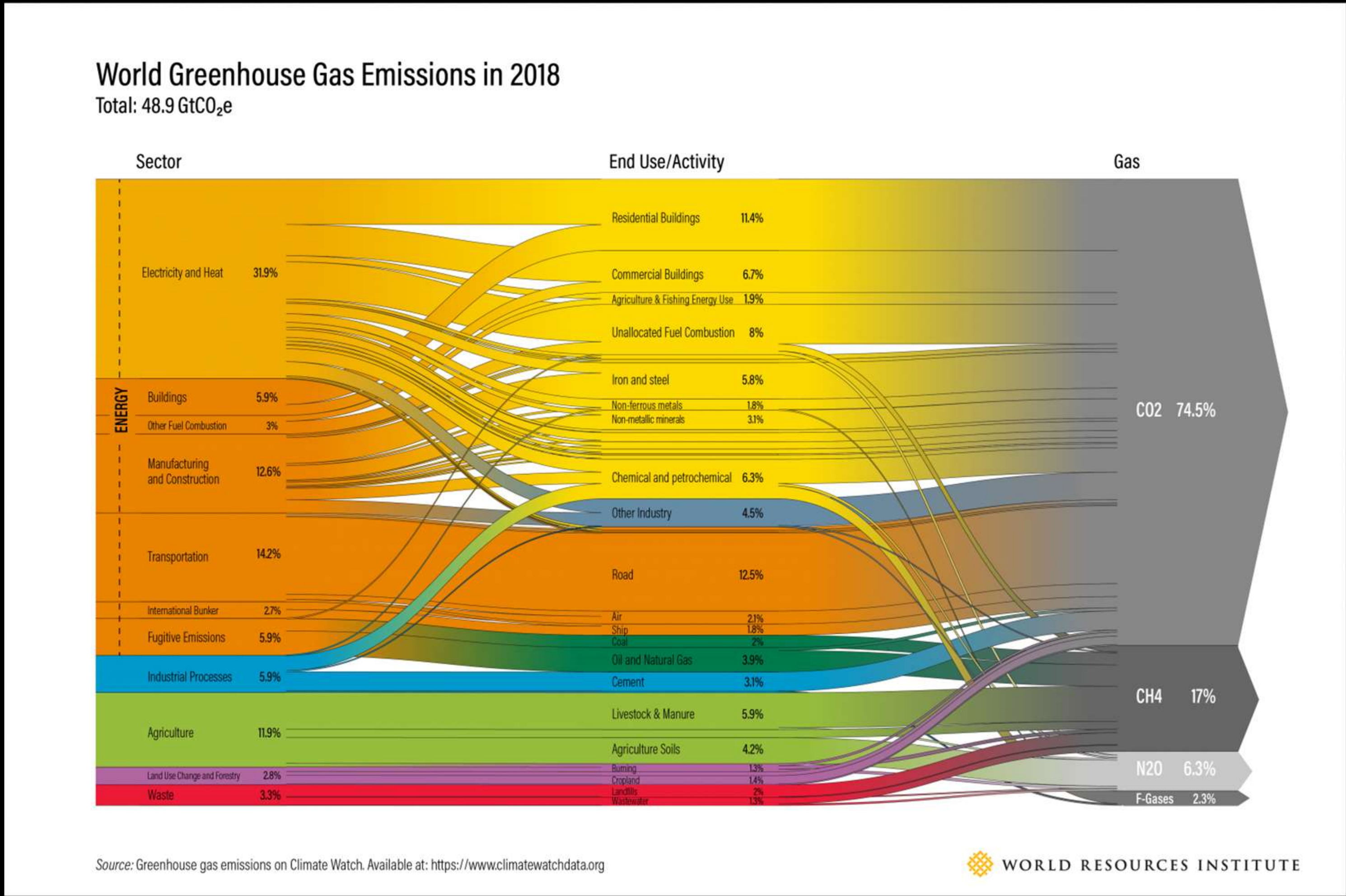
Electricity and heat (32%)

Industry (13%)

Transportation (14%)

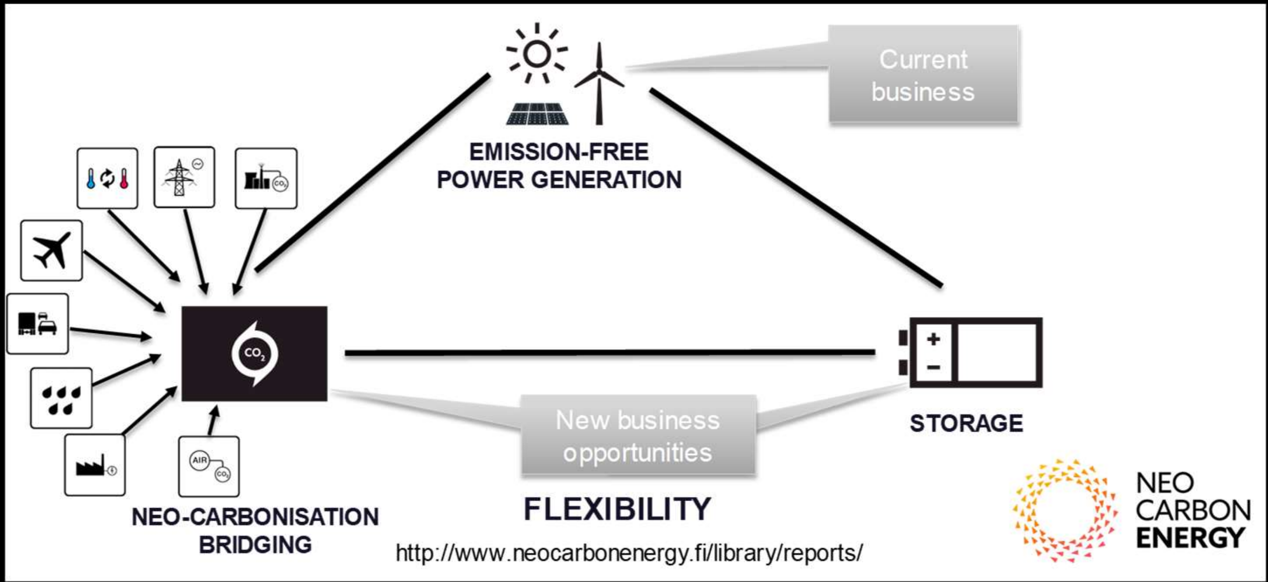
Agriculture and land use change (15%)

ENERGY (73 %)



For < +2 ºC climate goal we have to have net-zero GHG emissions by 2050

Solution to clean up the energy system: Electrify everything 1. directly or 2. indirectly



Many options available now in all sectors are estimated to offer substantial potential to reduce net emissions by 2030. Relative potentials and costs will vary across countries and in the longer term compared to 2030.

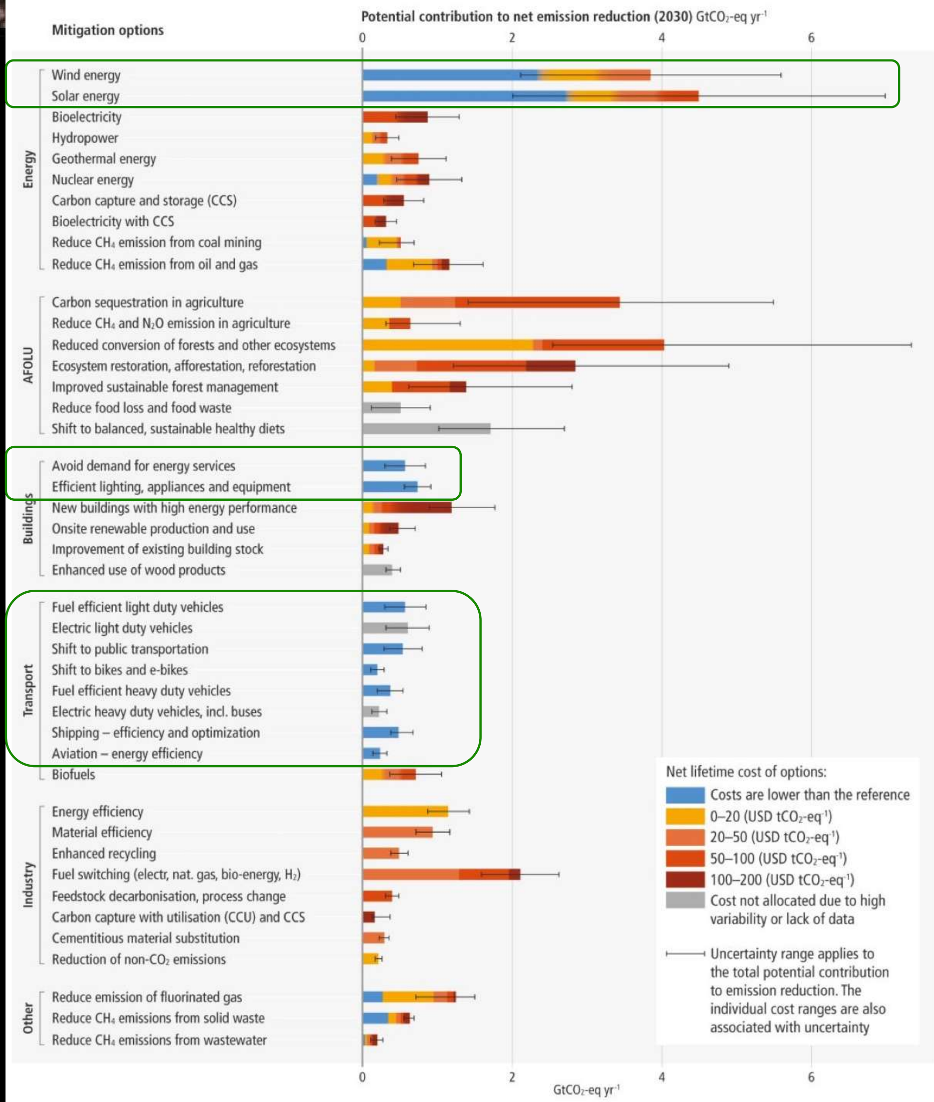


Figure SPM.7: Overview of mitigation options and their estimated ranges of costs and potentials in 2030.

