Energy Transition Diplomacy
Generation, Transmission and Distribution of Electricity

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Disclaimer

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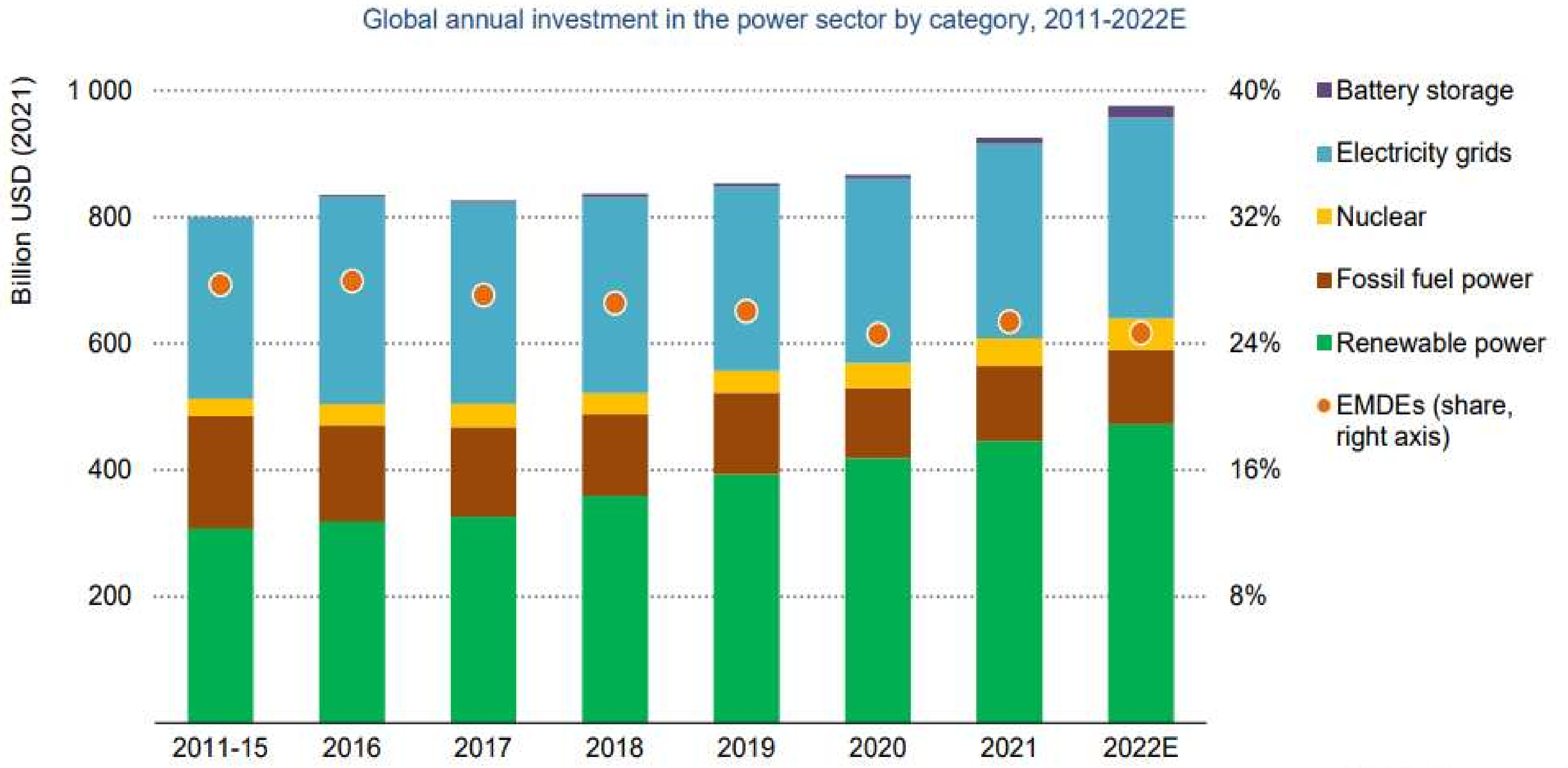
Electricity

- Scale of electricity systems, investments
- Generation, transmission, and distribution of electricity.
- Traditional grids, smart grids, storage technologies.
- Electrification and energy transition.
- Energy Industry cycles and Investment

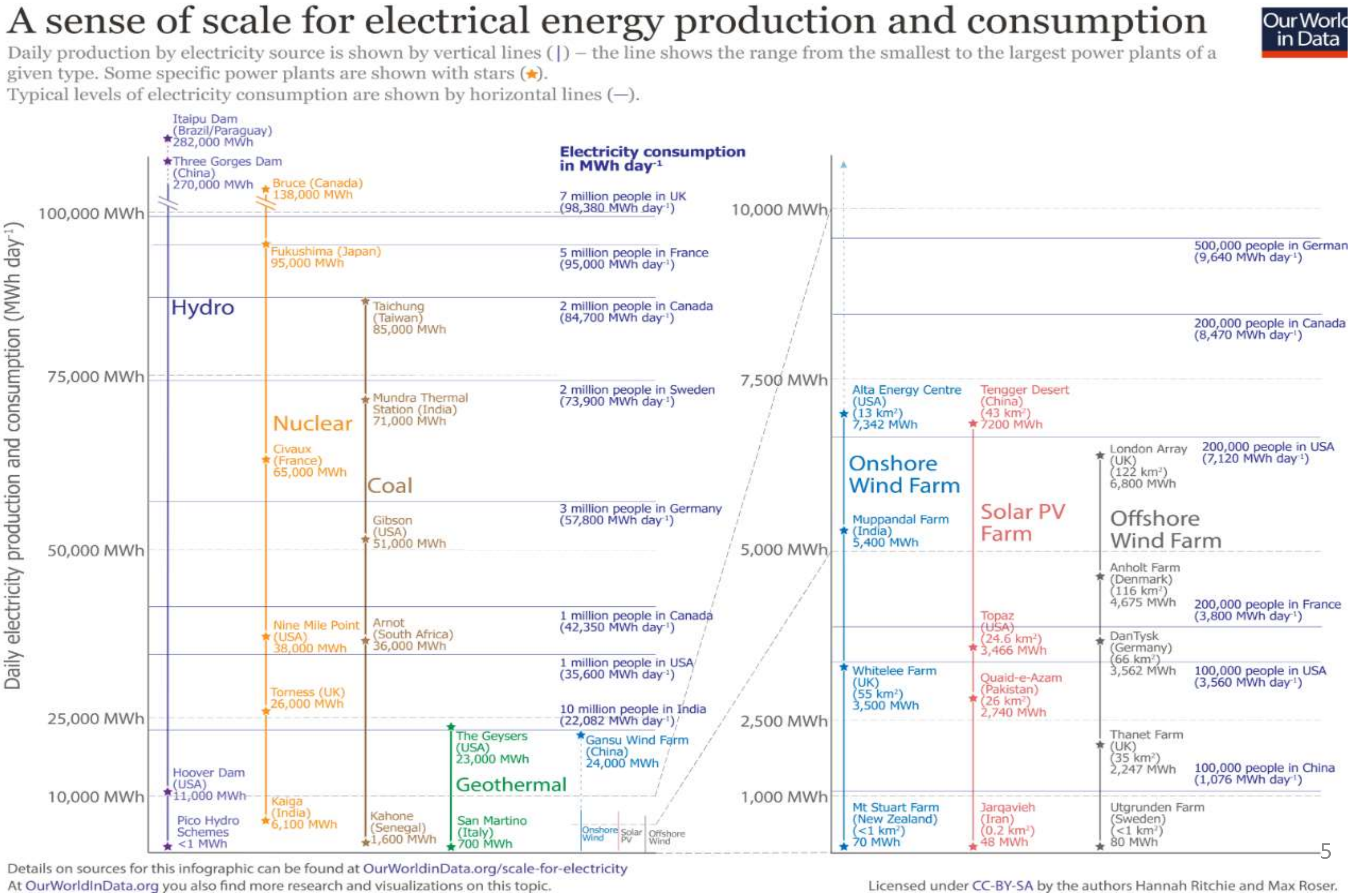
Global annual change in energy investment

