Energy Transition Diplomacy
Industries and Technologies Involved (II)

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Disclaimer

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Industries and Technologies involved II.

New energy industries

Solar, Wind, Grid Storage

Nascent energy industries

Hydrogen, Carbon Capture Storage and Utilisation

New technologies

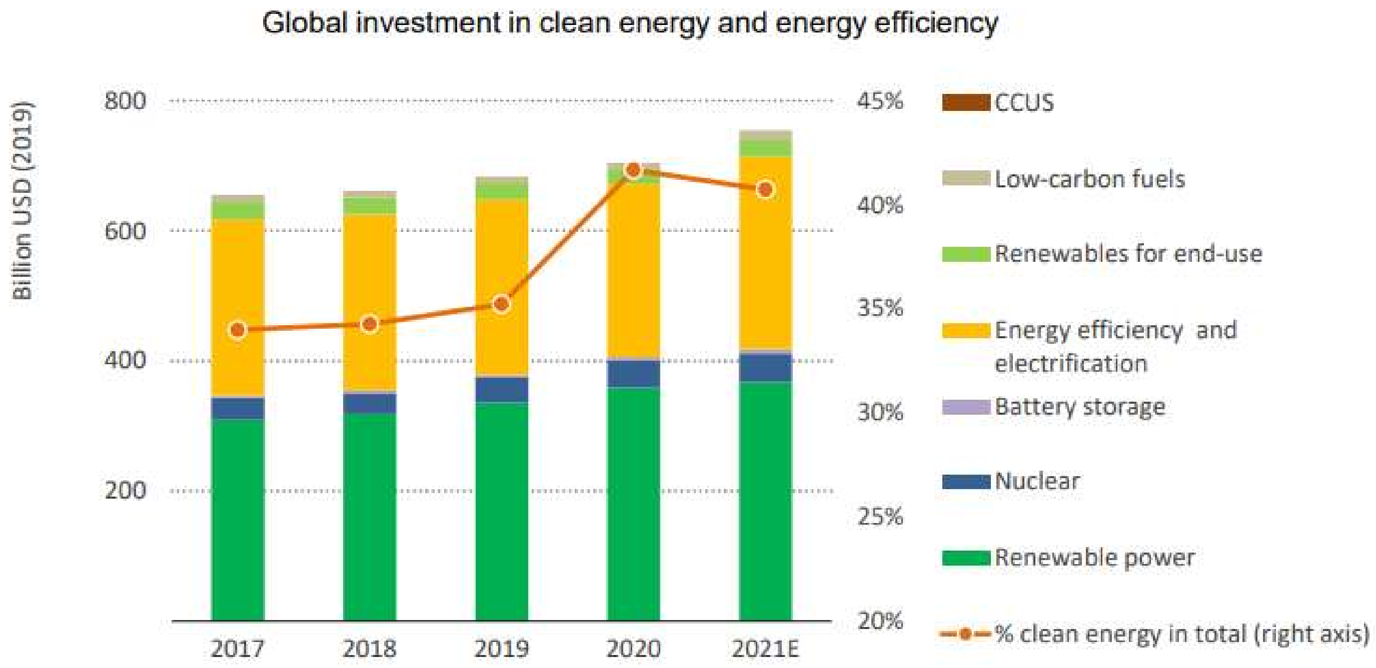
New Nuclear (4^{th} generation reactors, SNRs), Storage

New frontiers

Nuclear Fusion, Space Solutions, Fundamental Research

Global Investment in Clean Energy

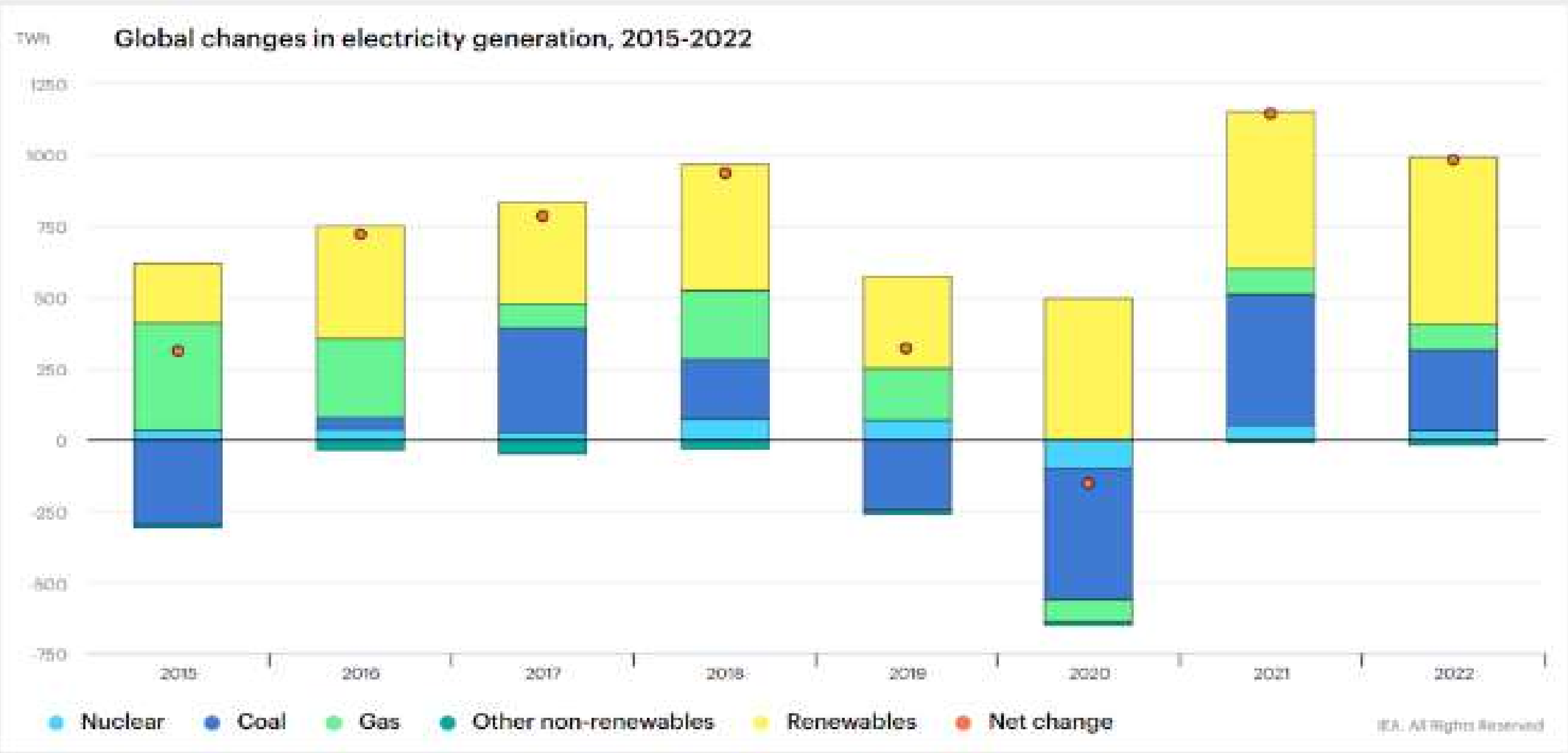
Clean energy investment is on a moderate upswing



The impact of stimulus plans is increasingly visible in buildings efficiency, low-carbon hydrogen and CCUS, while electrification, especially EVs, remains a major driver; but, clean energy spend is well short of a sustainable recovery

Positive trend in clean energy investments was continuing in 2022

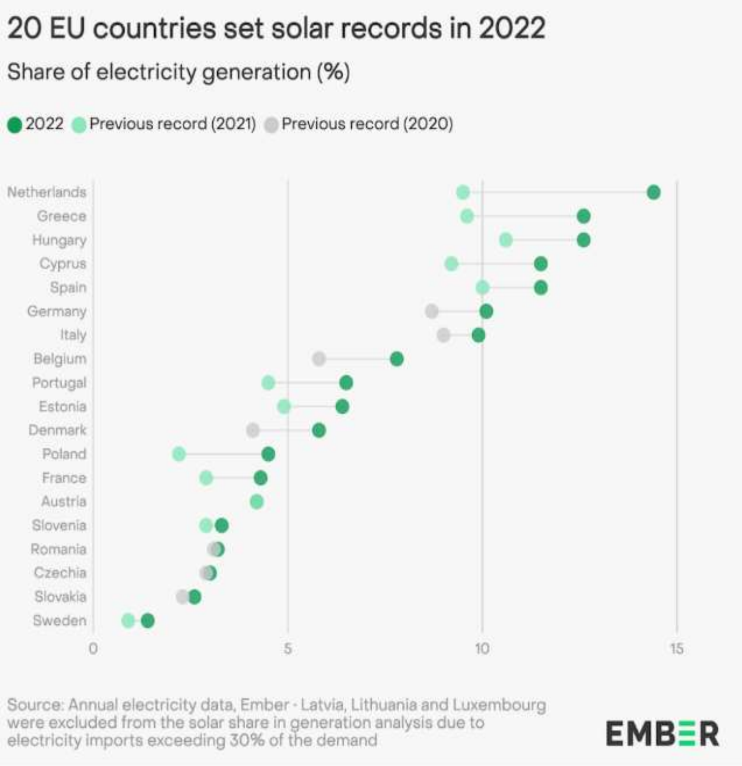
Global Electricity Generation



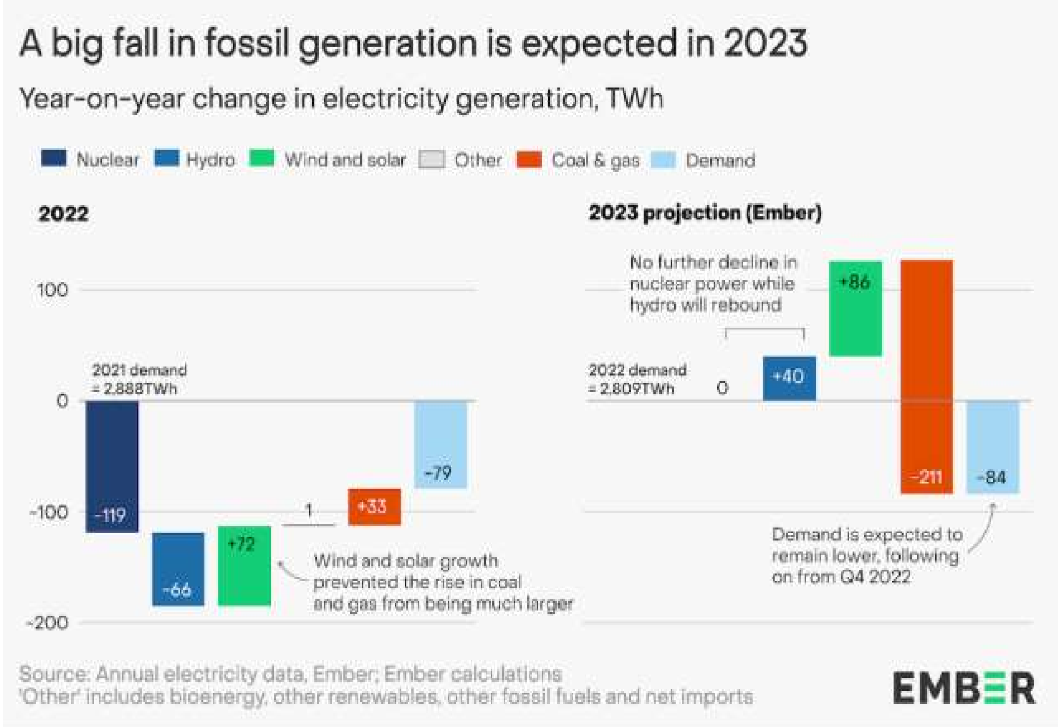
SOURCE: IEA

New Energy Industries in the EU

EU Energy Transition & Energy Crises 2022/3



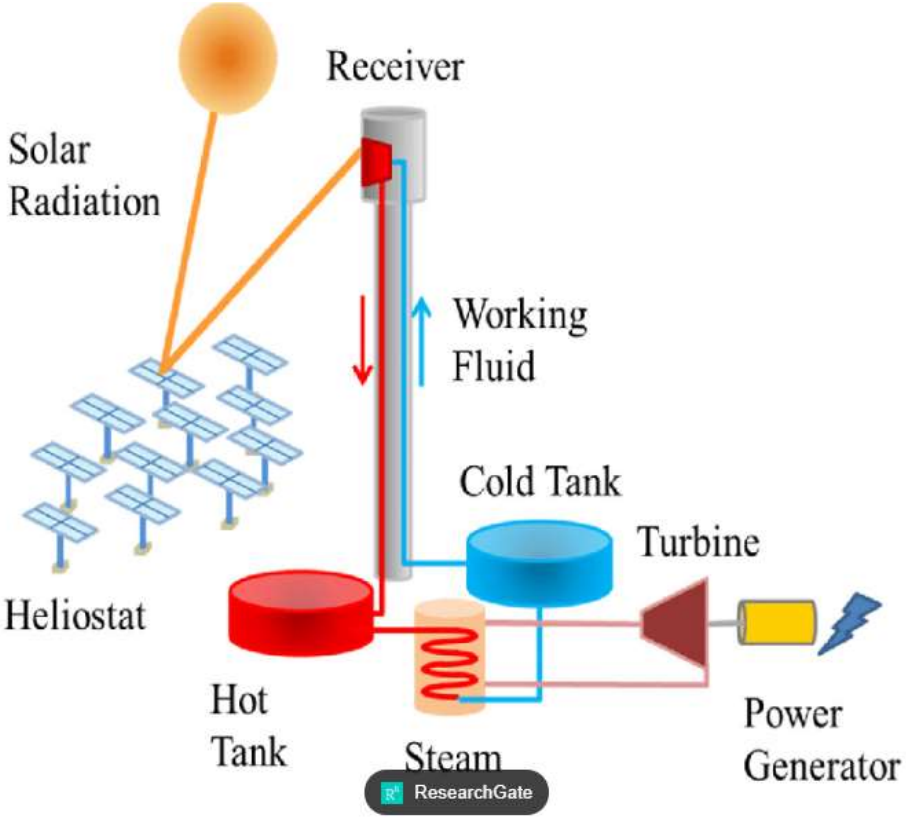
EU countries setting solar records in 2022 / SOURCE: Ember