Power-to-X economy – green hydrogen will be an essential part of it

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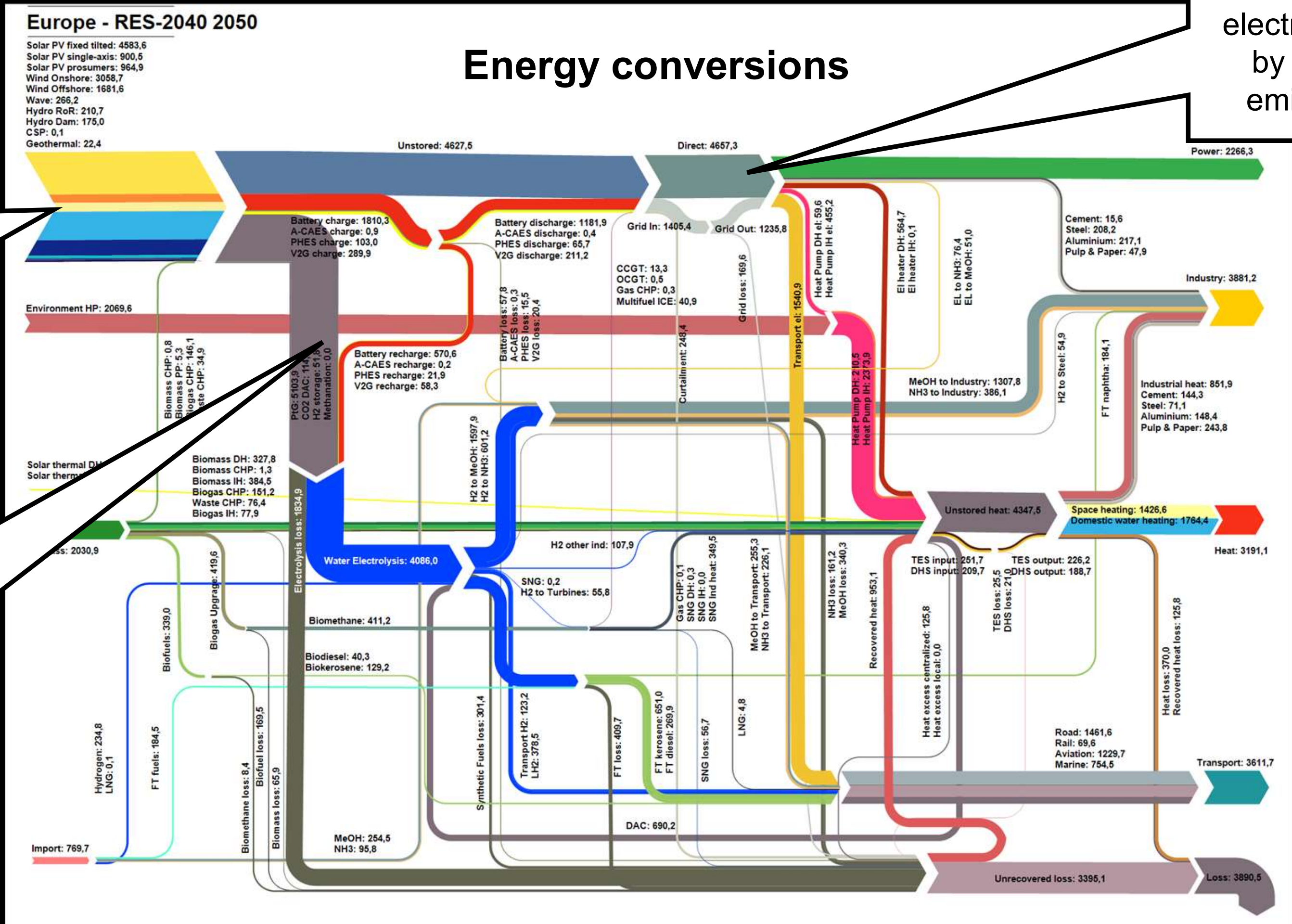
Primary energy, mostly electricity: solar & wind power

Primary energy

Priority 2: Indirect electrification, mostly by using green hydrogen: 40 % of electricity, driven by regulations, e.g. blending mandates

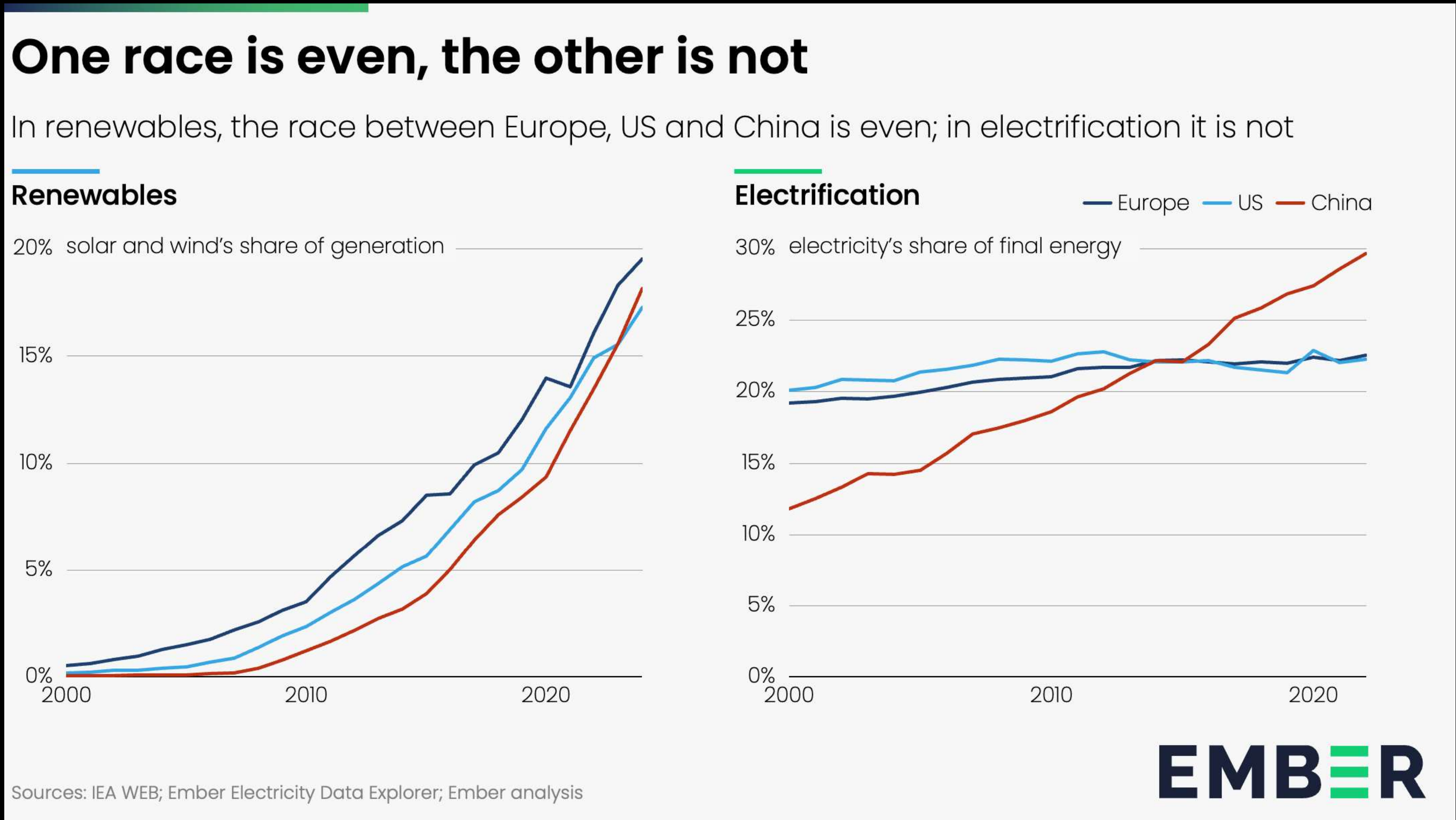


Priority 1: Direct electrification of energy end use: 60 % of electricity, driven e.g. by efficiency and emissions trading

Energy end use at different sectors

Christian Breyer, Gabriel Lopez, Dmitrii Bogdanov, Petteri Laaksonen, The role of electricity-based hydrogen in the emerging power-to-X economy,
International Journal of Hydrogen Energy, 2023,
ISSN 0360-3199,
https://doi.org/10.1016/j.ijhydene.2023.08.170
.

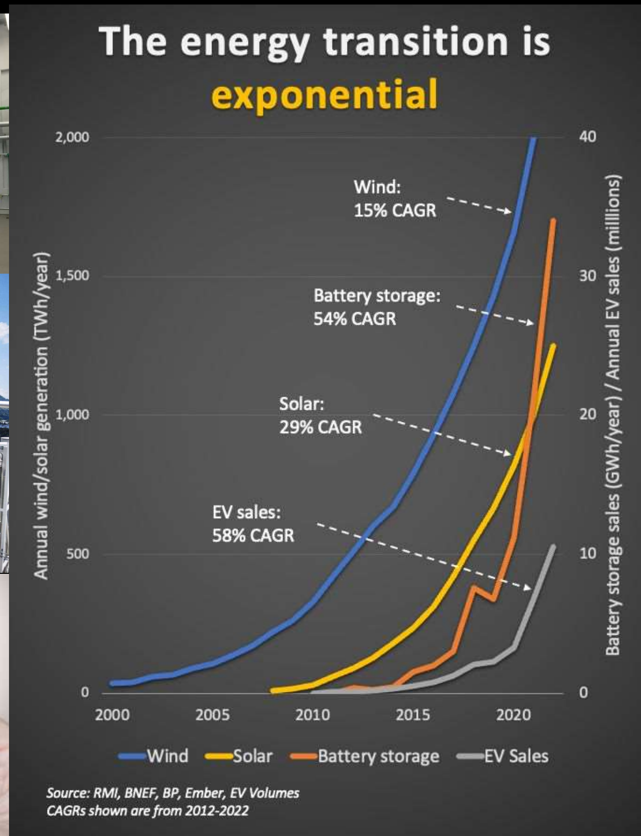
China is building renewables-based electric state



Shift from the extraction of fossil fuels to mass-produced electric energy technologies

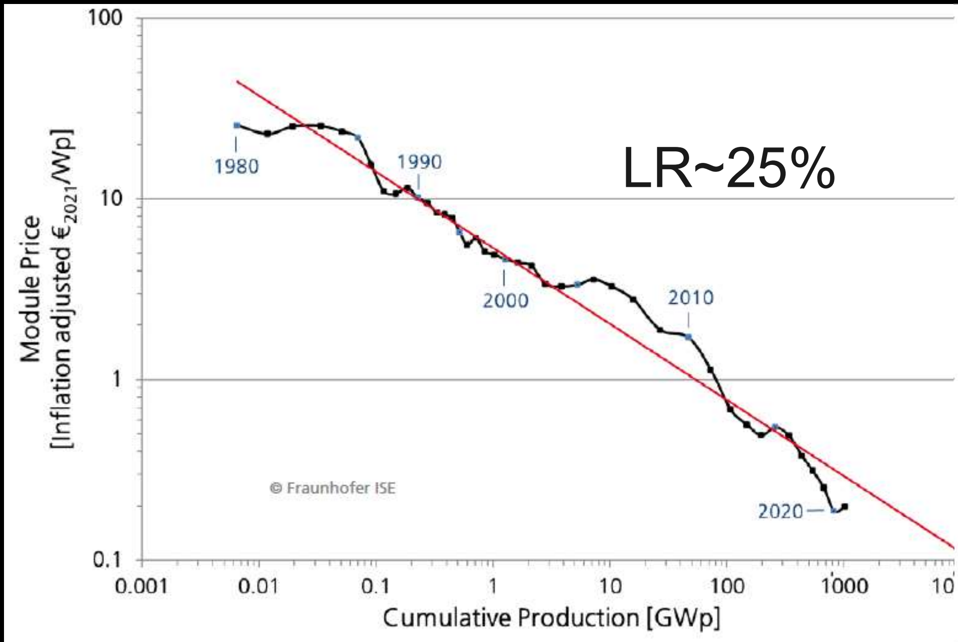
Era of fossil fuels:
Exploration, extraction, mining, refining, transportation, and combustion of fossil fuels.