Robust power sector investment is central to clean and secure energy transitions

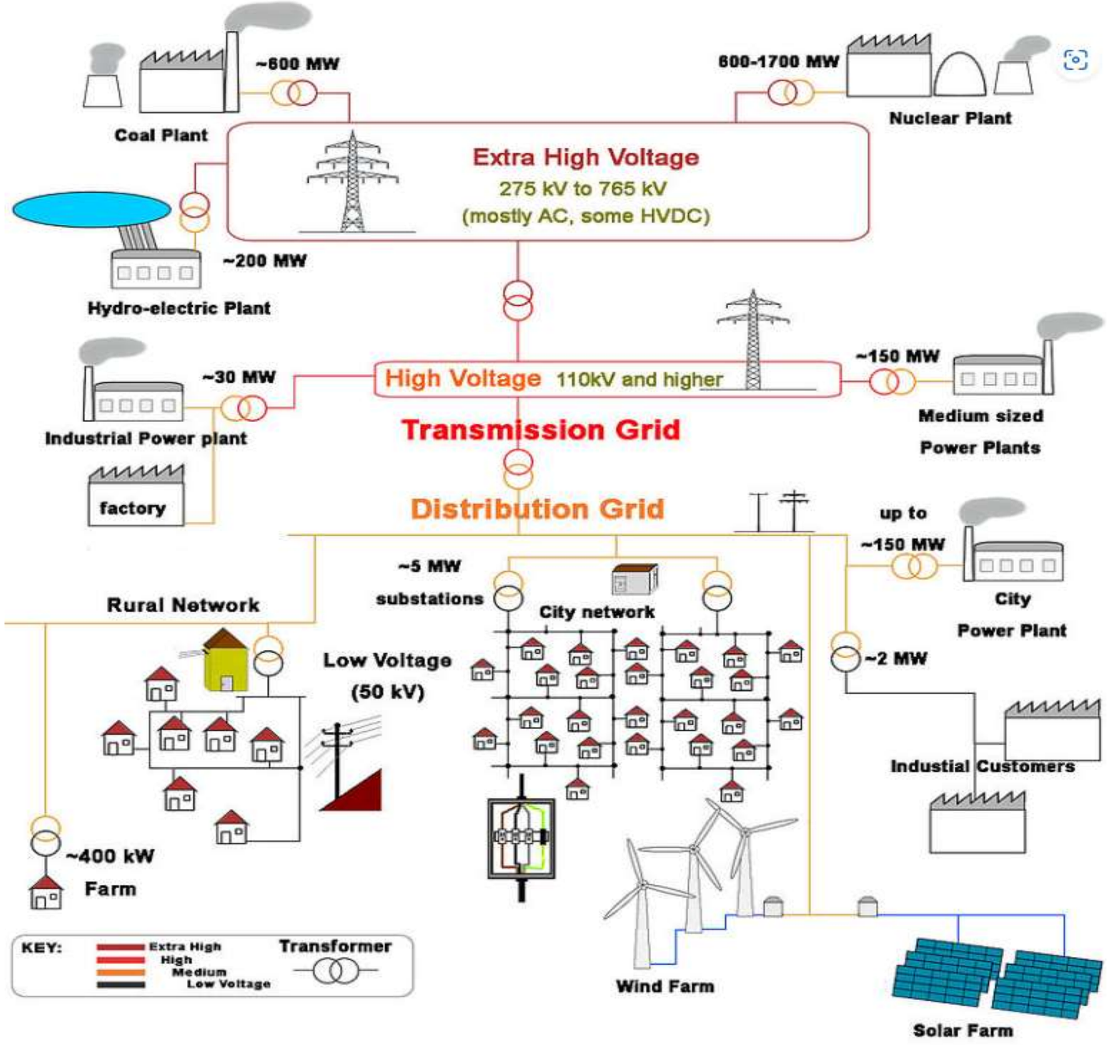


Notes: Investment is measured as ongoing capital spending on power capacity. EMDEs = emerging markets and developing economies, excluding China.

Scale of Electricity Systems



Traditional Electricity System



Generation

Transmission
&
Distribution

Consumption

Generation

Turbines generate almost all commercial electric power globally. The turbine drives a generator which is transforming mechanical energy into electrical energy by electromagnetic induction. The steam turbine, using a variety of heat sources currently generates about 80% of electricity in the world.

Heat sources: Coal, Gas, Oil, Peat, Biomass, Waste, Nuclear, Solar thermal, Geothermal

Direct movement turbines: Wind, Tide, Gravitation Water

Direct transformation: light to electricity - Solar PV (photovoltaic) radiation to electricity

Generation

Generation Capacity (MW) is the maximum electric output a power plant generator can produce under specific conditions. Installed (nameplate) capacity is determined by the power plant generator's manufacturer. It indicates the maximum output of electricity a generator can produce without exceeding design thermal limits. Present Capacity is a capacity of a power plant in a given moment, can be lower (obsolete equipment) or higher (modernization) than originally built.

Power (Electricity) Generation (MW/h) is the amount of electricity a generator produces during a specific period of time. For example, a generator with 1 megawatt (MW) capacity that operates at that capacity consistently for one hour will produce 1 megawatthour (MWh) of electricity. Many generators do not operate at their full capacity all the time

Capacity factor (%) of electricity generation is a measure of how often an electricity generator operates during a specific period of time using a ratio of the actual output to the maximum possible output during that time period.

