

The development of low carbon energy sources

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Recording

Decarbonization

- Driven by the climate change reasoning.
- Specified goal, in search for suitable technologies - vs. previous energy transitions.
 - Muscles + fire → draft animals → waterwheels and windmills → coal (oil, natural gas) → (coal) electricity → ?

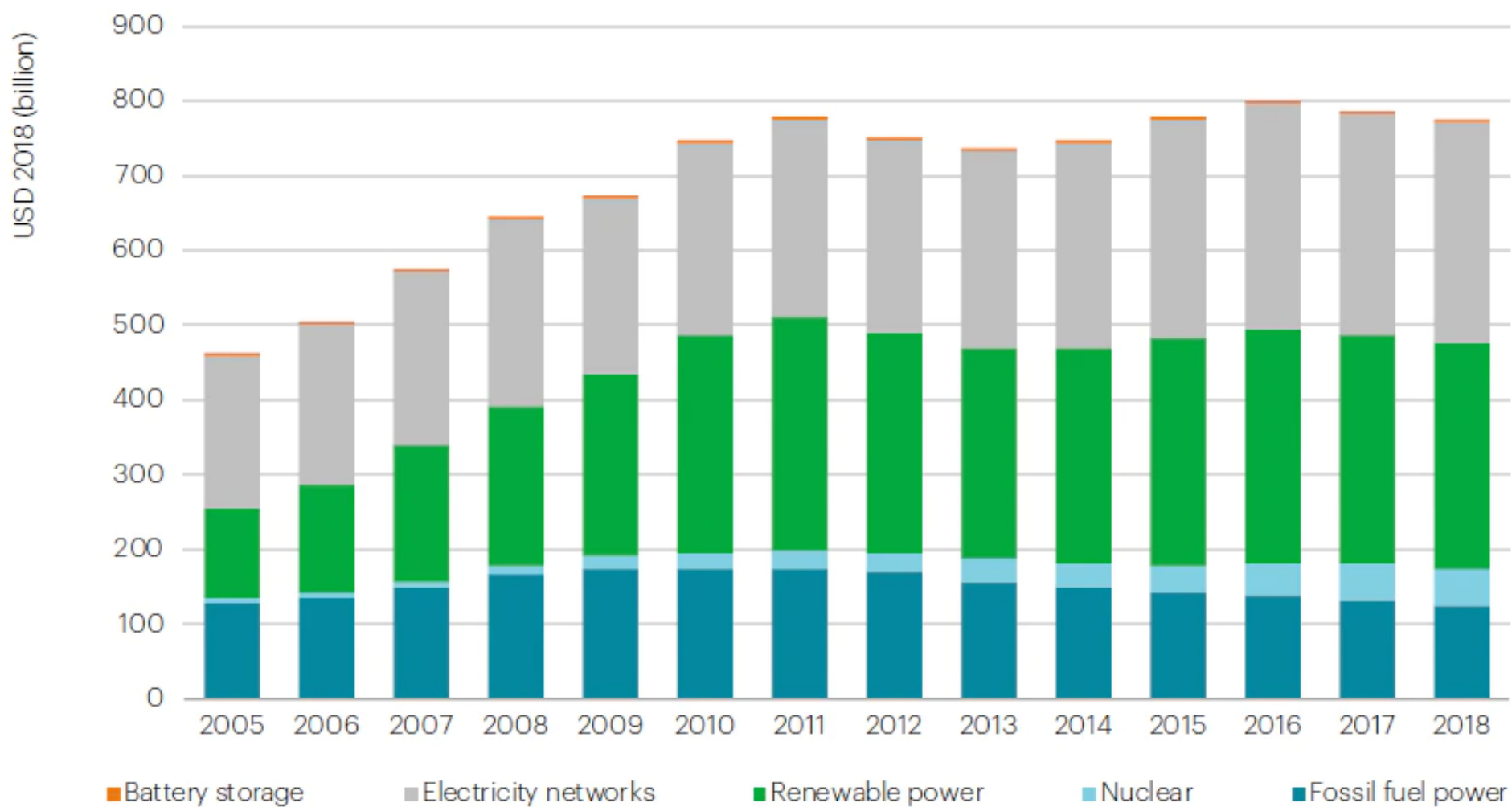
= The current energy transition is driven by policies rather than by technology improvements.