Era of renewable energy and its technologies:
Mass-produced wind and solar energy systems, batteries, electrolyzers, heat pumps, direct air capture of CO2, and heat storage solutions will dominate. Electricity is set to become the main energy source.

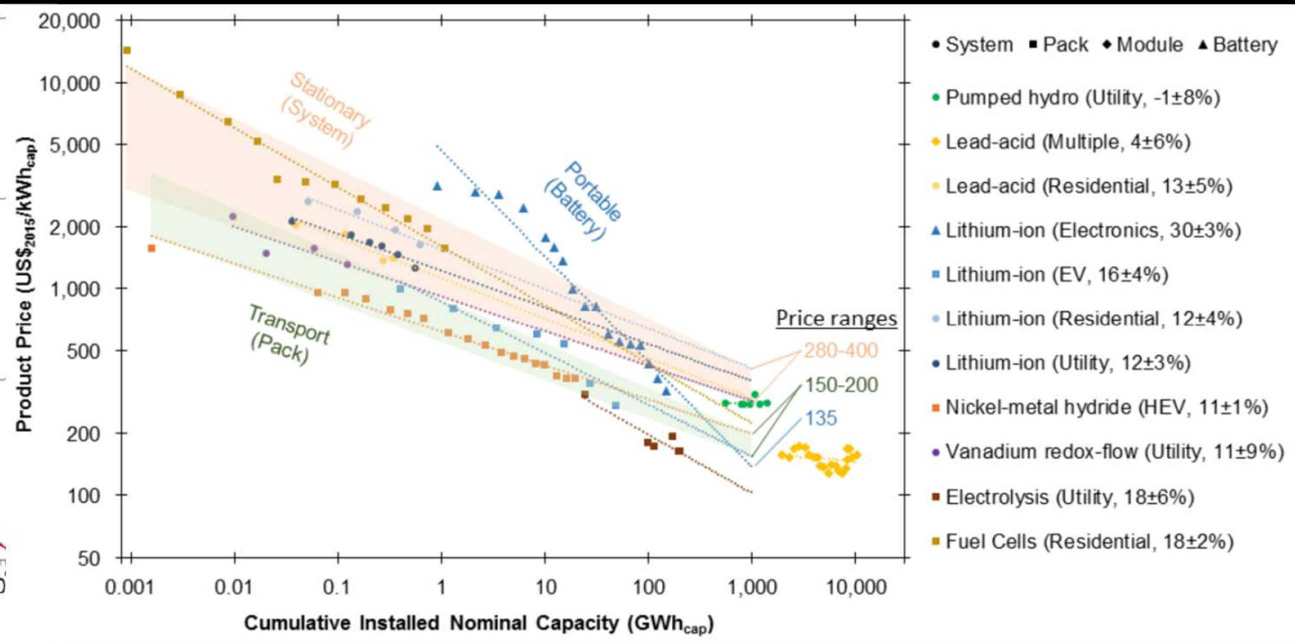


Progression of essential renewable electric energy technologies

Solar PV module learning curve



Learning curves for electricity storage and conversion technologies.



Source: Photovoltaics Report, Fraunhofer-ISE, Germany, 22.8.2022 https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Photovoltaics-Report.pdf

Source: O. Schmidt, A. Hawkes, A. Gambhir & I. Staffell, The future cost of electrical energy storage based on experience rates, Nature Energy volume 2, Article number: 17110 (2017)

What is the current state of solar and wind energy advancements?

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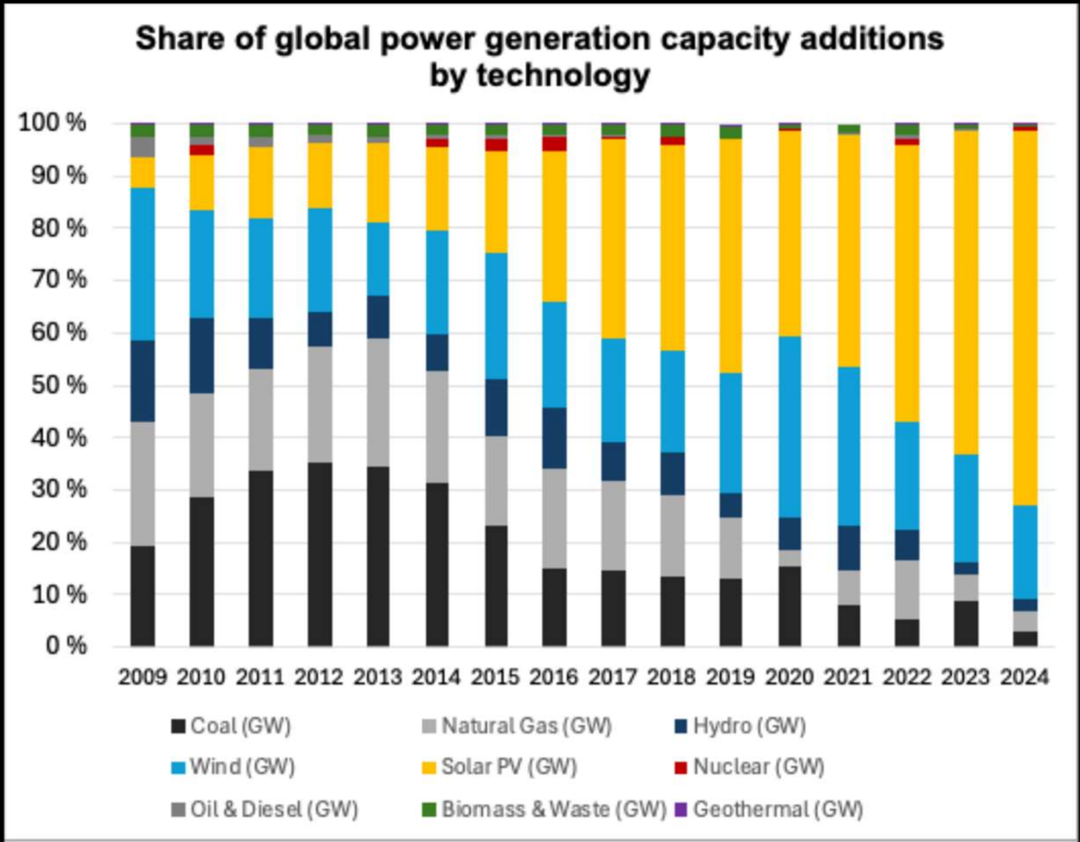
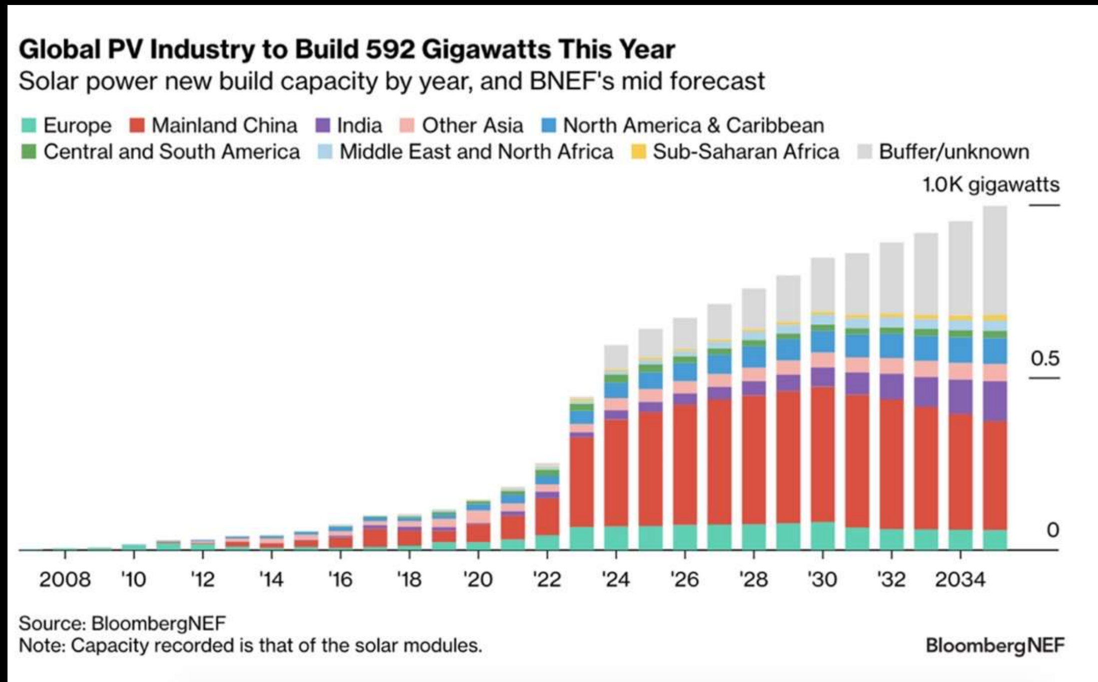
- As of March 2022, cumulative solar PV installations hit 1 TW.
- An additional 1 TW of solar PV was installed in 2023-24.
- According to the Ember, 593 GW of solar power, and based on WWEA 150 GW of wind power were installed globally in 2024.
- The global capacity for PV module manufacturing exceeds 1 TW per year.





Sources: IEA, IRENA, GWEC, Bloomberg NEF, etc

Baseload power plant of 1 GW in UAE by using 5.2 GW solar and 19 GWh Li-ion battery energy storage

UAE launches world's first 24/7 solar PV battery storage gigascale project

The facility will deliver up to 1GW of baseload power daily, generated from renewable energy sources.

January 15, 2025

Share

Baseload electricity supply cost ~60 €/MWh

The initiative positions the UAE as a leader in renewable energy deployment. Credit: PRnewswire/Masdar.

The United Arab Emirates (UAE) has launched the world's first large-scale round-the-clock gigascale energy storage project in Abu Dhabi, combining solar power and battery storage in a significant development for the country's energy sector.

Source: https://www.energymonitor.ai/news/uae-24-7-solar-pv-battery-storage/

China's CGN New Energy announces winning bidders in 10 GWh BESS tender

The procurement exercise has attracted 50 battery energy storage companies but only seven have emerged as winners. The lowest bid stood at CNY 0.458/Wh ($63/kWh).