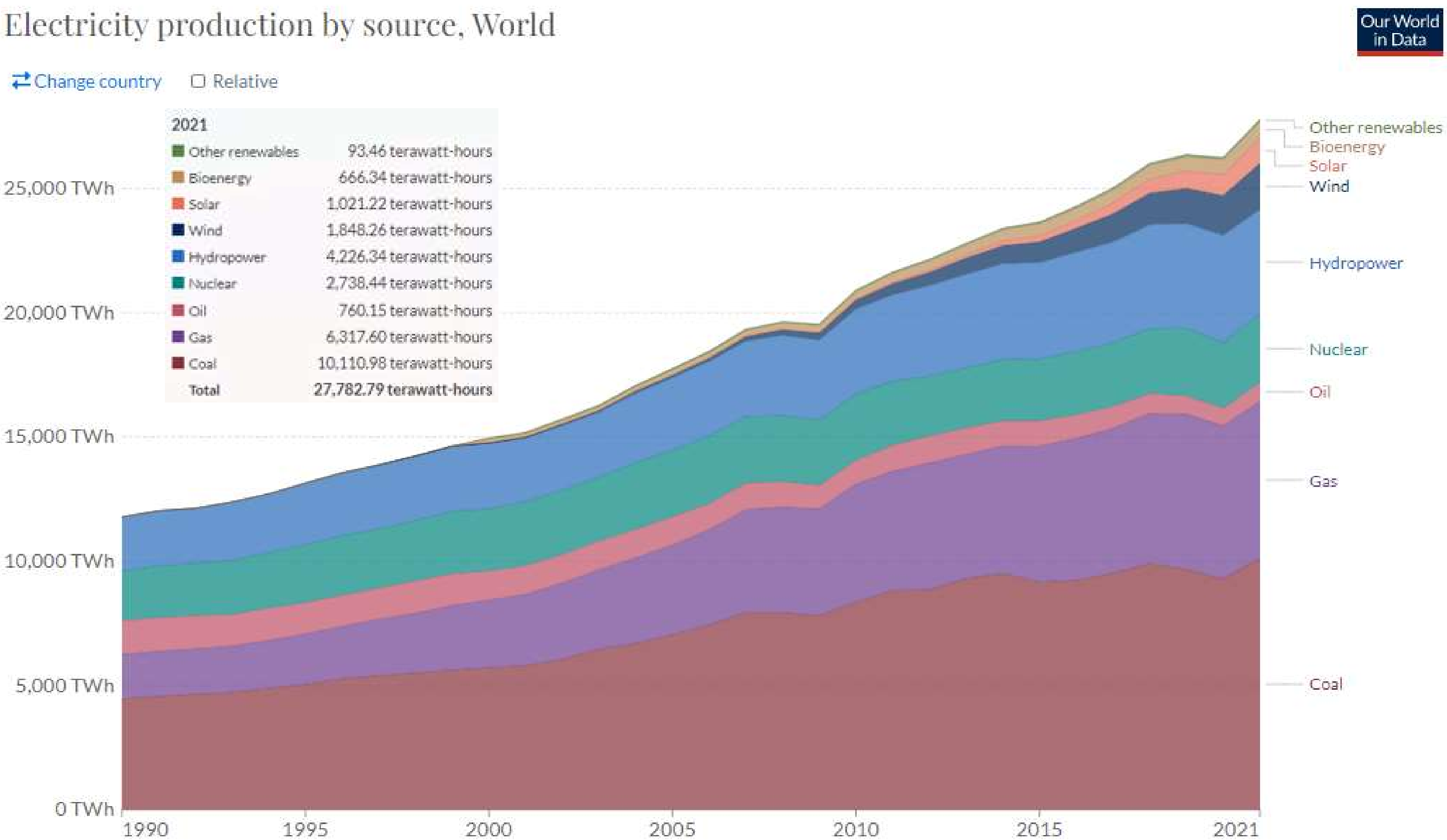
Generation

Ex. wind turbine with a **capacity of 1.5 MW** is running at its maximum capacity for 2 hours in a given day. At the end of the second hour, the turbine would have generated **3 MW/h of electricity** (i.e. 1.5 MW x 2 hours). **The capacity factor** for the turbine would be 8,3% in this day.

If the wind was not blowing strongly enough for the turbine to operate at its maximum capacity, and the same turbine was only producing 1 MW of power for 2 hours, the total generation would be 2 MW/h. The capacity factor in this case would be 6,5% only.

www.windpowerengineering.com

Generation by source

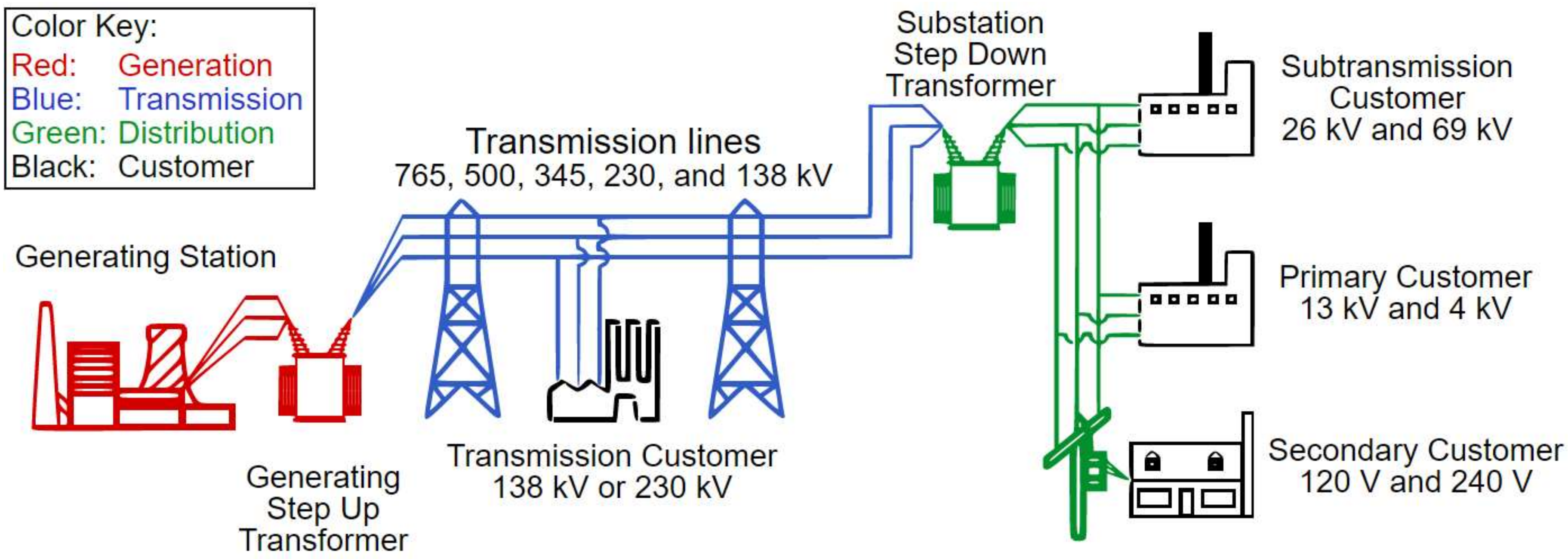


Source: Our World in Data based on BP Statistical Review of World Energy (2022); Ember's Global and European Electricity Reviews (2022)
Note: 'Other renewables' includes waste, geothermal, wave and tidal.

Transmission & Distribution

Transmission is the bulk movement of electricity from a power plant to an electrical substation. HVAC, HVDC lines | high voltage → less losses

Distribution is a local movement of electricity between high-voltage substations and customers. AC lines



By US DoE, SVG version by User:J Jmesserly,http://www.ferc.gov/industries/electric/indus-act/reliability/blackout/ch1-3.pdf

Electricity Consumption

Electricity has two quantities: current and voltage. These can vary with respect to time AC or can be kept at constant levels DC power.

AC - industrial machinery, refrigerators, air conditioners, pumps,

DC - digital equipment, electric cars

Electricity transformation

AC voltage step-up / step-down transformers – grid

AC/DC transformers – electronic equipment, EV chargers

DC/AC transformers – solar PV

Electricity Storage

Essential part of any sustainable and resilient energy system, which captures energy produced for a use at a later time.

