Which path of low carbon resources to choose? Discussion about nuclear and renewable resources

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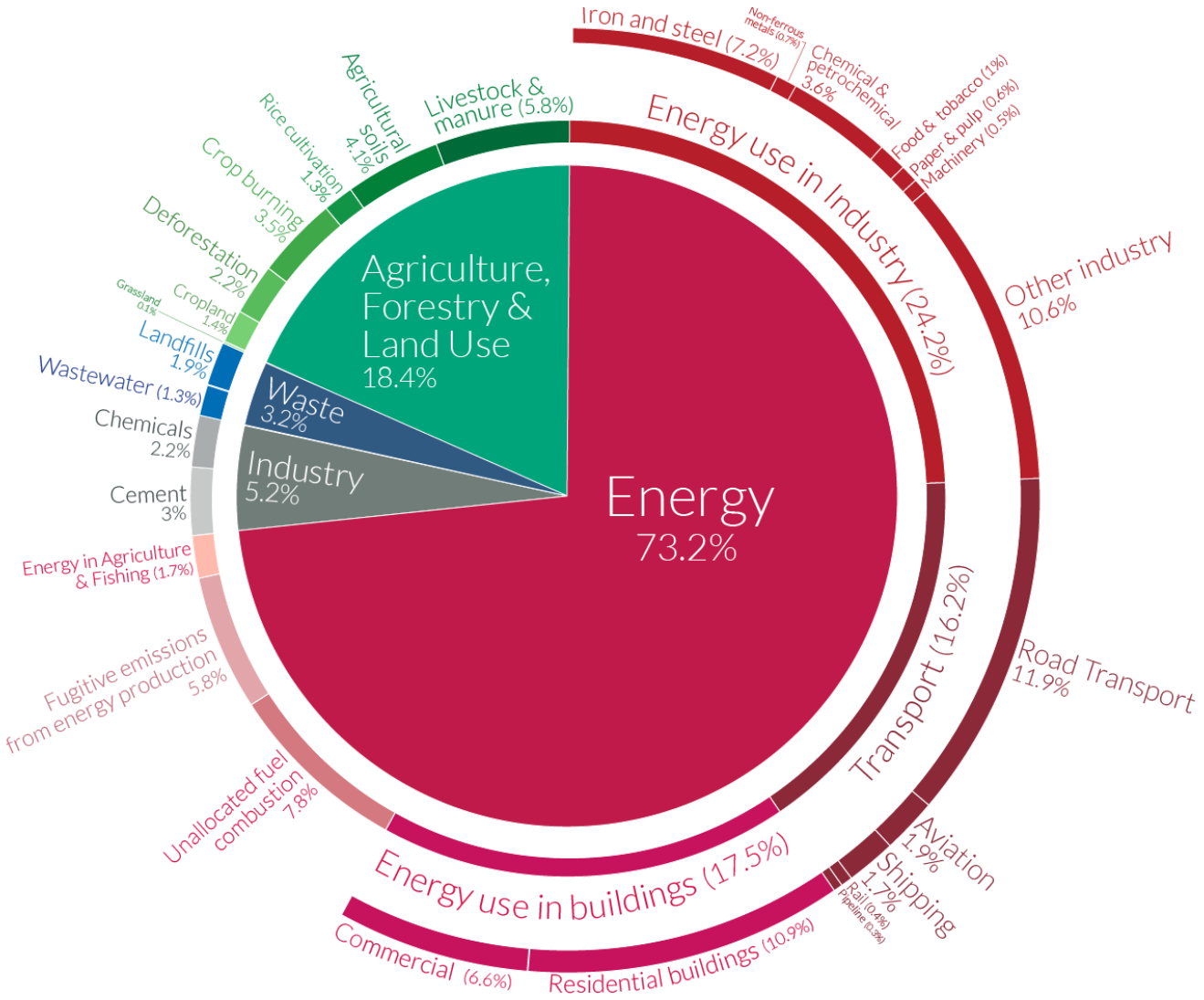
GLOBAL GREENHOUSE GAS EMISSIONS BY SECTOR



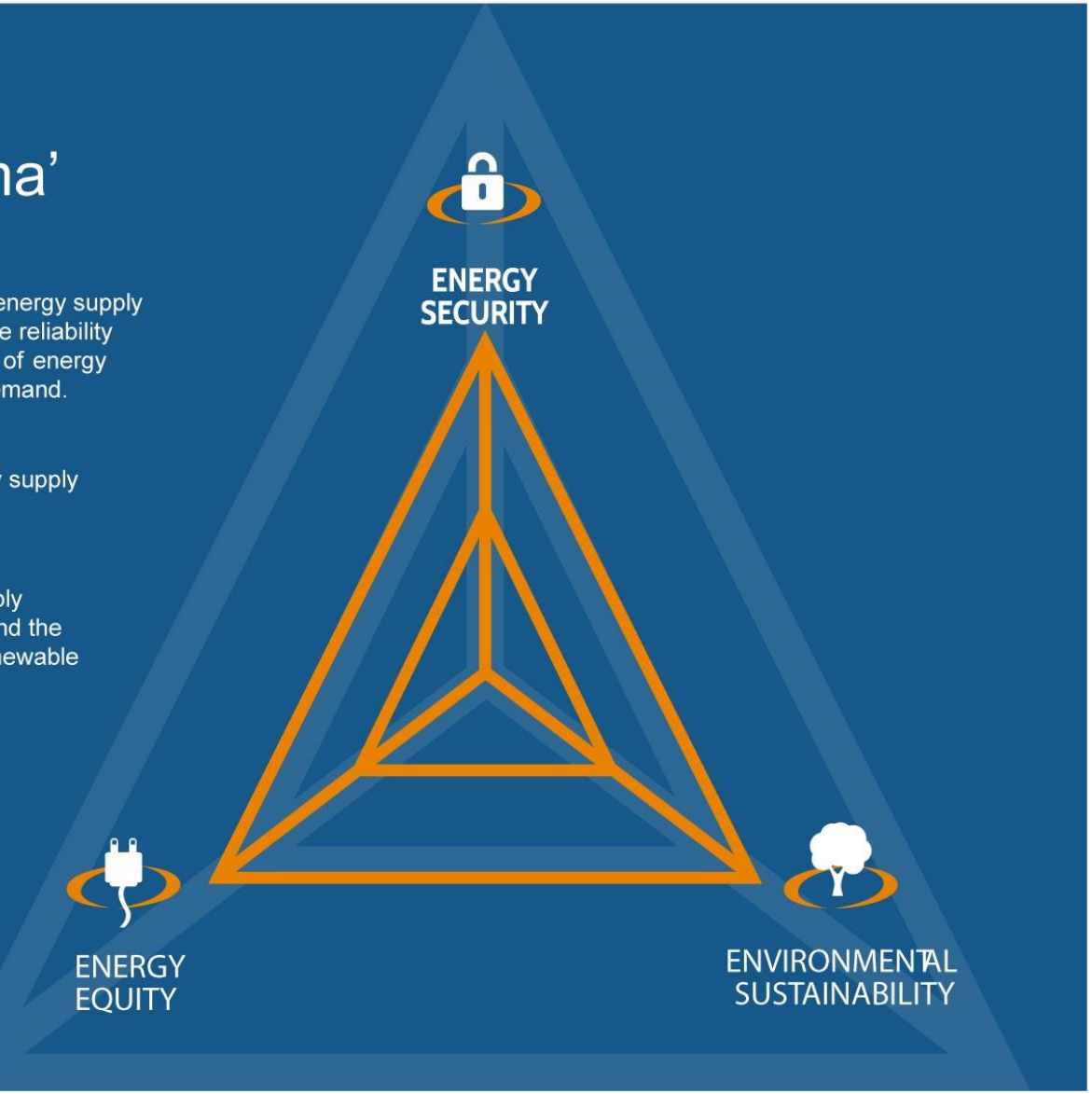
Source: https://ourworldindata.org/ghg-emissions-by-sector

Balancing the ‘Energy Trilemma’

Energy Security
The effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of energy providers to meet current and future demand.

Energy Equity
Accessibility and affordability of energy supply across the population.

Environmental Sustainability
Encompasses the achievement of supply and demand side energy efficiencies and the development of energy supply from renewable and other low-carbon sources.



Source: https://www.worldenergy.org/assets/images/imported/2015/11/Trilemma-what-is-the-energy-trilemma.jpg

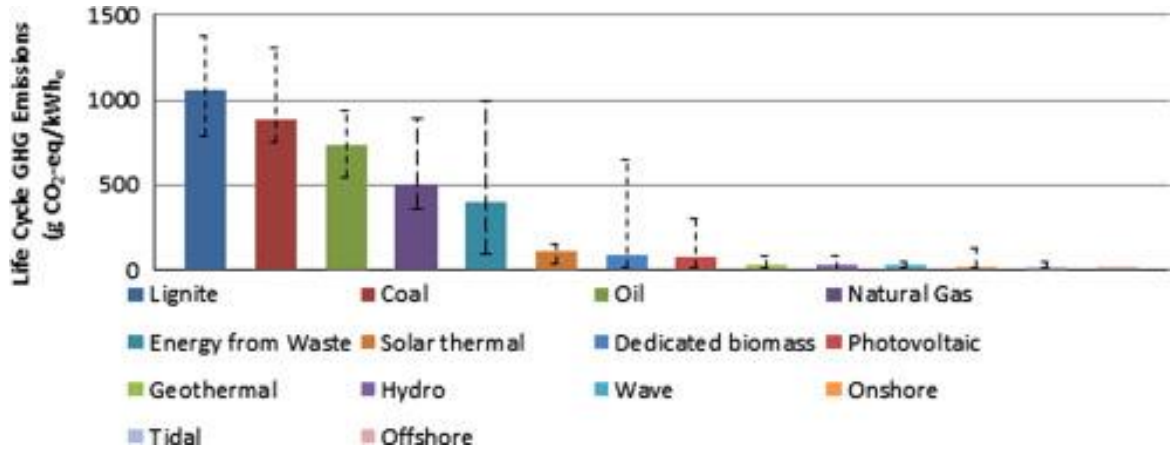
More info on energy trilemma: https://trilemma.worldenergy.org/#!/energy-index

Which energy resource will deliver low carbon energy?