By Marija Maisch | Jan 15, 2025

Battery energy storage cost 63 €/kWh

Markets | Supply chain | Tenders

Image: Canadian Solar

Source: https://www.ess-news.com/2025/01/15/chinas-cgn-new-energy-announces-winning-bidders-in-10-gwh-bess-tender/

LUT research: The optimization and economics of 1 GW renewable baseload power plant in Finland

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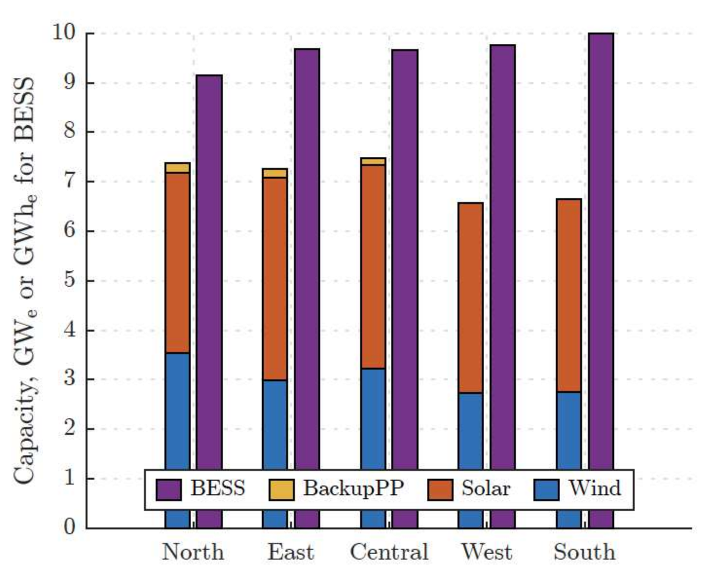
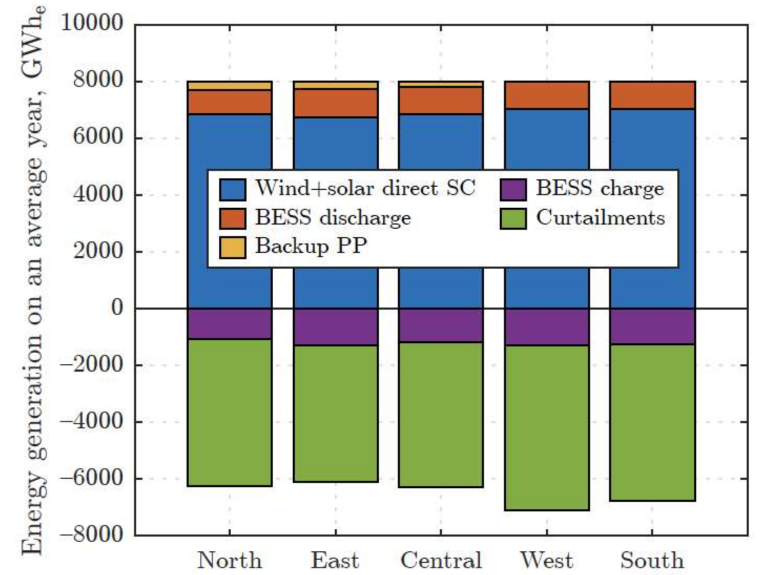
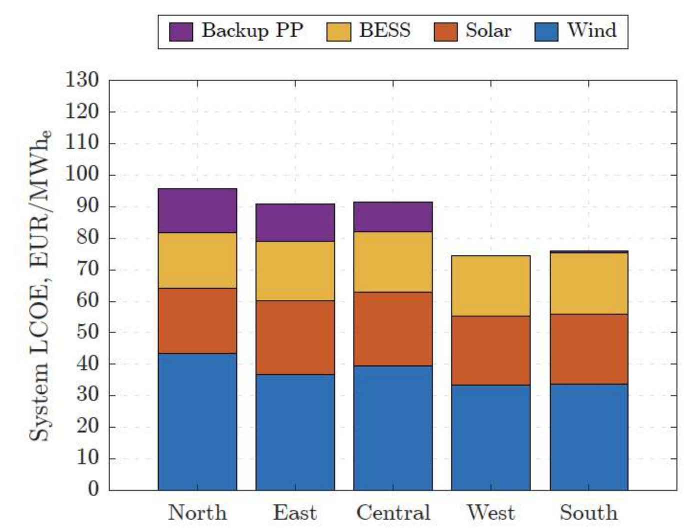
- **Baseload electricity generation cost 75-95 €/MWh (8000 h/a), 95-120 €/MWh (8560 h/a), interest 6 %**
- The baseload power plant required e.g. by data center consists of a wind power plant, solar power plant, battery and a peak power plant.
- Provides 1 GW of baseload power 8000 h/a, optimization based on 10 year hourly solar and wind data



Component capacities



Electricity production



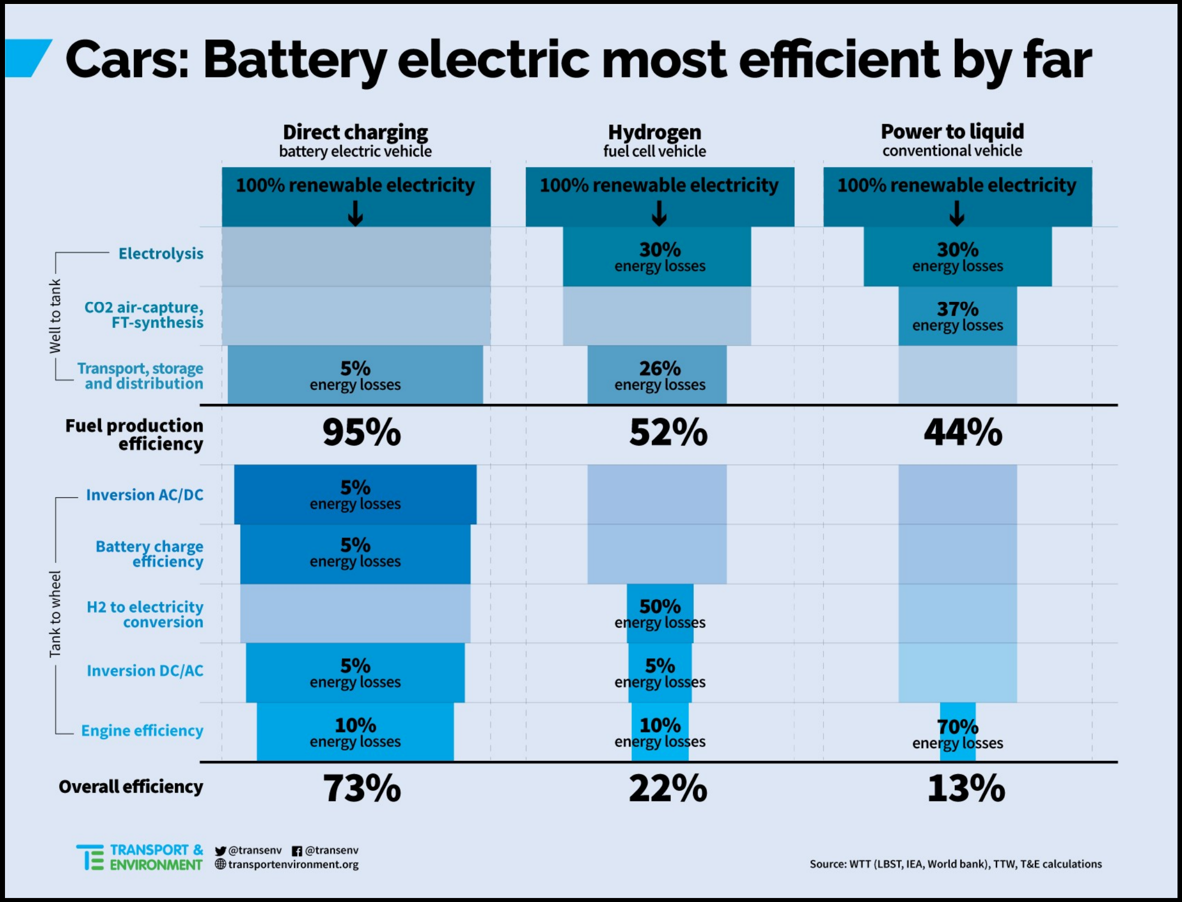
Cost of electricity

Source: The Economics of Firm Renewable Power: Analysis of a 1 GW Baseload for Data Centers (under review in Energy), LUT.