Energy accumulator or battery stores it in different forms: chemical, gravitational potential, electrical potential, temperature potential, electrochemical, kinetic... Energy storage technology involves extracting energy from forms of storage.

Energy storage technologies varies broadly in volumes and longevity.

Grid energy storages – most common are hydroelectric dams (conventional and pumped), which stores gravitational potential energy of water.
Industry energy storages – ice storage tanks for cooling peak use
Appliance energy storages – cell phone batteries

Grid Scale Energy Storages

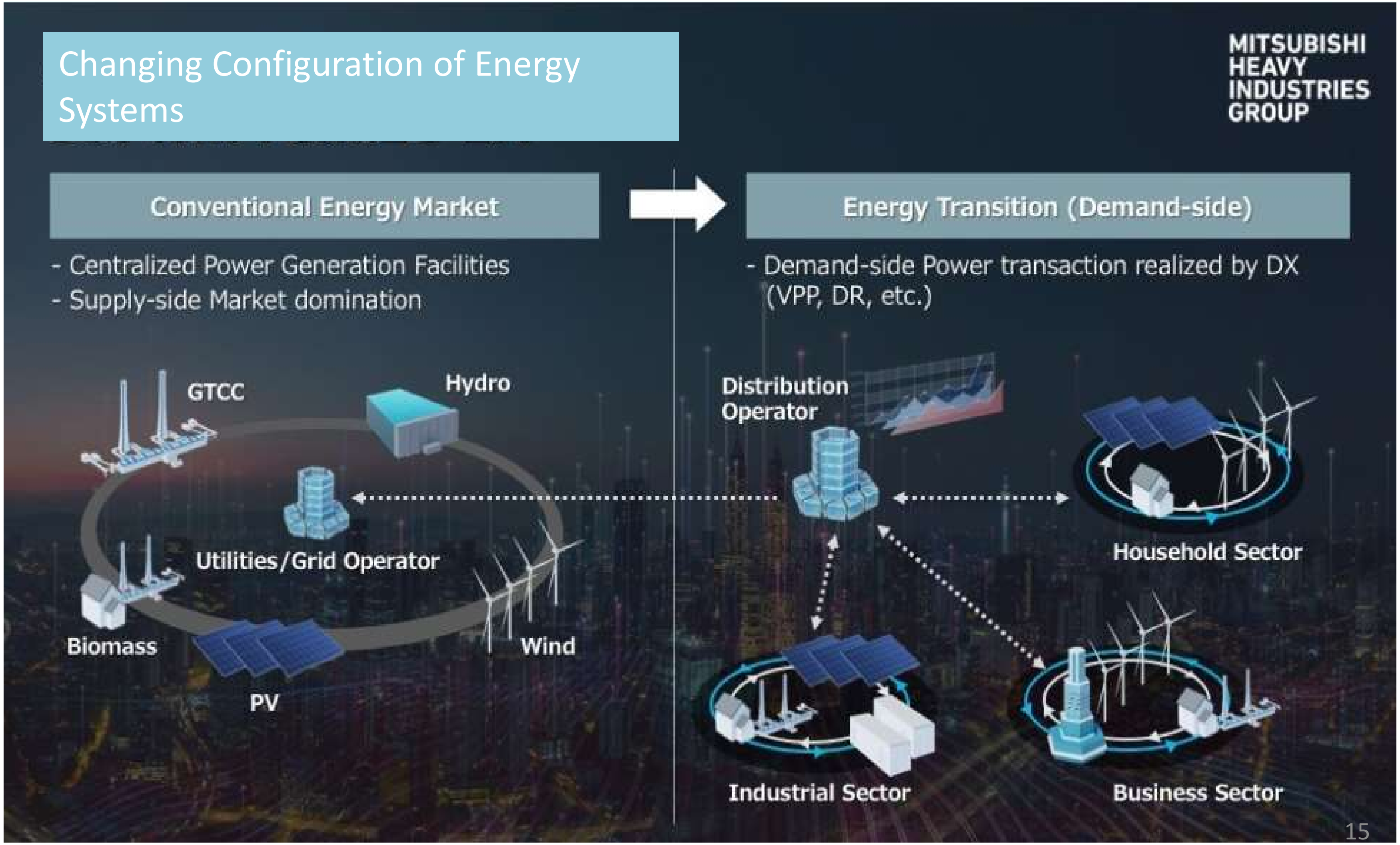
Economically viable grid scale storage is a precondition for full de-carbonisation of large energy systems. They can provide benefits and services such as power quality, load management and uninterrupted power to increase the efficiency and supply security.

Various technologies are suitable for grid-scale applications, however their benefits are different. For example, a pumped-hydro station is well suited for bulk load management applications due to their large capacities and power capabilities. HPPs use is limited when addressing quality issues.

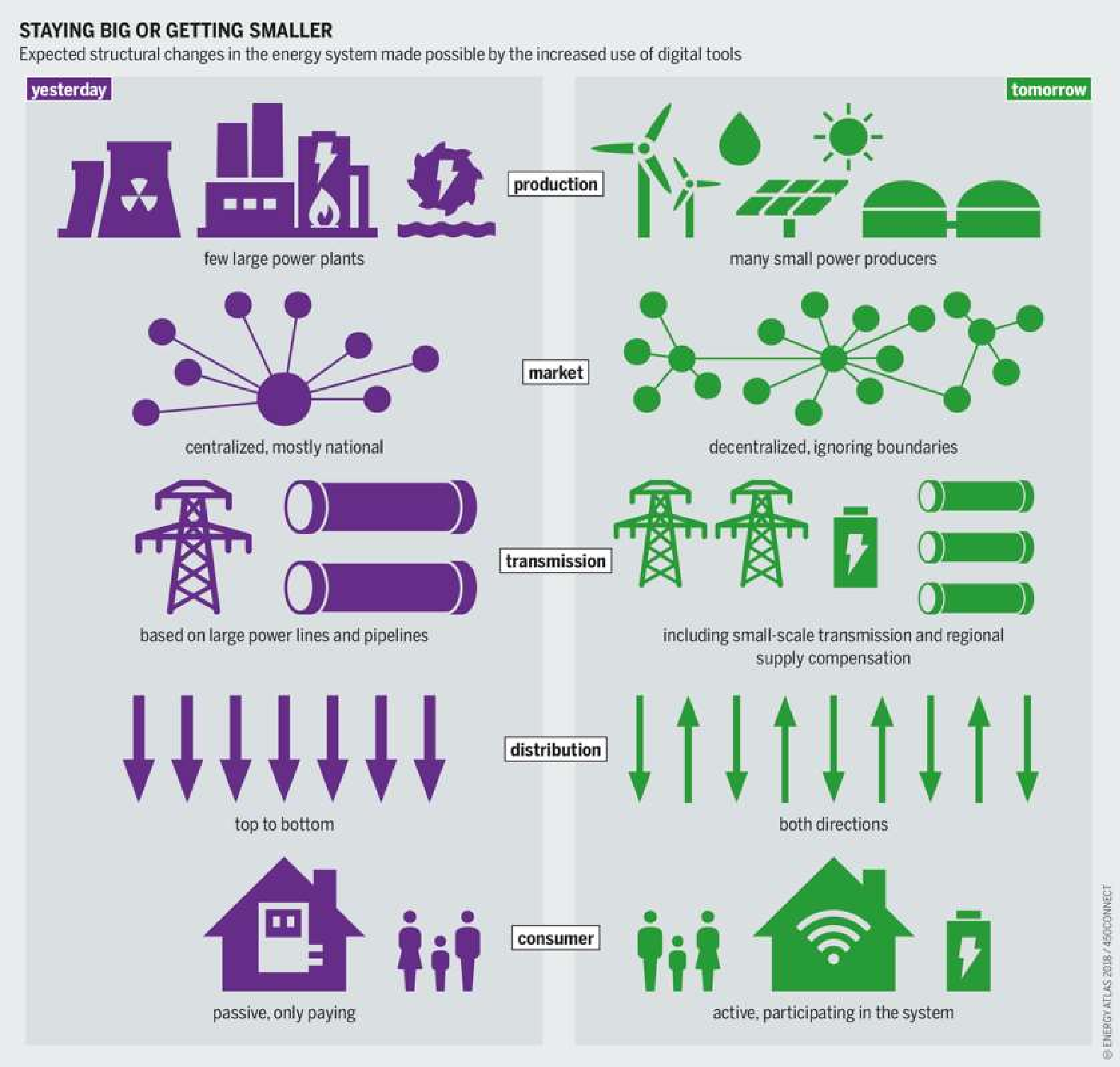
On the contrary flywheels and capacitors are most effective in maintaining power quality, but lack storage capacities to be used in larger applications.