- The future is in electrification
- Decline of coal
- Natural gas as a transition technology?
- **Nuclear energy at crossroads**
- **Rapid growth of renewable**

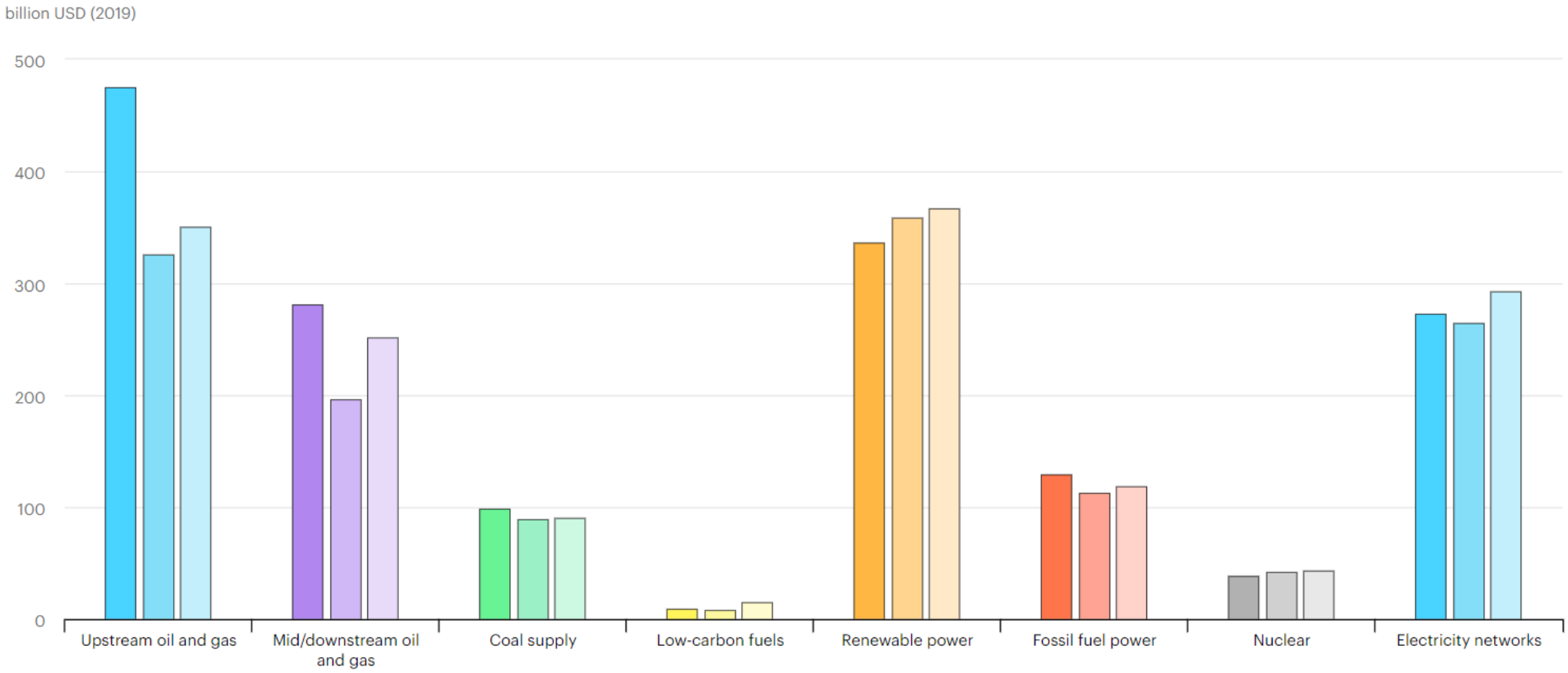
Life cycle CO_2 equivalent to selected electricity supply technologies

Technology	Median	Technology	Median
Coal	820	Geothermal	38
Biomass co-fired with coal	740	Concentrated solar power	27
Gas – combined cycle	490	Hydropower	24
Biomass – dedicated	230	Wind offshore	12
Solar PV – utility scale	48	Nuclear	12
Solar PV – rooftop	41	Wind onshore	11

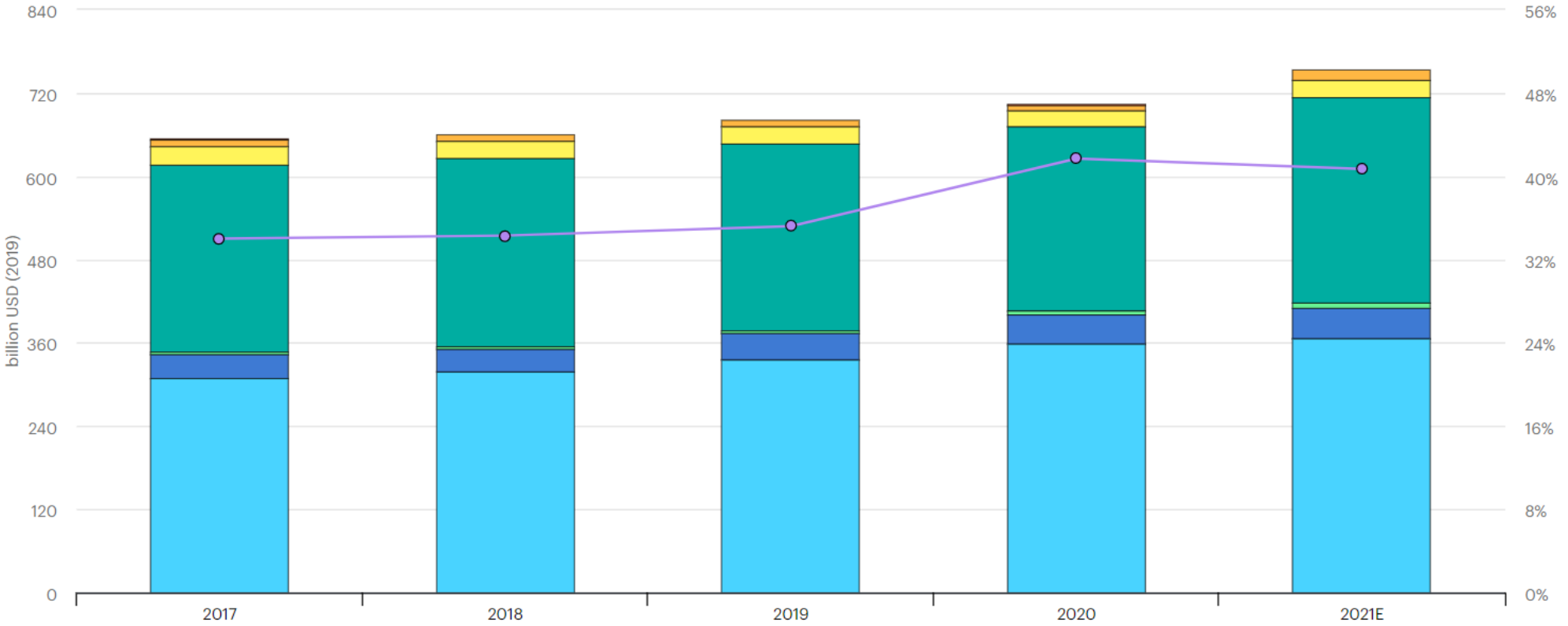


Arranged by decreasing median values. In gCO2eq/kWh

Global energy supply investment by sector, 2019-2021

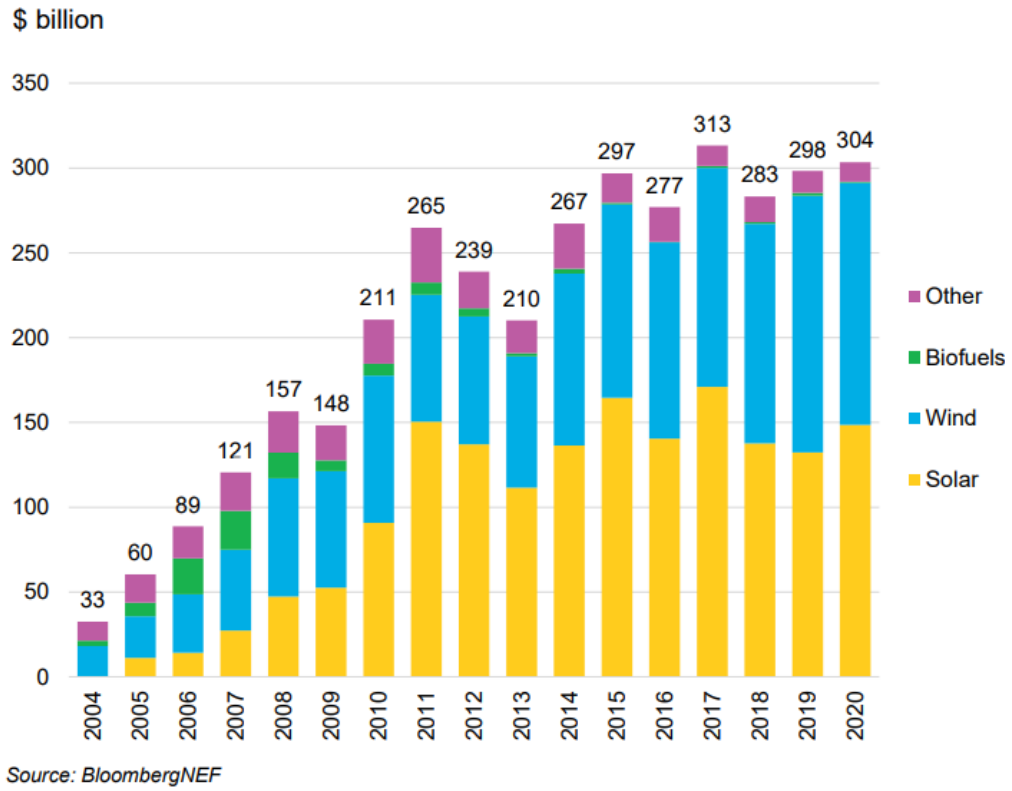


Global investment in clean energy and energy efficiency, 2017-2021

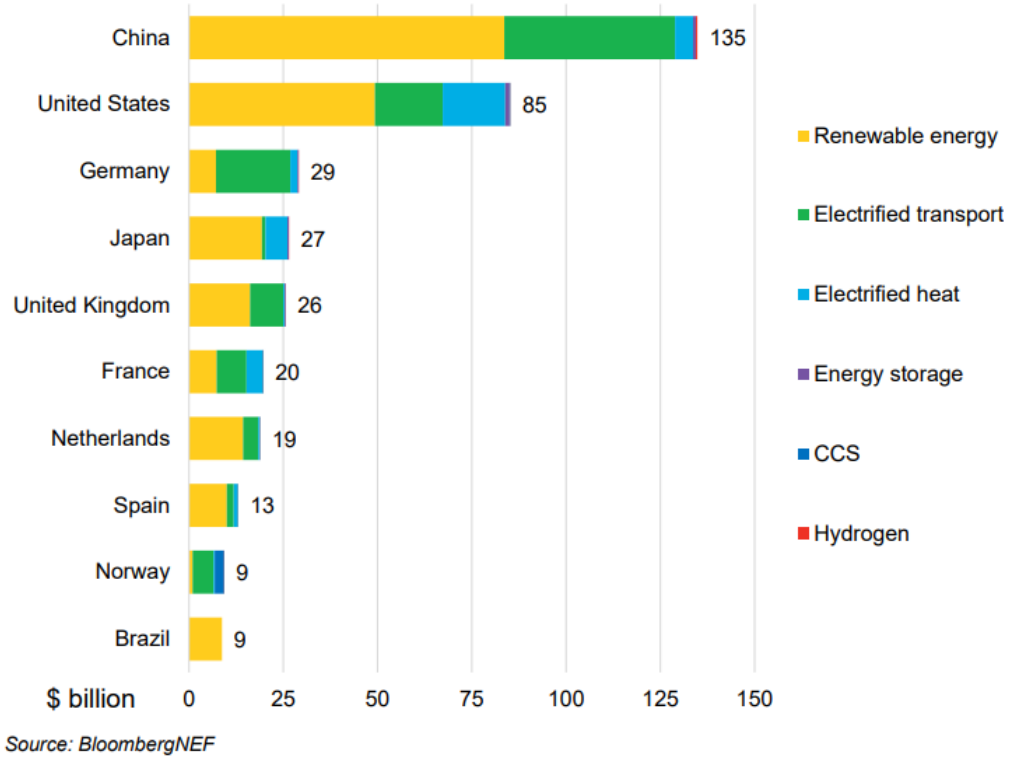


Renewable power · Nuclear · Battery storage · Energy efficiency and electrification · Renewables for end-use · Low-carbon fuels · CCUS · Clean energy in total