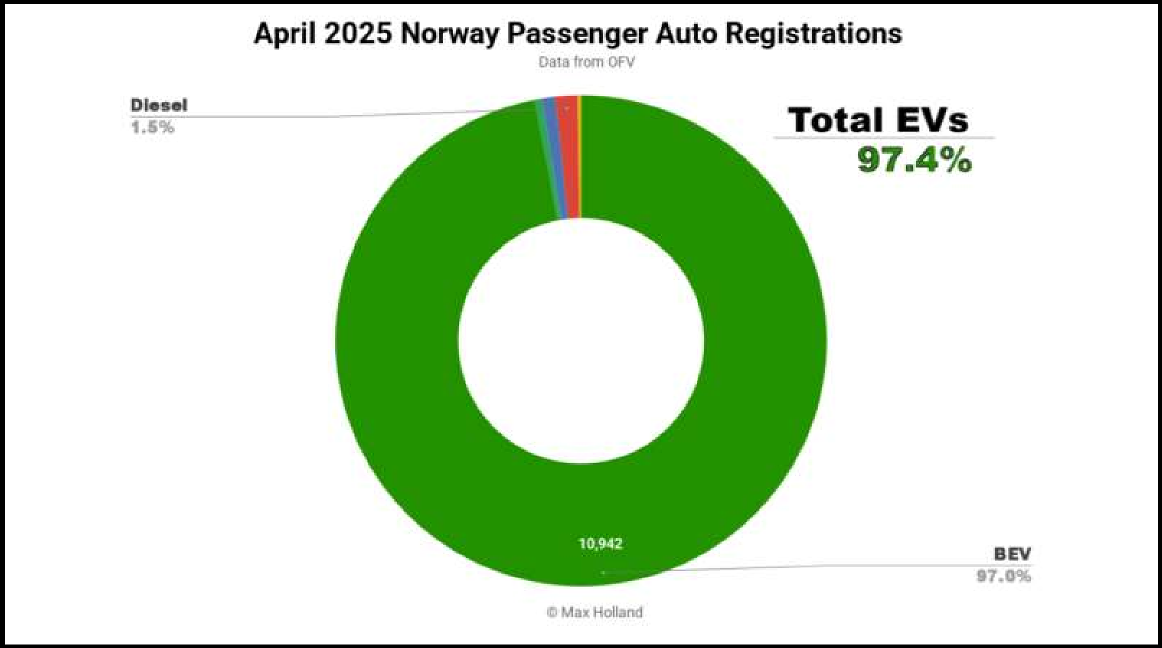
11.9.2025

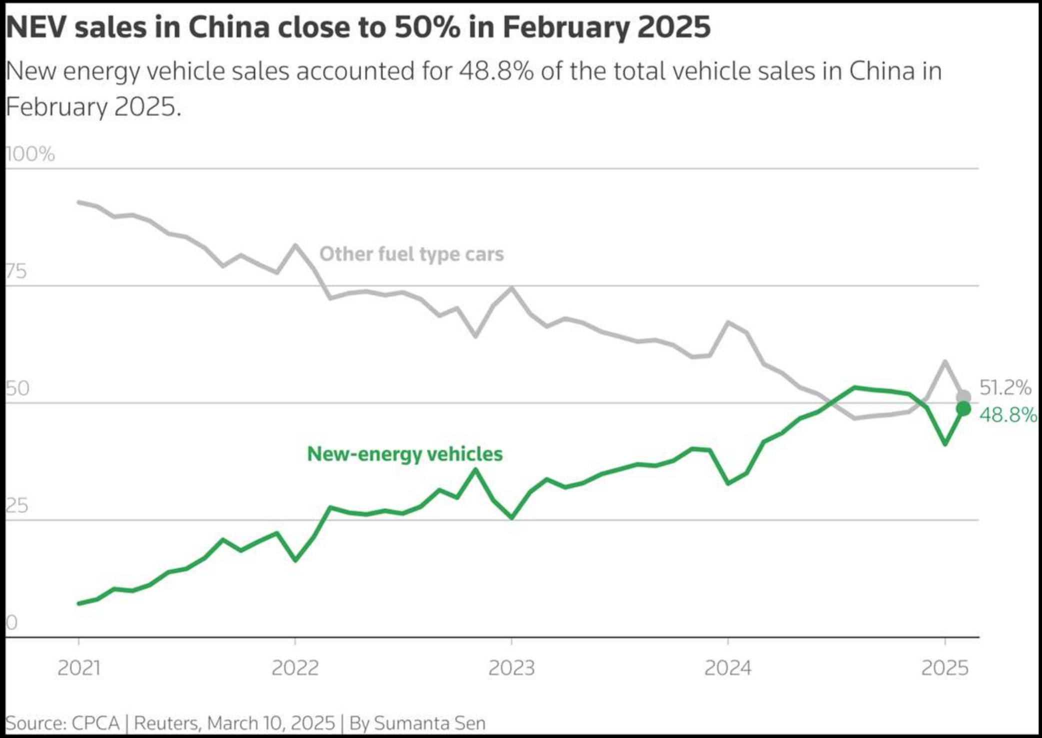
Direct and indirect electrification of transportation

Due to energy efficiency and resulting cost efficiency, the land-based transportation will be mainly electrified



Global shift from internal combustion engines to electric vehicles





- In 2023, worldwide car sales reached approximately 80 million vehicles annually.
- China emerged as the biggest car market, recording sales of 30 million cars that year.
- In 2026 passenger vehicles EV sales in China will exceed 50 % of total sales.

Battery-swapping for an electric truck

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LUT research: Competitiveness of battery swapping and megawatt charging in heavy transportation with diesel

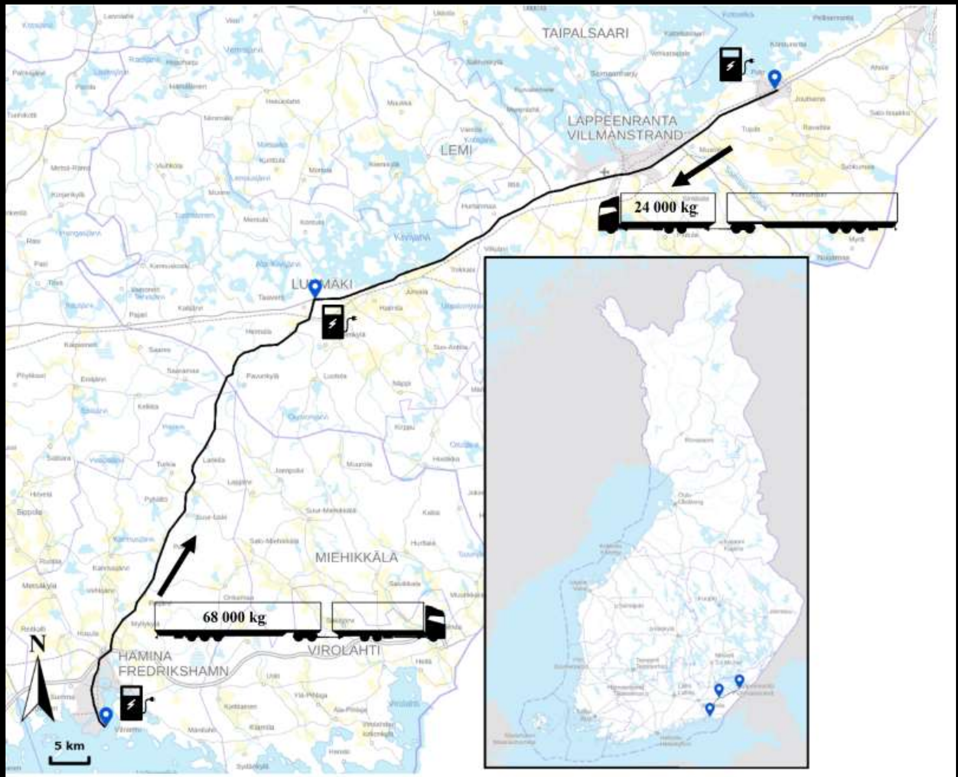


Fig. 2: Route of the case study. Possible charging station locations marked with charging station icon. Background map (raster) contains data from the National Land Survey of Finland Topographic Database 04/2024 [46]

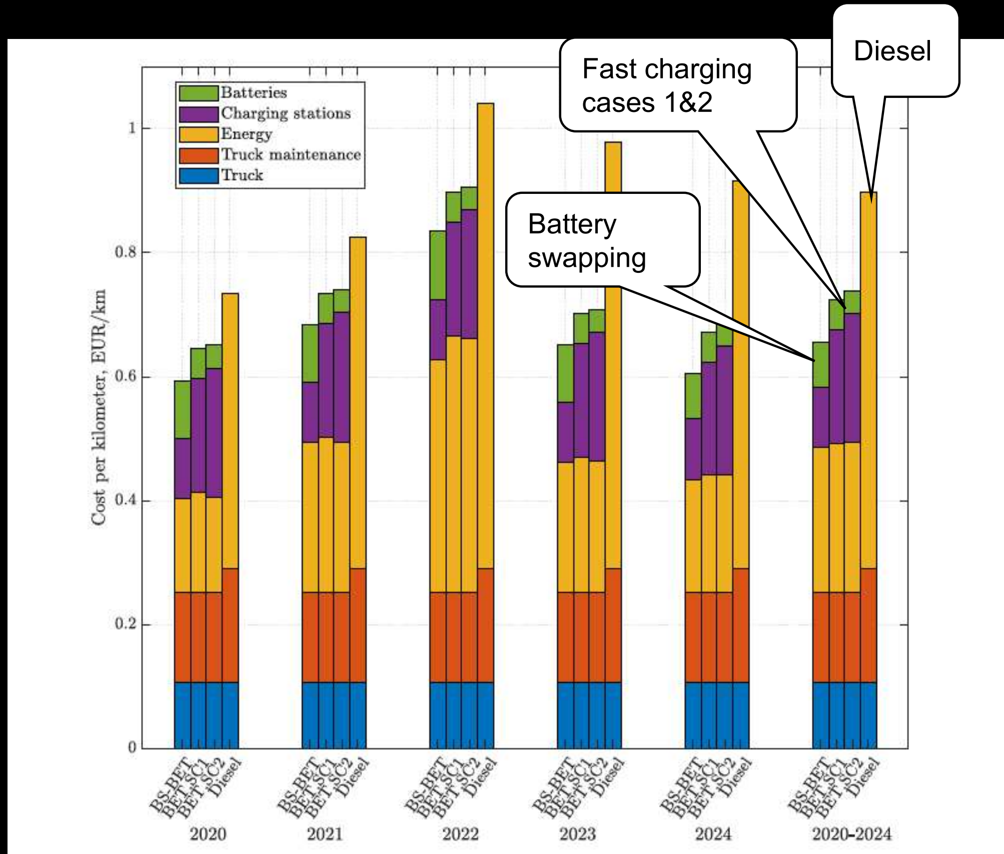
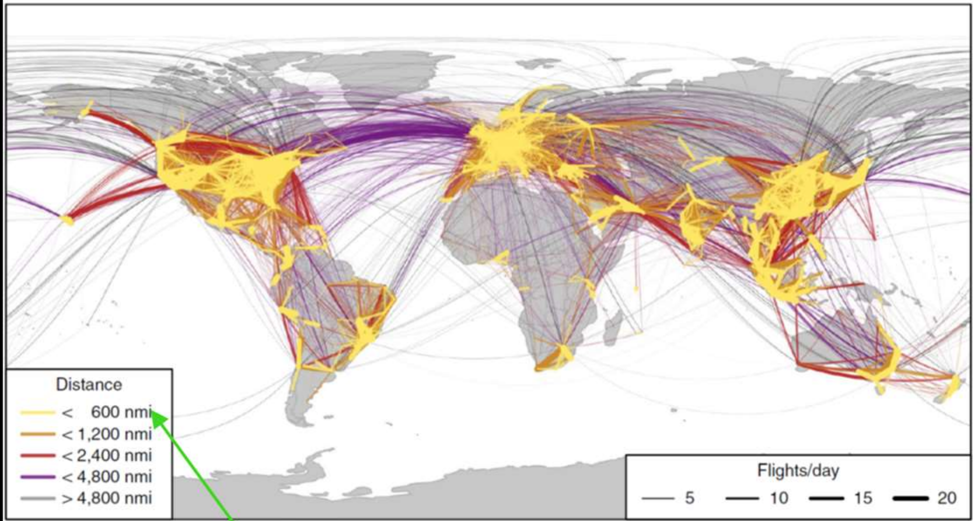
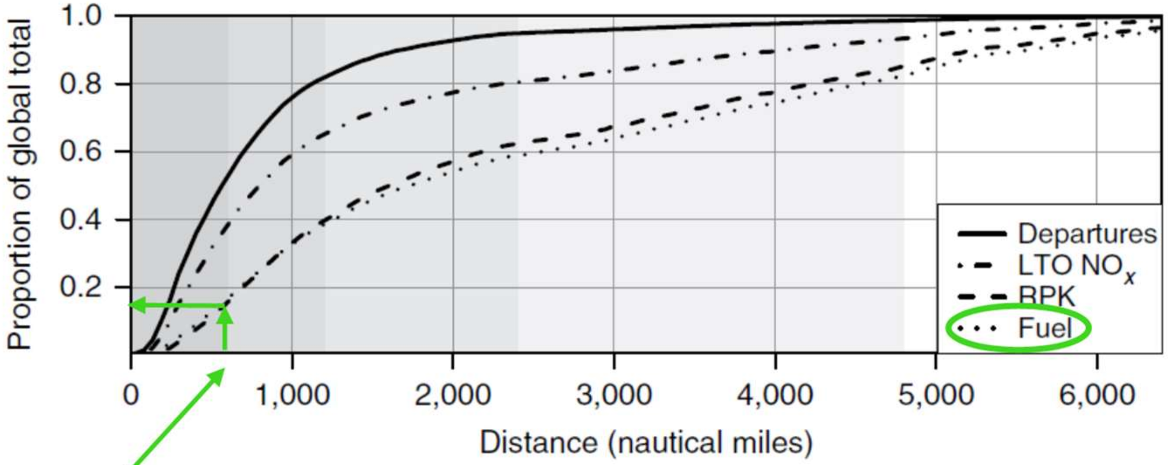


Fig. 4: Cost components for different scenarios with interest rate of 6 %. BS-BET refers to battery swapping, BET,SC1 to scenario one and BET,SC2 to scenario two.