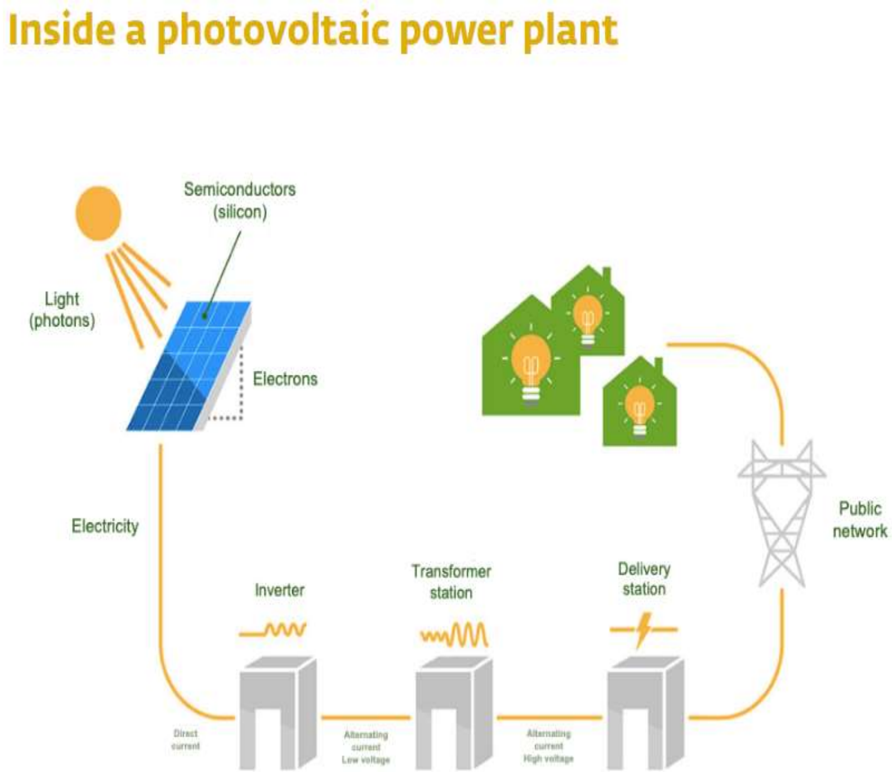
Change in EU electricity generation 2021-2022 and a projection for 2022-2023 / SOURCE: Ember

Solar

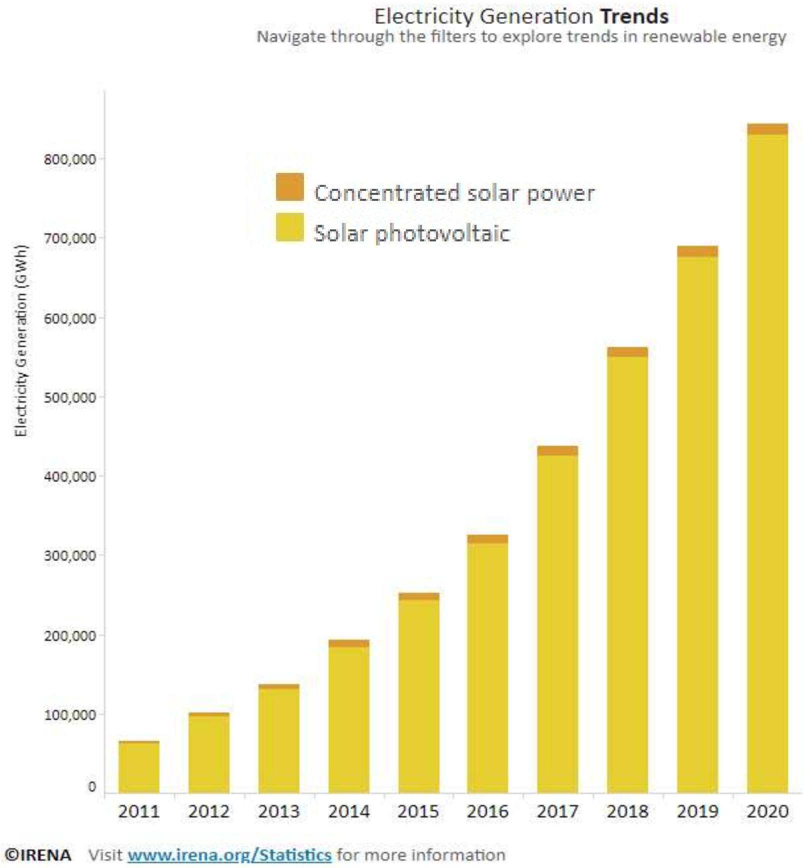
Concentrated Solar Power Plants **(CSP)** consists of a system concentrating solar heat, its accumulation and power generation trough steam turbine

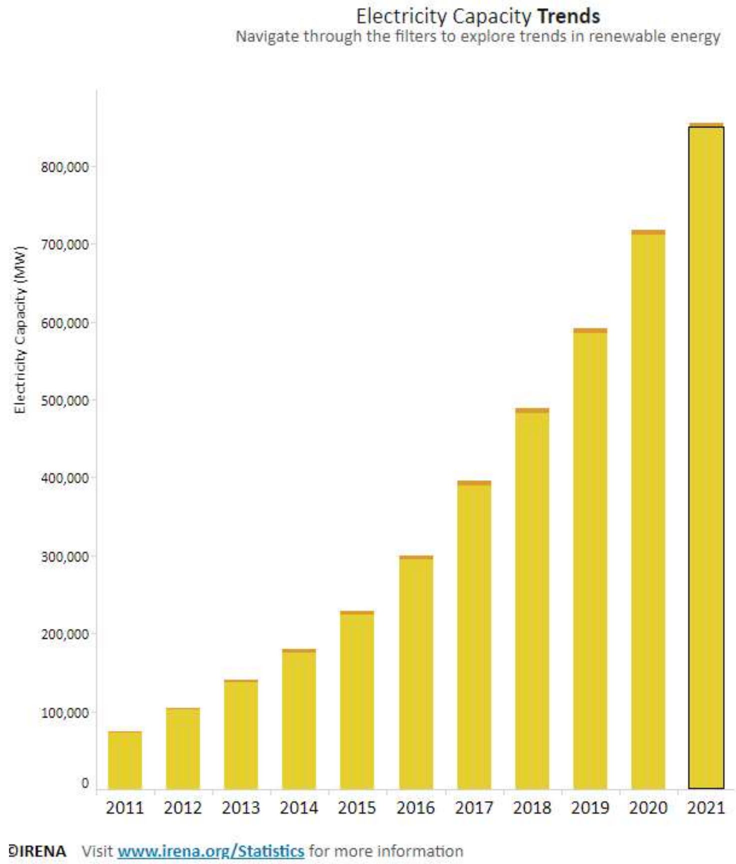


Solar Photovoltaic (PV) panels consists of solar cells generating 1-2 W each. 95% of installed solar PV are made of silicon semiconductors



Solar

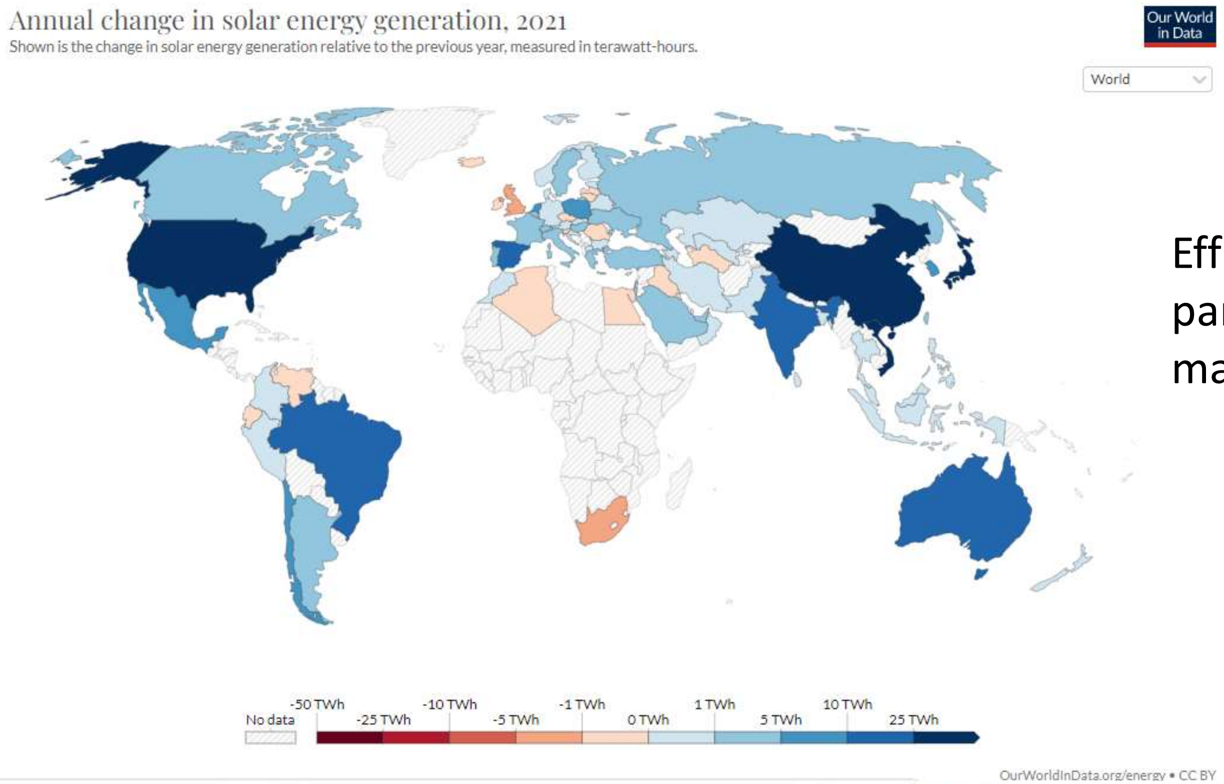


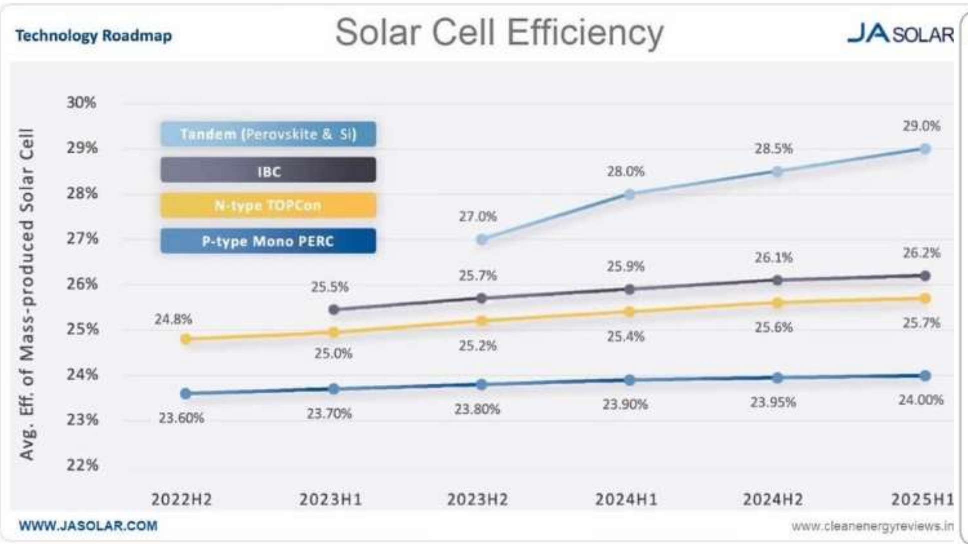


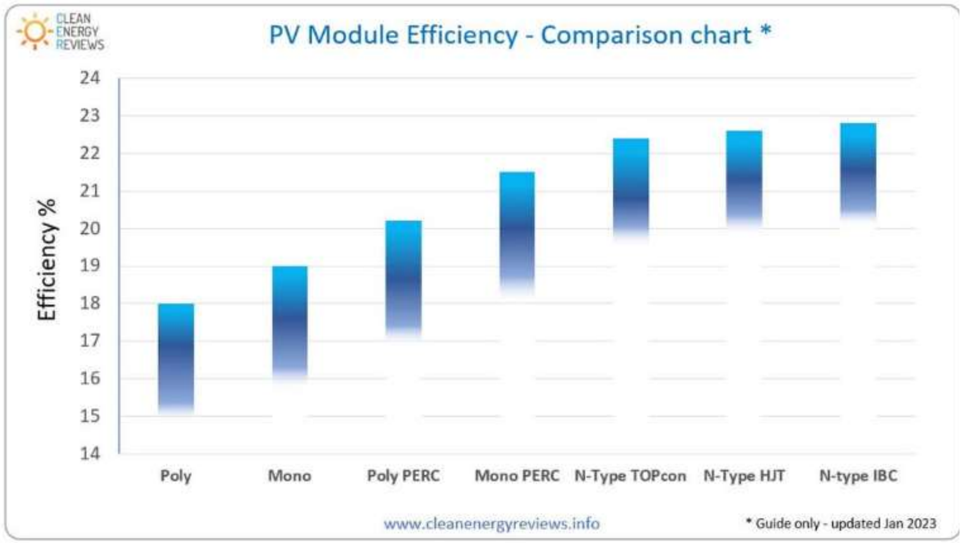
Capacity factor for Solar PV varies between 10 and 35%, for CSP up to 50%. Cost for intermittent power generated by PV can be 5 times lower than by CSP