Global new investment in RES by sector



Global investment in energy transition

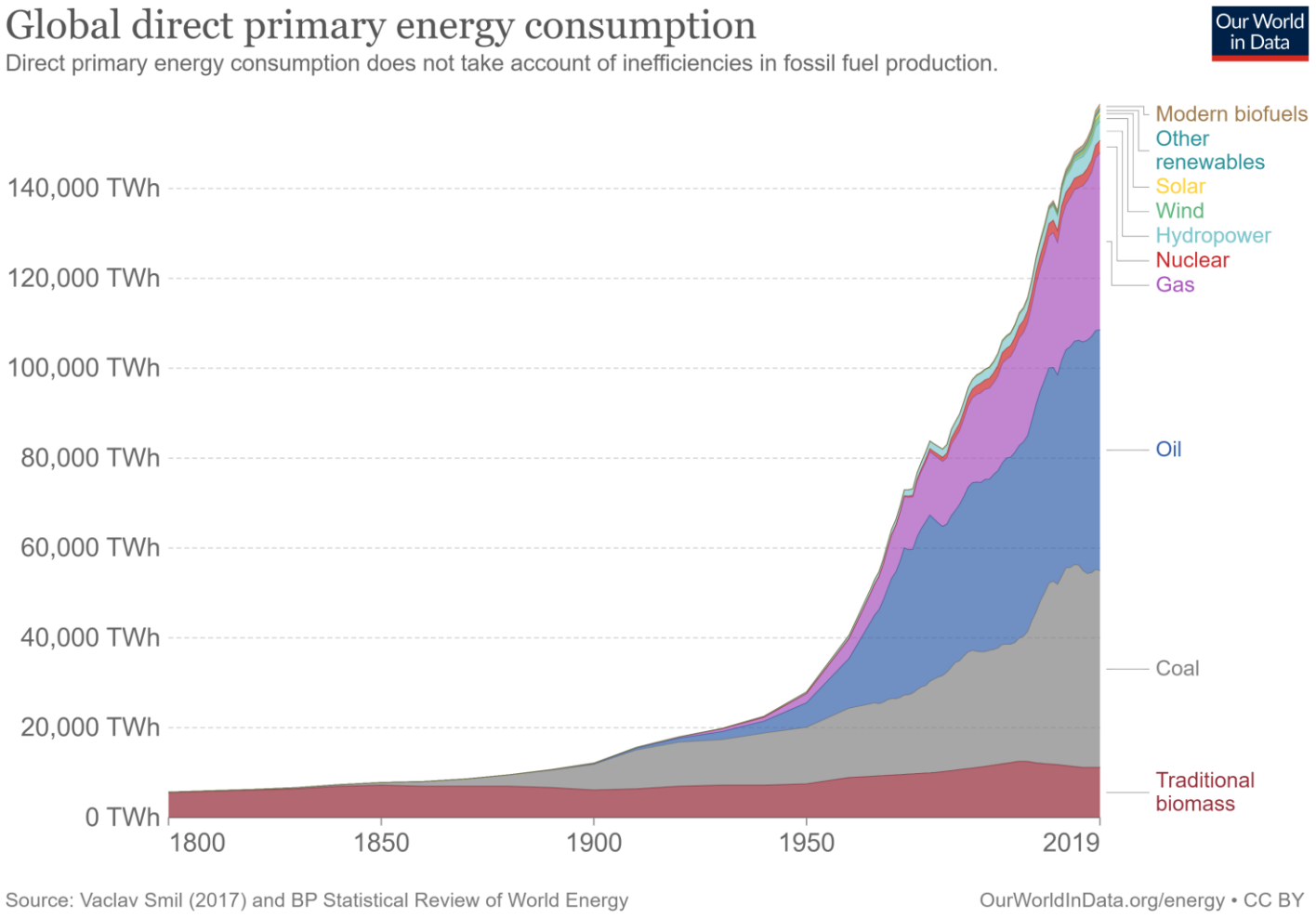


Source: https://www.pv-tech.org/bnef-solar-leads-renewables-growth-in-2020-despite-covid-19-slowdown/

Decarbonization

- **Driven by climate change reasoning**
- Technological transition vs. sustainable transition

→The current energy transition is driven by policies rather than by technology improvements.



Sustainable transition

„Sustainability transitions are fundamental changes in sectors such as energy, transportation, food, or water towards more sustainable modes of production and consumption“ (Markard, et al. 2021)

- Sustainable development
- Technological innovation and decline
- Substitution process
- Deliberate policy decisions
- Complementary interaction between new and of technology
- Positive but also negative consequences of transition

Causes of decline

- External causes
- Changing regulatory environment
- Changes in competing and complementary technologies
- Societal values and negative impact

Challenges of sustainable energy transition

- Path dependency
- Investment intensive
- Socio-economical challenge
- Loss of technology diversity
- Complementary interaction between new and old technology
- Public acceptance

→Energy systems are resilient to change

→Thus, role of government is important, but.. There is no certainty over the chosen path

Renewables
&
Nuclear energy

Both low carbon sources of electricity

Both playing different role

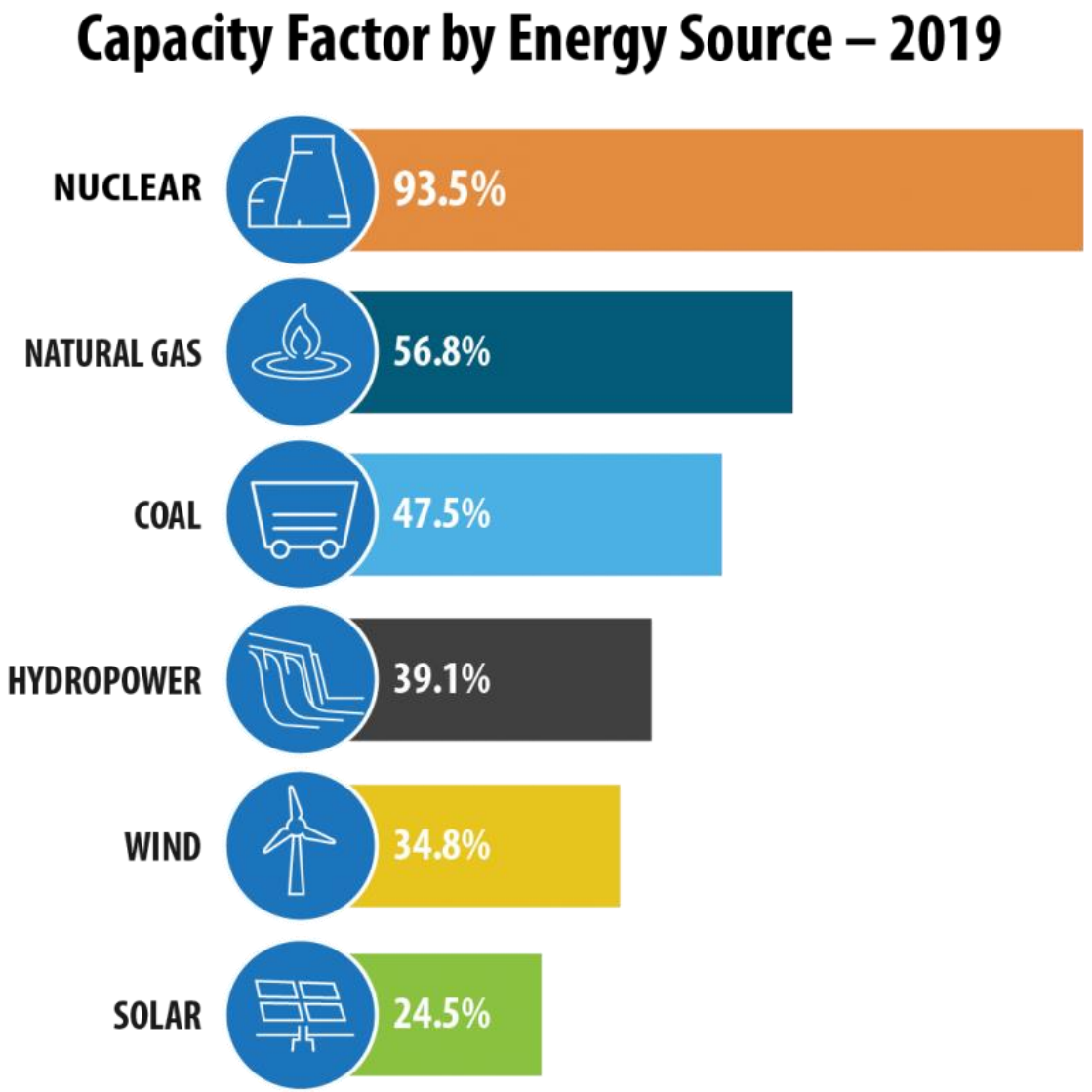
Comparison

Nuclear

- Complex and high-tech technology
- Need for security measures
- Centralized source
- Tested and reliable
- Base-load
- High-capacity factor
- High-power density
- Safety?

Renewables

- Easy installation
- Decentralized source
- Limited potential
- Intermittent character
- Low-capacity factor
- Low-power density
- Geographically determined
- Fast return on investment



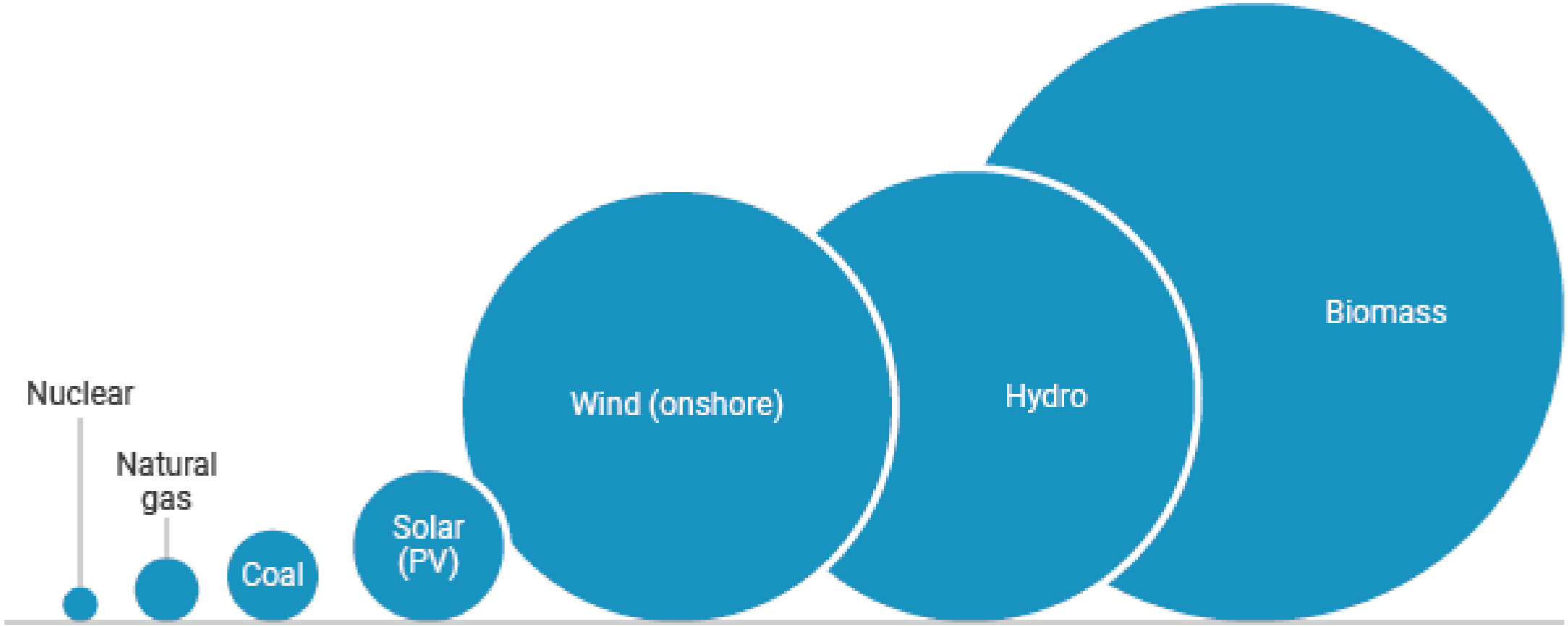
Note:

Capacity factor
= **basically measures how often a plant is running at maximum power**.