Life cycle CO₂ equivalent of selected electricity supply technologies

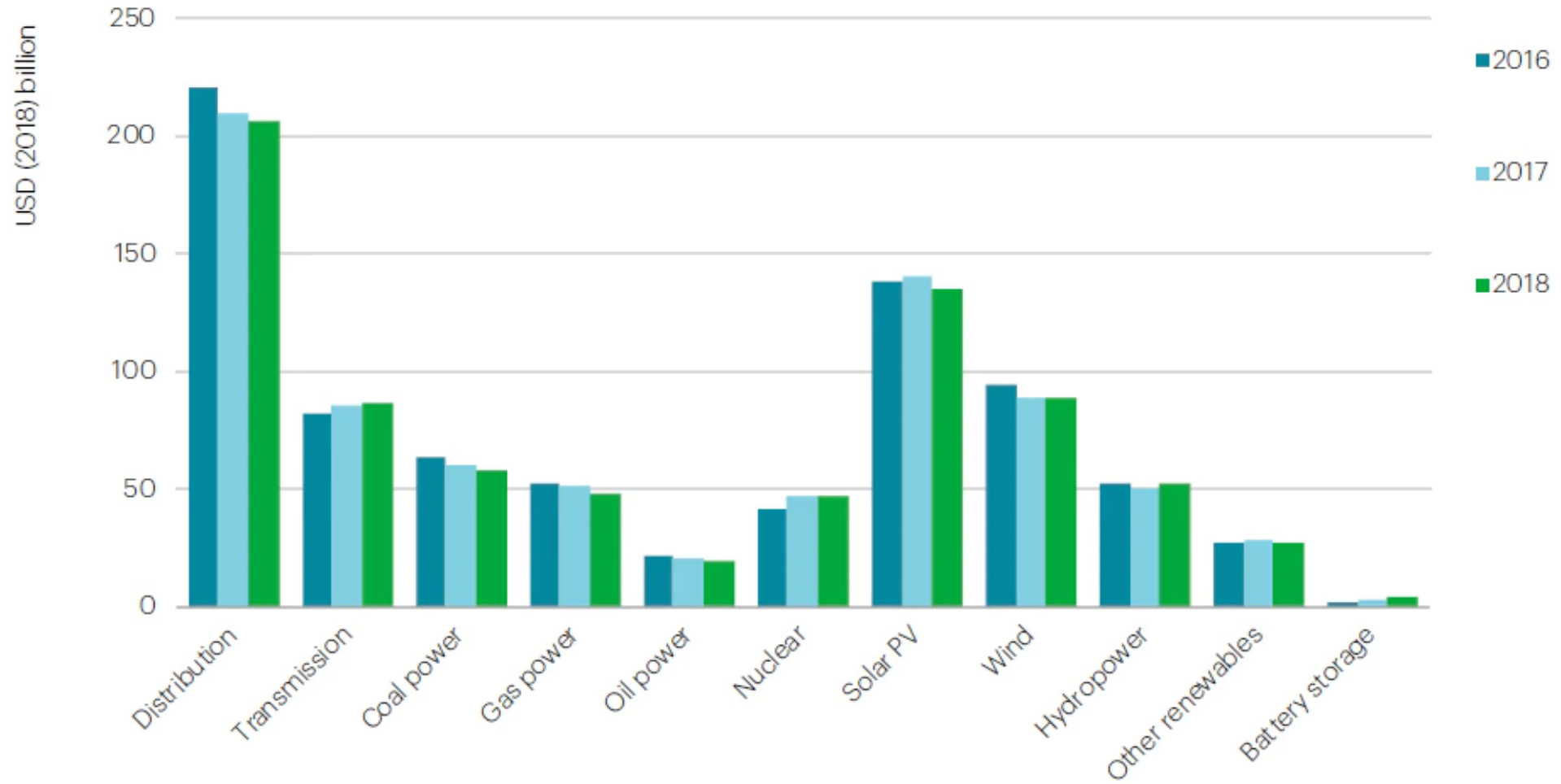
Technology	Median	Technology	Median
Coal	820	Geothermal	38
Biomass co-fired with coal	740	Concentrated solar power	27
Gas – combined cycle	490	Hydropower	24
Biomass – dedicated	230	Wind offshore	12
Solar PV – utility scale	48	Nuclear	12
Solar PV – rooftop	41	Wind onshore	11

Arranged by decreasing median values. In gCO₂eq/kWh

Global investment in the power sector by technology



Global investment in the power sector by technology



Technology performance

Nuclear

- Tested and reliable source of electricity.
- Base-load supplies.
- High load factor.
- High power density.

