Energia-alan tulevaisuuden näkymät ja sen tuomat innovaatiohaasteet alan yrityksille

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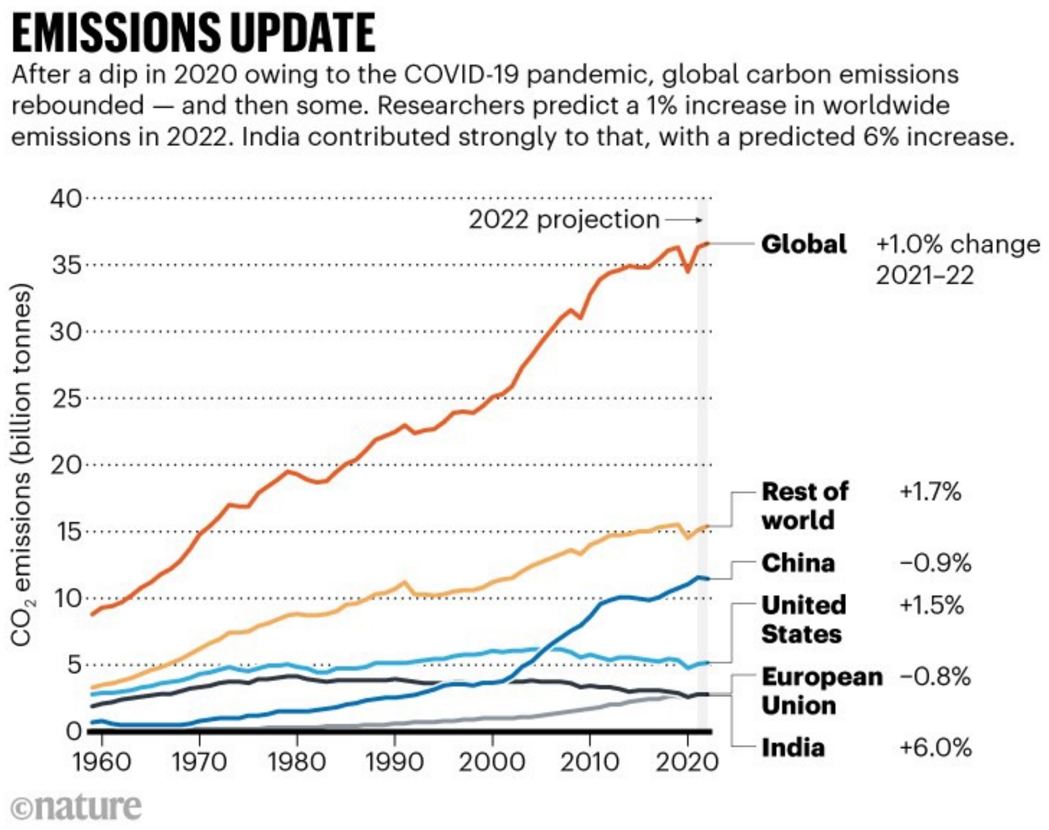
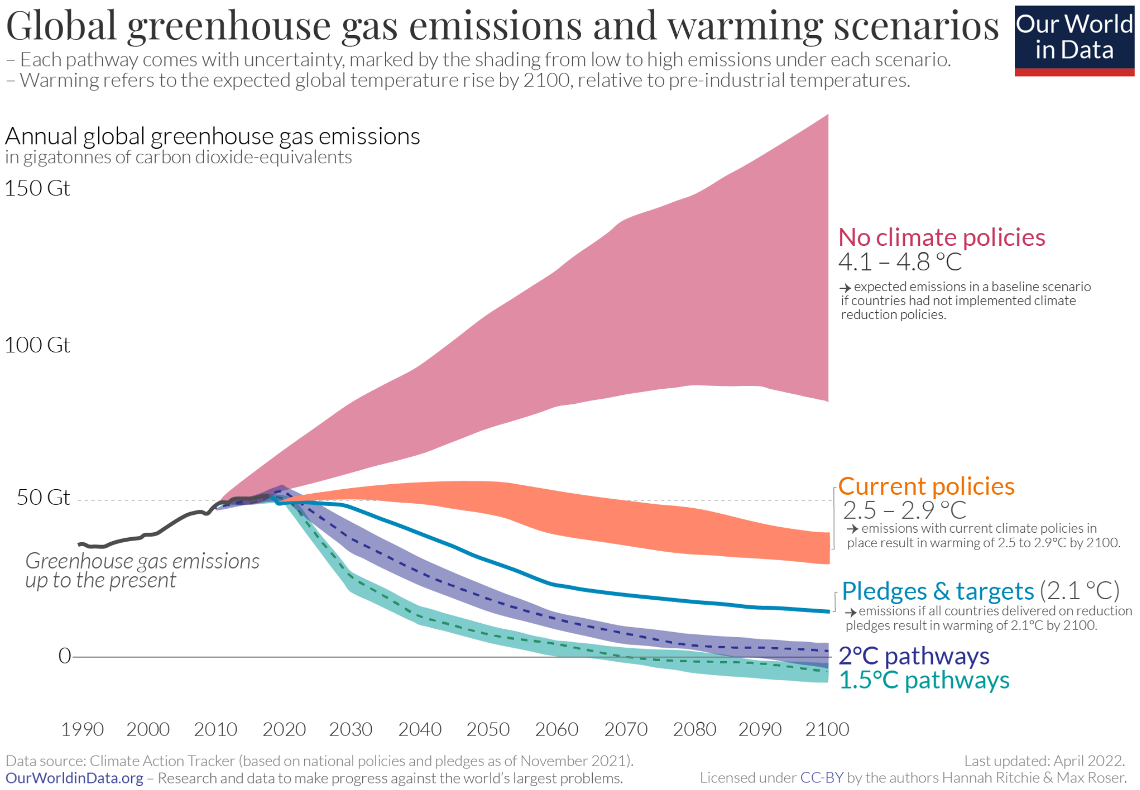
Pohjois-Savon Energiaklusteri Kick-off tilaisuus 12.1.2023

Outline of the talk

① Forthcoming energy transition and its consequences
② Examples of energy system solutions
③ New innovations and technology solutions for systems