The graph shows the maximum theoretical capacity factor

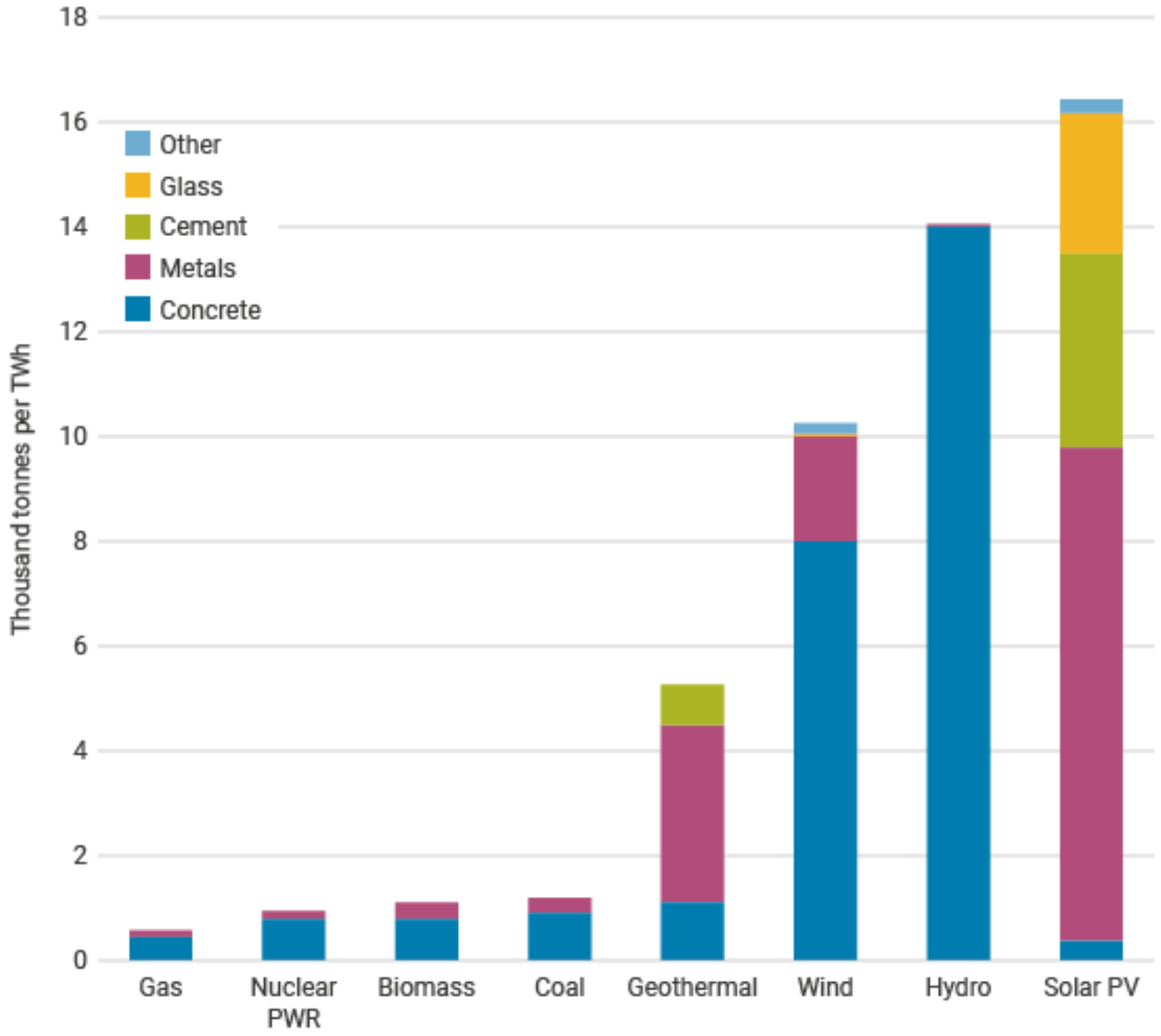
Source: https://www.energy.gov/ne/downloads/infographic-capacity-factor-energy-source-2019

Relative land use (fuel mining and generating footprint) of electricity generation options per unit of electricity

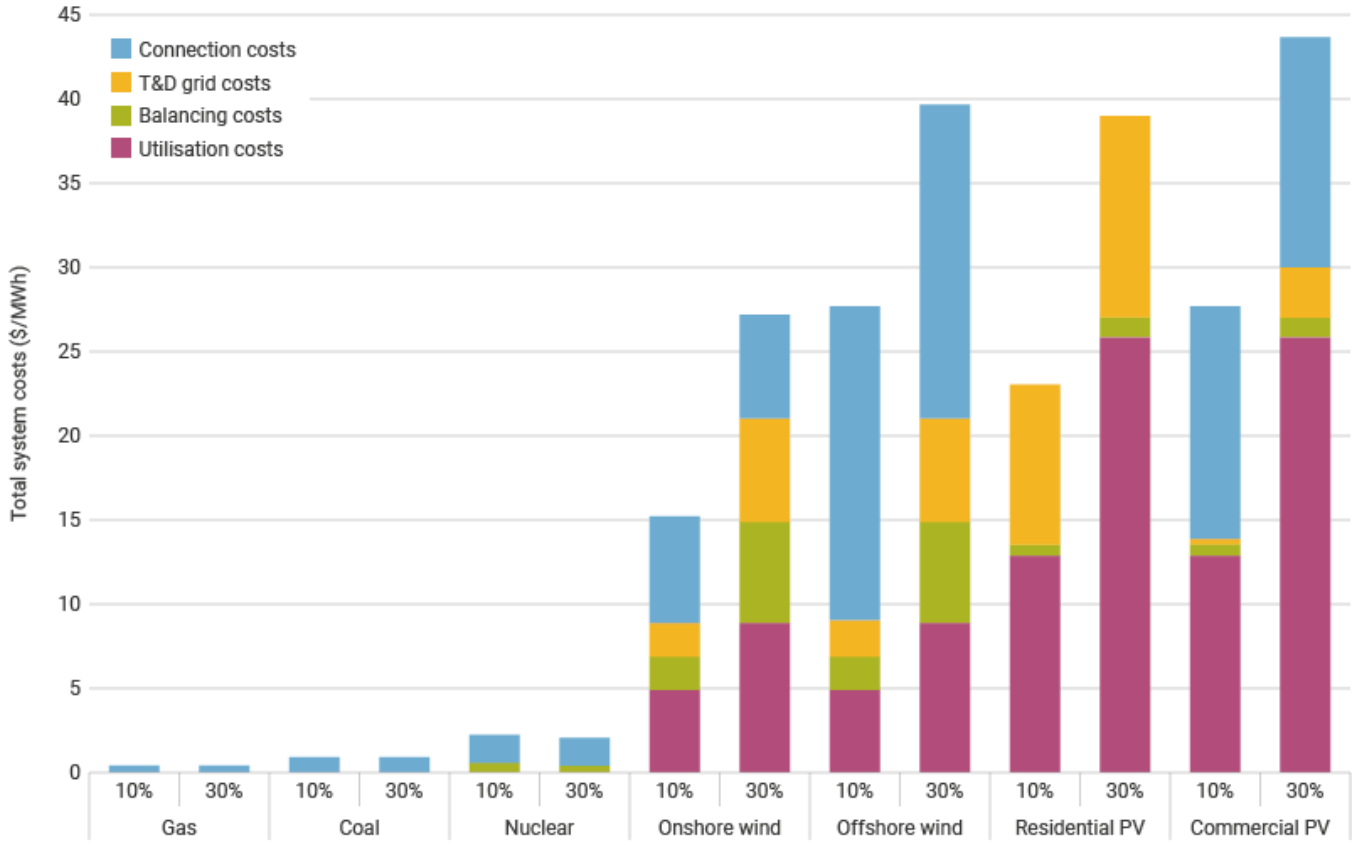


Materials requirement for various electricity generation technologies

More info here: https://world-nuclear.org/information-library/energy-and-the-environment/mineral-requirements-for-electricity-generation.aspx