Source:, Esa Tuviala, Altti Meriläinen, Teemu Hiltunen, Tuomo Lindh, Pertti Kauranen, Jero Ahola, Cost-optimization of battery electric heavy-duty vehicles from Nordic perspective: comparative cost-analysis of two separate charging solutions, submitted to a journal.

Despite of electrification and development of batteries, there will be plenty of need for electro-fuels in aviation and in shipping

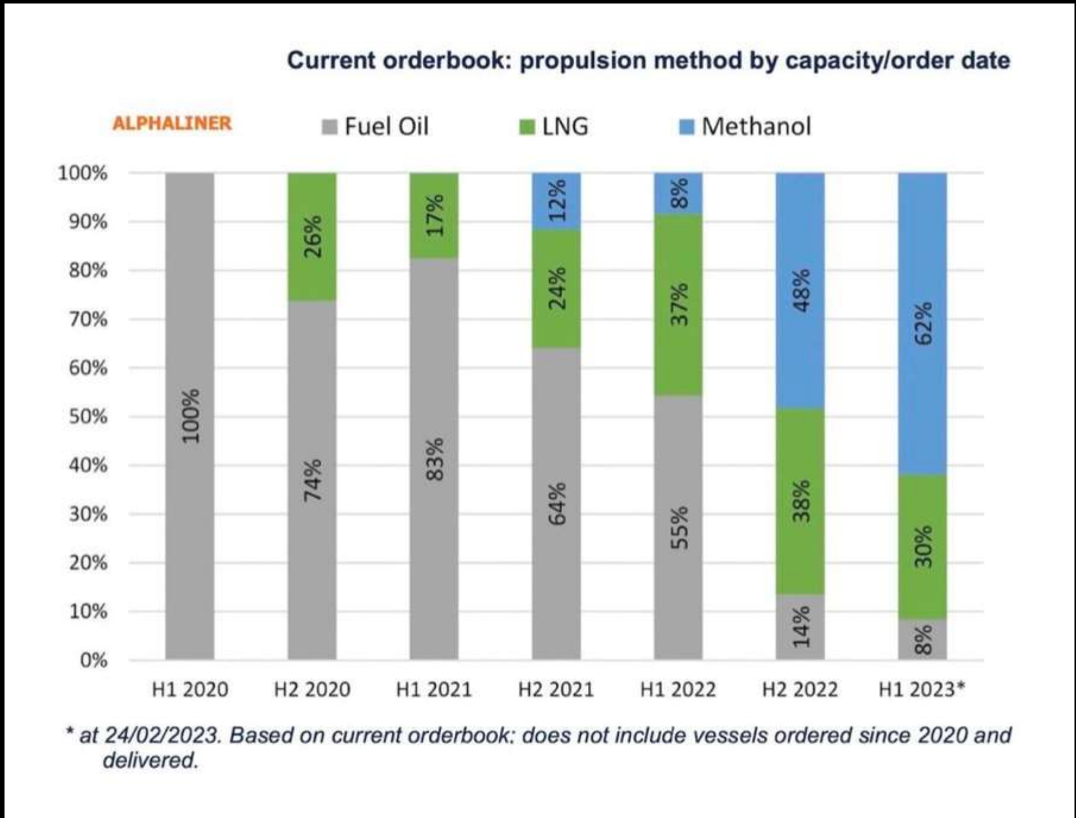




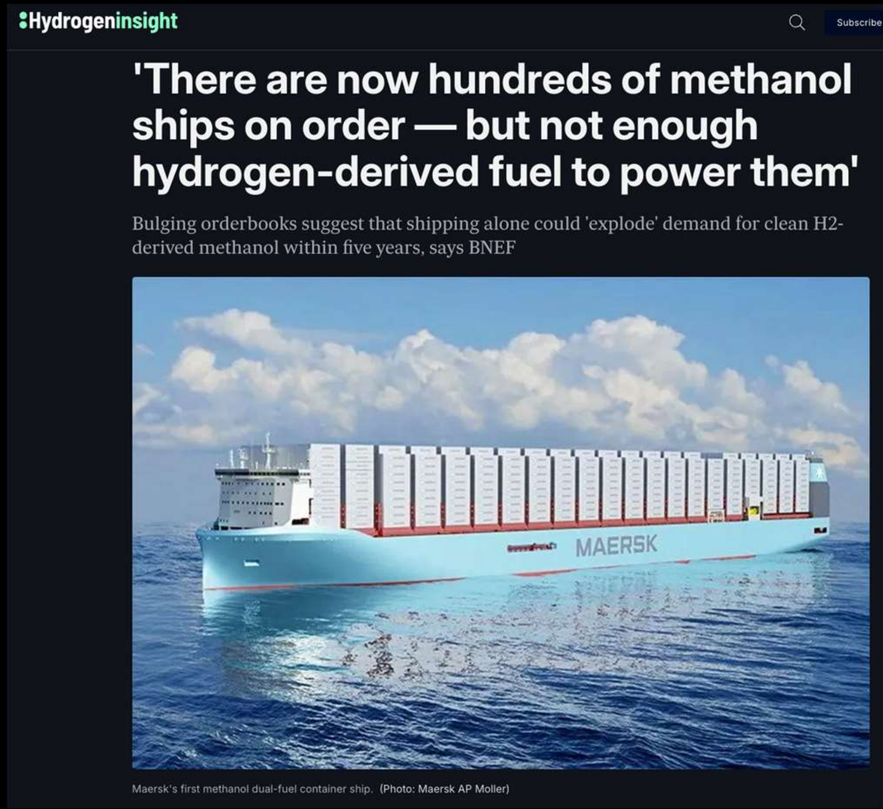
Electric flights at distances < 600 nmil (1100 km) ~15 % of total fuel consumption of battery energy density 800 Wh/kg will be reached

Source: Andreas W. Schäfer, et. Al., Technological, economic and environmental prospects of all electric aircraft, Nature Energy, Vol. 4, February 2019, pp. 160-166.

Methanol is becoming polular as a scalable carbon-neutral fuel in shipping



Source: https://splash247.com/methanol-boxship-orders-growing-more-rapidly-than-all-other-fuel-types/



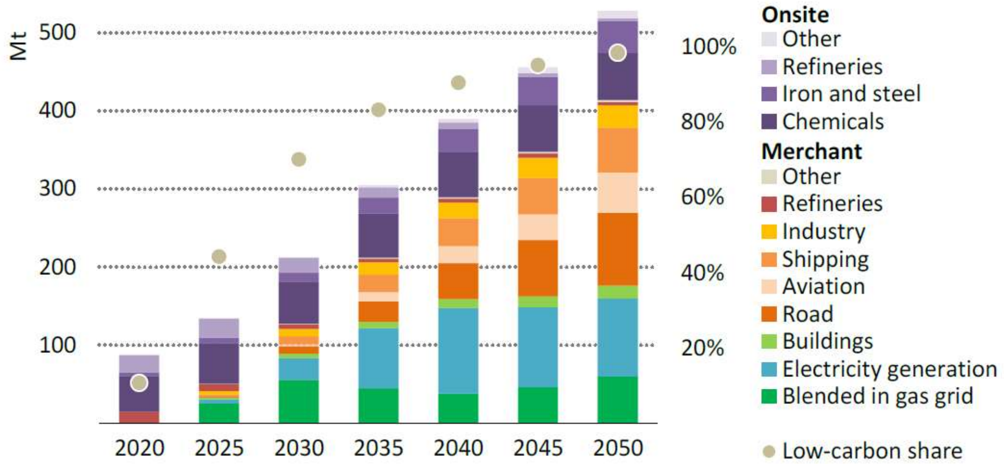
Source: https://www.hydrogeninsight.com/transport/there-are-now-hundreds-of-methanol-ships-on-order-but-not-enough-hydrogen-derived-fuel-to-power-them/2-1-1666234

11.9.2025

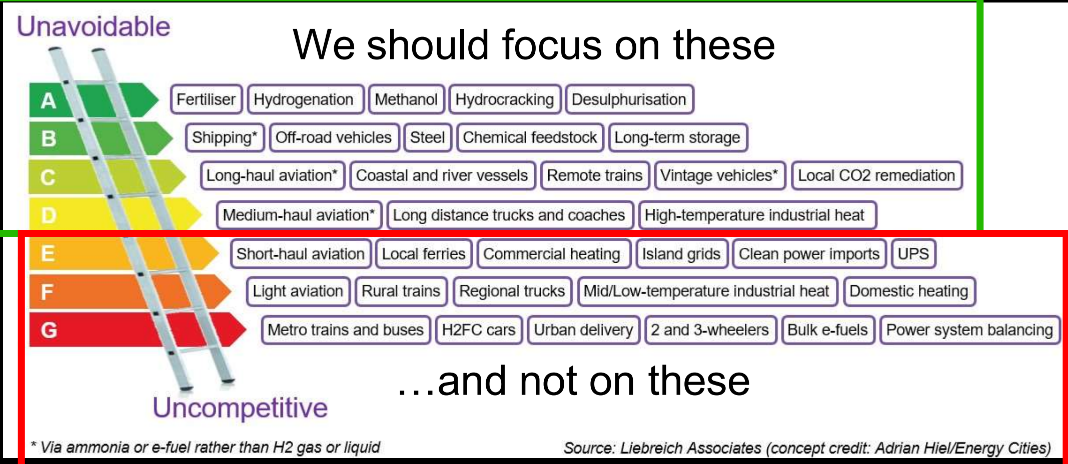
Demand of green hydrogen and hydrogen production technologies