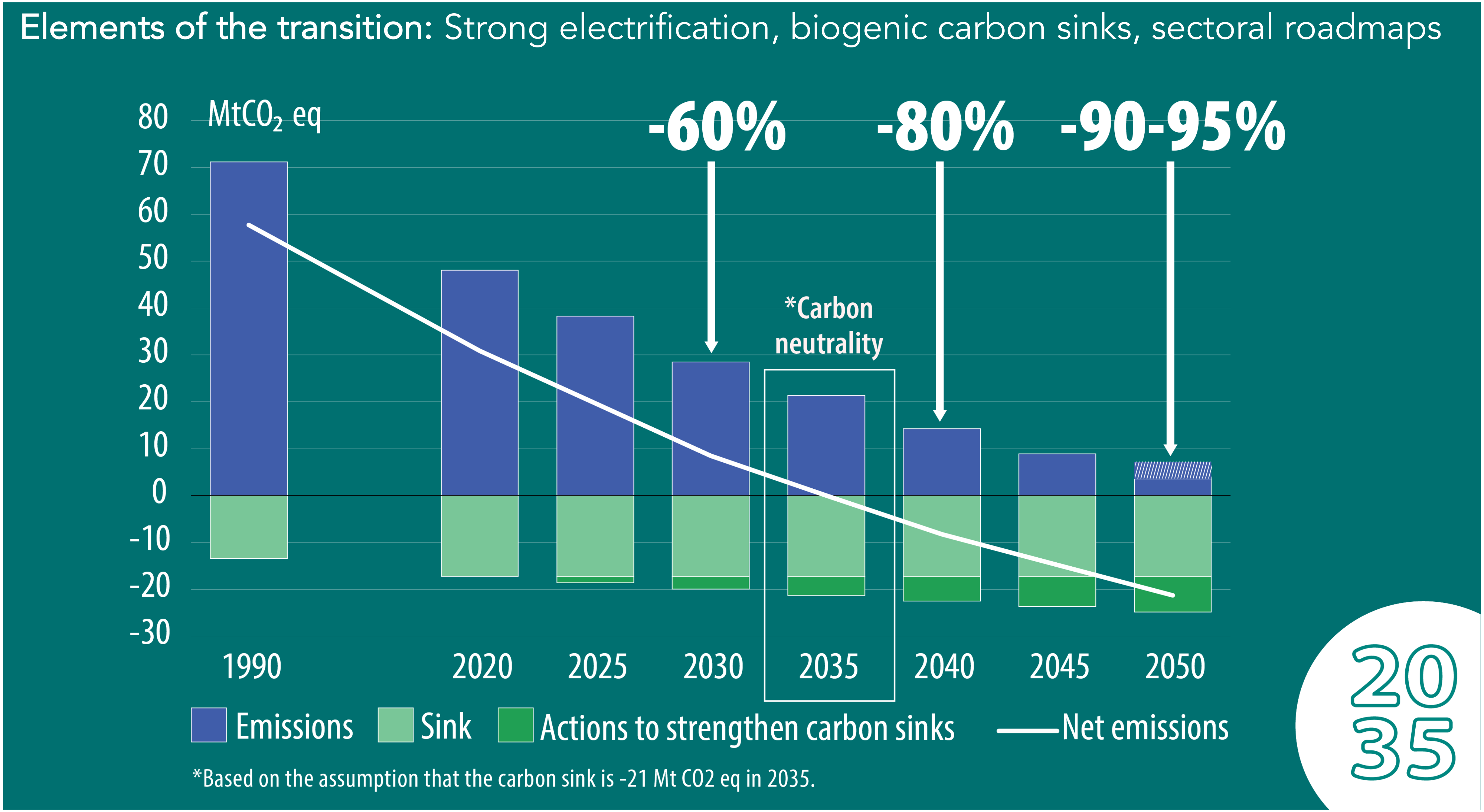
Global pathway to net-zero emissions





Nature 11 Nov 2022; doi: https://doi.org/10.1038/d41586-022-03657-w

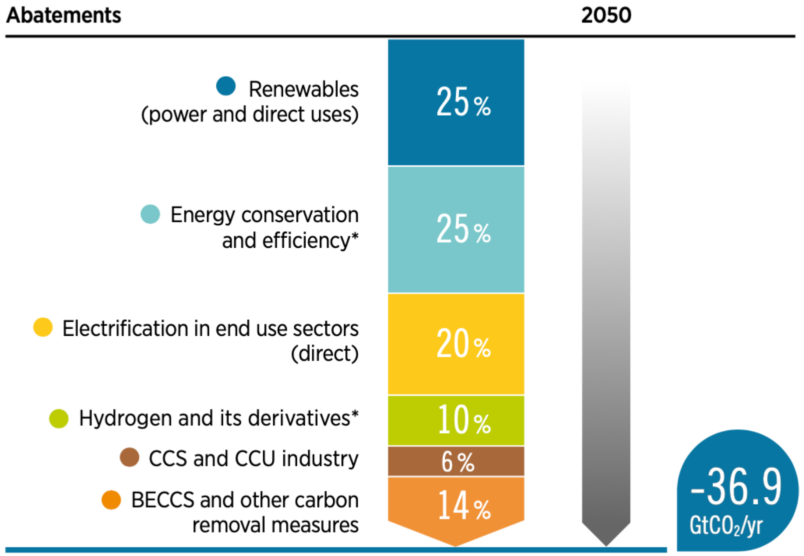
Finland aiming at carbon neutrality already by 2035



Approaching carbon neutrality through breakthroughs

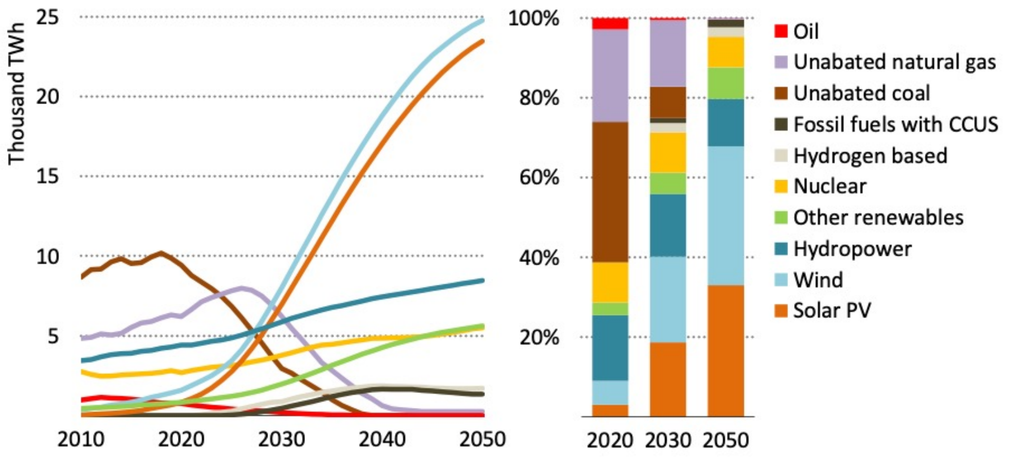
Solar and wind 70% of world electricity by 2050

FIGURE S.4 Carbon emissions abatements under the 1.5°C Scenario (%)



Source: IRENA, 2021

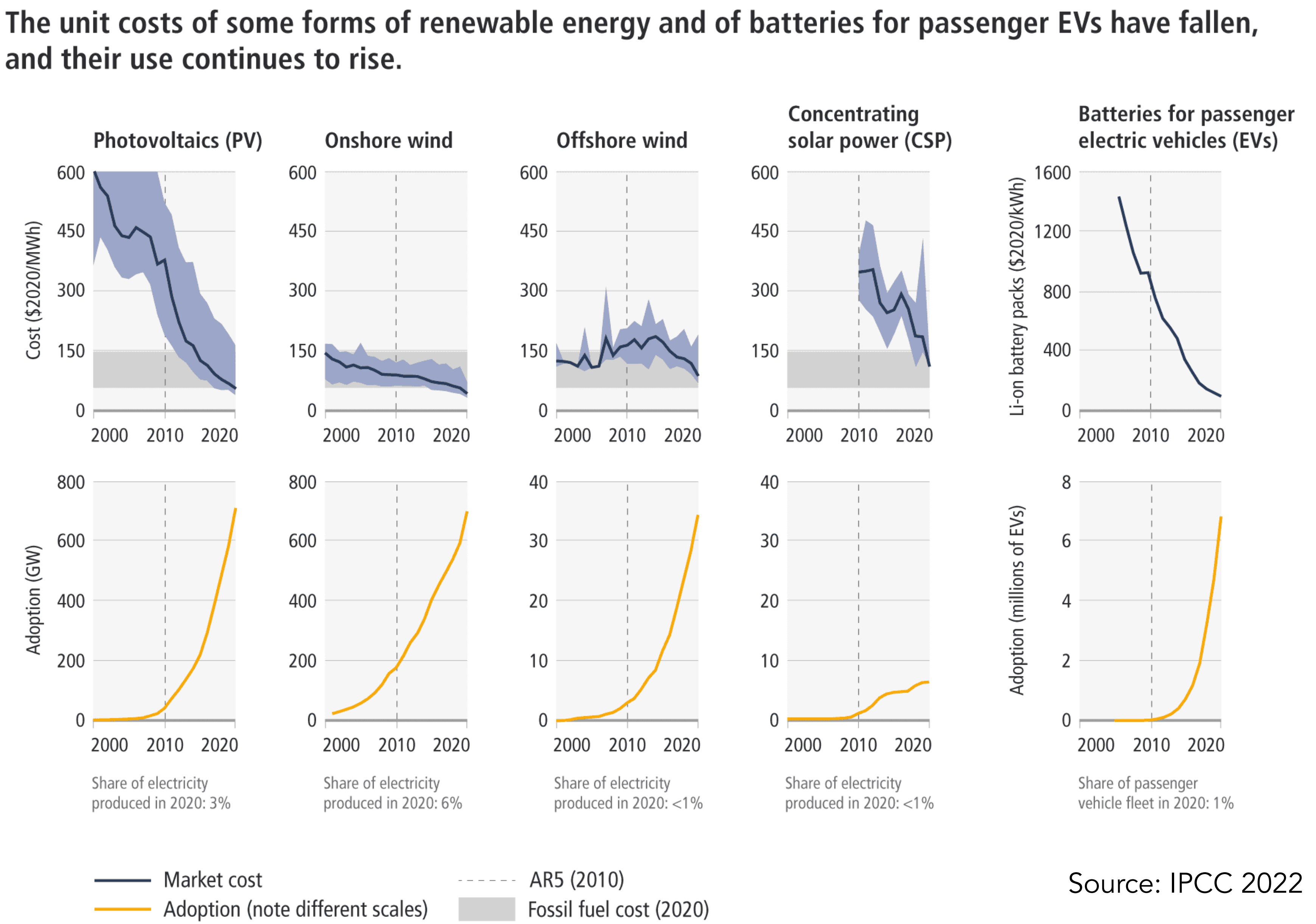
Figure 3.10 ▷ Global electricity generation by source in the NZE