Solar

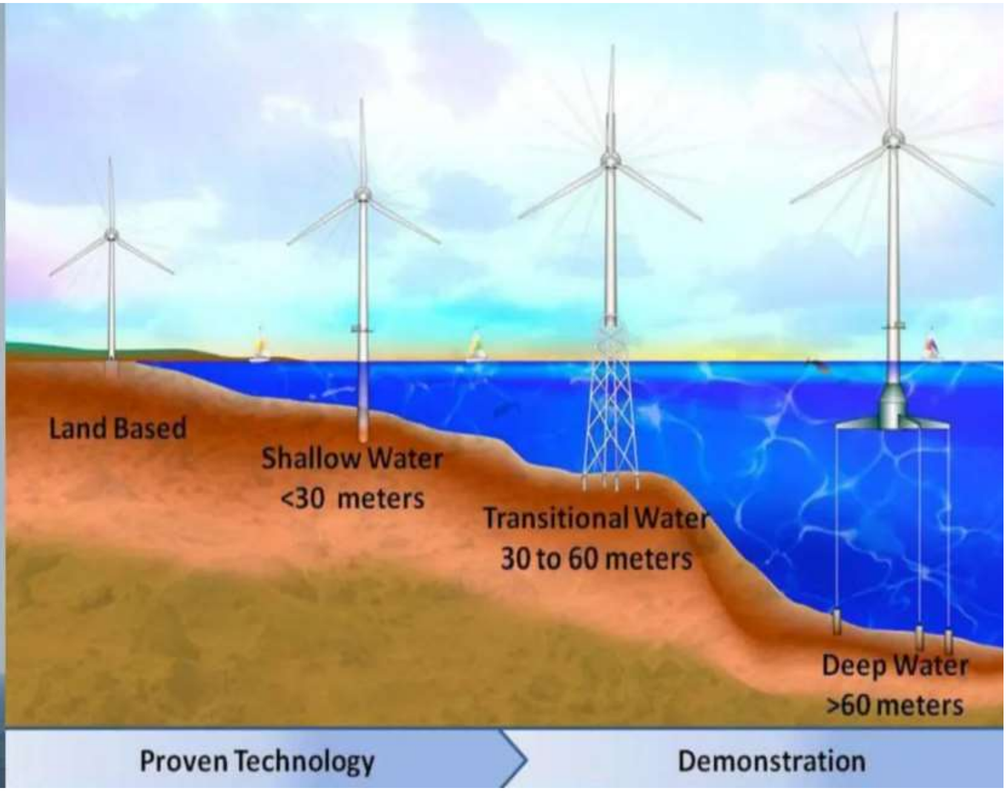
Efficiency of solar cells and panels are limited due to the material's physics and losses

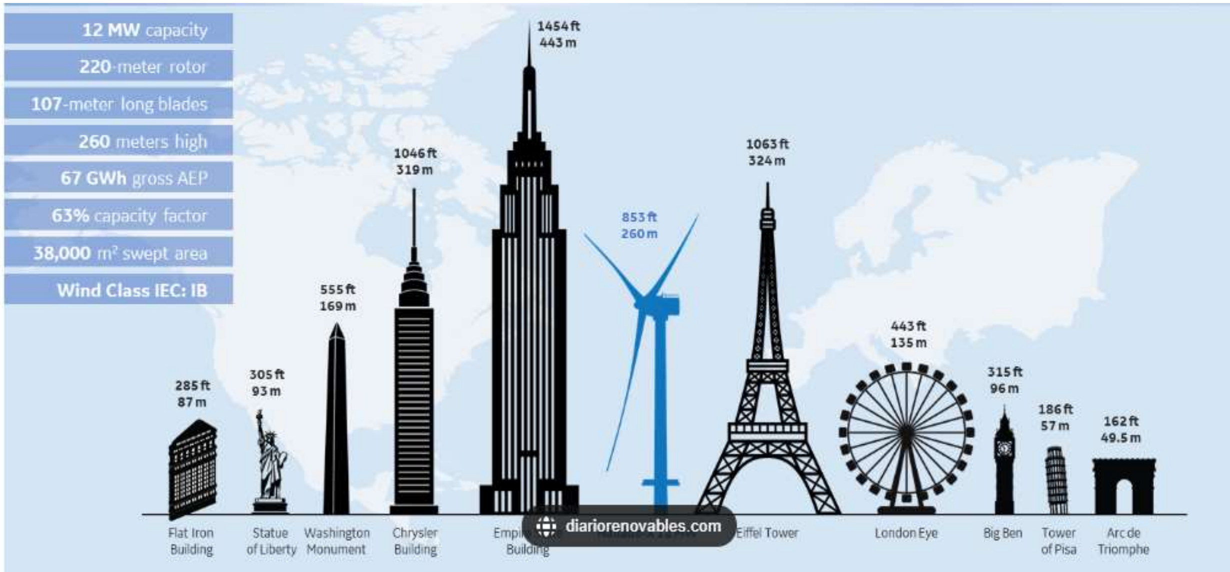






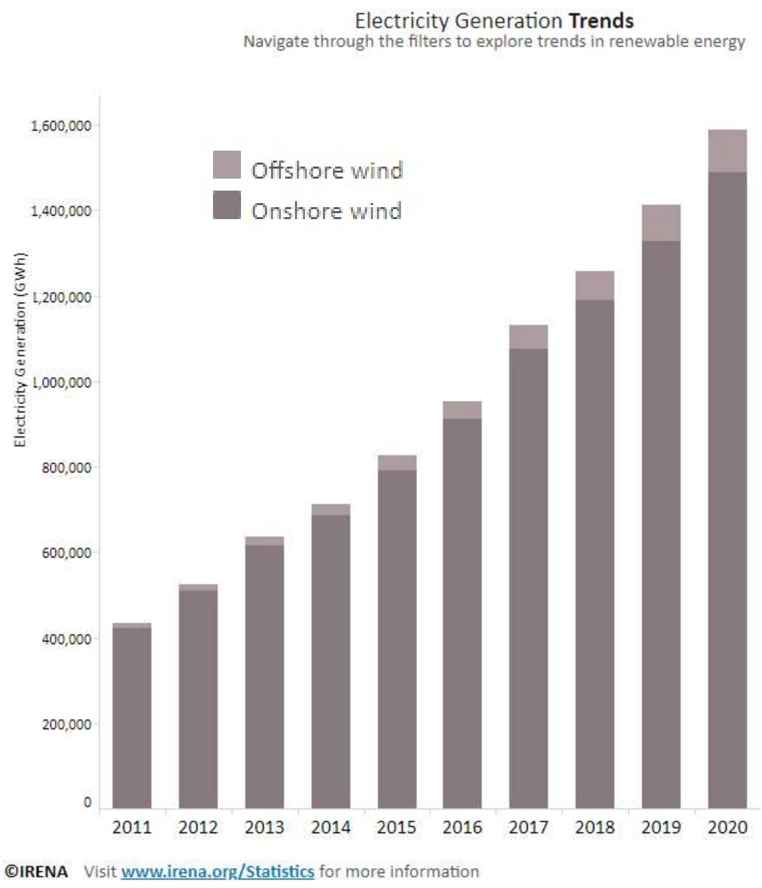
Wind





Haliade X-12,13,14
General Electric
(2022)
CSSC H260-18MW
China State
Shipbuilding
Corporation
MySE 18.X-28X
MyngYang
(Jan 2023)

Wind



Electricity Generation **Trends**
Navigate through the filters to explore trends in renewable energy
Offshore wind
Onshore wind
Electricity Generation (GWh)
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
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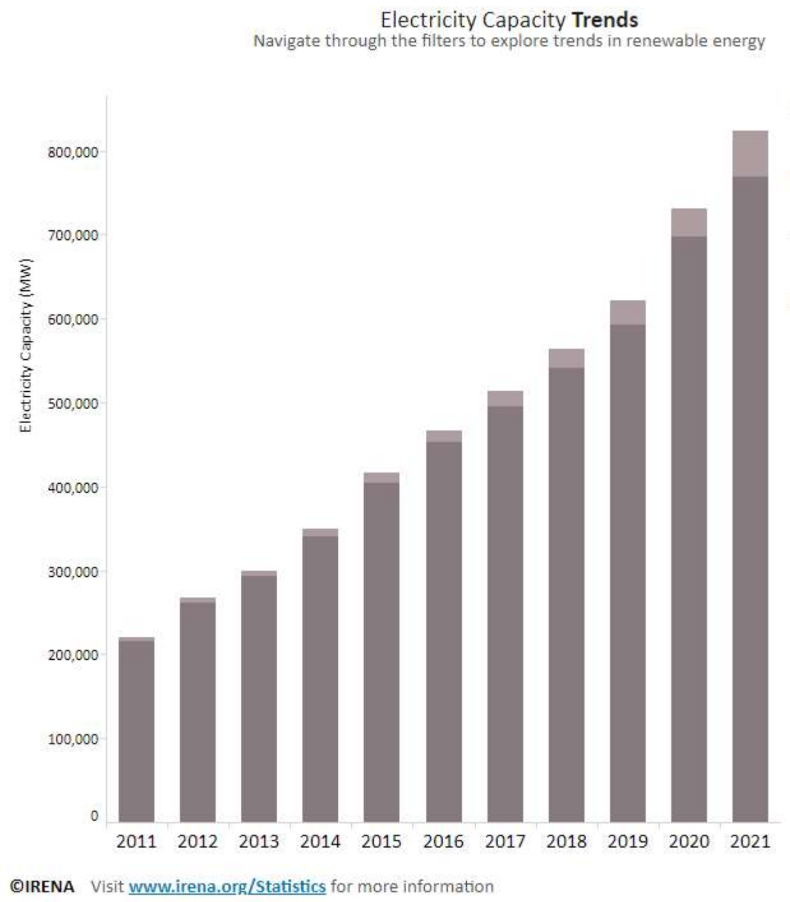