Potential future demand of green hydrogen

Figure 2.19 ▷ Global hydrogen and hydrogen-based fuel use in the NZE



Source: IEA, Net Zero by 2050 A Roadmap for the Global Energy Sector, 2021 : https://www.iea.org/reports/net-zero-by-2050



To produce 500 Mt/a of green hydrogen:

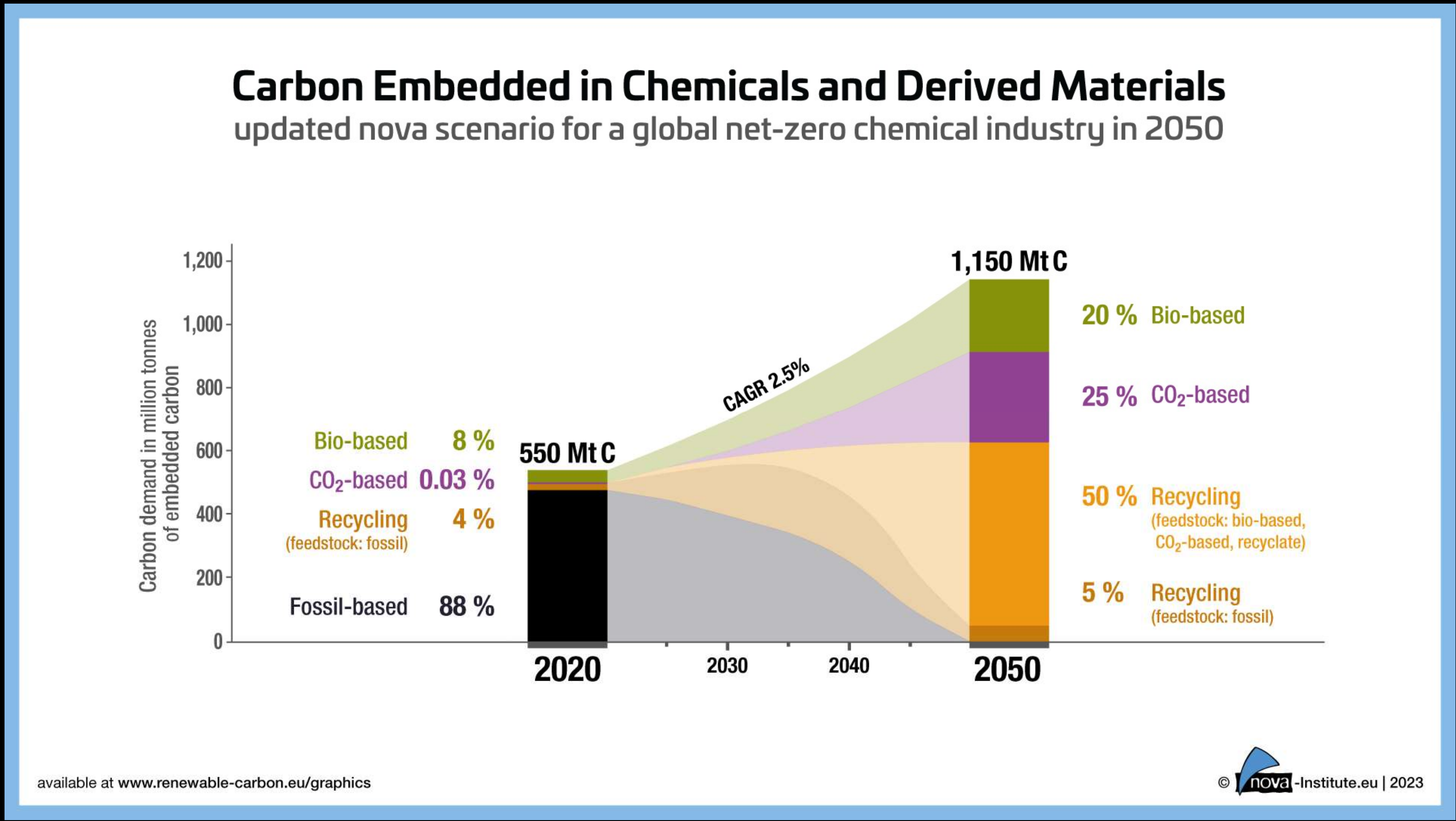
- 7 TW of electrolyzers is needed 500 Mt_{H2}/a capacity factor 4000 h/a (wind power)
- 14 TW of electrolyzers is needed if solar power is used (capacity factor 2000 h/a)

European objectives approved by the Parliament and the Council	AVIATION Incorporation rate of low-carbon fuels	MARITIME Carbone intensity reduction
2025	2%	2%
2030	6%	6%
2035	20%	14,5%
2040	34%	31%
2045	42%	62%
2050	70%	80%

Table 1: Decarbonisation trajectories for the aviation and maritime sectors, as adopted by the European Parliament and Council in 2023.

The chemical industry will continue to require carbon in the future

- Roughly 10-15 % of all oil and gas is used as a raw material of chemical industry

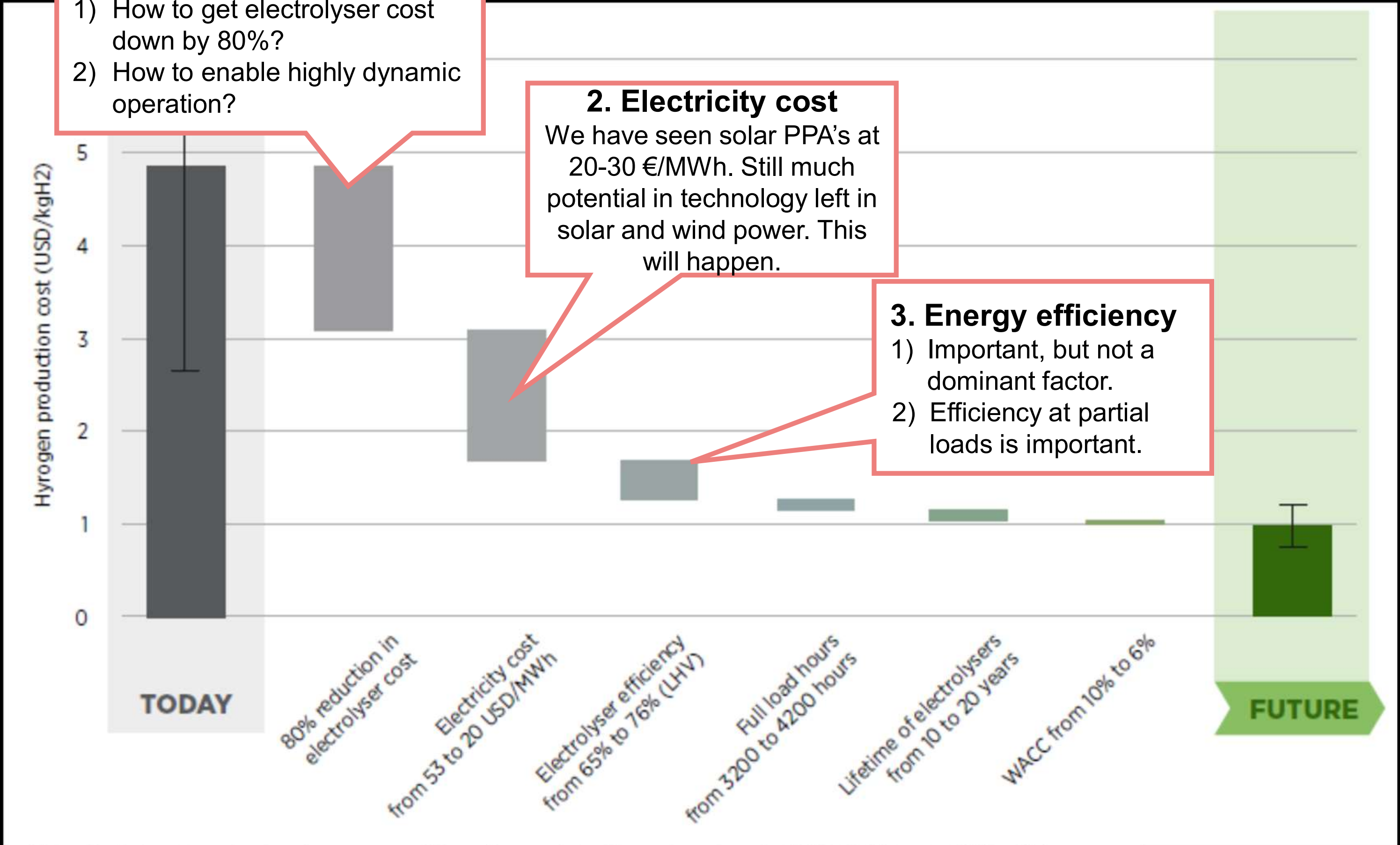


Industrial-size alkaline water electrolysis plant (Woikoski Oy, Kokkola)

Summary:

- Located in Kokkola, Finland
- Power-to-Hydrogen: 1800 Nm^3/h (H_2)
- 3x3 MW pressurized alkaline water electrolyzers, 3x600 Nm^3/h, 16 bar (H_2)
- The main use of H_2 plant is at nearby Cobalt plant, hydrogen delivery by a pipeline
- The rest of H_2 compressed to 200-300 bar and stored in bottles for delivery with trucks

How to achieve low-cost green hydrogen?



Note: 'Today' captures best and average conditions. 'Average' signifies an investment of USD 770/kilowatt (kW), efficiency of 65% (lower heating value – LHV), an electricity price of USD 53/MWh, full load hours of 3200 (onshore wind), and a weighted average cost of capital (WACC) of 10% (relatively high risk). 'Best' signifies investment of USD 130/kW, efficiency of 76% (LHV), electricity price of USD 20/MWh, full load hours of 4200 (onshore wind), and a WACC of 6% (similar to renewable electricity today).

1. Electrolyser cost

1) How to get electrolyser cost down by 80%?
2) How to enable highly dynamic operation?

2. Electricity cost

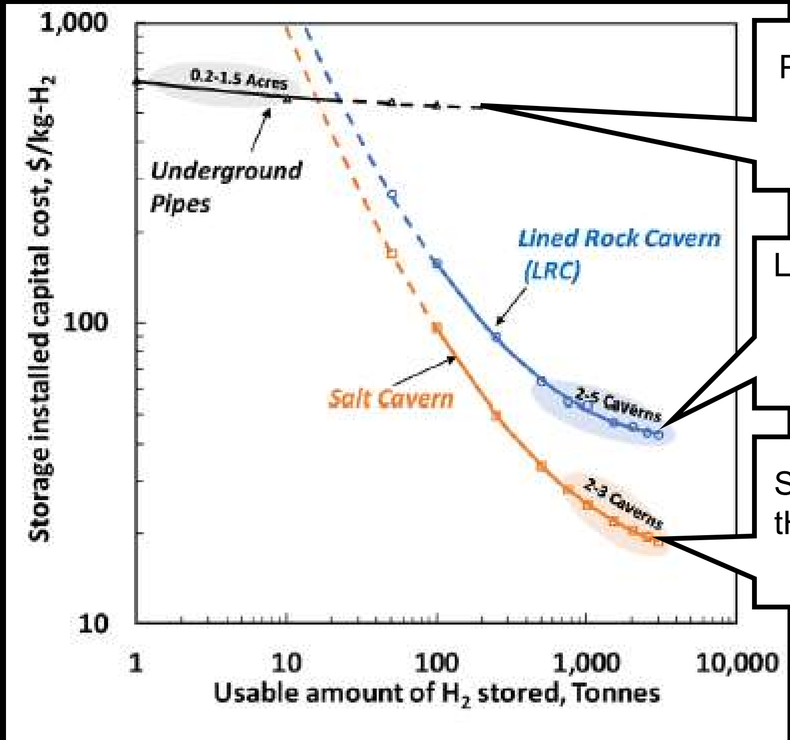
We have seen solar PPA's at 20-30 €/MWh. Still much potential in technology left in solar and wind power. This will happen.