Solar and wind power race ahead, raising the share of renewables in total generation from 29% in 2020 to nearly 90% in 2050, complemented by nuclear, hydrogen and CCUS

Source: Net Zero by 2050. International Energy Agency, May 2021

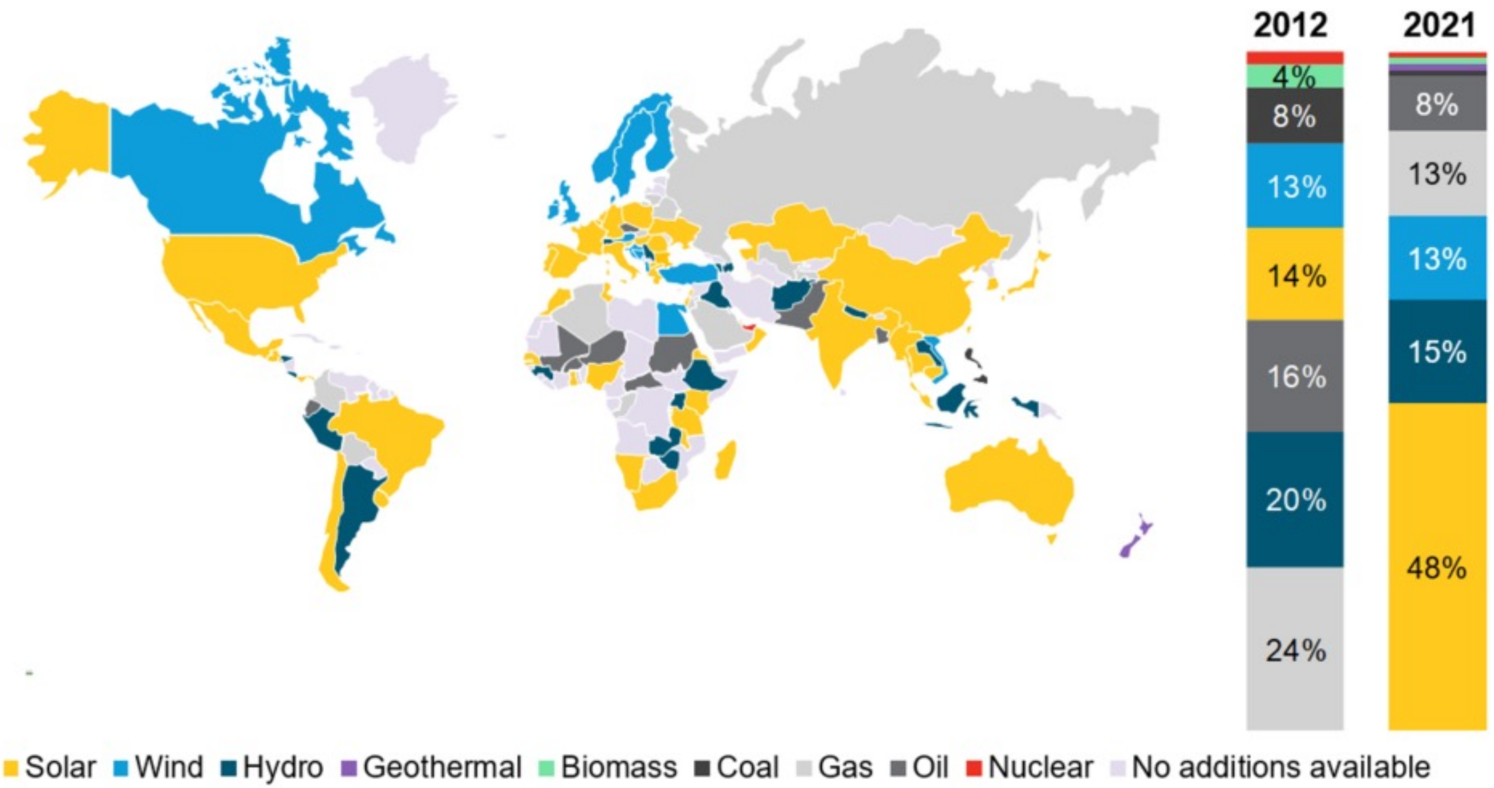
Positive trends in new energy technologies



Source: IPCC 2022

Solar and wind are the most popular forms for new power investments - New renewables 10% of global electricity

Figure 1: Most popular new power-generating technology installed, 2021

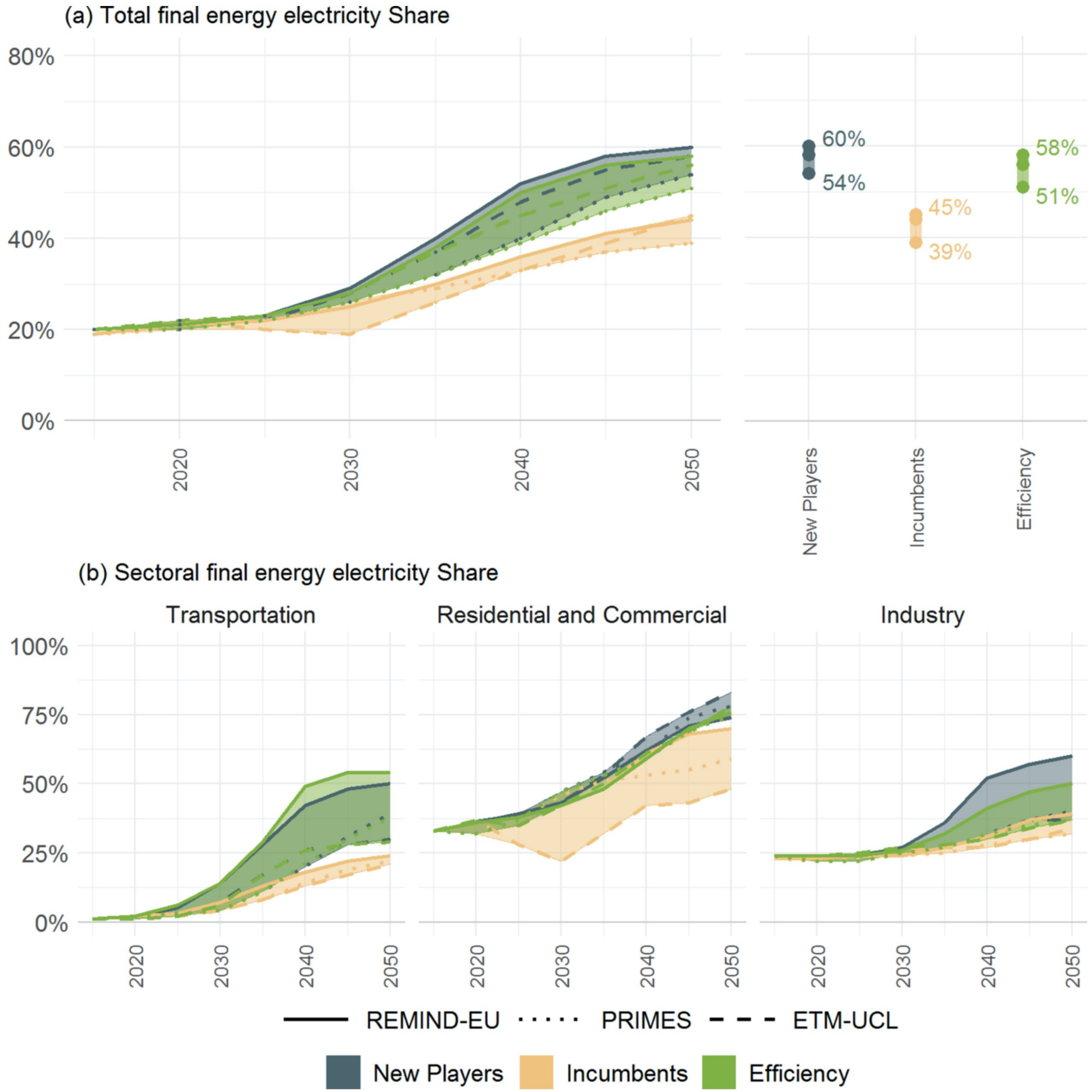


Source: BloombergNEF. Note: Map colored by which technology was most installed in 2021 alone. Depicts the percentage of nations that installed the most MW of each technology. It is based on country-level data for 136 countries but excludes countries that have not recorded any capacity additions. Solar includes small-scale PV.