Electricity Capacity **Trends**
Navigate through the filters to explore trends in renewable energy
Electricity Capacity (MW)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
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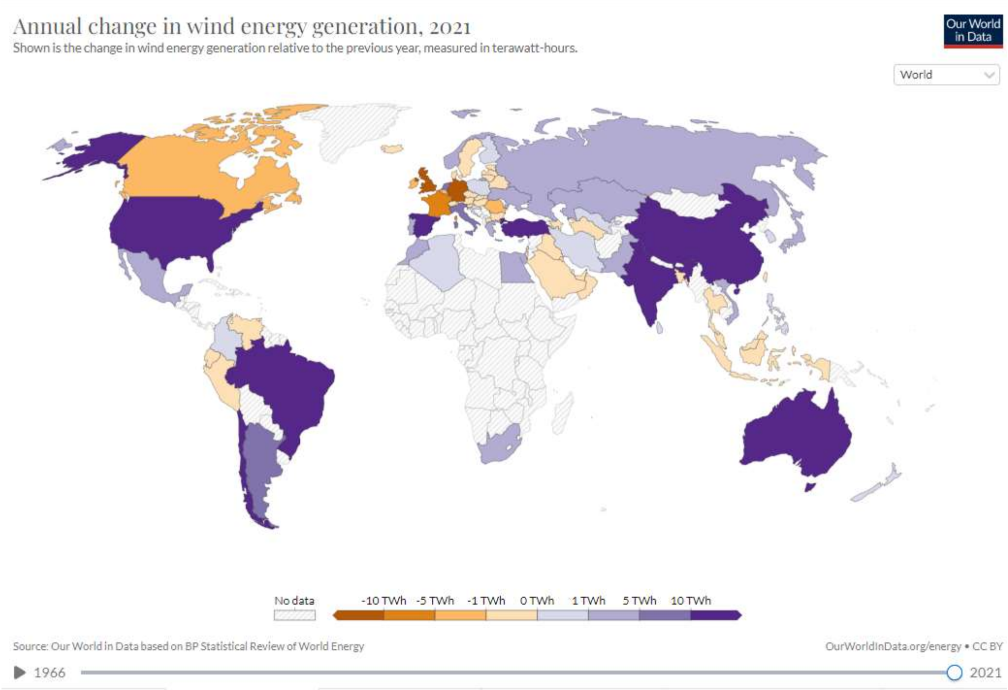
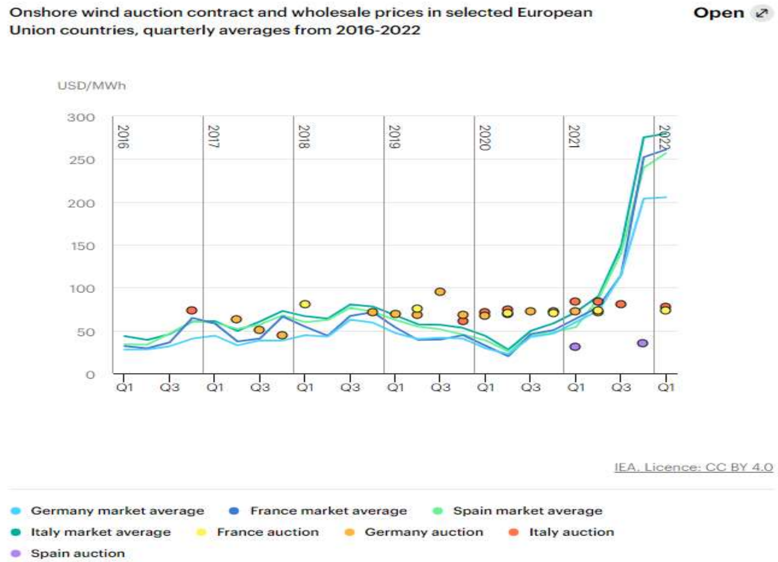
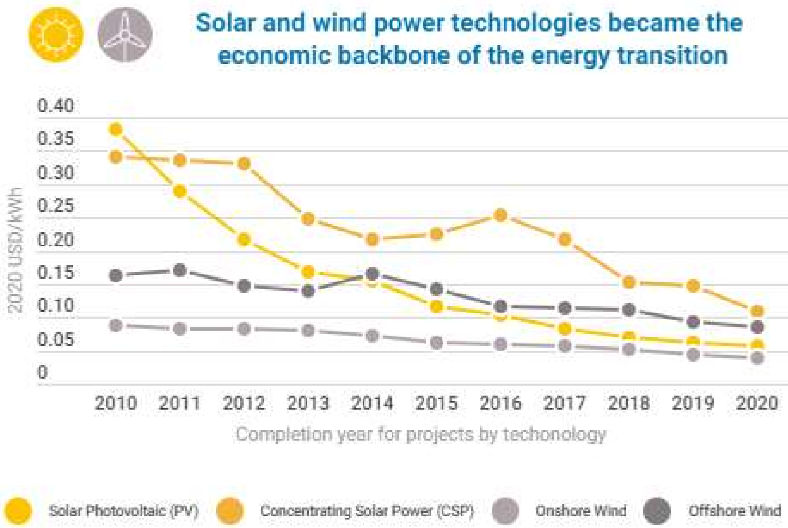
Wind





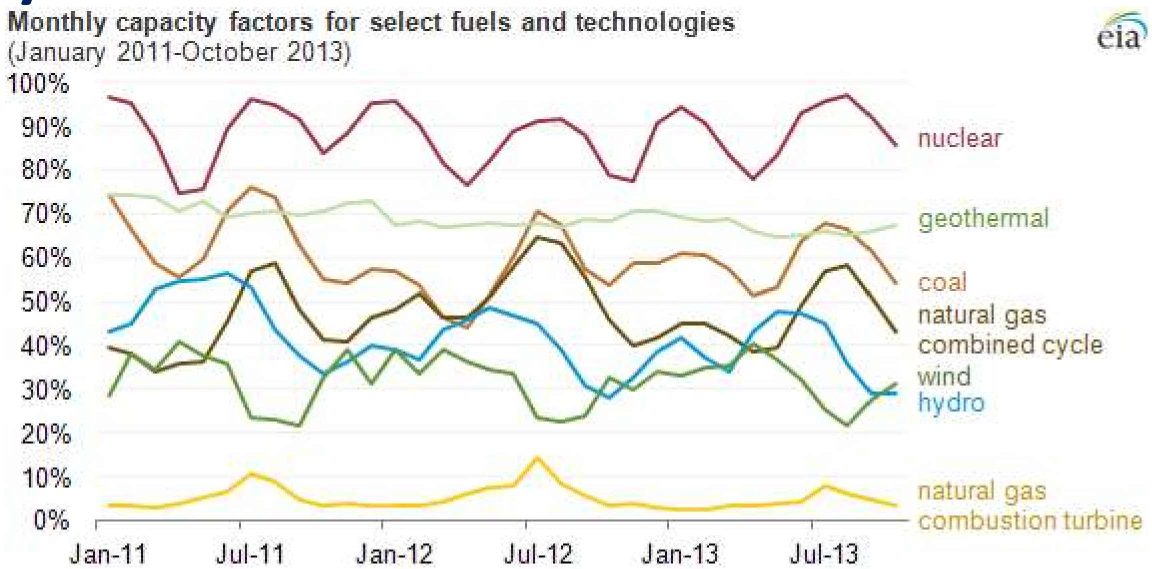
On-shore wind is the cheapest RES

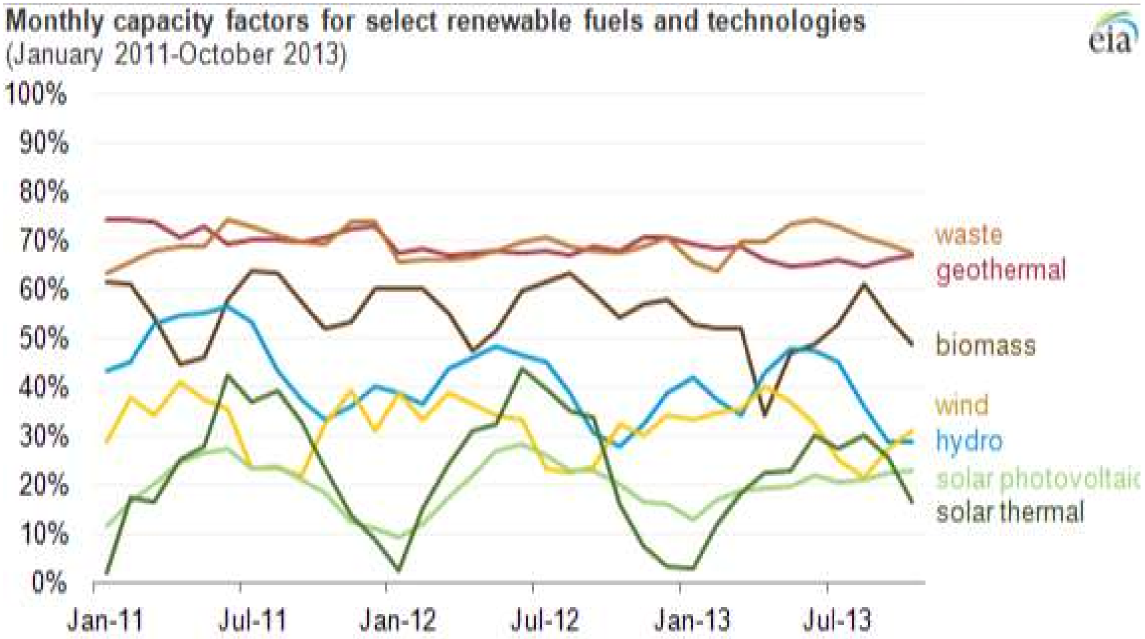
Pros of wind energy	Cons of wind energy
Renewable & clean source of energy	Intermittent
Low operating costs	Noise and visual pollution
Efficient use of land space	Some adverse environmental impact
Wind energy is a job creator	Wind power is remote



Capacity factor of Power Plants

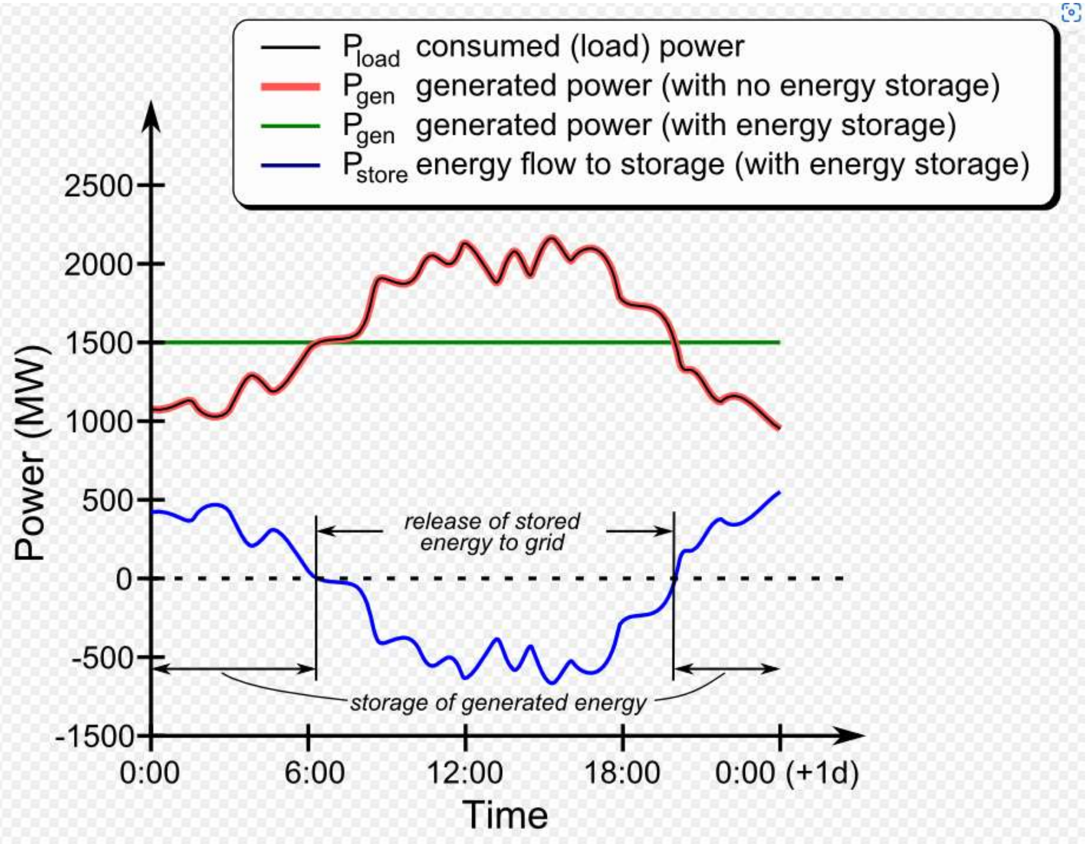
Capacity factor is the ratio of actual electrical energy output over a given period of time to the theoretical maximum electrical energy output over that period.





Source: EIA, U.S.A.

Grid Storage



Electrical energy is stored during times when it is plentiful and inexpensive (especially from intermittent sources) or when demand is low, and later returned to the grid when demand is high, and electricity prices tend to be higher.

Two alternatives to grid storage are the use of **peaking power plants** to fill in supply gaps and demand response (smart grids) to shift load to other times.