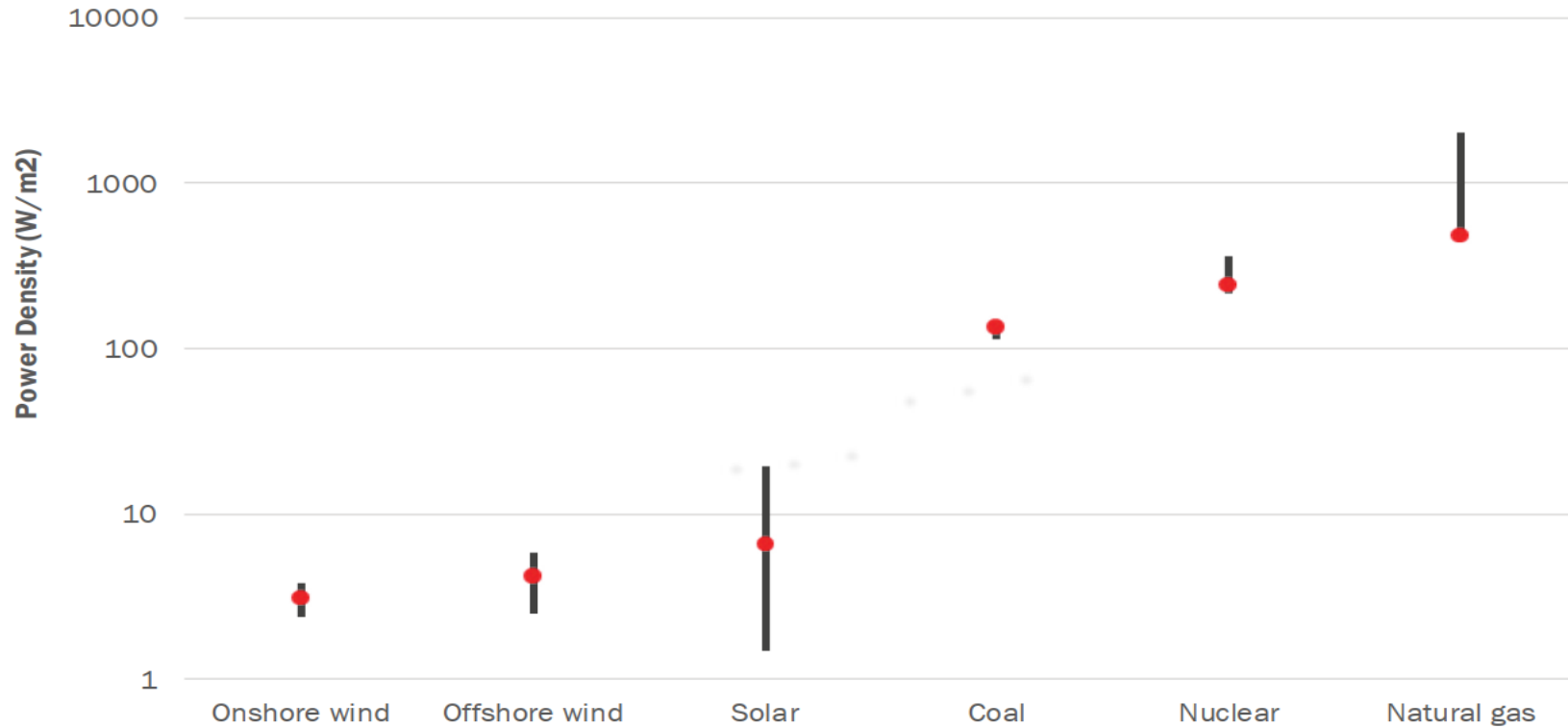


Renewables

- Limited potential of water and bioenergy, expected increase in wind and solar.
- Intermittent supplies, low load factor.
- Low power density.
- Geographical determination.



Power density of selected sources of electricity



The bars represent the range of values and the dot represents the median value.

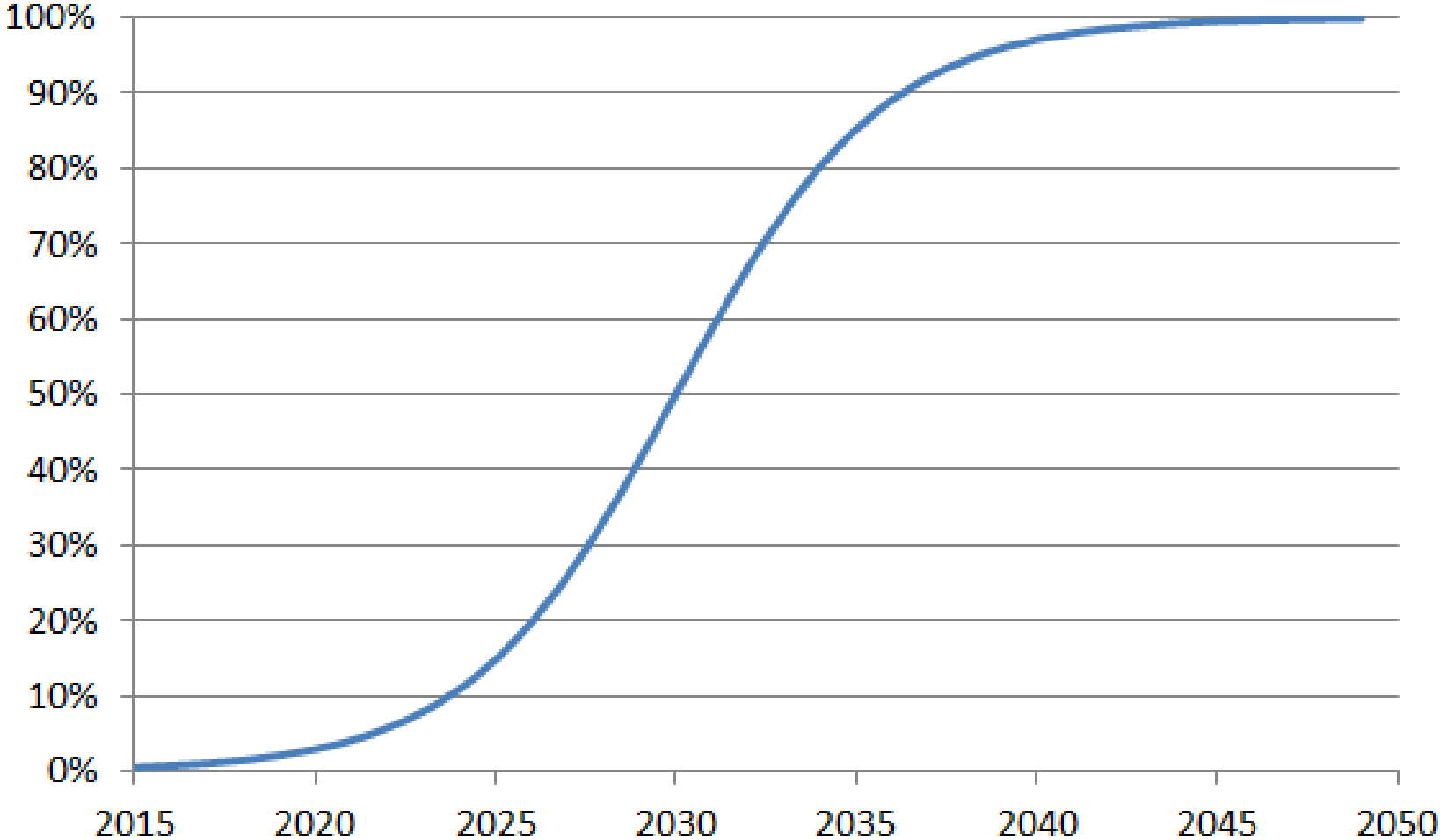
Avg. U.S. households – 2500w.