New technologies: Li-Ch, Li/phosphate batteries, Hydrogen, synthetic gas

Electric System Transformation



Smart Grids and Demand Response



Digital technology that allows for two-way communication between the utility and its customers, and the sensing along the transmission lines is what makes the grid smart.

It is an important element of the EU long term energy strategy

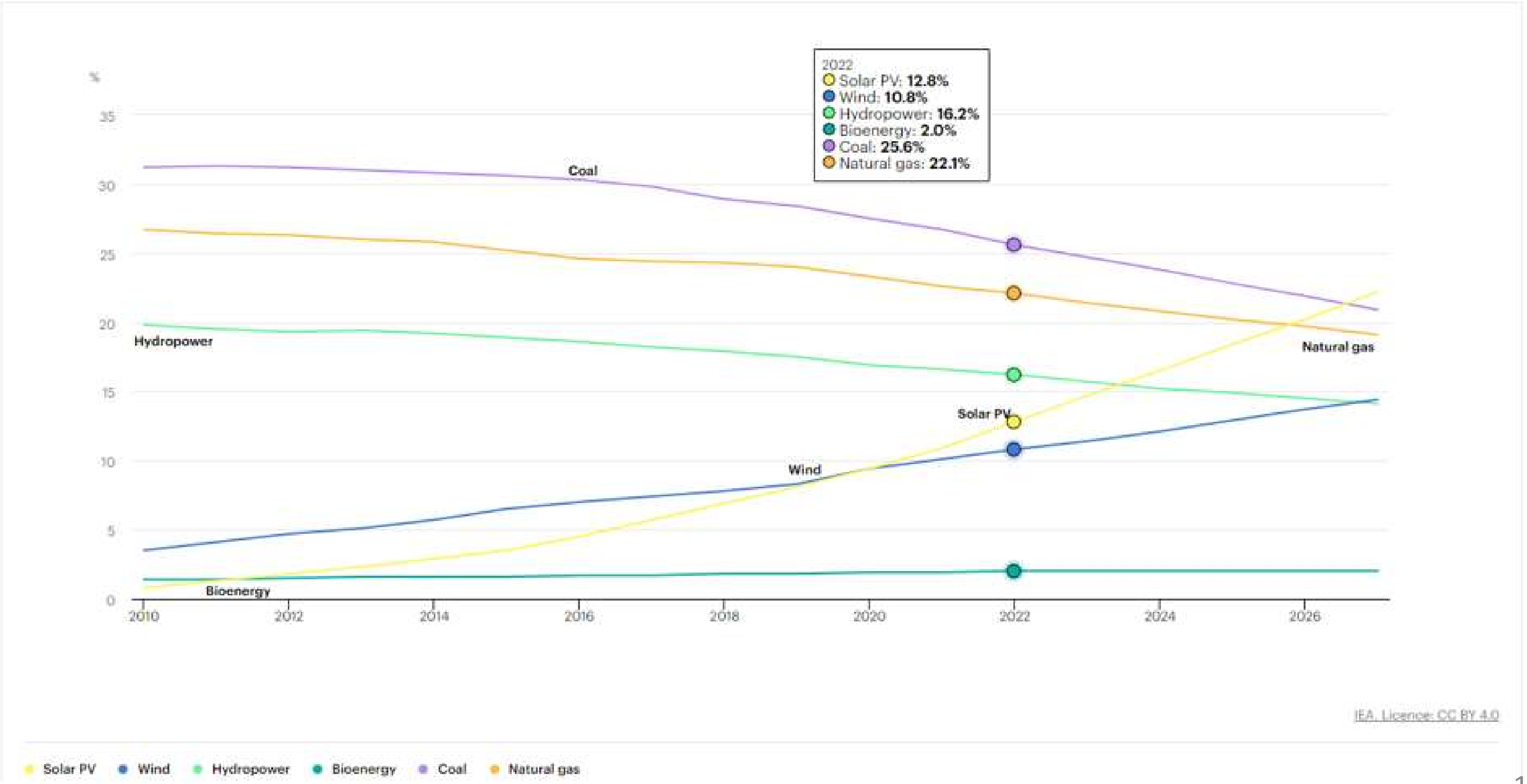
Decarbonisation of Generation

Share of cumulative power capacity by technology, 2010-2027

Last updated 5 Dec 2022

Download chart ↓

Cite Share



Smart Grids

Benefits :

- More efficient transmission of electricity across the grid
- Reduced peak demand, which may help lower electricity rates
- Increased integration of large-scale renewable energy systems
- Real-time consumption management
- Better integration of prosumers (individual, mostly PV RES)
- Reduced operations and management costs for utilities
- Enables new services – energy aggregators and other ESCOs

Risks & Vulnerabilities:

- Complexity and heterogeneity of the grid
- Dependence on communication integrated with power
- Cyber security vulnerability
- Privacy issues for end customers
- Physical security of components