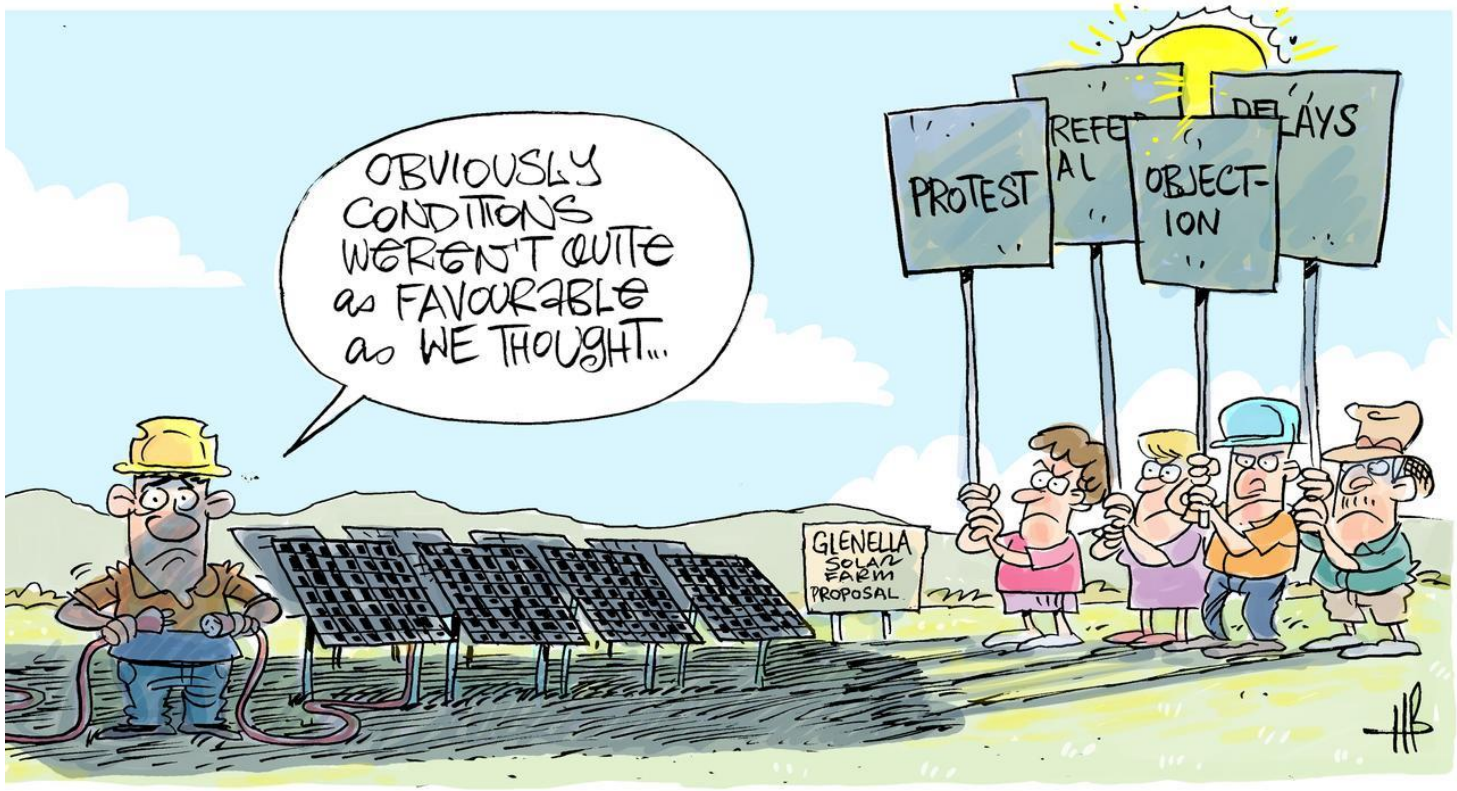


Grid-level system costs for dispatchable and renewable technologies



Reverse side of renewables

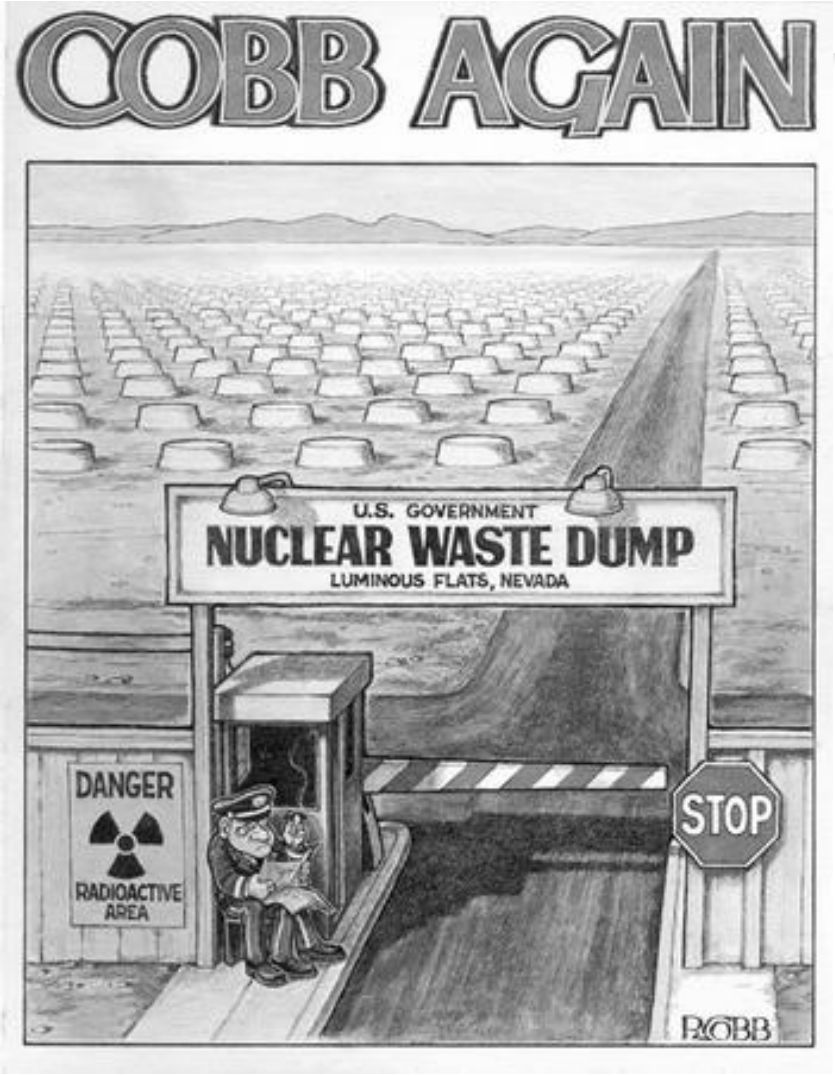
- **Place attachment**
- Also, some harmful impact on environment
  - Scarce materials
  - Landscape
  - Land use
  - Not easy to recycle
- Increased demand on the network stability
  - Intermittent source – higher demand for ancillary services
  - Decentralized energy
- **Slow technological development of storage capacity**



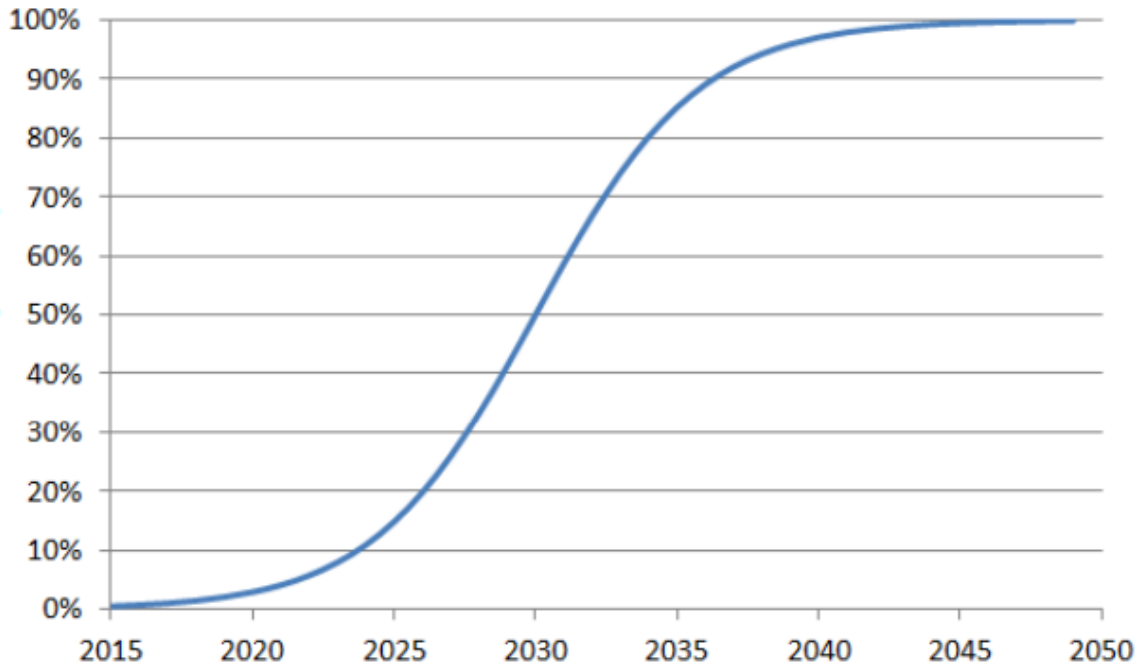
Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.dailymercury.com.au%2Fnews%2Fplug-pulled-on-70m-glenella-solar-farm%2F4160373%2F&psig=AOvVaw0aG1Ri1otav5IuCt5qGRGo&ust=1635804434343000&source=images&cd=vfe&ved=0CAsQjRxqGAoTCNirocfU9fMCFQAAAAAdAAAAABCPAQ

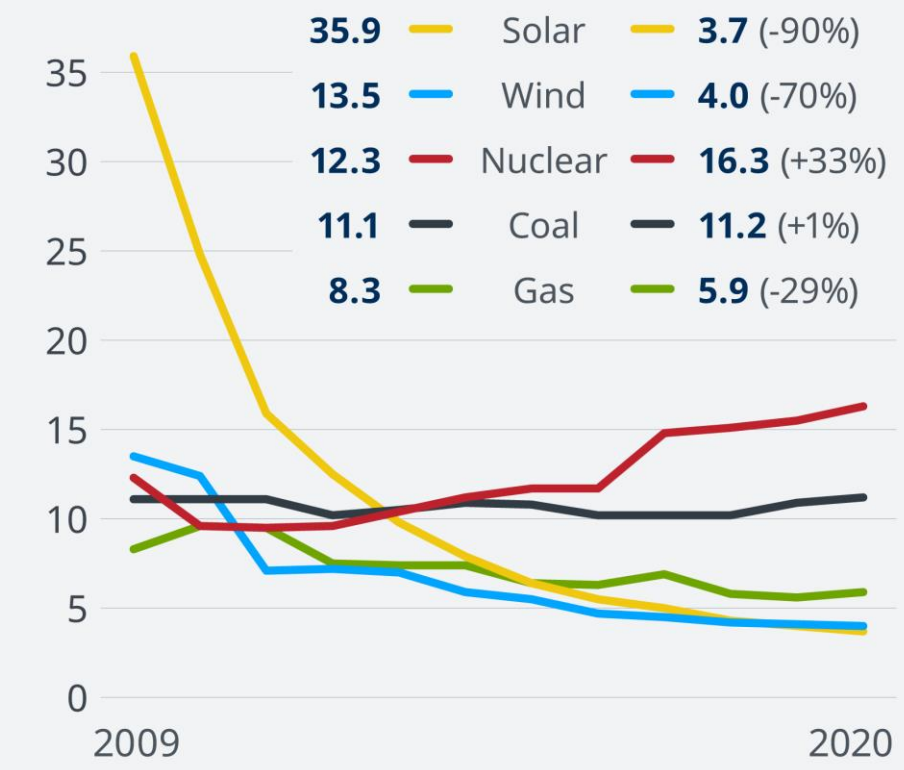
Reverse side of nuclear energy

- **Public acceptance**
- Complex technology, difficult to explain, people are afraid of unknown
  - Nuclear disasters, nuclear waste
- **Long term project**
- Long time on return of investment
- **Capital intensive**
- **Cost and time overrun**
- Need for state support
- High regulatory measures