Economy of nuclear and renewables

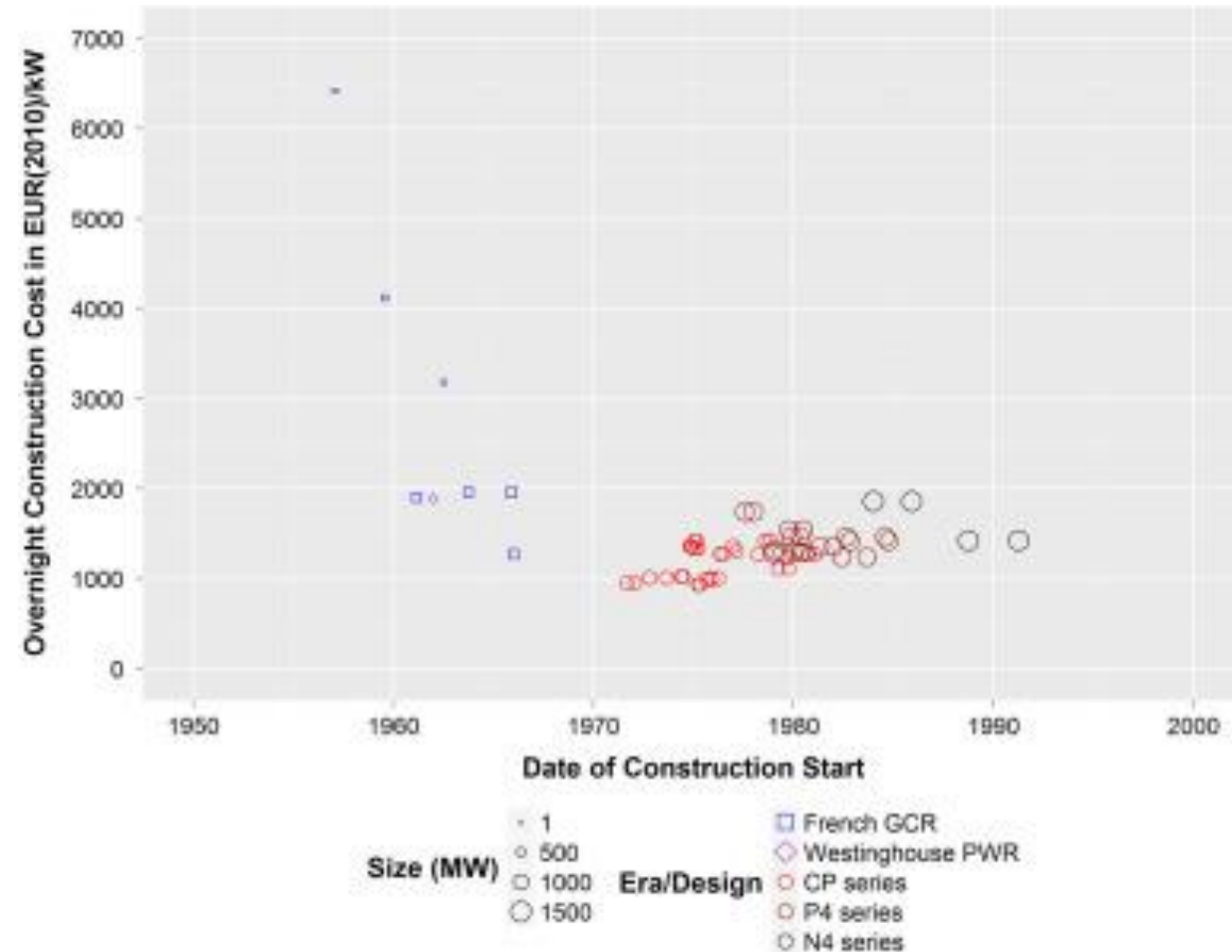
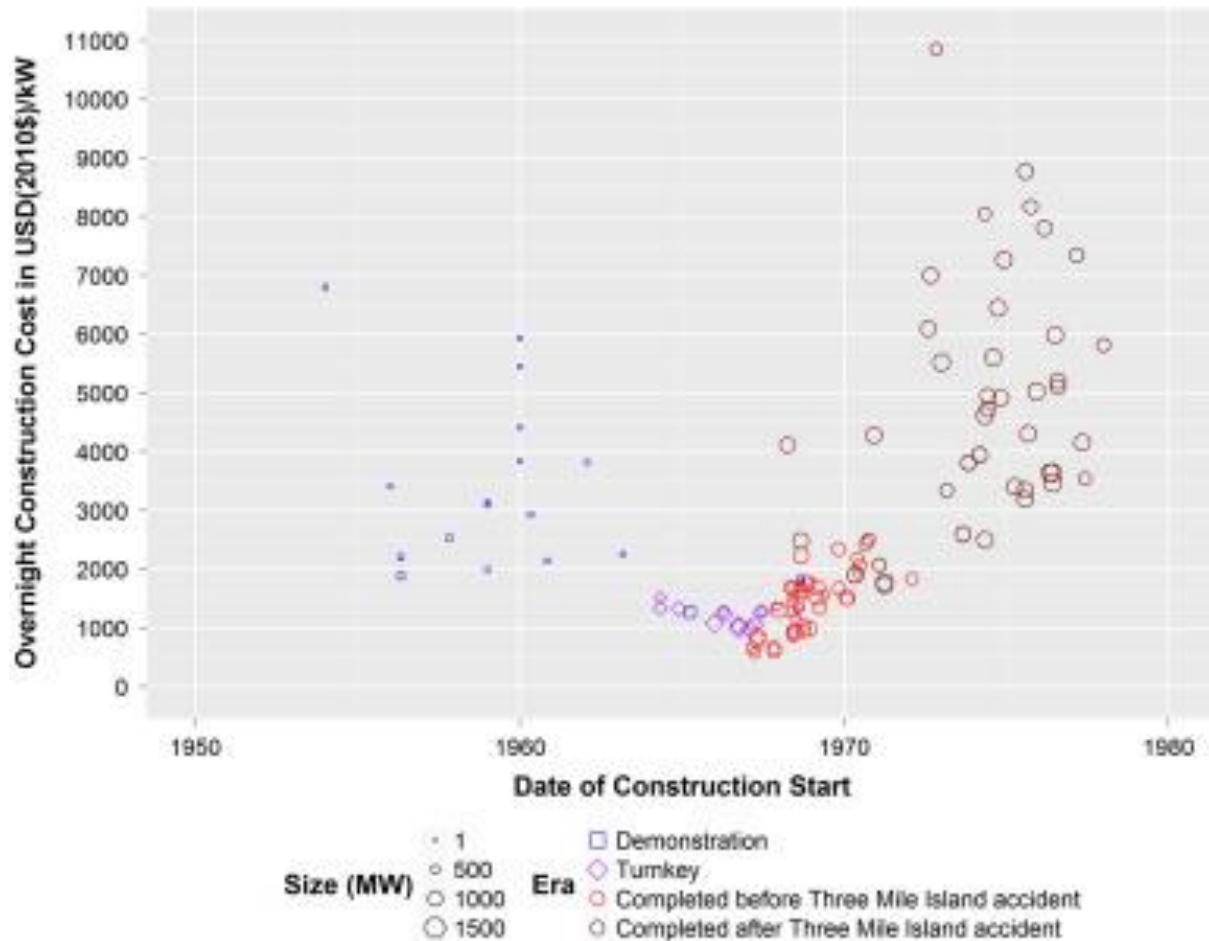
Learning curve

- Decreasing costs due to:
 - Research and development itself.
 - Learning by doing – a byproduct of manufacturing and deployment, with companies incrementally improving industrial operations, installation procedures, sales, and financing processes.
 - Economy of scale – companies and industries getting larger, spreading some fixed costs over a larger volume of product sales.
 - Learning by waiting – harnessing the spillover effect from other industries, technologies, or countries.