Grid Storage

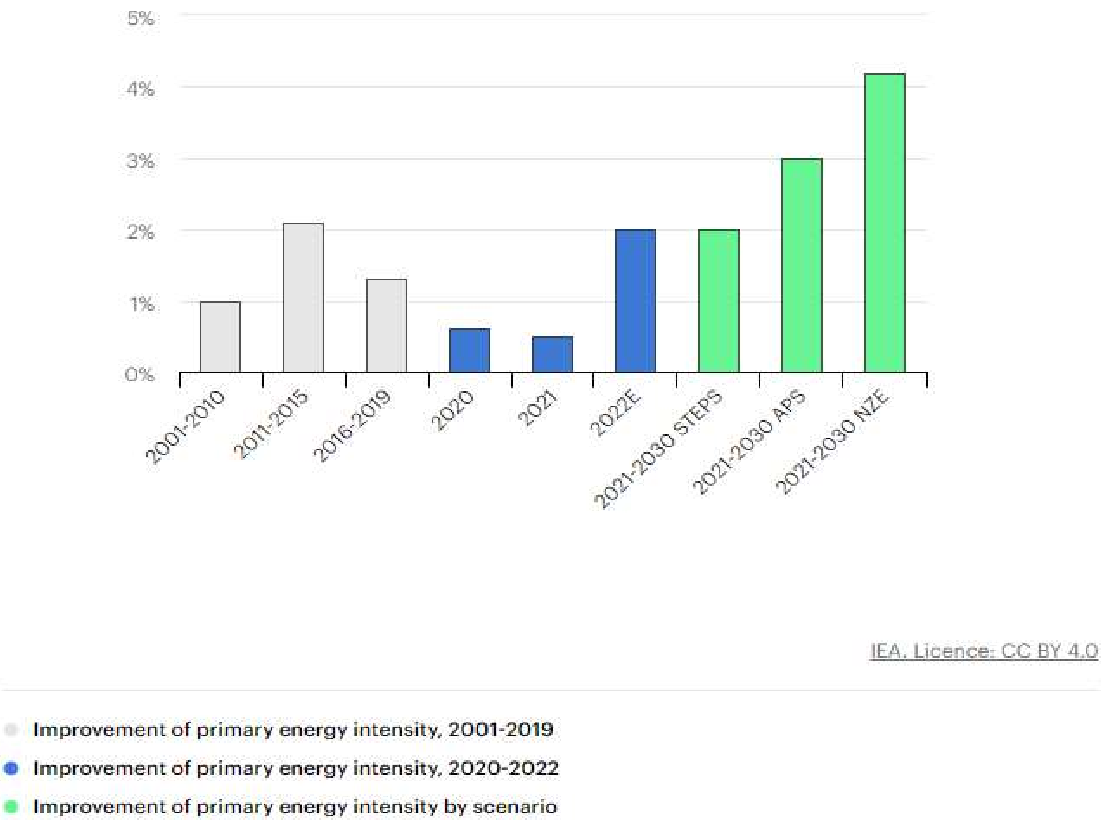
Čierny Váh pumped storage power plant is Slovakia's largest pumped storage power plant and with its installed capacity **735 MW** also the largest hydroelectric power plant in Slovakia.

Pumped-storage PP now represents 95% of all electricity storage worldwide even though the proportion from highcapacity electrochemical batteries is steadily increasing.

Vistra Moss Landing
Monterey County, CA
is currently considered to be the biggest grid-scale lithium-ion storage battery system in the world with its installed capacity **400 MW**

Energy Efficiency

The first fuel of a sustainable global energy system (IEA)

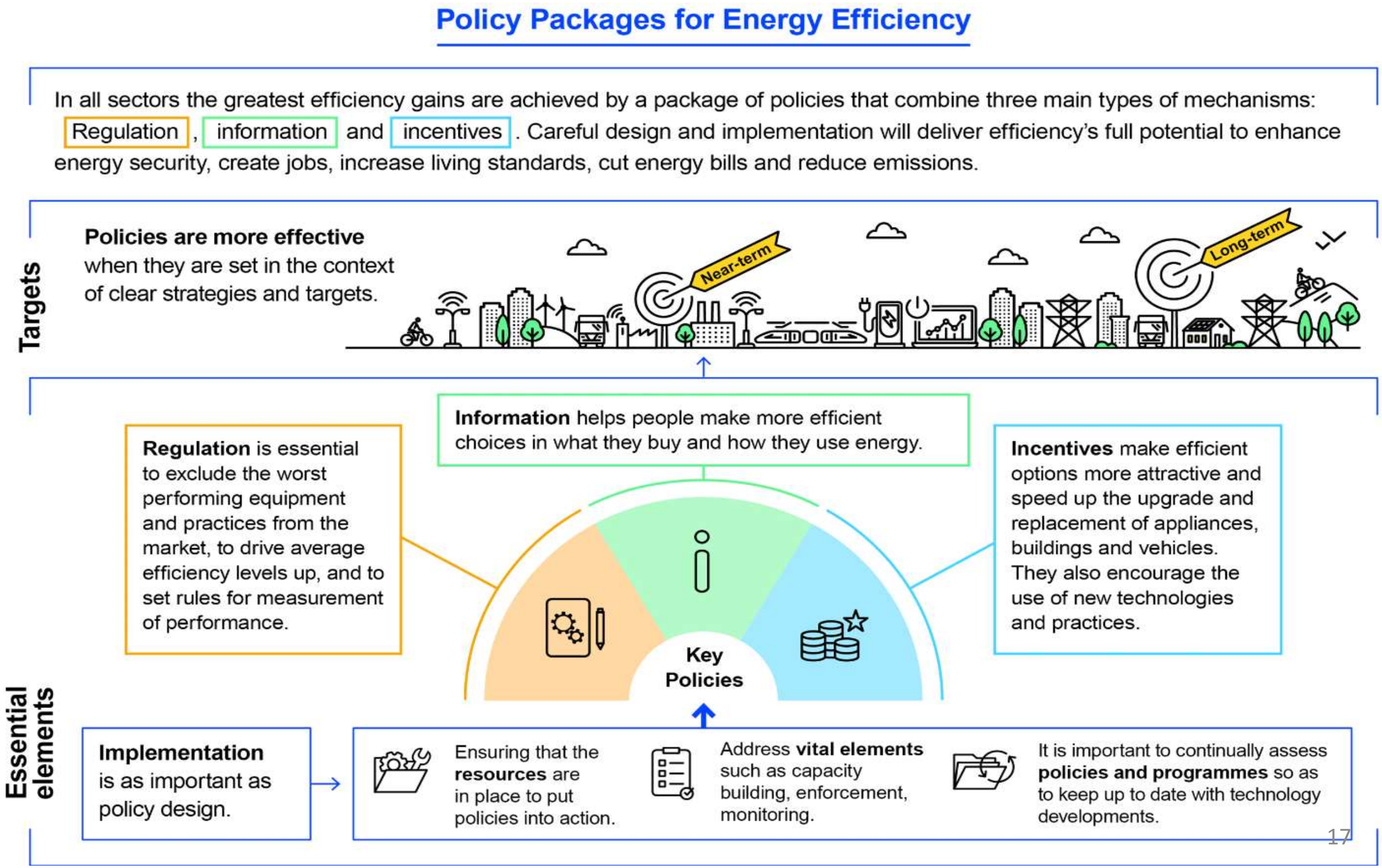


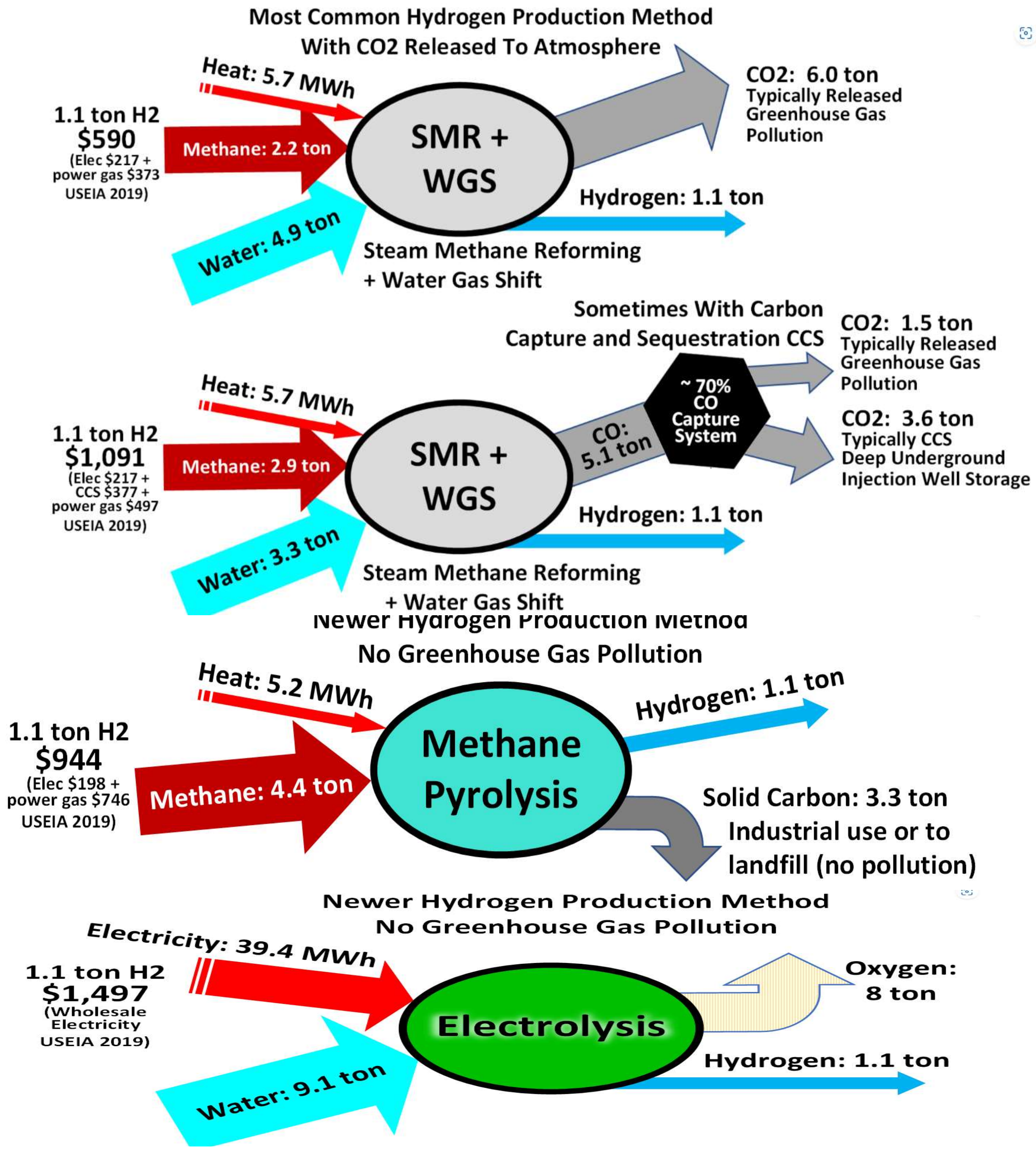
Energy efficiency-related actions such as energy, labeling, building retrofits, public transport and infrastructure projects, and electric vehicle support.

With households and businesses facing significantly higher energy bills, governments in all regions have brought forward a range of interventions to provide support for consumers, including new or increased broad-based fuel subsidies as well as direct cash payments to assist households.

Energy Efficiency vs. Energy Subsidies ?

Energy Efficiency





Hydrogen

Production methods & Taxonomy

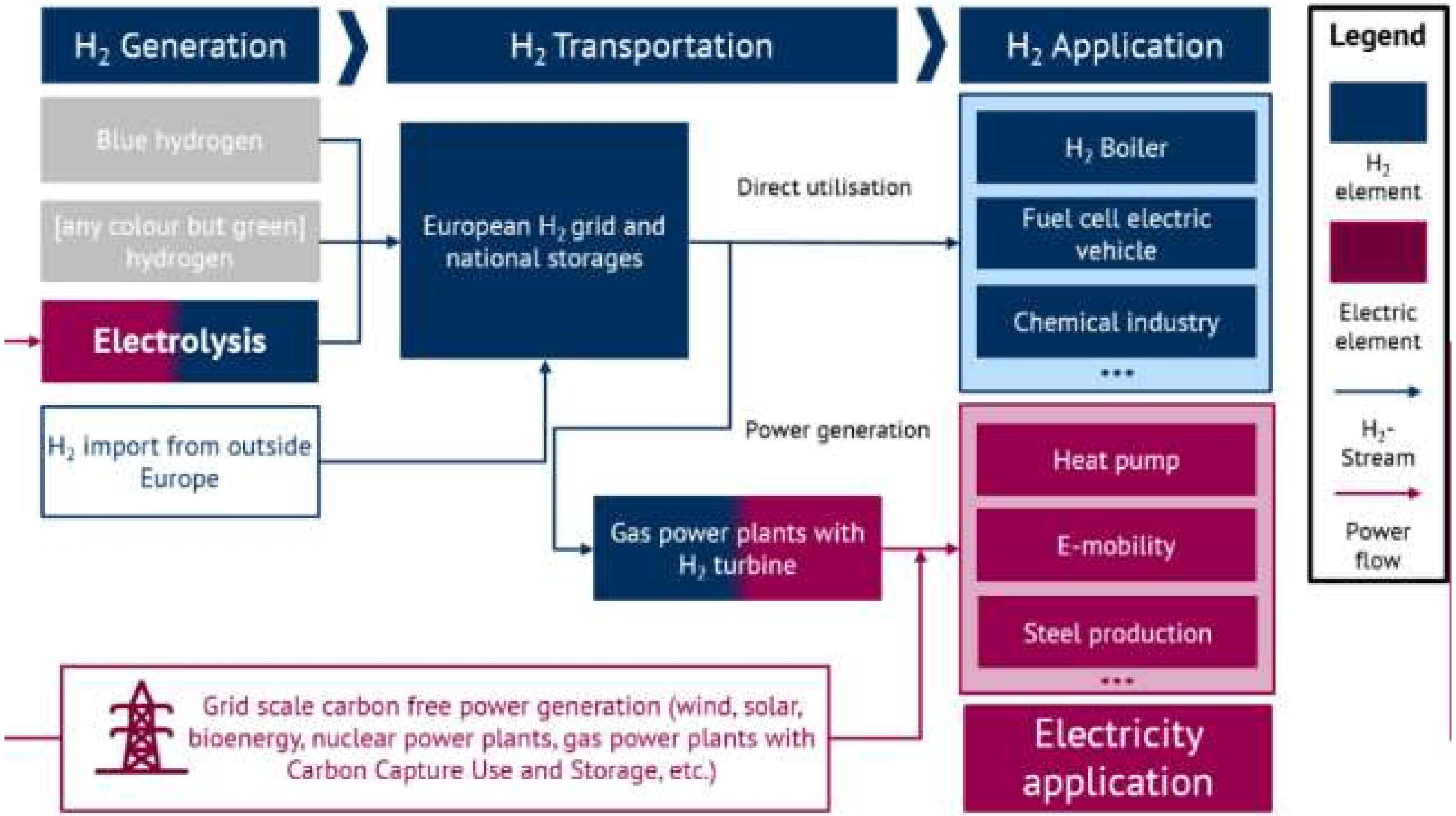
Green H2 - electrolysis RES

Pink H2 – electrolysis Nuclear

Blue H2 – SMR + CCSU

Grey H2 – SMR without CCSU

Hydrogen



Detailed modelling of EU sector coupling of electricity and hydrogen in the GoHydrogen scenario (Source: Energy Brainpool, 2022)