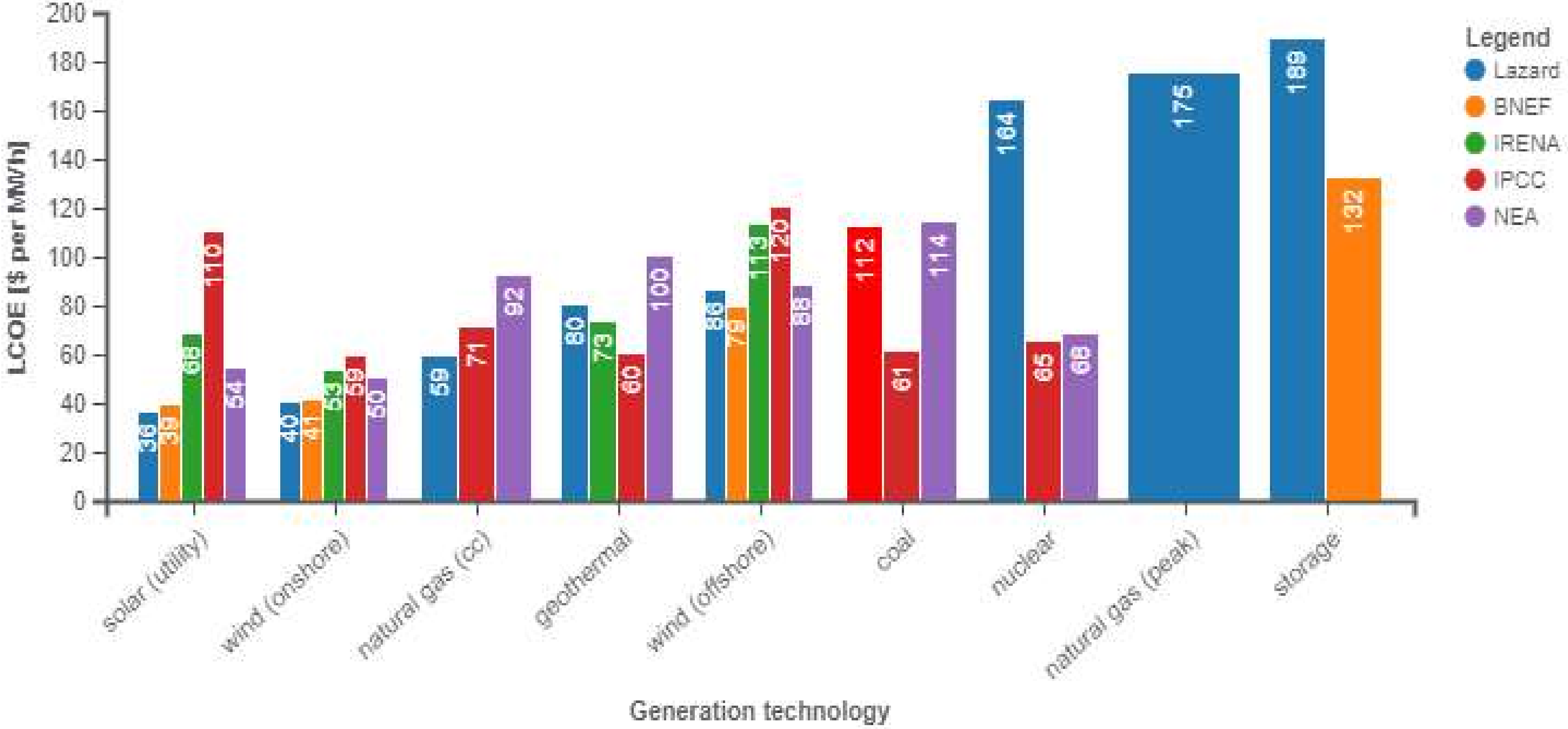
Decarbonisation of the Consumption

- Electrification of demand involves an increase in the use of electricity by households and companies and enables a reduction in the use of technologies that emit CO_2 **= Decarbonisation of the Consumption**
- **Electrification** means replacing fossil fuels with electricity in all sectors. To combat climate change, EU has targeted achieving carbon neutrality by 2050.
- Beyond promoting electricity production based on zero carbon technologies, decarbonisation requires the electrification of energy demand, i.e. households and businesses making greater use of electricity instead of using technologies that emit CO_2.
- Electricity is therefore a key energy vector to help combat climate change and protect the environment.

Electrification of the Economy

- GHG emissions reduction of in all sectors of the economy, mainly in transport, housing and industry. **EV** are three to five times more efficient than vehicles with an internal combustion engine. **Heat pumps** use four times less energy than oil or gas boilers. Energy intensity decreases significantly with the **electrification of industrial processes.**
- Improvements in air quality, greater use of EV and a reduction in heating that generate GHG and other pollutants.
- Electrical appliances to increasingly allow greater digitalisation for greater flexibility and convenience, it also improves efficiency and reduces time and costs.
- Green electrification of the economy will bring new jobs and more than cover losses of carbon based economy

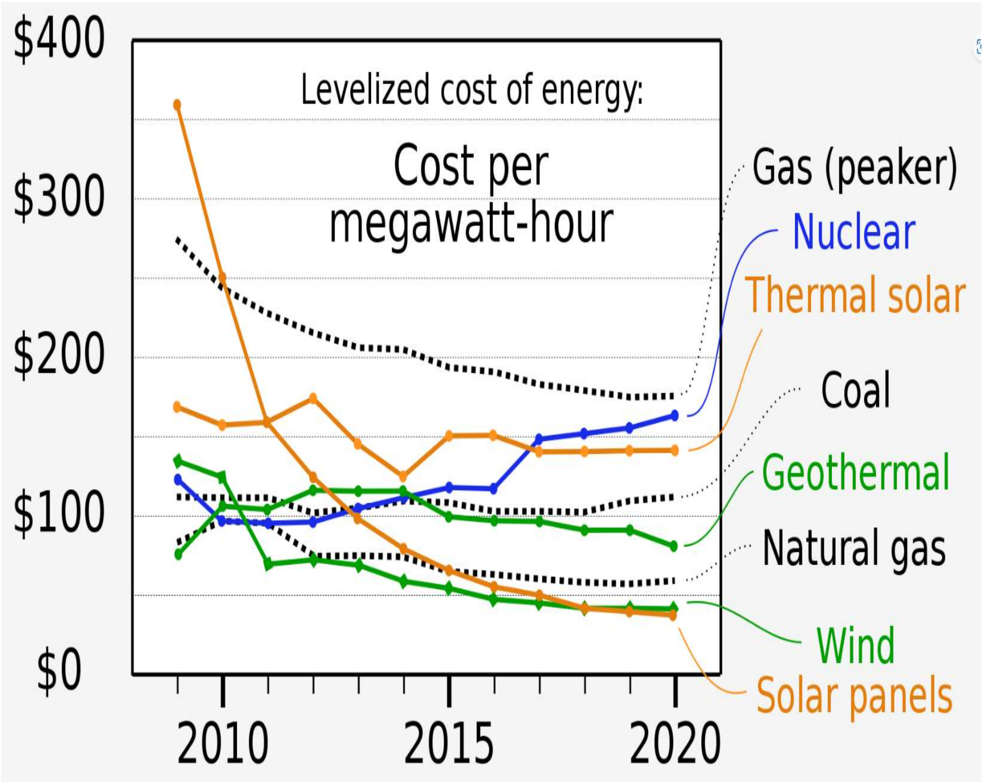
Levelized Cost of Energy (LCOE)