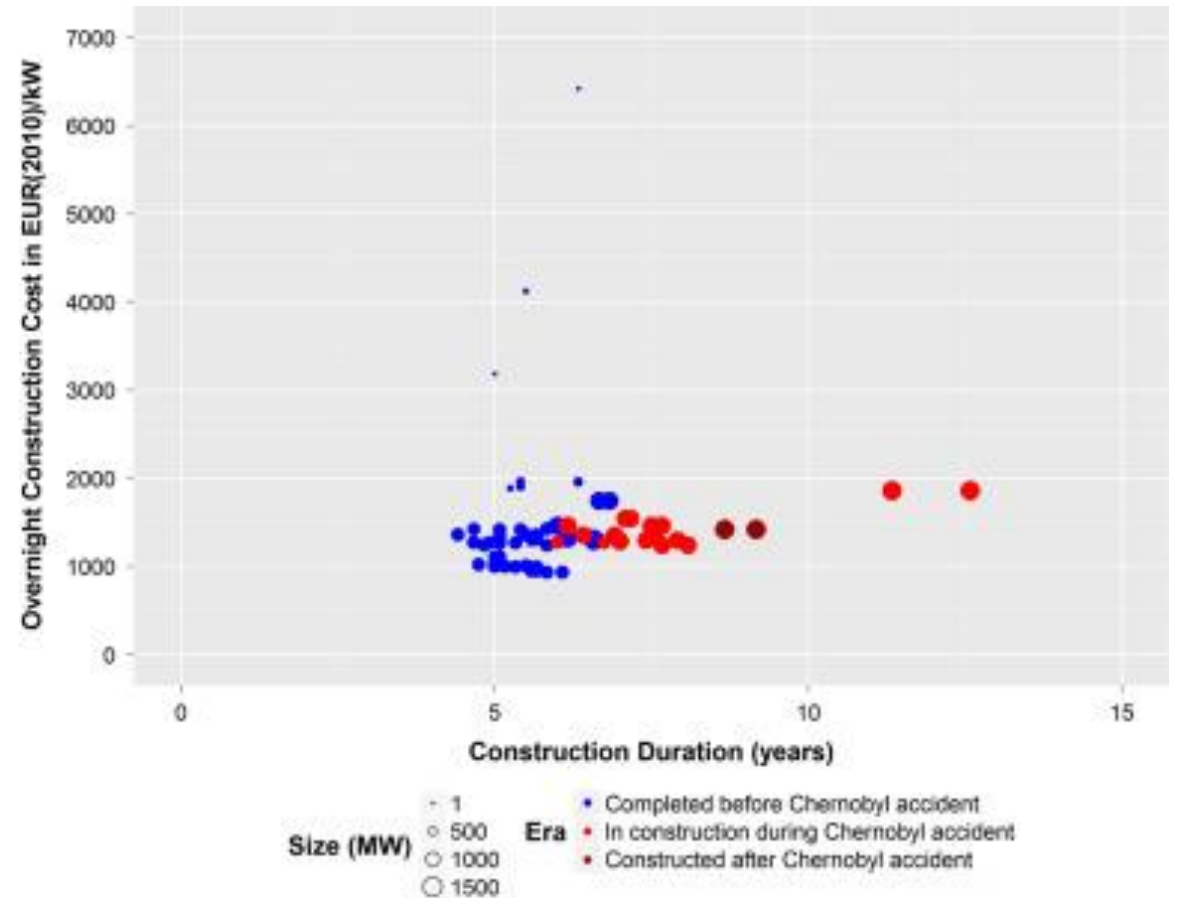
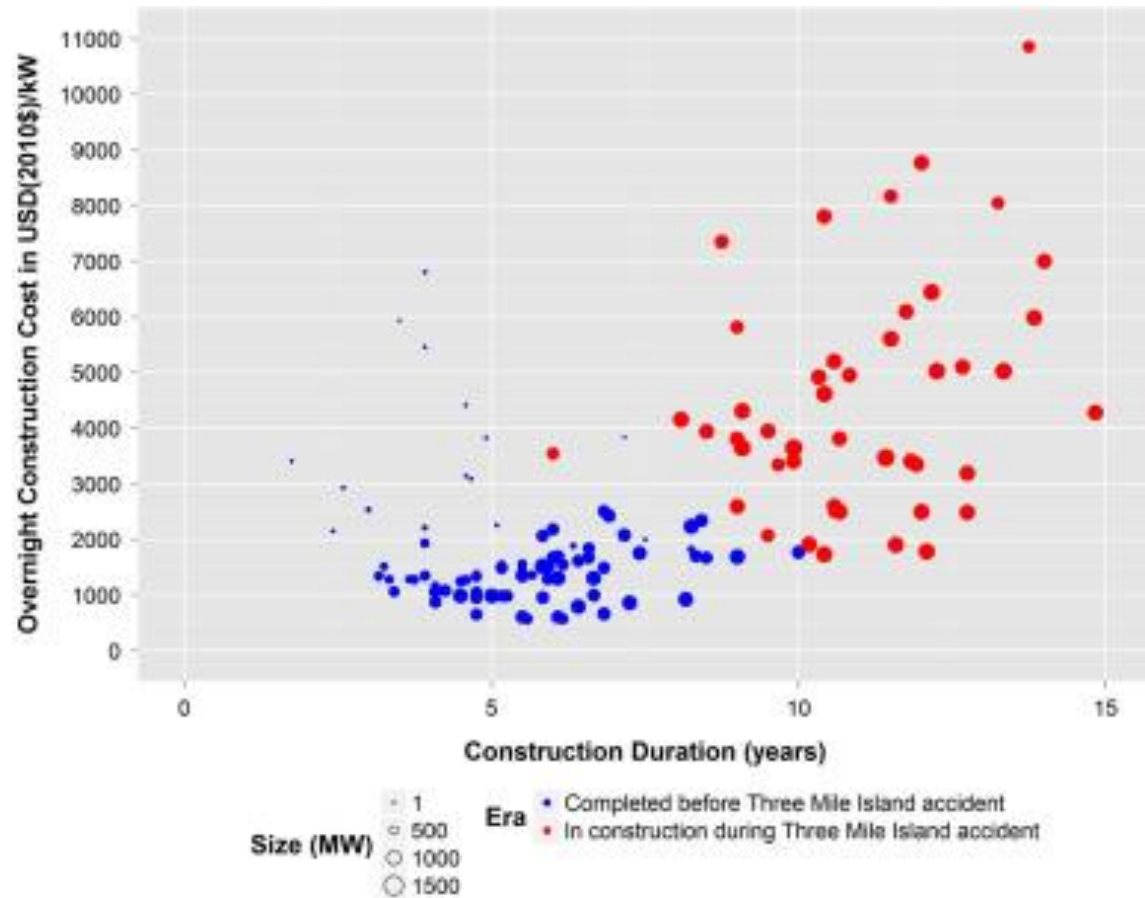
Learning curve