Strong electrification ahead - EU stakeholder views

<u>Stakeholder</u>-designed narratives of future energy system development

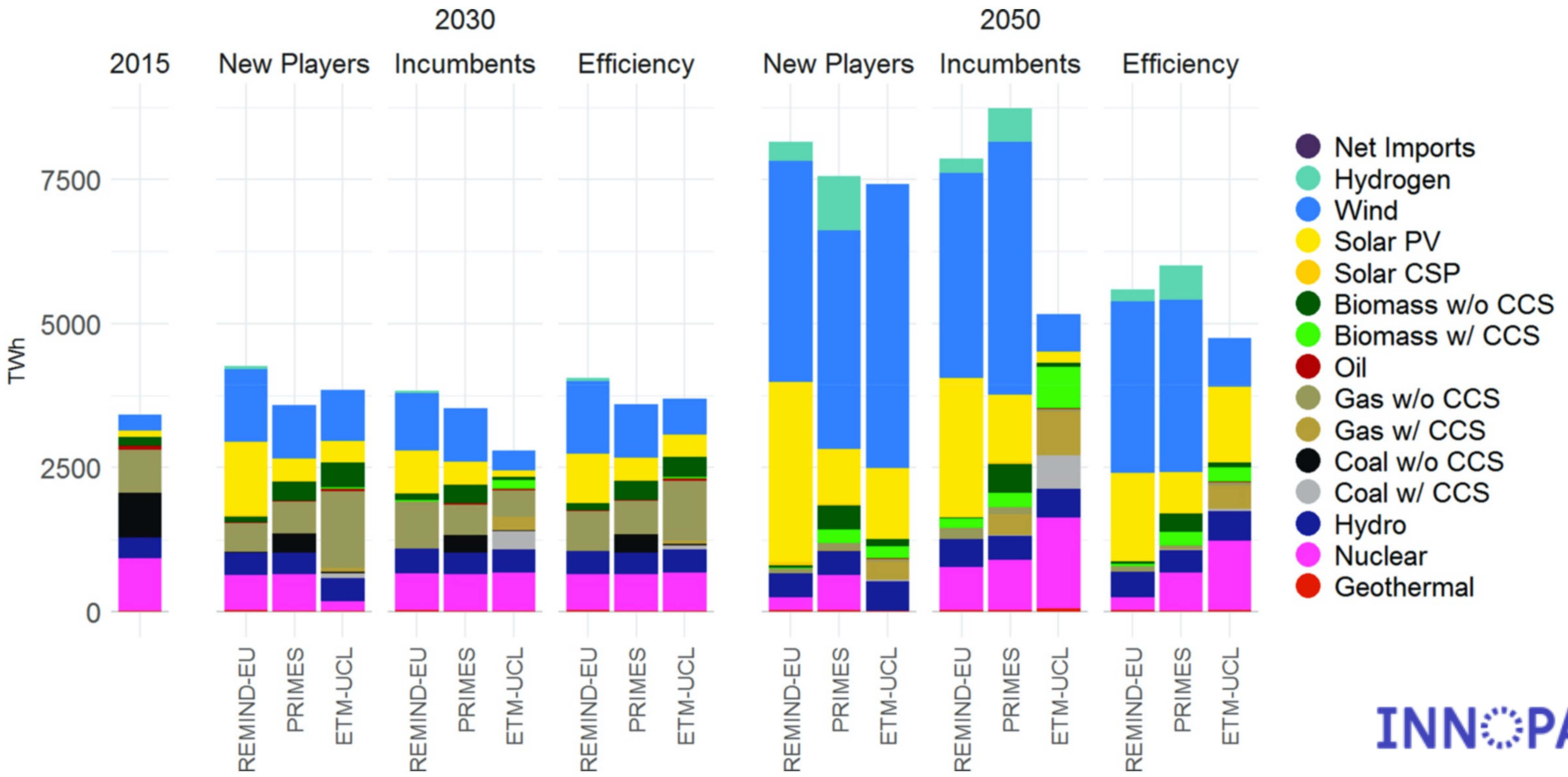
- *New Players*: emergence of new players in the energy system bridging the divide between utilities and customers
- *Incumbents*: today's big utilities adapt to remain relevant, promoting a supply side
- *Efficiency*: energy and resource efficiency is a goal in itself, and stronger awareness for health and non-material well- being changes lifestyles



- REMIND is a global multi-regional energy-economy-climate model
- PRIMES model simulates the energy system of all EU Member States
- European TIMES Model (ETM-UCL) minimises total discounted system costs; technology-rich, bottom-up model

Ref. Energy 239 (2022) 12190
https://doi.org/10.1016/j.energy.2021.121908

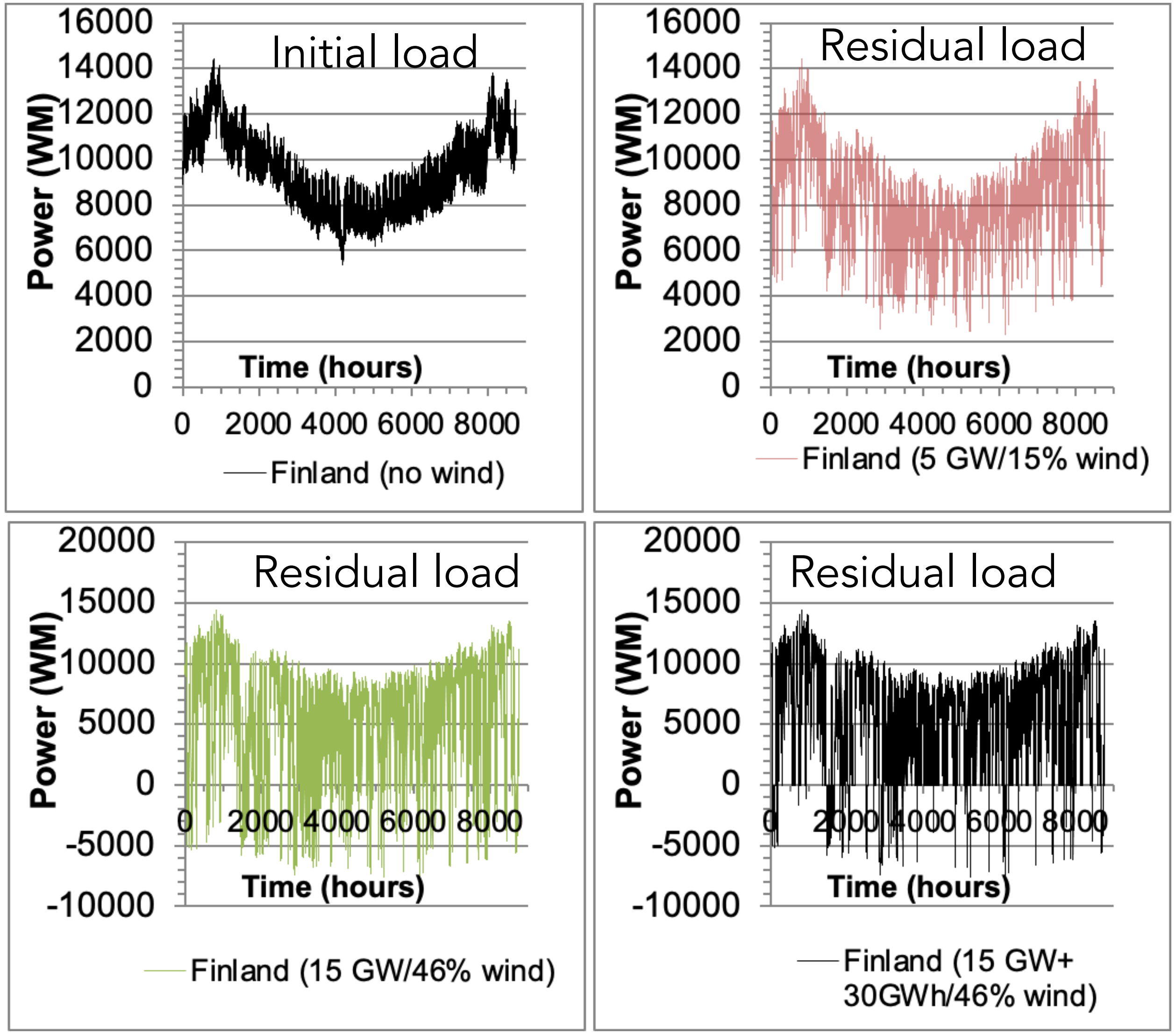
Power sector development in the EU



INNOPATHS

Ref. Energy 239 (2022) 12190
https://doi.org/10.1016/j.energy.2021.121908

Impact of variable renewables on power profiles



Residual load

(= Initial load – wind/solar power)