Hydrogen

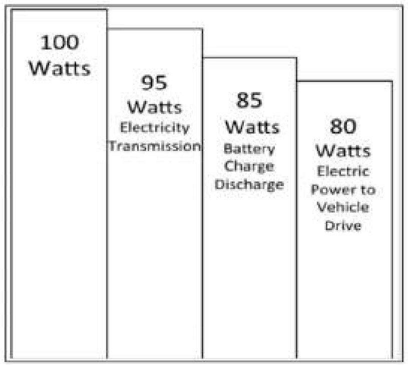
The **hydrogen economy** is using H2 to decarbonise economic sectors which are hard to electrify, essentially, the "hard-to-abate" sectors such as cement, steel, long-haul transport, etc. Hydrogen can also react in a fuel cell, which produces electricity in a process that is the reverse of electrolysis of water.

Hydrogen is an energetic fuel, frequently used as rocket fuel, but technical challenges and costs prevented the creation of a large-scale hydrogen economy yet – e.g. long-term storage, pipelines, engine equipment, safety concerns regarding the high reactivity of hydrogen fuel with O2 in ambient air; the expense of producing it by electrolysis.

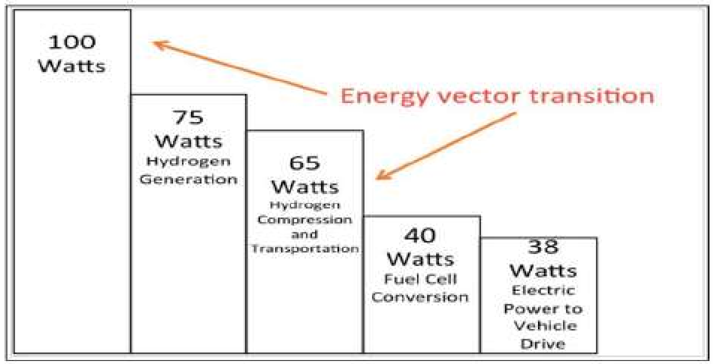
HYDROGEN IS NOT A SILVER BULLET FOR THE ENERGY TRANSITION

Fuel cells for automotive? Not very efficient …..

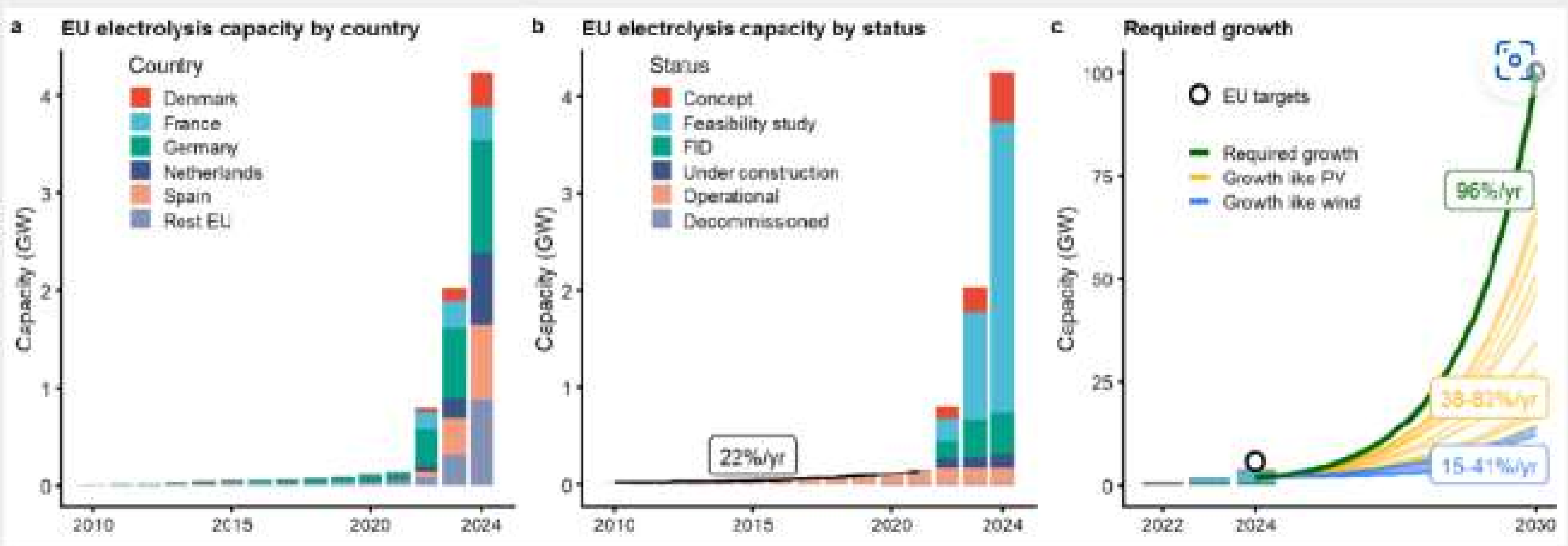
Battery EV 20 kW/km



H2 Cell 60 kWh/km



Green Hydrogen in the EU



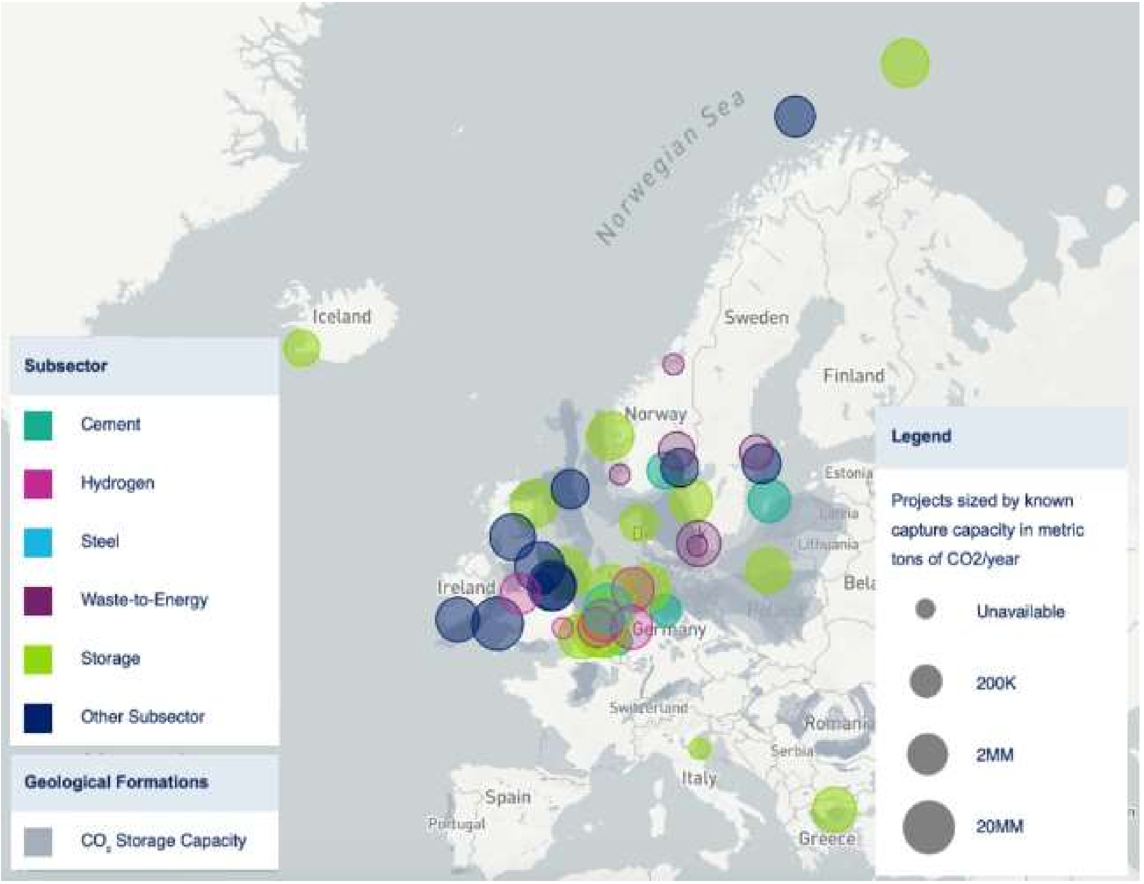
Electrolysis project announcements in the EU until 2024 and required growth to achieve the 2030 REPowerEU target / SOURCE: PIK analysis.

The recent REPowerEU package sets a target of producing 10m tonnes (Mt) of green hydrogen by 2030, as well as importing another 10Mt. Producing each 10Mt of hydrogen would require around 100 gigawatts (GW) of electrolyser capacity.

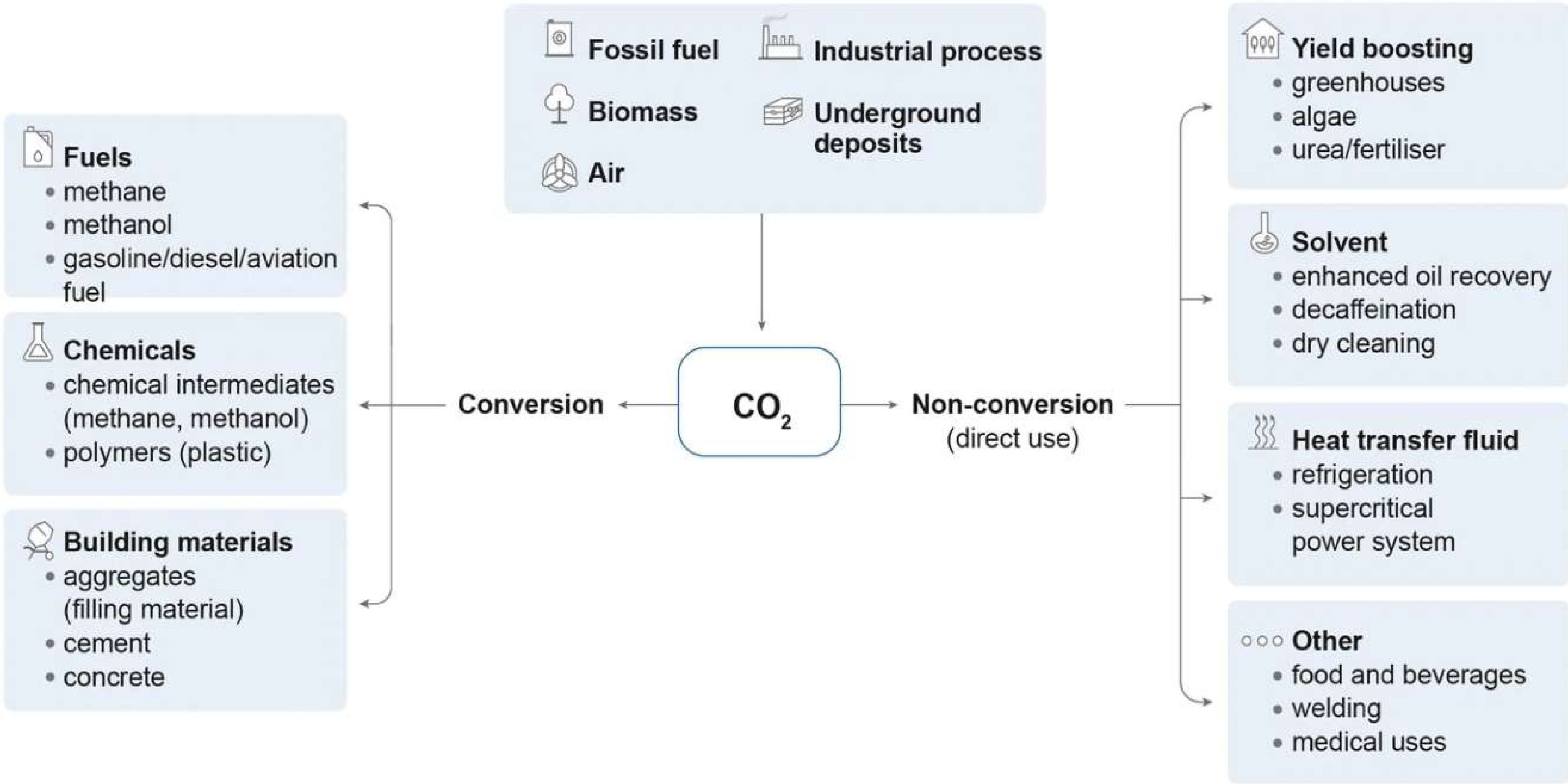
Carbon Capture, Storage and Utilisation

Fossil fuels can be (at least in theory) combined with CCSU technologies
Technological barriers – how to capture and process CO2
Efficiency – costs, leakages
Storage – longevity