Overnight construction costs (OCC) in 2015USD/kW, USA (left) and France (right)

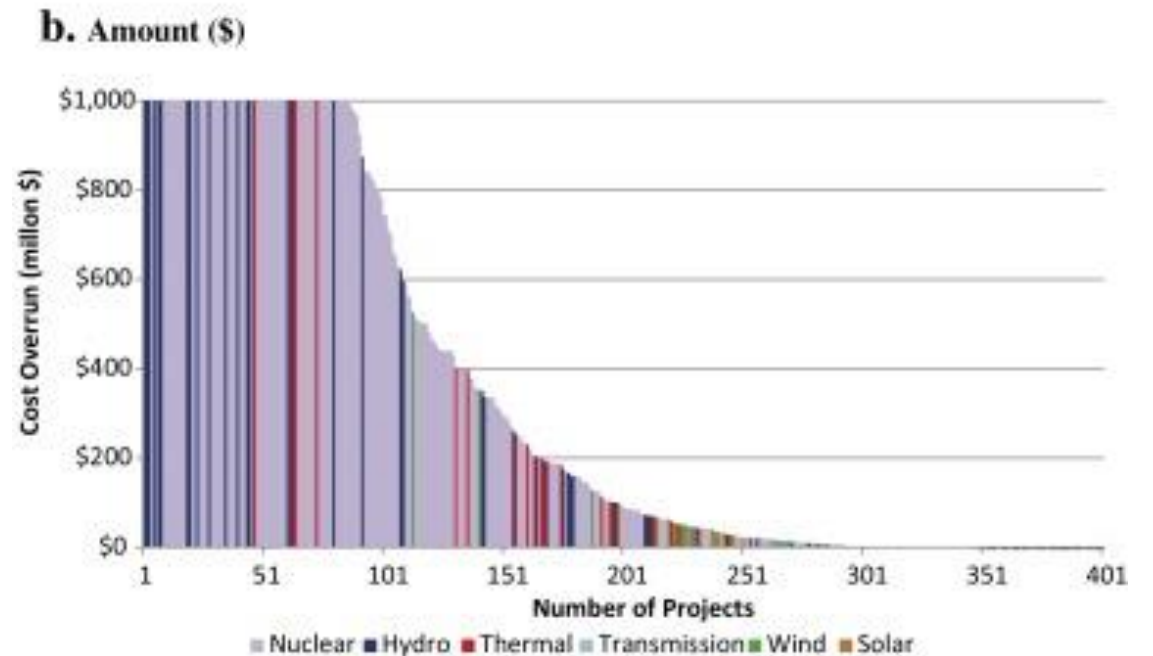
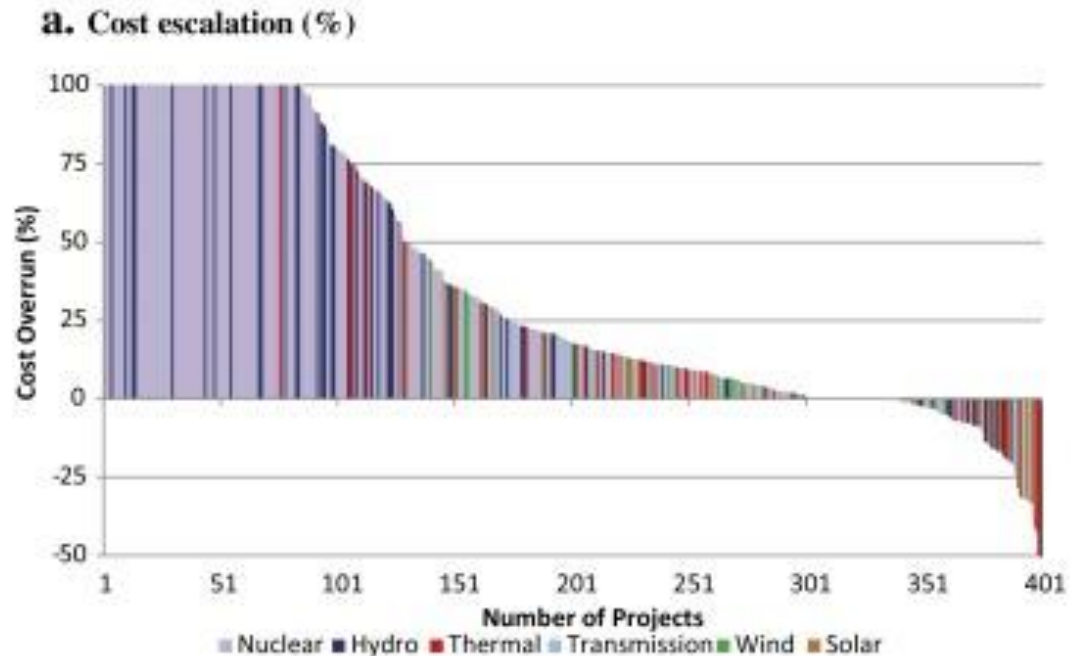