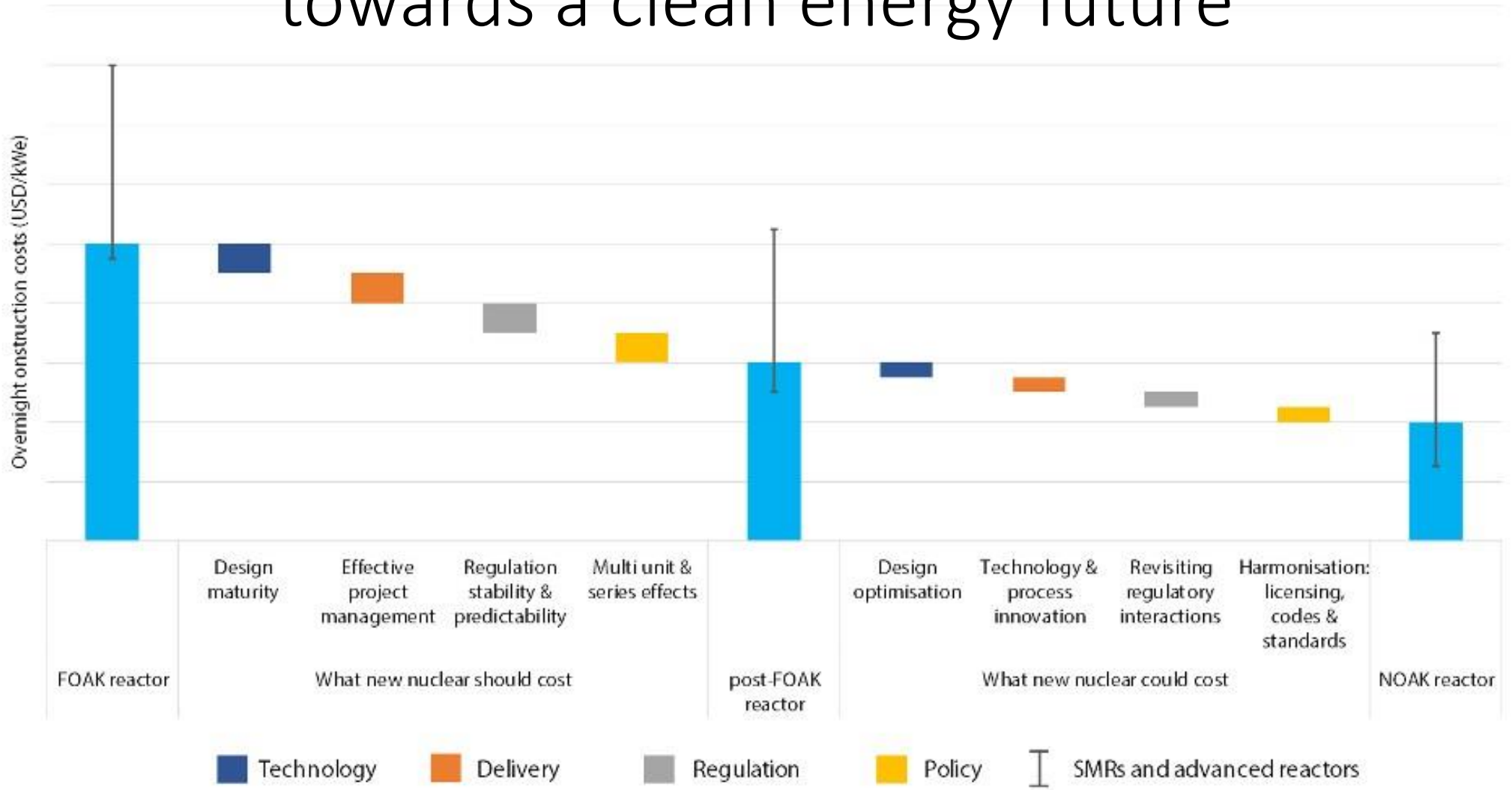


Learning curve vs. price





Reducing the costs of nuclear power on the path towards a clean energy future



Source: NEA (2020), *Unlocking Reductions in the Construction Costs of Nuclear: A Practical Guide for Stakeholders*, OECD, Paris.

Economics of nuclear energy

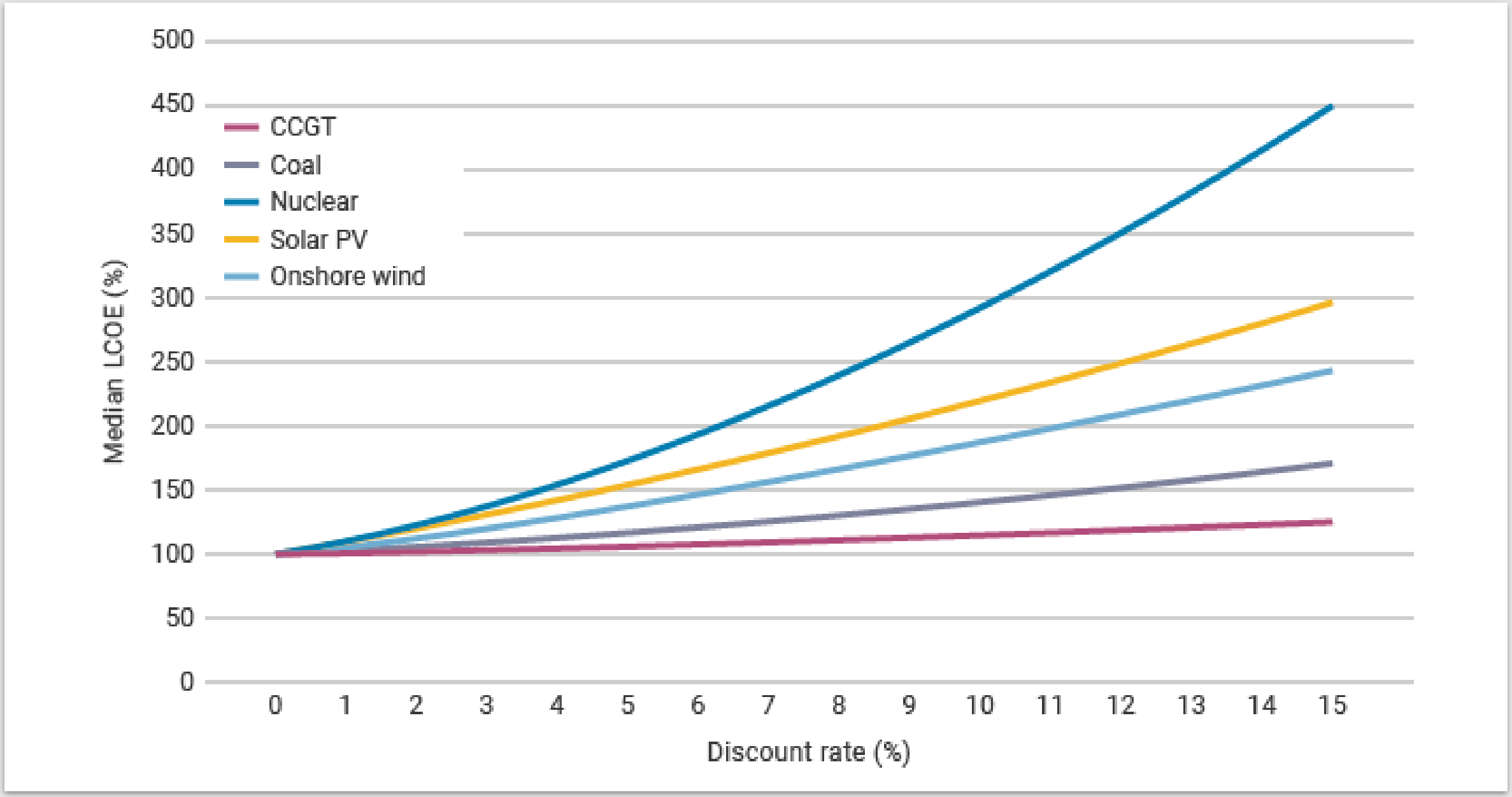
Nuclear energy at crossroads

- Shrinking opportunities in liberalized electricity markets
- Loss of legitimacy
- Increasing cost and time overruns
- Abandoned projects

- Or is there a chance for renaissance?
- Constructions in Asia
- Increasing urgency to mitigate climate change

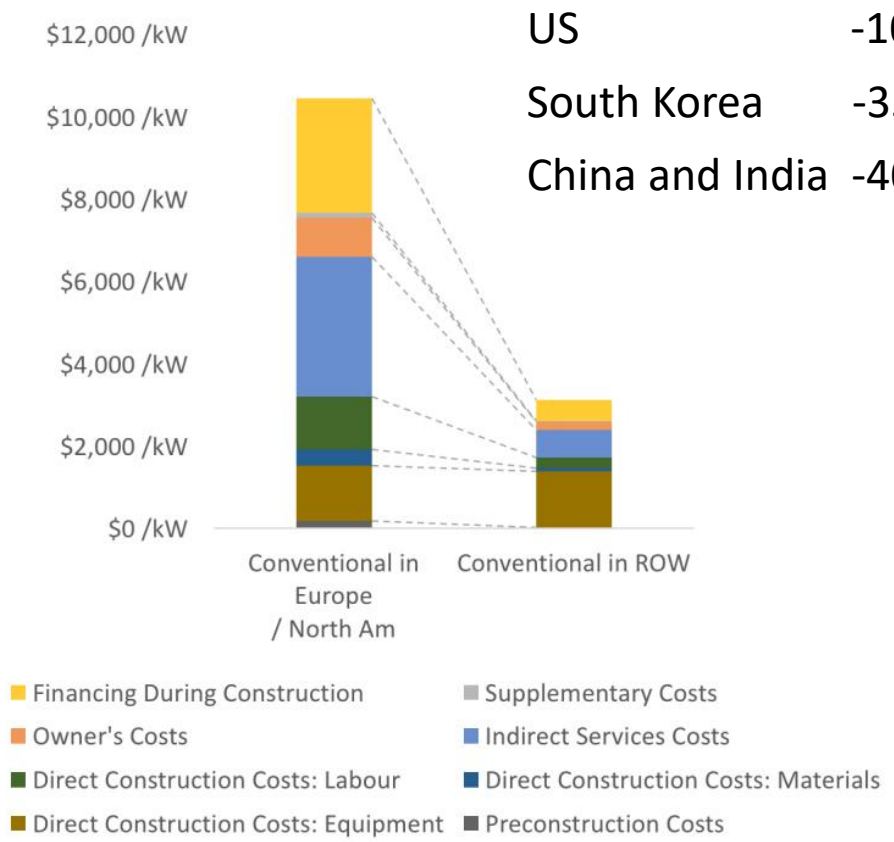
Key characteristics

- **Low-carbon energy technology**
- **High capital cost**– 60-85 %
  - Low operation cost– 10-25 %
  - Fuel cost – 7-15 %
- A long time before the project starts to generate profit– around 8-10 years
- **Long payback period** – more than a decade
- Complicated investment environment – political and regulatory risks
- High-tech technology – technical complexity, safety elements
- **Increasing cost and time overrun** – demanding on management and supply chain
- States presence needed