40+ EU projects announced
0 commercially implemented
(at best on pilot or demonstration phase)



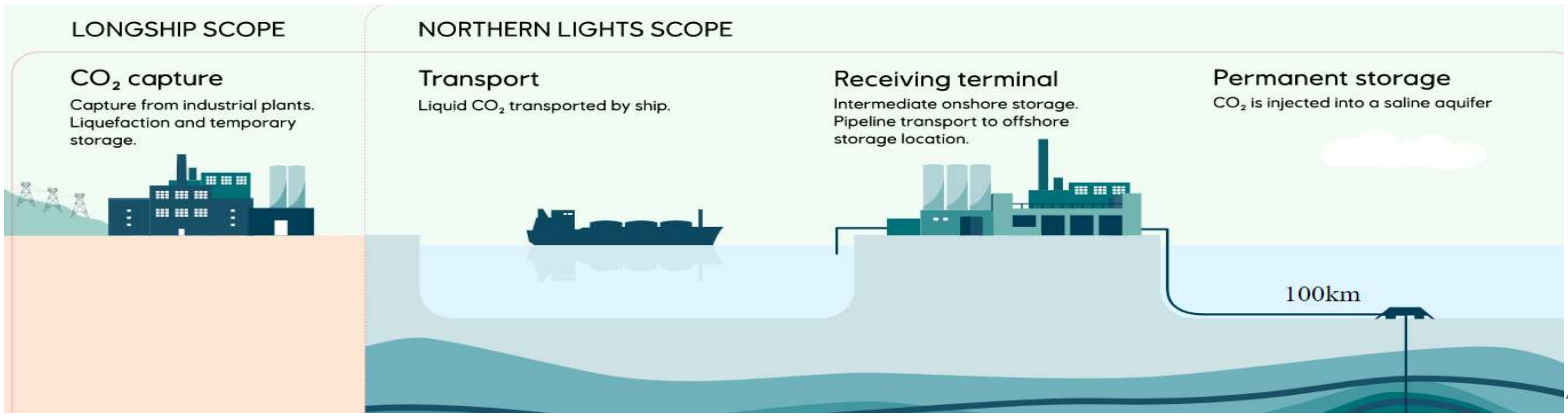
Carbon Capture, Storage and Utilisation



Carbon Capture, Storage and Utilisation

The Alberta Carbon Trunk Line is the world's largest carbon capture, storage and utilization project. It consists of a 240 km pipeline and processing unit which will gather, compress and store up to 14.6 mil. t of CO2/y, and inject this CO2 into depleted oil reservoirs for enhanced oil recovery. Fully operational since 2020.

Norwegian Longship-Northern Lights CCS was launched in 2020, 1.phase operational in 2024 (1,5 mil t CO2/y). Total capex + opex 10 years 25 bln. NOK (16,5 by NO Gov)



New Nuclear - Size matters

Small Modular Rectors (<300 MW) Prefabricated units

Manufactured, shipped and installed on site (more affordable to build than large custom designed reactors)

More than 70 different design (Russia's Akademik Lomonosov, the world's first floating NPP 3x35 MWs SMRs that began commercial operation in May 2020. Other are under construction or in the licensing stage in Argentina, Canada, China, Russia, South Korea and the U.S.A.

Micro Reactors (<20 MW) size of 40ft shipping container

To operate safely for many years (several decades)

Self-controllable, operating without the need for a constant human presence.

Low-enriched uranium fuel (difficult to weaponise)

Passive cooling with heat pipes (no pups needed)

Helium gas-cooled reactors

Argonne National Laboratory, U.S.A.

New Nuclear – technology matters too

Type	Thermal vs. Fast	Materials	Capacity	Sample Cost Predictions
Molten Salt Reactors (MSRs)	Either	Coolant is generally molten fluoride salt; moderator varies.	Varies: <300 MW for SMR; Terrestrial Energy MSRs **range** up to 600 MWe	Less than $1 billion total and about $50 per megawatt-hour (**Terrestrial Energy**)
Sodium-Cooled Fast Reactors (SFRs)	Fast	Coolant is generally liquid sodium; no moderator is used.	Varies: As a small modular reactor, 50-300 MW; can range **up to 1,500 MW**	**Overnight** capital cost **estimated** at $1633/kW for 1500MW plant
Lead-Cooled Fast Reactors (LFRs)	Fast	Coolant is molten lead or lead-bismuth eutectic alloy; no moderator used.	Examples range from a **25-MW** micro-reactor to the **450-MW** Westinghouse Lead Fast Reactor	Overnight construction cost **estimated** at ~$200,000 per kW for ELECTRA model, with high uncertainty.
Gas-Cooled Fast Reactors (GFRs)	Fast	Coolant is generally helium gas; no moderator is used.	Examples range from **0.5 MW** to **2,400 MWth thermal power capacity**	$3,800 per kW for General Atomics's **500-MW** Energy Multiplier Module
Supercritical Water-Cooled Reactors (SCWRs)	Either	Coolant is supercritical water; moderator is generally water.	Varies, including ranges between **300 MW and 1,700 MW**	For a **submarine powered by SWCRs**: $2.71 billion in capital cost, plus $50 million annual operating cost
High Temperature Gas Reactors (HTGRs)	Thermal	Coolant is generally helium gas; moderator is generally graphite.	**Often designed as SMRs** with capacities under 300 MW	**200-MW first-of-a-kind HTGR** (2015$): ~$4 billion capital investment; $76 million per year for operation, maintenance, and fuel

New Nuclear – technology matters too

Benefits of Advanced Nuclear Reactors

Safety Benefits: Advanced reactors can operate with significantly enhanced safety compared to traditional light-water nuclear reactors. (lower pressures, special coolants, passive safety measures). These passive safety measures allow reactors to withstand a broader set of accident conditions without causing damage.

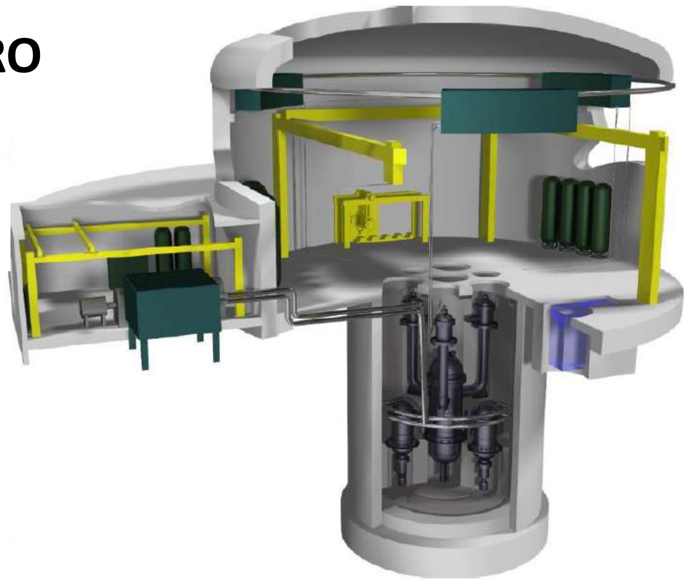
Lower Costs: There is ongoing debate about whether the capital cost of an advanced nuclear reactor (the up-front, one-time-only costs to construct a reactor) would be lower than those of a contemporary light-water reactor. ???

Industrial Decarbonization: Some advanced nuclear reactors produce high temperatures that can be used for industrial processes (e.g. Hydrogen generation). Many industrial processes currently rely on fossil fuels to produce necessary heat levels, and advanced reactors could substitute for fossil fuels in processes that would be difficult to electrify. In this way, advanced reactors have the potential to help decarbonize industries that are currently heavily reliant on fossil fuels.

New Nuclear – technology matters too

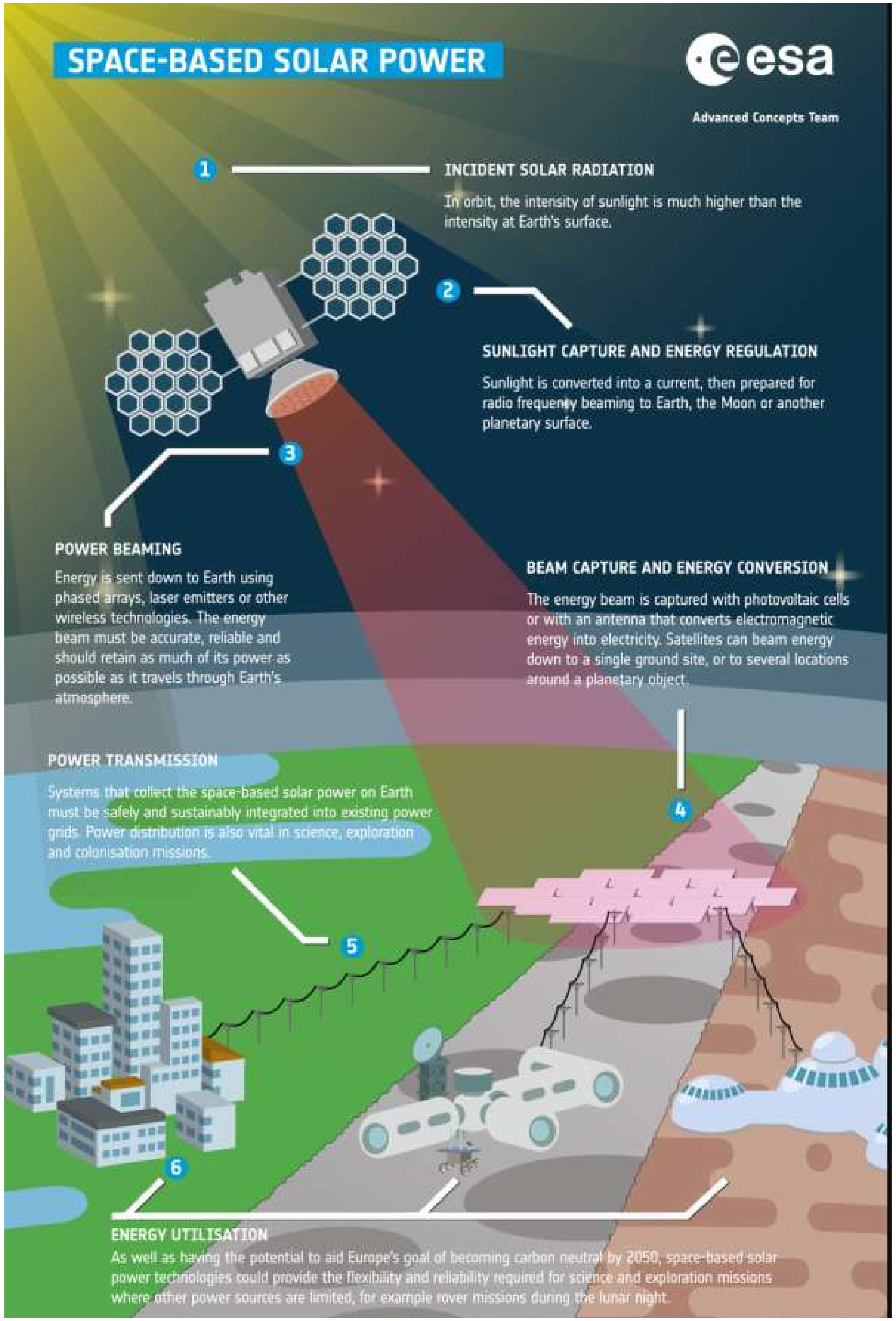
Gas Cooled Fast Reactor GCFR – Project ALLEGRO