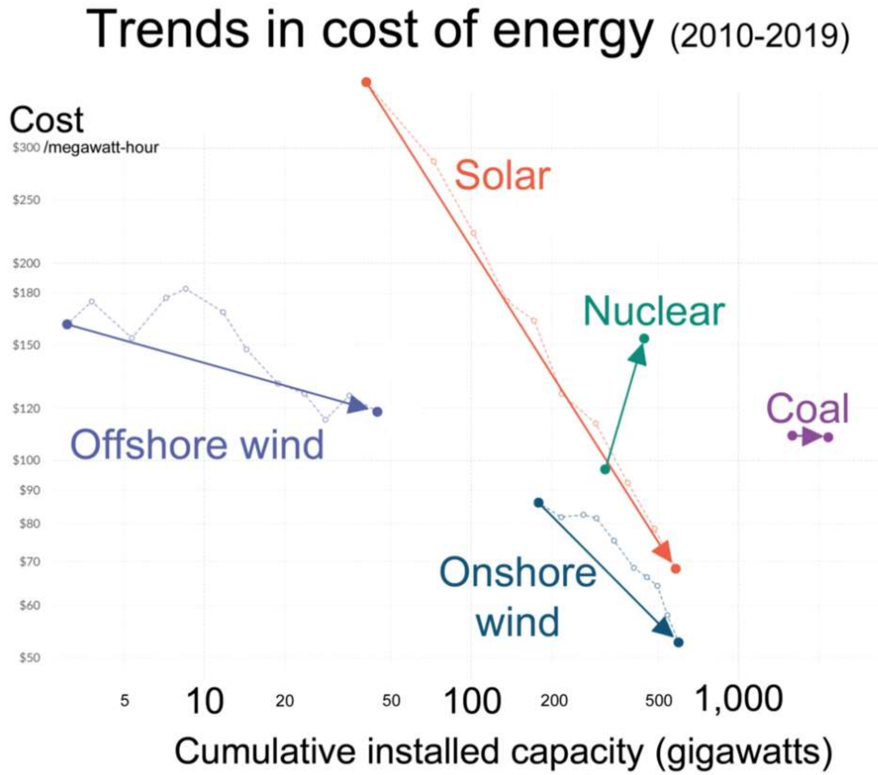


LCOE - the average total cost of building and operating the asset per unit of total electricity generated over an assumed lifetime.

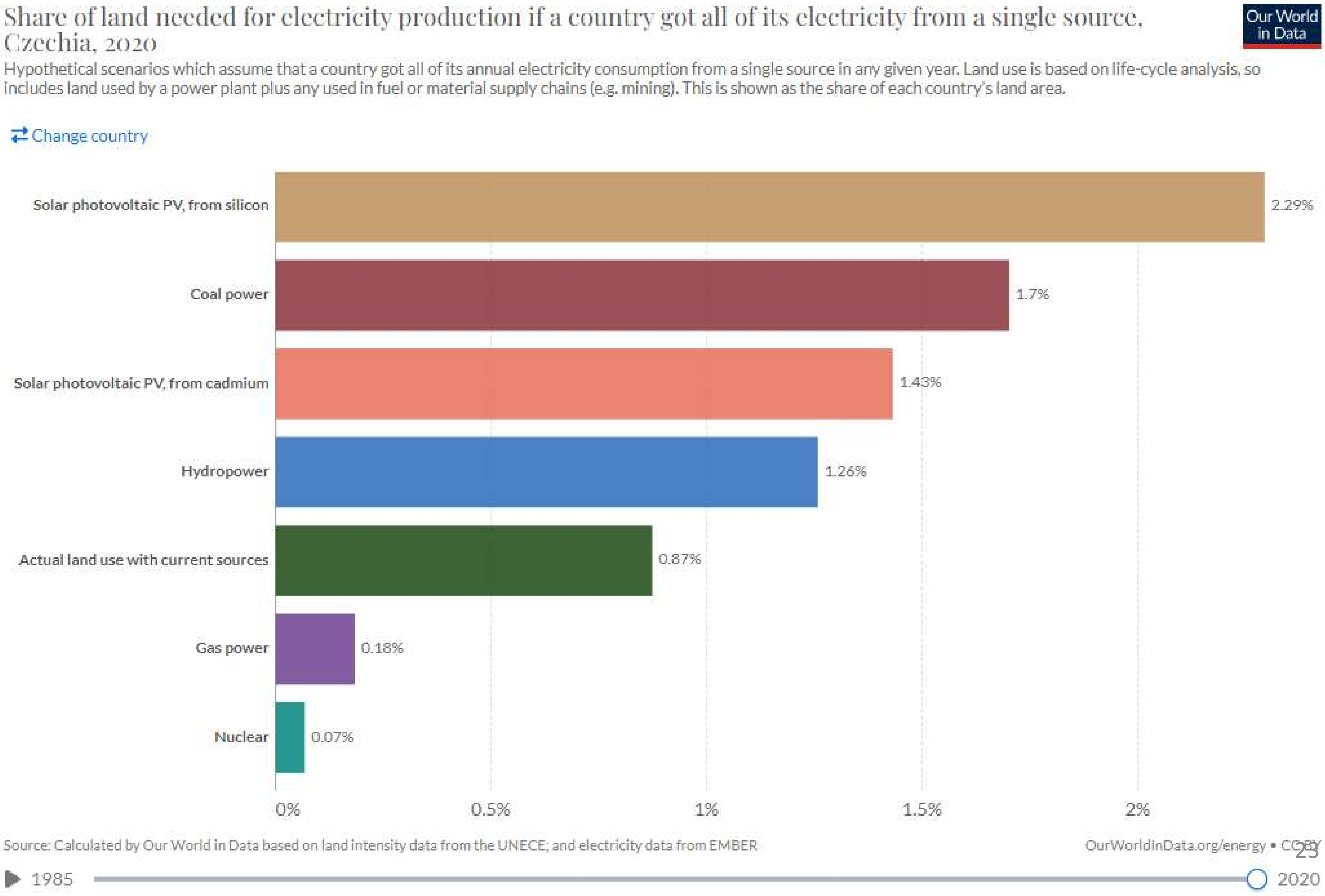
www.corporatefinanceinstitute.com (2021)