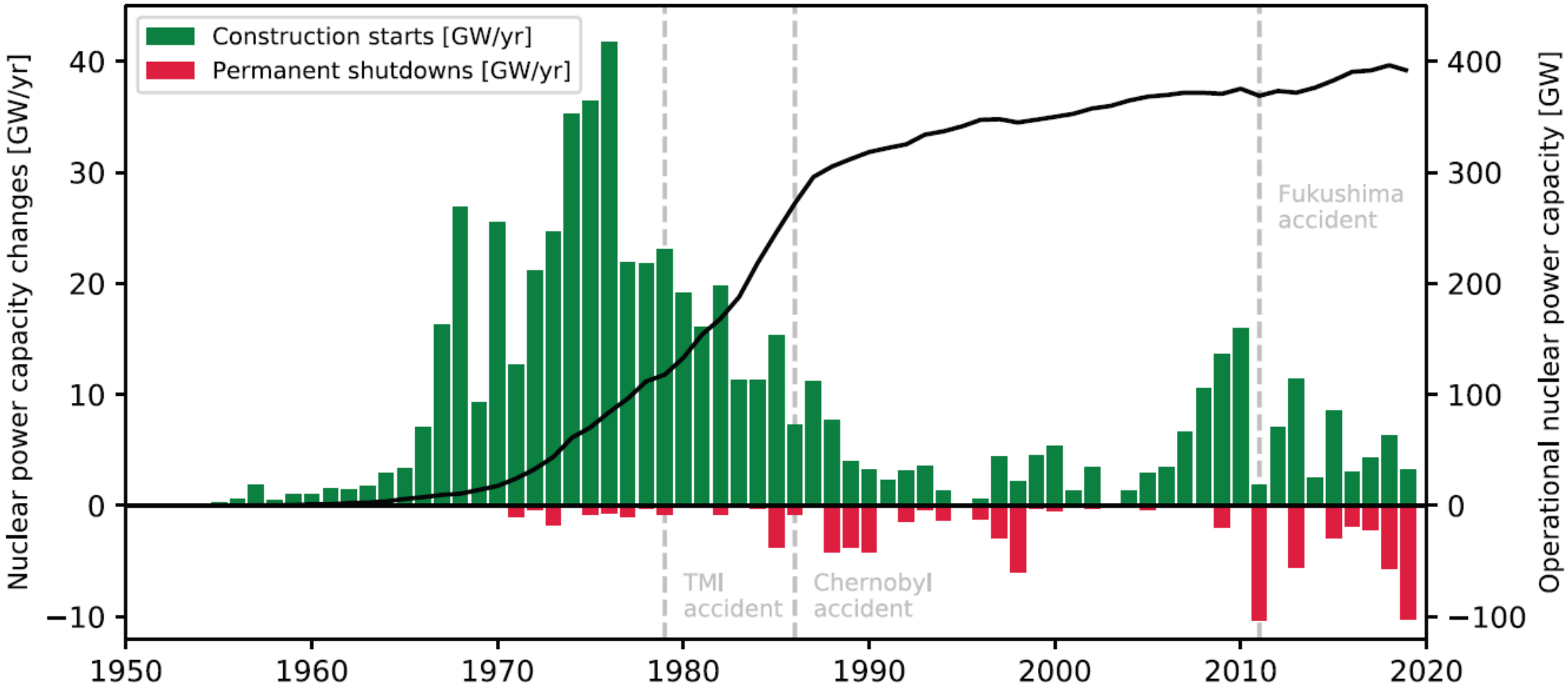

500
450
400
350
300
250
200
150
100
50
0
Median LCOE (%)
CCGT
Coal
Nuclear
Solar PV
Onshore wind
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Discount rate (%)

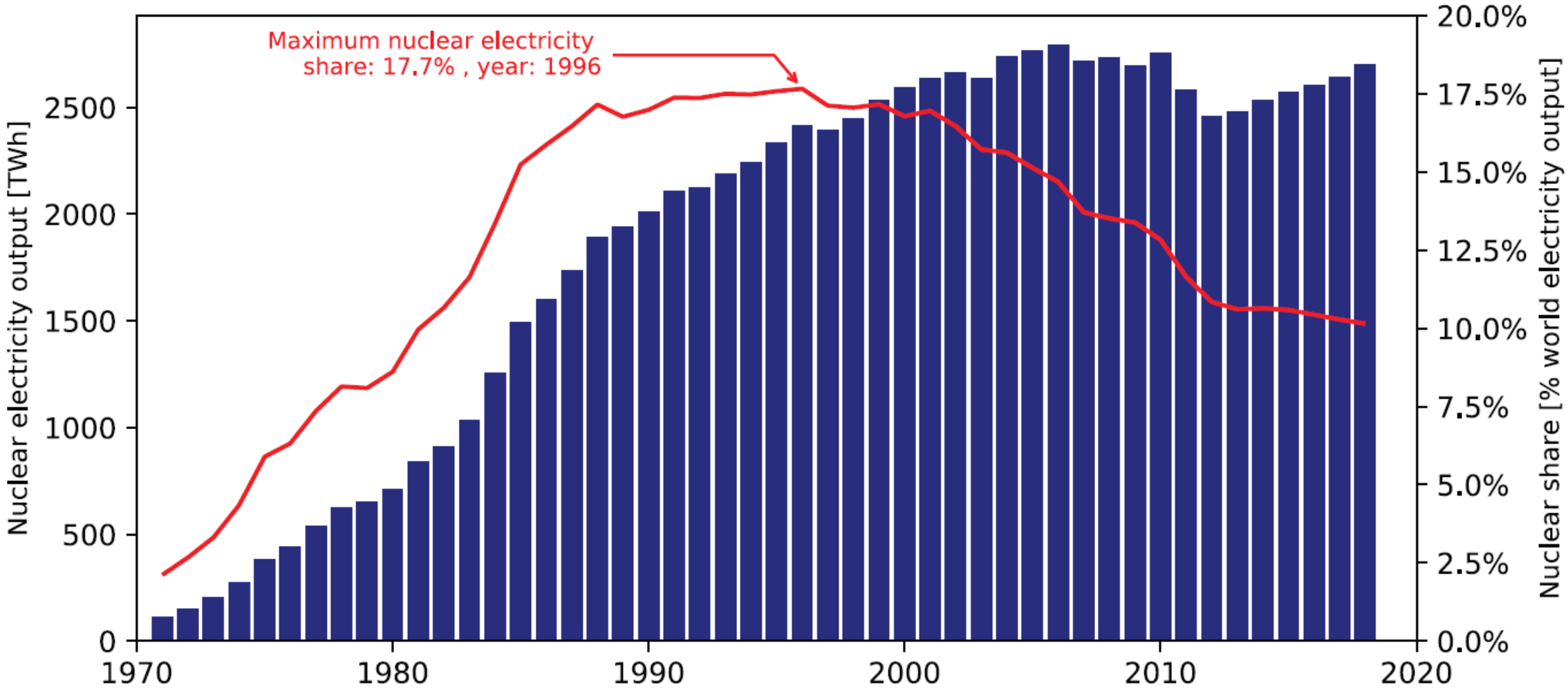
Factors influencing the final price

- Political and regulatory context
- Project design
- Reactor size
- The nature of the investor
- Construction time
- Project management
- Supply Chain
- Cost of labor
- Unclear financial framework



US	-10 %
South Korea	-35 %
China and India	-40 %


Construction starts [GW/yr]
Permanent shutdowns [GW/yr]
Nuclear power capacity changes [GW/yr]
Operational nuclear power capacity [GW]
40
30
20
10
0
−10
400
300
200
100
0
−100
1950
1960
1970
1980
1990
2000
2010
2020
TMI accident
Chernobyl accident
Fukushima accident


Maximum nuclear electricity
share: 17.7% , year: 1996
Nuclear electricity output [TWh]
Nuclear share [% world electricity output]
0
500
1000
1500
2000
2500
0.0%
2.5%
5.0%
7.5%
10.0%
12.5%
15.0%
17.5%
20.0%
1970
1980
1990
2000
2010
2020

Units under constructions by region year-end 2020

	BWR	FNR	HTGR	PHWR	PWR	Total
Asia	2	2	1	4	27	36
East Europe & Russia					6	6
North America					2	2
South America					2	2
West & Central Europe					6	6

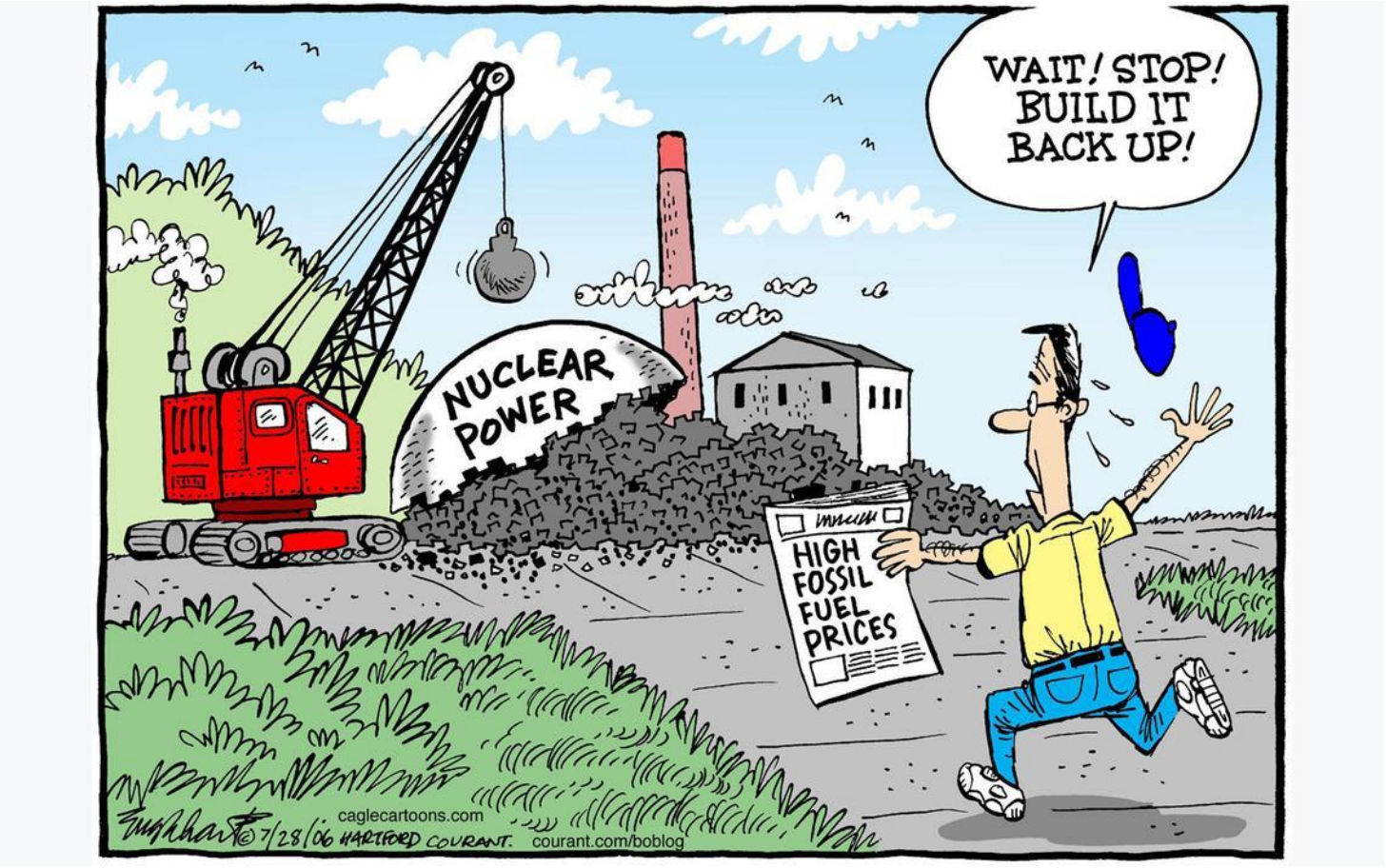
Source: World Nuclear Association, IAEA PRIS

Nuclear decline?

- Decline
  - **Phase-out policies**
  - Not compatible with the principles of liberalizes markets
  - Decline in construction and the industry involved
  - **Uncompetitiveness** – time and cost

- Renaissance
  - **Low-carbon technology** – and increasing attention to the climate change
  - New constructions in Asia
  - **High-tech** – developed and complex technology, know-how
  - Geopolitical strategies
  - Technological diversity, highly expert sector
  - Small modular reactors

What if the electricity prices start rising?



Source: https://thebreakthrough.org/blog/treadmill-decarbonization-doesnt-help

Examples of policy measures

Energy systems are very resilient to change.
Thus, the role of government is important, but…
There is no certainty over the chosen path.