V4+France scientific cooperation



High Temperature heat (850-900 C) and Electricity Co-Generation

Can be used for Hydrogen generation



New frontiers – Space Solutions

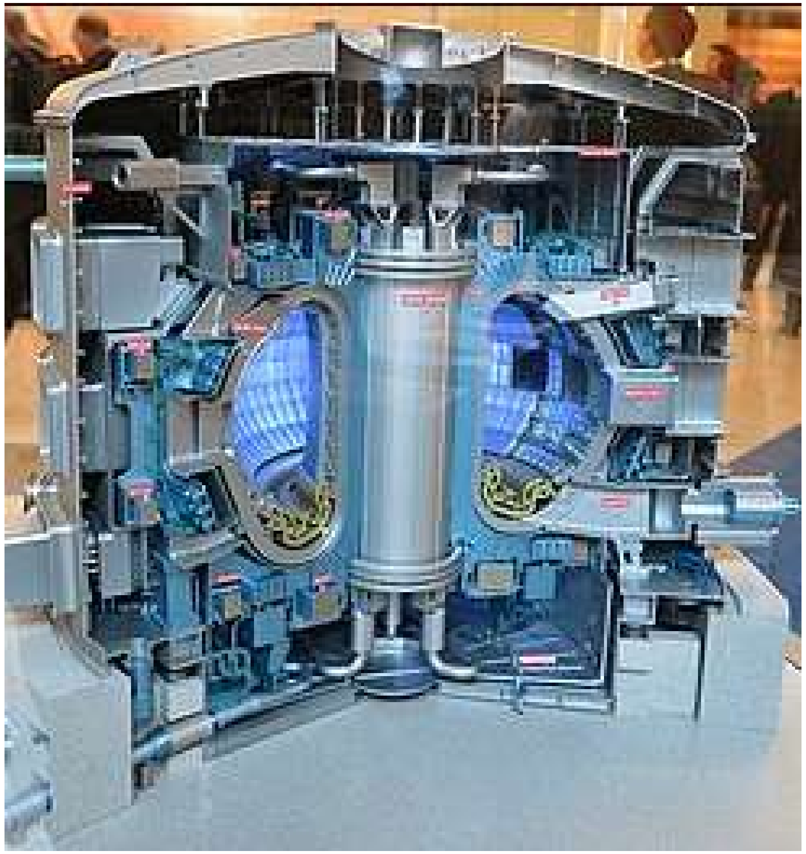
European Space Agency **SOLARIS** project (2022)

A constellation of several enormous satellites situated 36,000 kilometers from Earth to provide space-based solar power.

Each of these satellites would weight 5000+ ton (ISS-450 t) The launch of these satellites' components would need thousands of heavy-lift rocket missions.

According to Physicist Casey Handmer space-based solar power will be unaffordable due to transmission losses, heat losses, logistical expenses, and a space technology penalty. www.sciencetimes.com

New frontiers – Nuclear Fusion



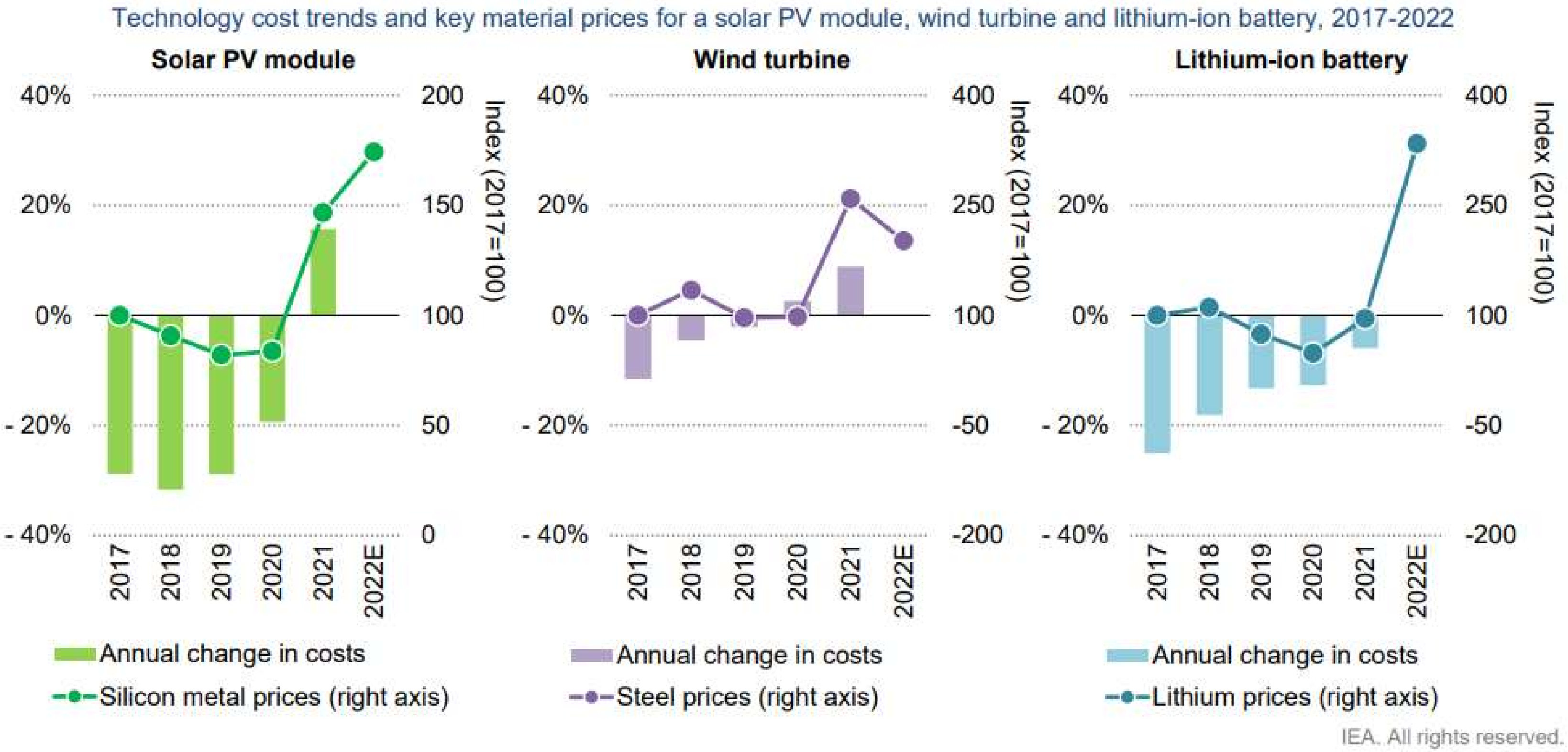
Building started 2013, completion of "la machine" expected by 2025

International Thermonuclear Experimental Reactor (big tokamak reactor located in France).

ITER's stated purpose is scientific research, and technological demonstration of a large fusion reactor, without electricity generation. ITER's goals are to achieve enough fusion to produce 10 times as much thermal output power as thermal power absorbed by the plasma for short time periods; to test technologies that would be needed to operate a fusion power plant including cryogenics, heating, control and diagnostics systems and remote maintenance; to achieve and learn from a *burning* plasma; to test tritium breeding and to demonstrate the safety of a fusion plant.

Projected costs 6 bn. EUR, total costs up to 60 bn. EUR (unofficial estimates)

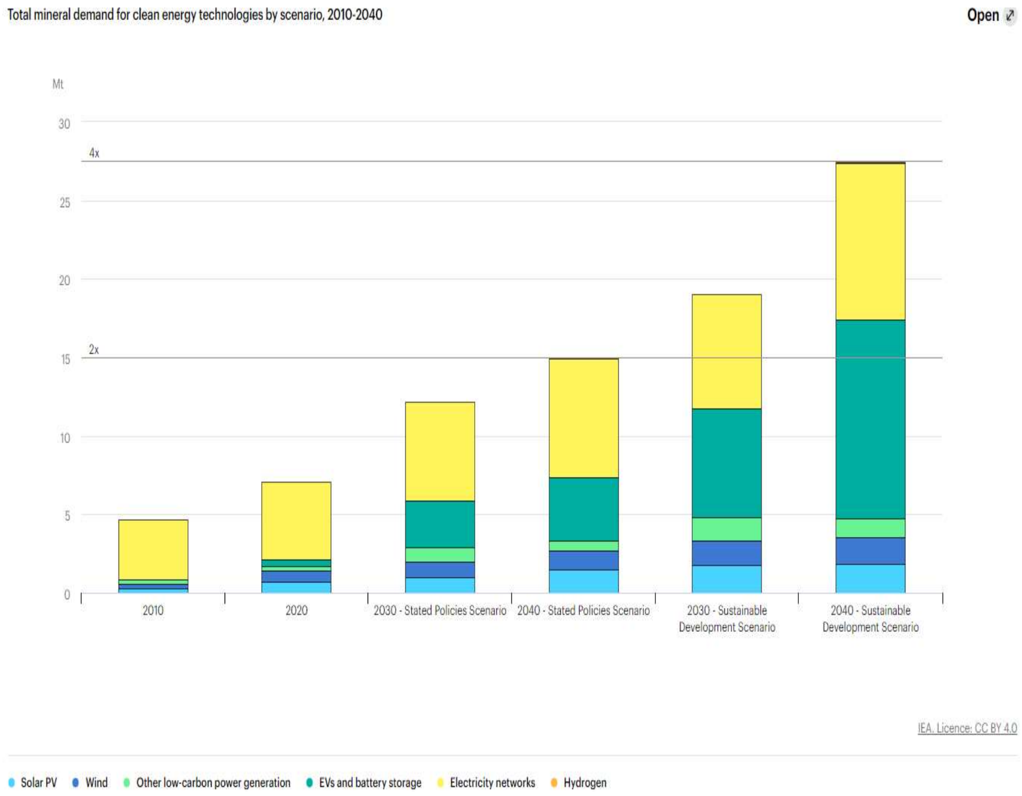
Reverse of costs trends for RES

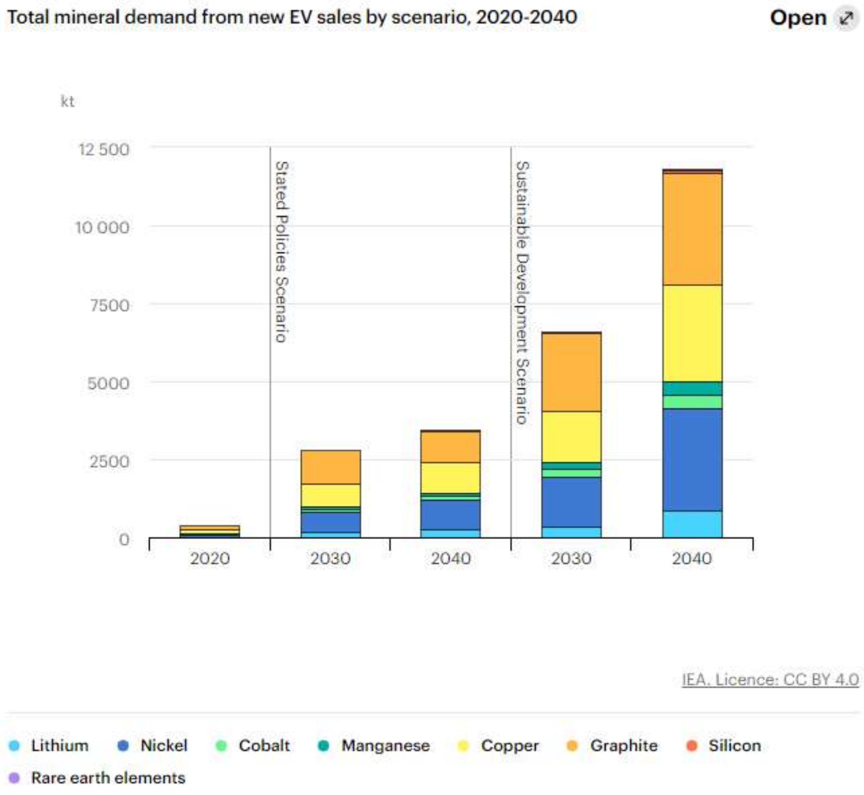


New mineral requirements

Total mineral requirement for clean technologies

New EV requirements





STEP vs. SDS scenarios for existing renewable generation and storage technologies

??? Questions for Participants ???

What are key primary sources and technologies providing humanity with modern energy?

What are weak and strong points of oil?

What are weak and strong points of gas?

What are weak and strong points of coal?

What are weak and strong points of hydro?

What are weak and strong points of nuclear?

What are the IEA energy and climate scenarios?

Key Takeaways

- Mature energy technologies are the main reason for the need of the Energy transition
- Modern energy technologies can provide the Energy transition on a high cost
- New technologies may need lot of time for development and deployment with unclear side effects
- From technological perspective there is a need for a mix of technologies, all low or lower carbon technologies should be welcomed
- Energy efficiency and behavioral change is a part of the long term solution and successful Energy transition

People in the Energy Transition Diplomacy

Nur Bekri,
Administrator,
National Energy
Administration,
China
G-20 Energy
Ministerial meeting

The End

Urban.Rusnak@gmail.com

LESSON 4 – INDUSTRY AND TECHNOLOGIES (2)

NEXT

LESSON 5 – ELECTRICITY