Cost of Energy

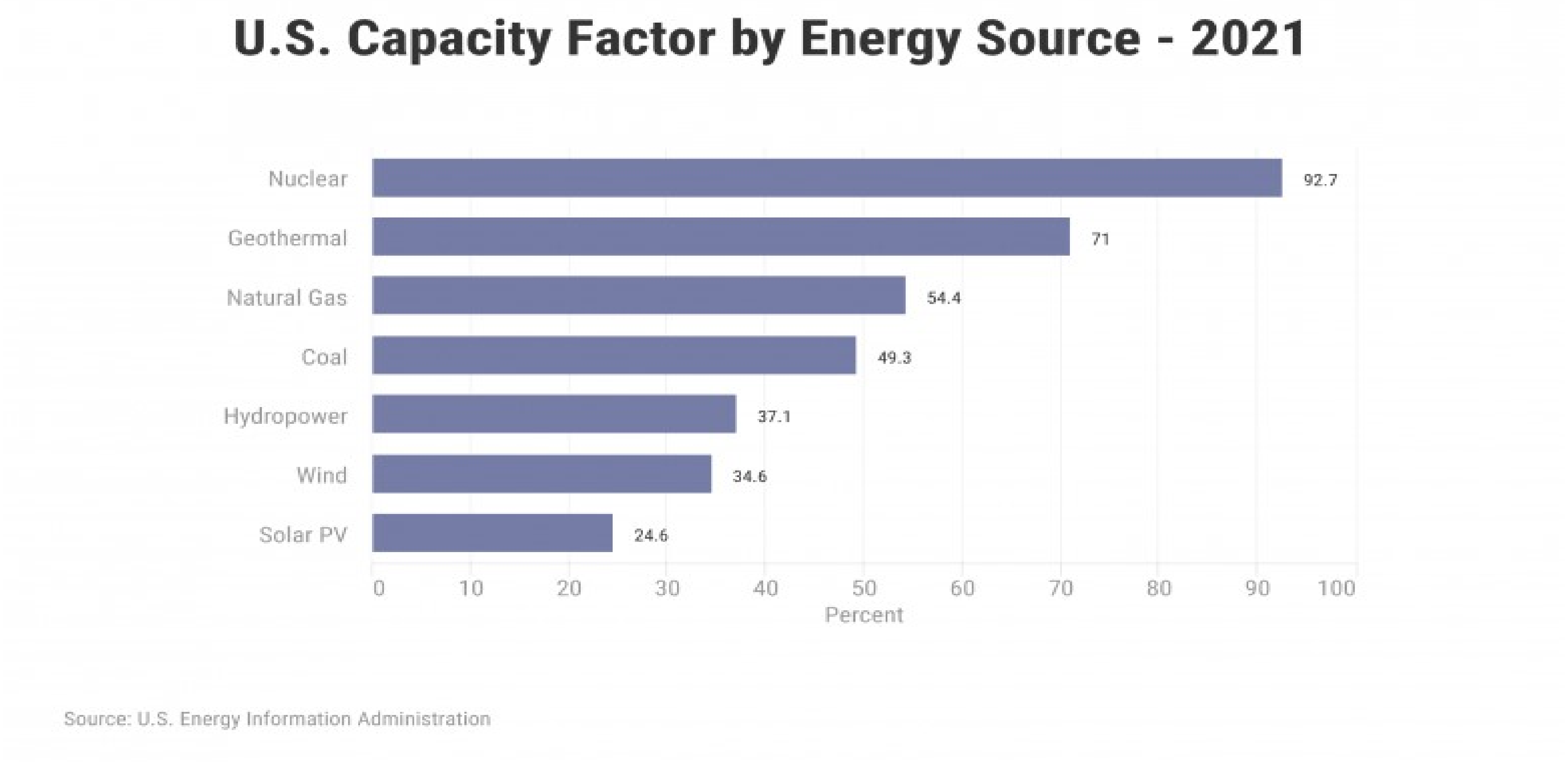




Land requirement

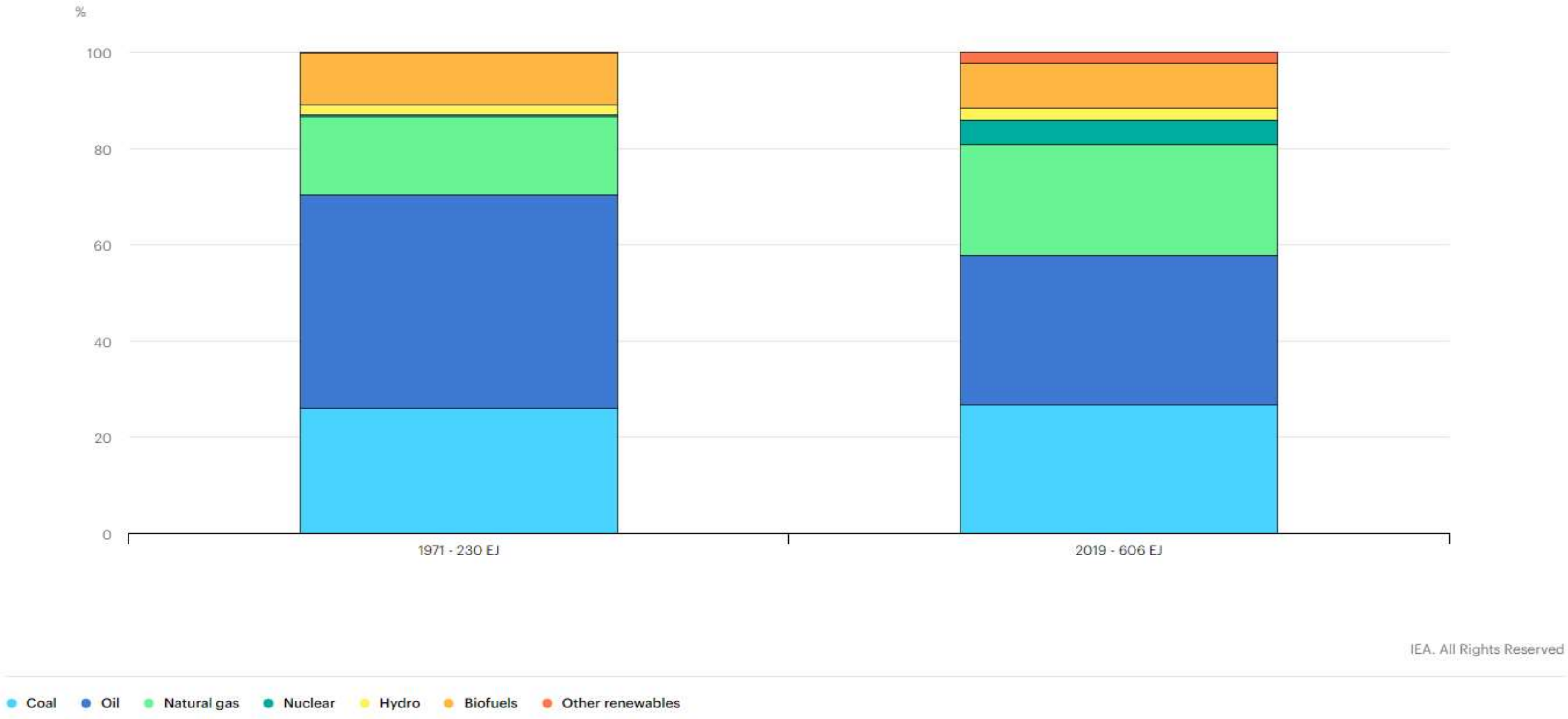


Capacity factor



Capacity factors varies across countries, but for renewable energy sources tend to be lower

Total primary energy supply by fuel



IEA, Total primary energy supply by fuel, 1971-2019, IEA, Paris

??? Questions for Participants ???

What is the importance of electrification for the energy transition?

What are the differences between conventional and smart grids?

Which energy generation technology has biggest land requirements and why?

What is the capacity factor in power generation? Why it matters?

Can nuclear a power plant reach 100% capacity factor?

Key Takeaways

- Electrification with low carbon sources is the key for successful energy transition and climate change mitigation
- Up-date of power systems can not be done by simply adding more clean generation capacity or through substituting fossil fuels by renewables
- Overhaul of the power grid and it's digitalization (smart grid) is a long-term objective
- Further research, development and deployment of low carbon sustainable technologies is essential
- There is no "silver bullet" solution, the gradually changing mix seems to be the rational approach. Speed of transition could be increased through proper policies and incentives

People in Energy Transition Diplomacy

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Maroš Šefčovič,
UNECE Executive Secretary
Oľga Algayerová
Astana, Kazachstan

The End

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LESSON 5 – ELECTRICITY

NEXT

LESSON 6 – ENERGY SECURITY AND DIPLOMACY