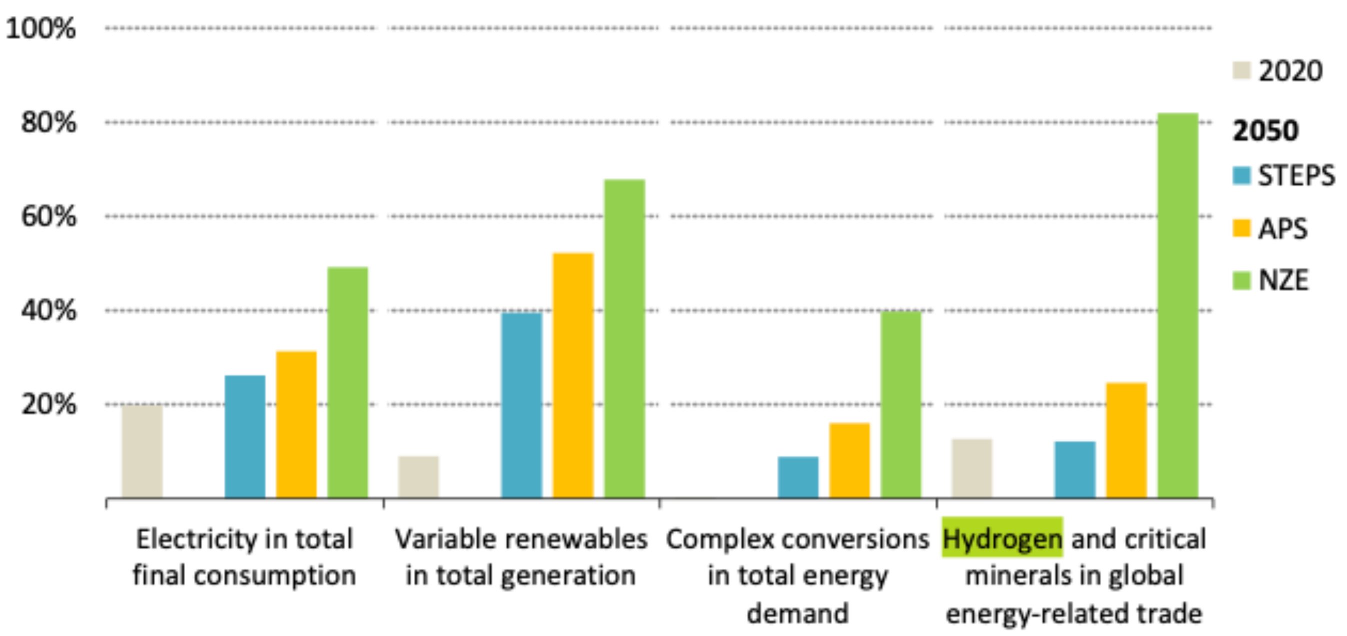
- Increasing variability
- More zero and negative loads
- Less influence on peak demand

- Increasing solar and wind shifts the optimal power mix of the residual load towards cyclic& peak power plants = more flexibility

- Fuel-based or fuelless solutions?

The complexity of the energy transition

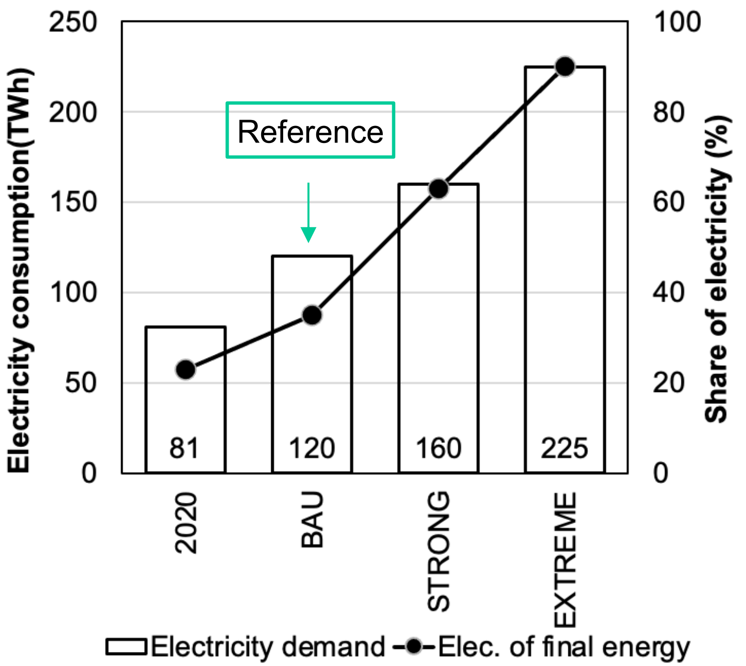
Figure 1.23 ▷ Key indicators of energy system change by scenario

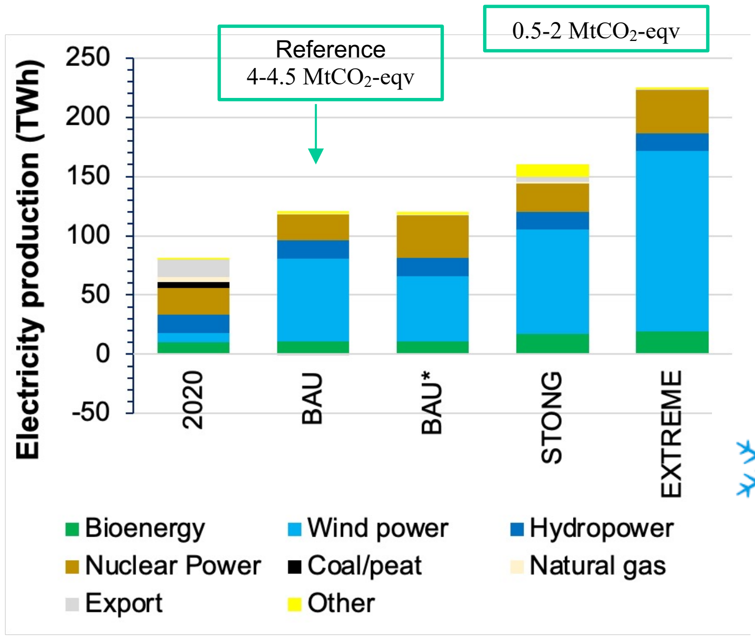


New energy security challenges arise in systems increasingly reliant on electricity, low-carbon technologies, higher levels of supply variability and more complex conversions

Note: Complex conversions are a primary energy source that has undergone two or more conversions before being delivered to end-users. It includes roundtrip battery storage.