3. Energy efficiency

1) Important, but not a dominant factor.
2) Efficiency at partial loads is important.

IRENA (2020), Green hydrogen cost reduction: Scaling up electrolysers to meet the 1.5 °C climate goal, International Renewable Energy Agency, Abu Dhabi.

Hydrogen storages are needed to convert intermitted renewable hydrogen production into baseload hydrogen. The investment cost of industrial-size hydrogen storage is 1% of battery storage.

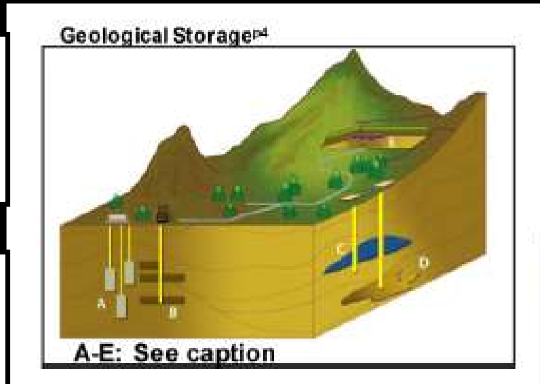


(a) Installed capital cost

Pipe storage 550 €/kgH_2 = 17 €/kWhH_2

Lined rock cavern (3000 tH2), 44 €/kgH2 = 1.3 €/kWhH2

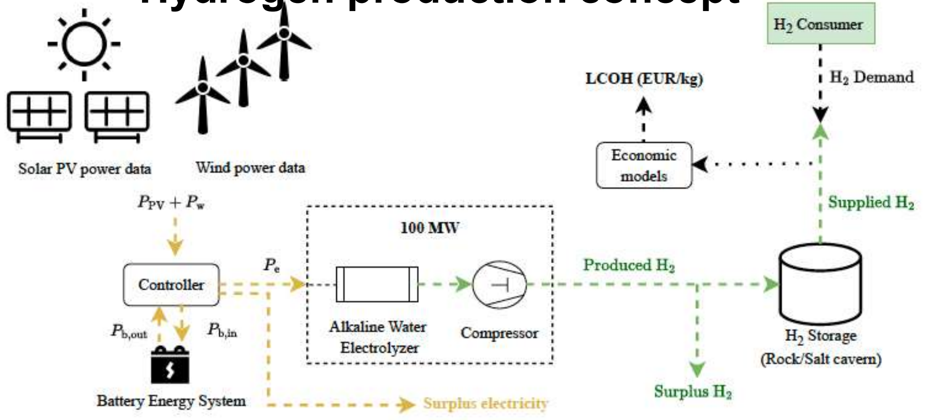
Salt cavern (3000 tH2), 17 €/kgH2 = 0.5 €/kWhH2



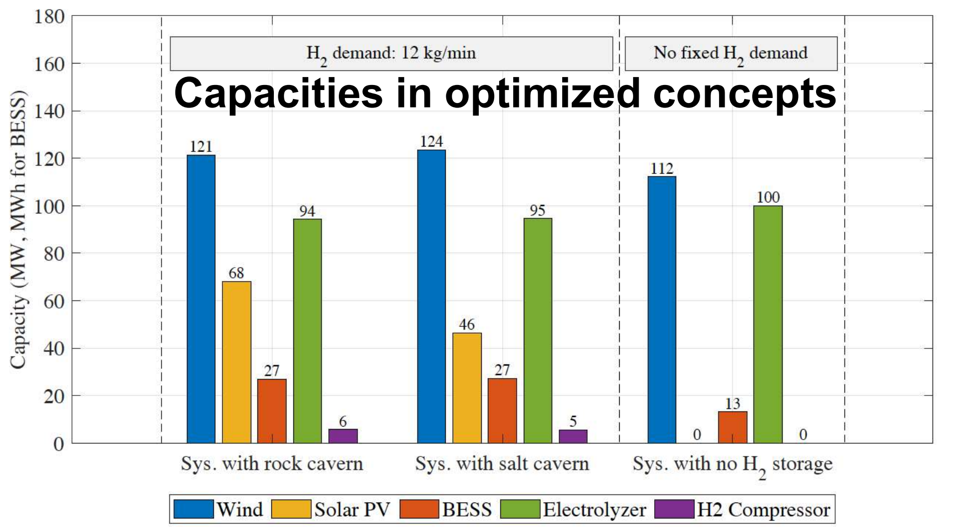
Source: D.D Papadias, R.K. Ahluwalia, Bulk storage of hydrogen, International Journal of Hydrogen Energy 46, 2021, pp. 34527-34541

LUT research: Optimizing costs for constant green hydrogen supply from renewables

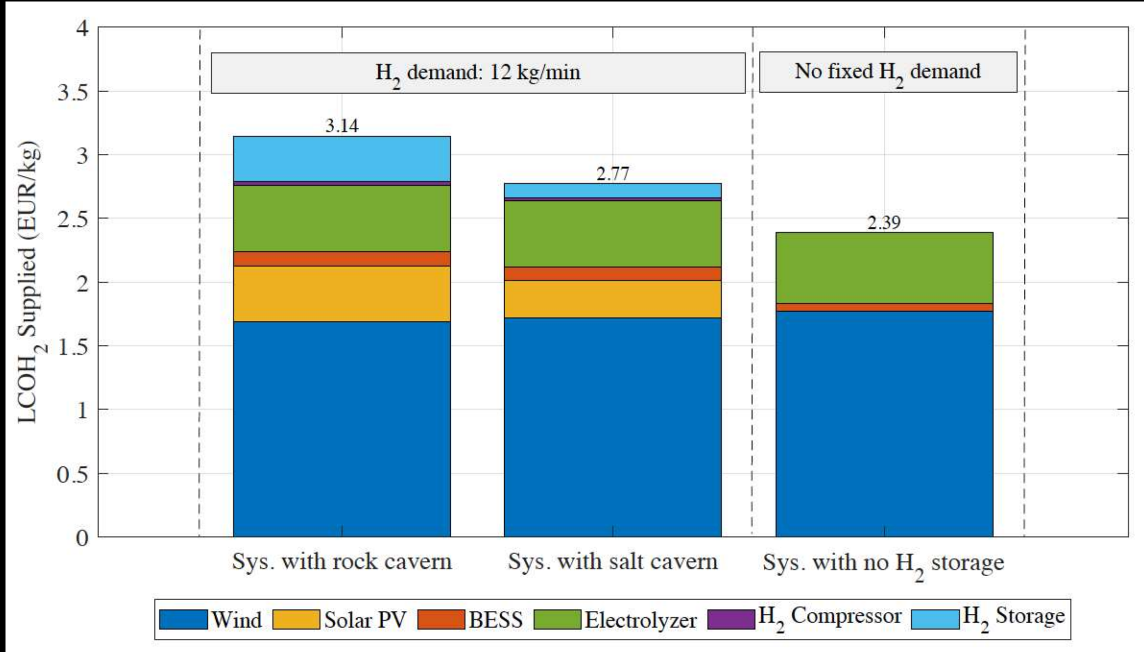
Hydrogen production concept



Capacities in optimized concepts



Optimized hydrogen production costs



Source: Alejandro Ibáñez-Rioja, Pietari Puranen, Lauri Järvinen, Antti Kosonen, Vesa Ruuskanen, Katja Hynynen, Jero Ahola, Pertti Kauranen, Baseload hydrogen supply from an off-grid solar PV–wind power–battery–water electrolyzer plant, Energy, 2025,135304, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2025.135304

LUT is one of the world's

TOP 10 UNIVERSITIES

in terms of climate actions – SDG 13

The Times Higher Education Impact Rankings 2021 assess the social and economic impact of universities against the UN's Sustainable Development Goals.

SUSTAINABLE DEVELOPMENT GOALS

13 CLIMATE ACTION

LUT ELECTRICAL ENGINEERING 2025

LUT University

RESEARCH LABORATORIES AND TEAMS

Applied Electronics
- Prof. Pertti Silventoinen

Control Engineering and Digital Systems
- Assoc. Prof. Tuomo Lindh
- Prof. Olli Pyrhönen
- Prof. Pedro Nardelli
- Assistant prof. Niko Nevaranta -> (Assoc. 1.8.)

Electricity Markets and Power Systems
- Prof. Samuli Honkapuro
- Prof. Behnam Mohammadi-Ivatloo
- Prof. Jukka Lassila

Electrical Drives Technology
- Prof. Pasi Peltoniemi
- Assoc. Prof. Lassi Aarniovuori (Lahti activities)
- Prof. Juha Pyrhönen -> (20 % 1.7.-30.6.2026)

Renewable Electricity Generation and Storage
- Prof. Jero Ahola
- Prof. Pertti Kauranen (Kymenlaakso activities)
- Prof. Antti Kosonen

Solar Economy
- Prof. Christian Breyer

Industry prof. Jukka Ruusunen, Prof. Jarmo Partanen

FOCUS ON ENERGY SYSTEM ELECTRIFICATION

1. **Power-to-X Economy**
   - Energy system modelling
   - Wind and solar power generation
   - Electrochemical energy conversion and storage
   - Energy Efficiency
2. **Smart grids and Electricity Markets**
   - Smart grids
   - Sector integration and electricity grids
   - Electricity markets
   - IoT in energy systems
3. **Electric Power Conversion**
   - Electrified drivelines for different industrial and mobile applications
   - Electric transportation systems
   - Measurement, control, estimation, identification, optimization and communication methods
   - Power electronics: control, sensors, aging, design, optimization, diagnosis

Staff (~200, summer 2025): 14 profs., 48 doctors, 66 post-graduate students, 67 research assistants, turnover ~15 M€

Head of Department
- Prof. Jero Ahola

Vice Head of Department
- Prof. Pertti Silventoinen

Head of Education
- Assoc. Prof. Katja Hynynen

Vice Head of Education
- Adjunct Prof. Janne Nerg