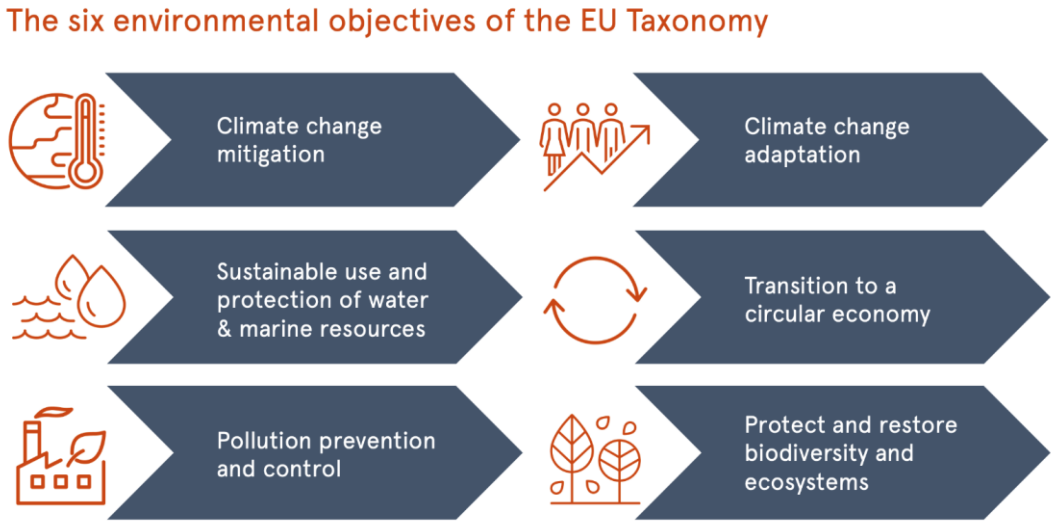
EU approach

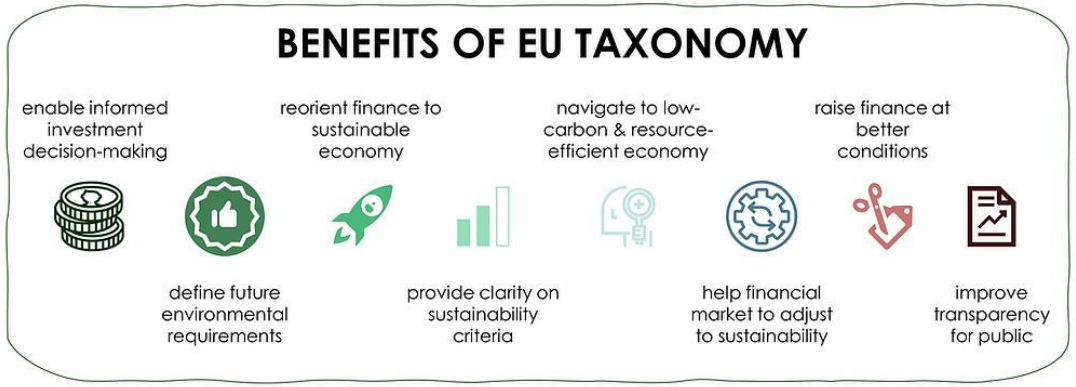
- **Article 194 of the Treaty on the Functioning of the European Union** (TFEU)
  - Energy is a shared responsibility between EU Member States and the EU. However, each Member State has the right to decide the conditions for exploiting its own energy resources, choose between different energy sources and decide the general structure of its energy supply.

- However, the energy mix is shaped by:
  - Liberalized energy market
  - EU's commitments is reducing greenhouse gas emissions

EU – Taxonomy

- **Classification system**, establishing a list of environmentally sustainable economic activities.
- The EU taxonomy would provide companies, investors and policymakers with **appropriate definitions for which economic activities can be considered environmentally sustainable**.
- The Taxonomy Regulation establishes six environmental objectives



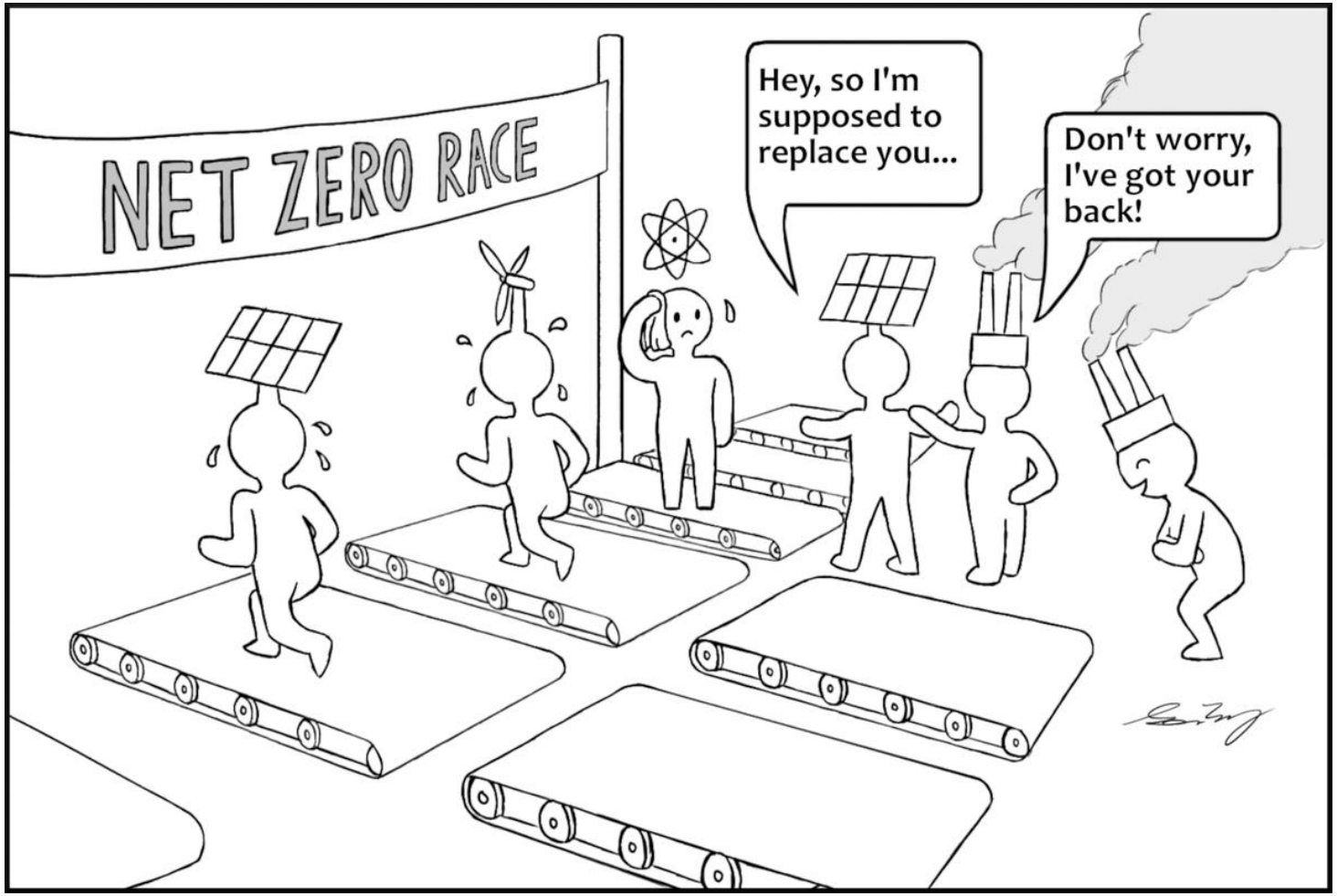


Taxonomy and nuclear energy

- The nuclear energy is not excluded, but it is not among the supported activities
- In **2020** the Commission launched **in-depth work to assess whether or not to include nuclear energy in the EU taxonomy of environmentally sustainable activities**.
- The EC has promised that it will be included, but it is delaying it
- Carbon neutrality in 2050 without NPPs will not be achieved unless there is a technological breakthrough elsewhere
- 3 expert groups
  - JRC - Joint Research Center
  - SCHEER - Scientific Committee on Health, Environmental and Emerging Risks
  - EURATOM Expert Group (Article 31)
- If the nuclear power is not in taxonomy
  - More expensive construction in the EU
  - Another obstacle to private sector involvement
- **Like-minded group** - FR, V4, RO, BG, SI, FI, (HR, SE, NL)
  - Coordinated approach

Nuclear phase-outs

- **Political decision motivated by the opinion of people**
- Example of countries
  - Austria – 1997
  - Germany – 2011
  - Italy – 1987 (after Chernobyl)
  - Sweden - 1980 (after Three Mile Island), renounced in 2010.
  - New Zealand – 1987
  - Philippines – 2004
  - South Korea – 2017
  - …



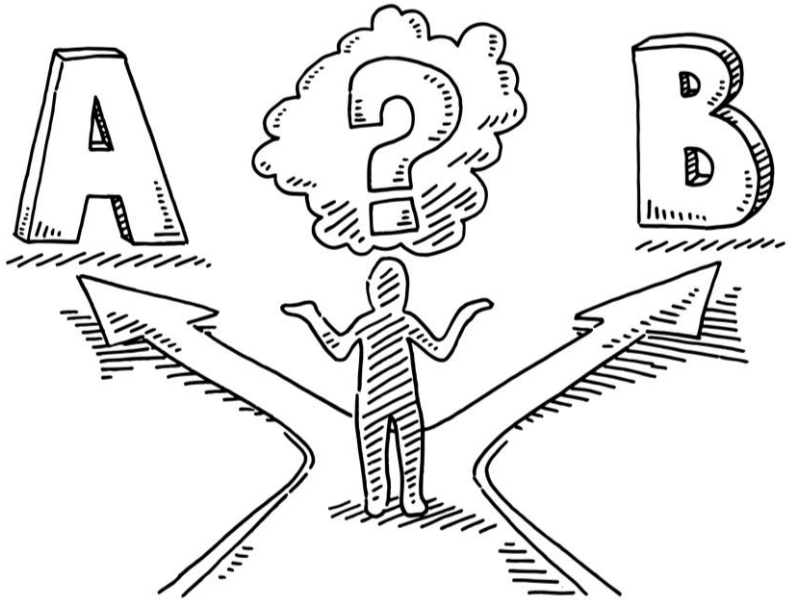
Source: https://thebreakthrough.org/blog/treadmill-decarbonization-doesnt-help

South Korea

- Korea is one of the world's largest nuclear energy producers.
- In 2017, the country chose to phase out nuclear power plants due to concerns of possible accidents.
  - anti-nuclear policy was one of the key campaign pledges of President Moon Jae-in
  - Big opposition
- Korea has been constructing nuclear reactors for decades, so it has advanced technology and supply chains for making nuclear plants
  - **KEPCO E&C** = power plant design and engineering company in South Korea
- NP as Korea's only viable way to reach net-zero emissions by 2050

Conclusion

- Renewable energy and nuclear power are not competitors.
- On the contrary. They both emit little CO_2 and complement each other.
- As important as renewable energy is, it is not yet sufficient to meet current electricity demand.
- The main task for now is on the governments and their decision they make about their future energy mix, could it be:
  - RES?
  - RES and nuclear?
  - RES and fossil fuels?
  - RES and expectation of technological breakthrough?



Source: https://nuclear.engie-electrabel.be/en/nuclear-energy/nuclear-power-plants-and-climate/energy-transition

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