Source: IEA World Energy Outlook 2021





Basic scenarios for strong electrification in Finland by 2050

- Finland should have negative emissions 2050
- Electricity demand could double, becomes more weather and behaviour dependent
- Peak power demand increases, but could be affected by energy efficiency measures

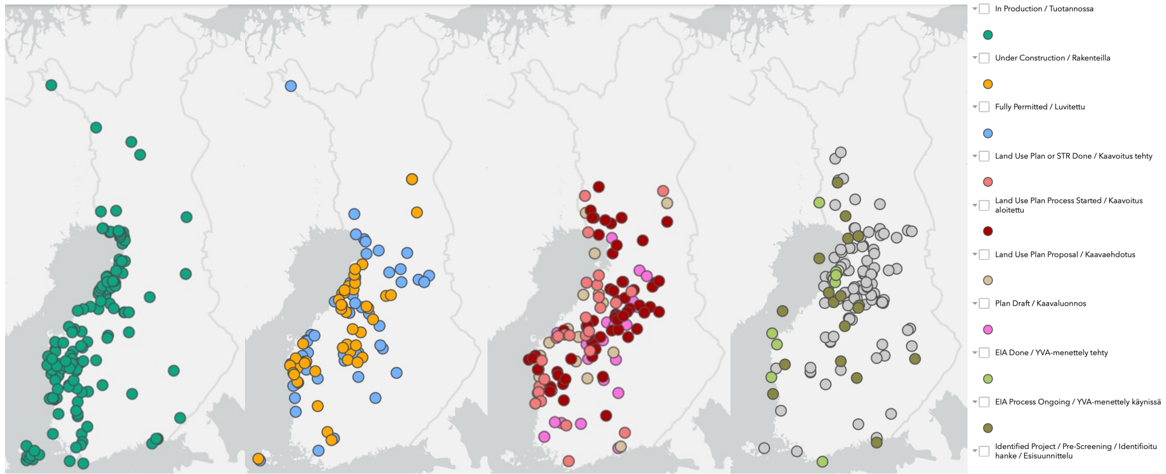
- Reference scenario (2050): The most cost-effective solution shown (BAU) with given assumptions and boundary conditions.
- Wind and nuclear power replacing each other (BAU vs. BAU*)
- More flexibility needed (e.g. sector coupling, demand response, etc.)
- Need of fuel: bioenergy vs. electrofuels (PtX)

SUOMEN ILMASTOPANEELI The Finnish Climate Change Panel

P.D. Lund: Effects and possibilities of electrification in the Finnish energy system, Report 1/2022.

Windpower in Finland

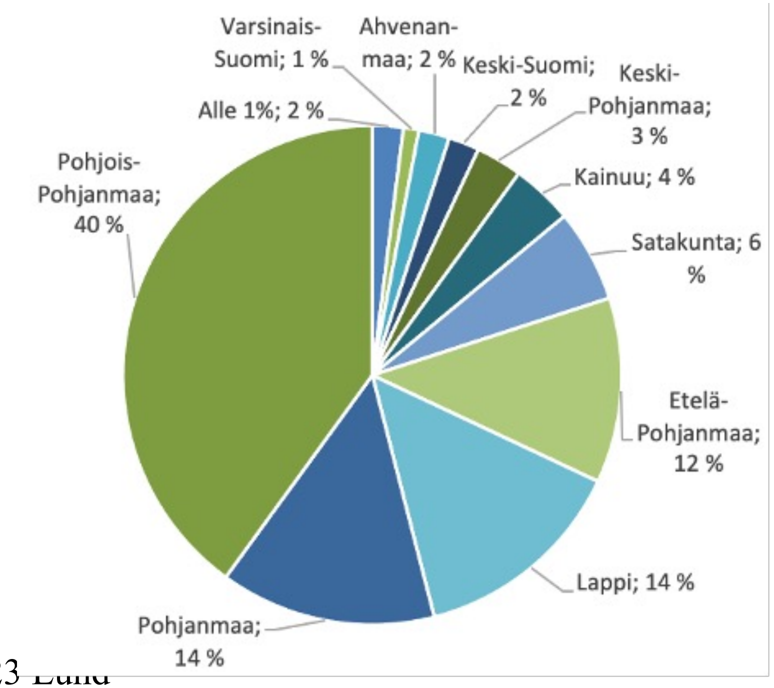
Cheapest form of new electricity (€30-40/MWh)



(a), (b), (c), (d)

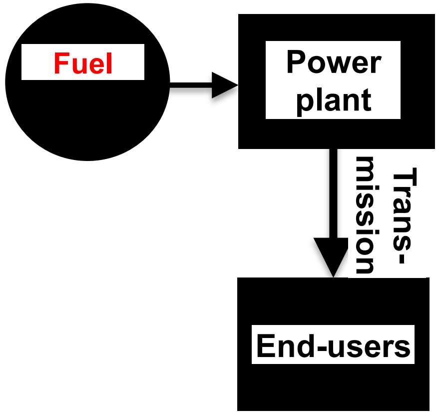
Tuulivoimaloiden hanketilanne maaliskuussa 2022. (a) Nykyiset tuulivoimalat, (b) Rakenteilla ja luvitetut, (c) Kaavoitus tehty, kaavoitus aloitettu, kaavaehdotus, kaavaluonnos, (d) YVA-menettely tehty, YVA-menettely käynnissä, identifioitu hanke. [Lähde: Suomen Tuulivoimayhdistys https://tuulivoimayhdistys.fi]

- In use 4037 MW (30.6.2022), n 17% of elec)
- Under construction 4252 MW
- Planned on-shore 44466 MW (n 2x el. demand)
- Planned off-shore 9905 MW

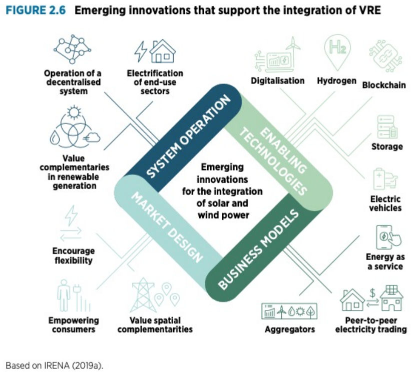


Changing ’system typology’ of power systems

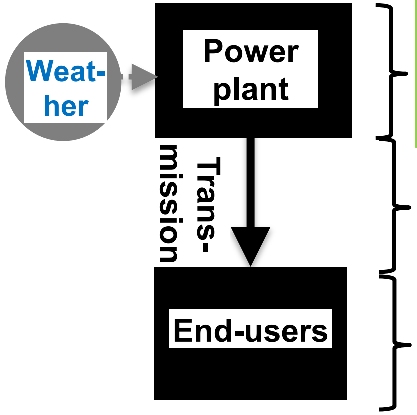
Fuel-based centralized electricity systems



Integration



Weather-dependent, data-based decentralized electricity system



Up/down reserves
Battery storage
Hydrogen/E-Fuels
Multi-fuel engine PP
Etc.

Virtual inertia
Coordination of flex.
Data, forecasting
Etc.

Sector-coupling
Energy storage
DS flexibility/DSM
Digitalisation
Prosumers,
Etc.

Future outlook on energy demand – importance of energy efficiency

EU final energy demand could decrease by 67%, or, increase by 40% in 2050

- Reduced demand reduces transition costs, increases energy security
  - Synergies between demand and supply chain and other impacts
  - Electrification may increase efficiency in replacing inefficient fuel conversion processes
  - Low Energy Demand (LED) scenario has not yet been down-scaled to the EU level

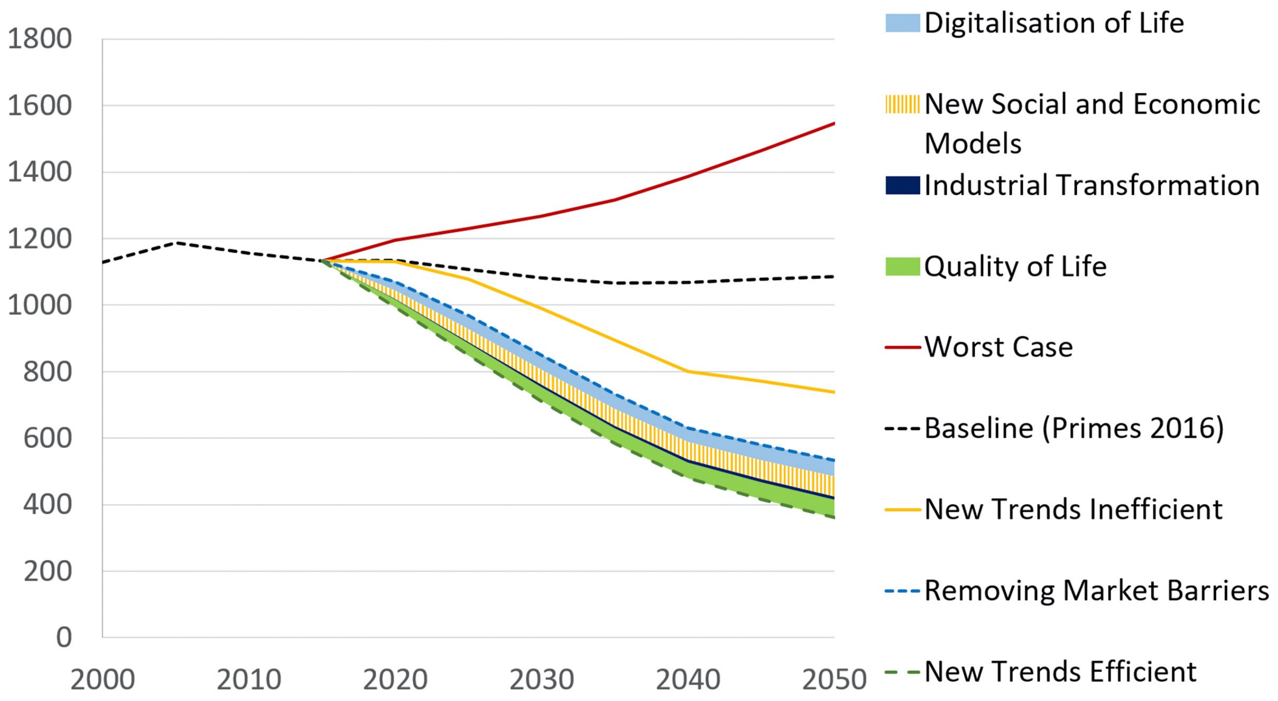


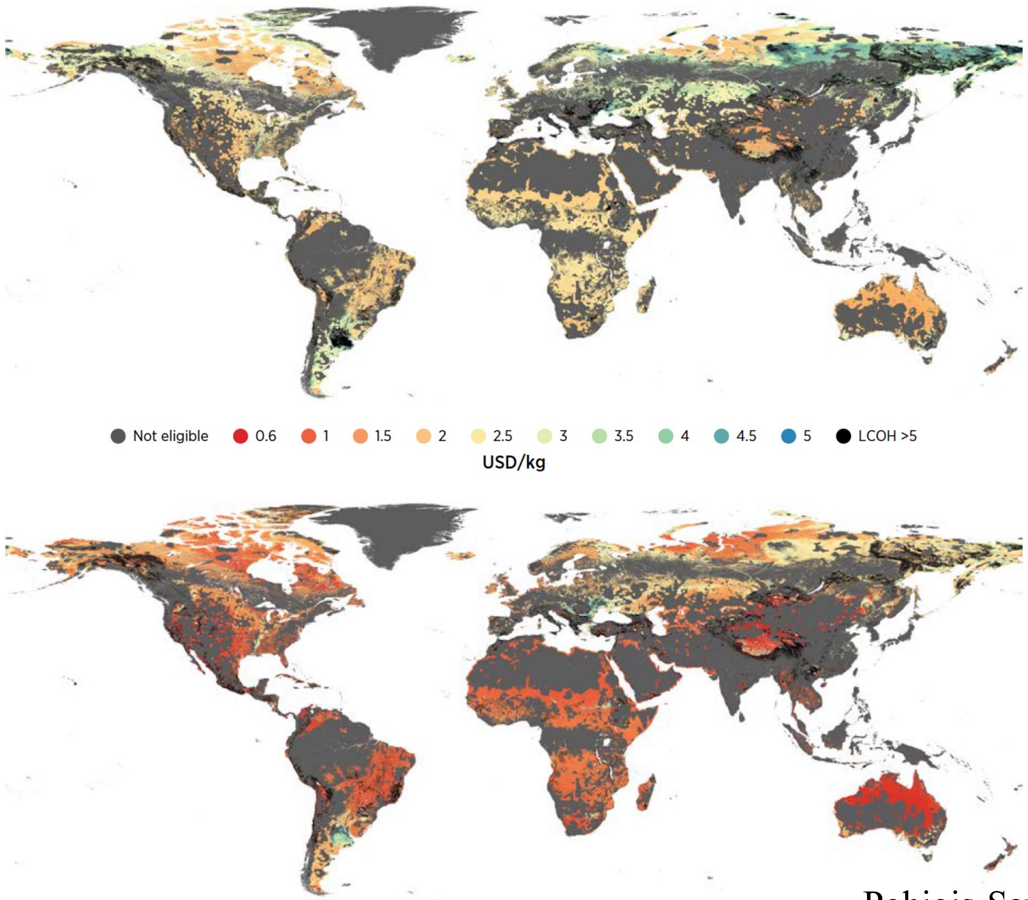
Figure. *Final energy demand (EU-28) in four scenarios and the baseline (in Mtoe) from the PRIMES model (from Brugger et al., 2021)*

Global view on hydrogen

¼ of H_2 through trade, of which ca ½ via pipelines

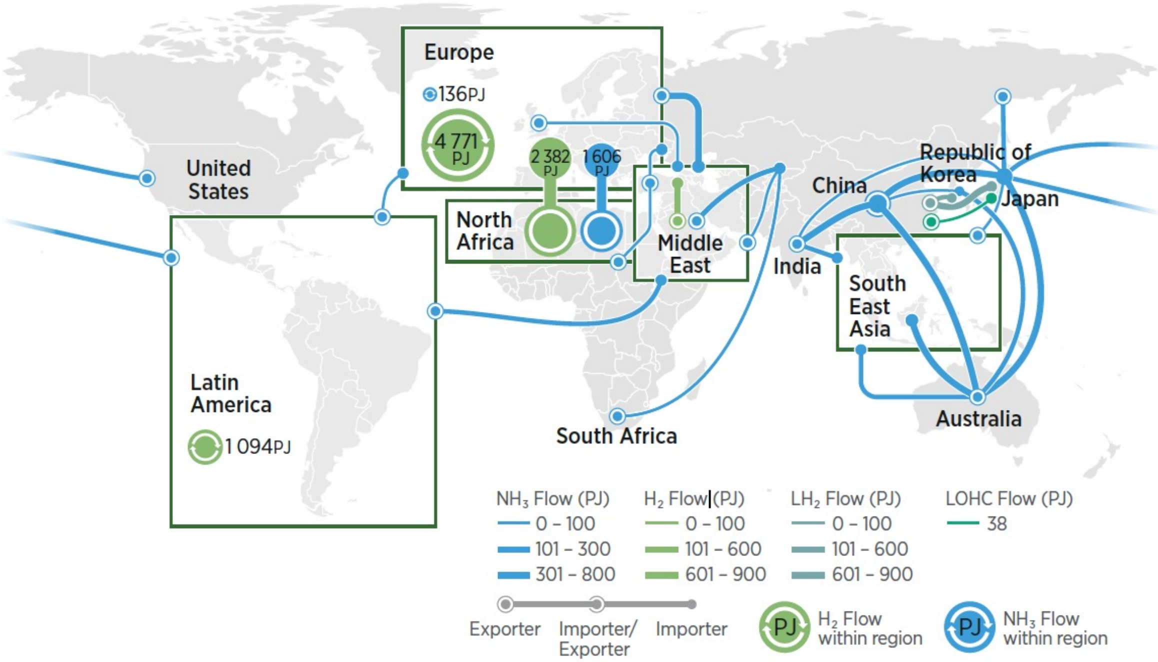
Production cost of H_2 in 2030/2050

FIGURE 1.3. Global levelised cost of hydrogen (LCOH) in 2030 (top) and 2050 (bottom)



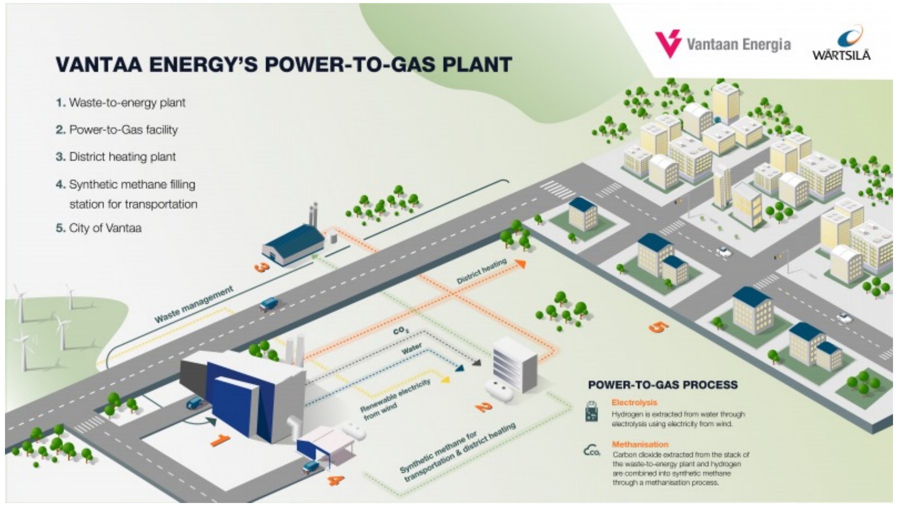
Global trade of H_2

FIGURE 0.1. Global hydrogen trade flows under *Optimistic* technology assumptions in 2050



REF: IRENA (2022), Global hydrogen trade to meet the 1.5°C climate goal: Part I – Trade outlook for 2050 and way forward, International Renewable Energy Agency, Abu Dhabi.

Nordic Hydrogen Route



Hydrogen production and use

- Electrolytic H_2, biogenic H_2 ?
- Iron and steel, process and chemical industries

Nordic Hydrogen Route

- 1000 km of H_2-pipelines (yellow.)
- Cost of transport 0.1-0.2 €/kgH_2
- 65 TWh H_2/year by 2050
  - 28 GW off-shore wind 2030, 48 GW in 2040

https://nordichydrogenroute.com/fi/hanke/

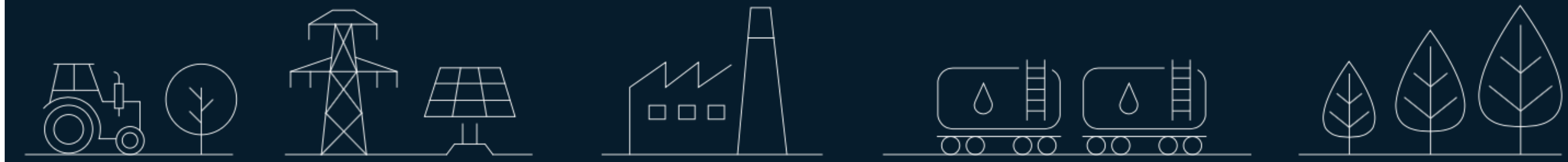
Power-to-H_2/Gas development in Finland

- Several large-scale demonstration sites under way (ca 10 projects, >10 MW, largest 300 MW)
- Green Hydrogen production: H_2 or H_2-derivatives (PtG)
- Industrial applications, municipal use (integrated systems)

Quantum computing could bring about step changes throughout the economy that would have a huge impact on carbon abatement and carbon removal.

Digitalization 2.0

Visualizing postquantum climate action



Reform food and forestry

- Green fertilizers
- Methane-reducing vaccines for ruminants

Electrify our lives

- Higher-density electric batteries for heavy-goods electric vehicles
- Higher-density electric batteries for energy storage

Reshape industrial operations

- Zero-carbon cement clinkers
- New carbon-capture utilization and storage (CCUS) solvents

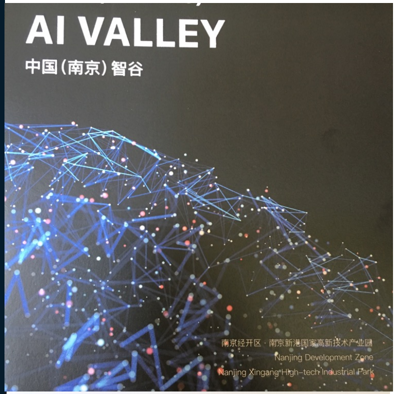
Decarbonize power and fuel

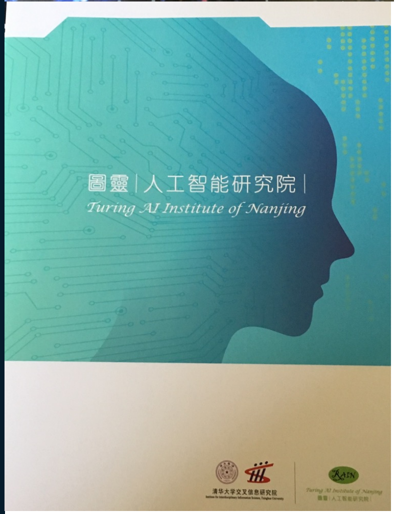
- CO_2 chemistry improvements for synfuels
- Better polymer electrolyte membrane and pulse electrolysis in H_2 generation
- More efficient perovskites for solar
- FeMo cofactor for green ammonia
- Green ammonia for shipping

Ramp up carbon markets

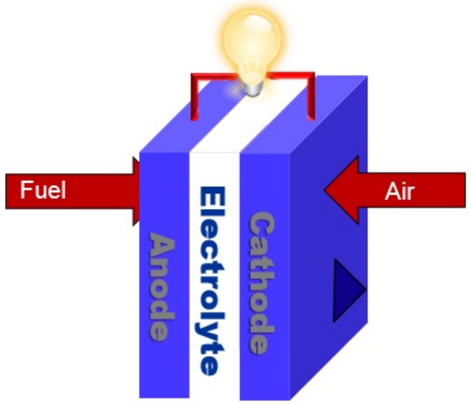
- New direct-air capture (DAC) adsorbents

McKinsey & Company

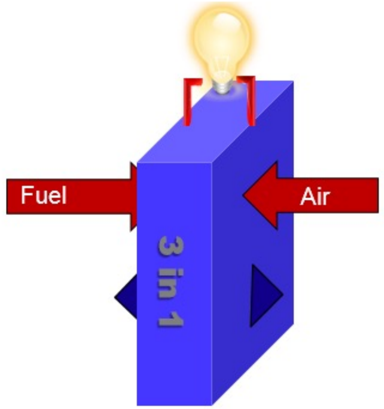




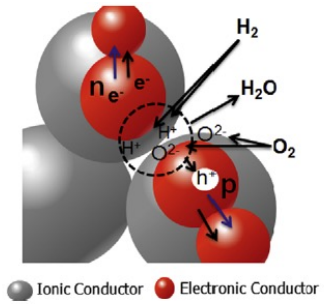
Next generation materials:
example on fuel cells & electrolyzers (single layer ceramic fuel cell)

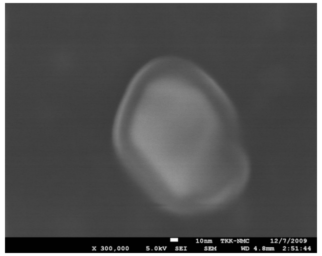


Conventional Fuel cell



EFFC





A homogenous mixture of ionic conductor (e.g. doped-ceria) + electrode material (e.g. LSCF, BSCF, $CuFe_2O_4$, etc.)

Main advantages
- Lower manufacturing costs
- Simplified system design
- Improved thermal stability

Performance:
200-1000 mW/cm^2 at 550^oC

[1] Asghar, M. I., Jouttijärvi, S., Jokiranta, R., Valtavirta, A., and Lund, P. D., Wide bandgap oxides for single-layered nanocomposite fuel cell, Nanoenergy, 53, 391-397, (2018).
[2] Asghar, M. I., Yao, X., Jouttijärvi, S., Jokiranta, R., Hochreiner, E., and Lund, P. D., Intriguing electrochemistry in low-temperature single layer ceramic fuel cells based on CuFe2O4, International Journal of Hydrogen Energy, (2019).
[3] B. Zhu, R. Raza, H. Qin, L. Fan, Single-component and three-component fuel cells, J. Power Sources. 196 (2011) 6362–6365.
[4] B. Zhu, H. Qin, R. Raza, Q. Liu, L. Fan, J. Patakangas, P. Lund, A single-component fuel cell reactor, Int. J. Hydrog. Energy. 36 (2011) 8536–8541.
[5] B. Zhu, R. Raza, G. Abbas, M. Singh, An Electrolyte-Free Fuel Cell Constructed from One Homogenous Layer with Mixed Conductivity, Adv. Funct. Mater. 21 (2011) 2465–2469.
[6] B. Zhu, Y. Ma, X. Wang, R. Raza, H. Qin, L. Fan, A fuel cell with a single component functioning simultaneously as the electrodes and electrolyte, Electrochem. Commun. 13 (2011) 225–227.

Conclusions

1. Energy transition contains complex energy systems
2. From single energy technology to 'whole systems'
3. Importance of uncertainities and resilience
4. Importance of efficiency for the whole energy chain
5. 'Fuel/storage' needs attention (e.g. peak demand)
6. New science opens up promising prospects!