Construction duration, USA and France



Distribution of construction overrun costs by technology

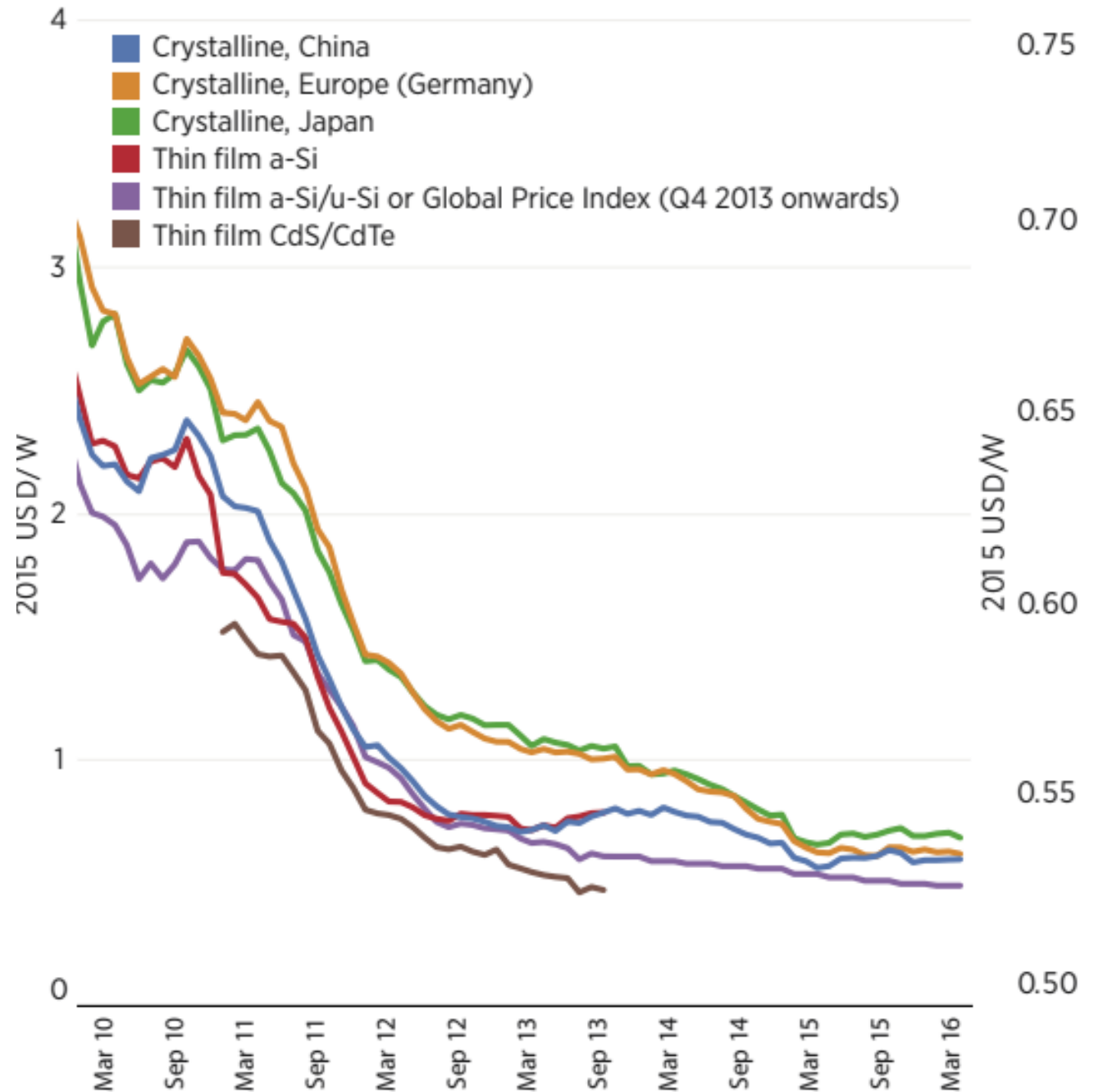
- 401 electricity infrastructure projects built between 1936 and 2014 in 57 countries.
- USD 820 bn. worth of investments, 323 515 MW of installed capacity, and 8495km of transmission lines.



NPP in the EU in progress

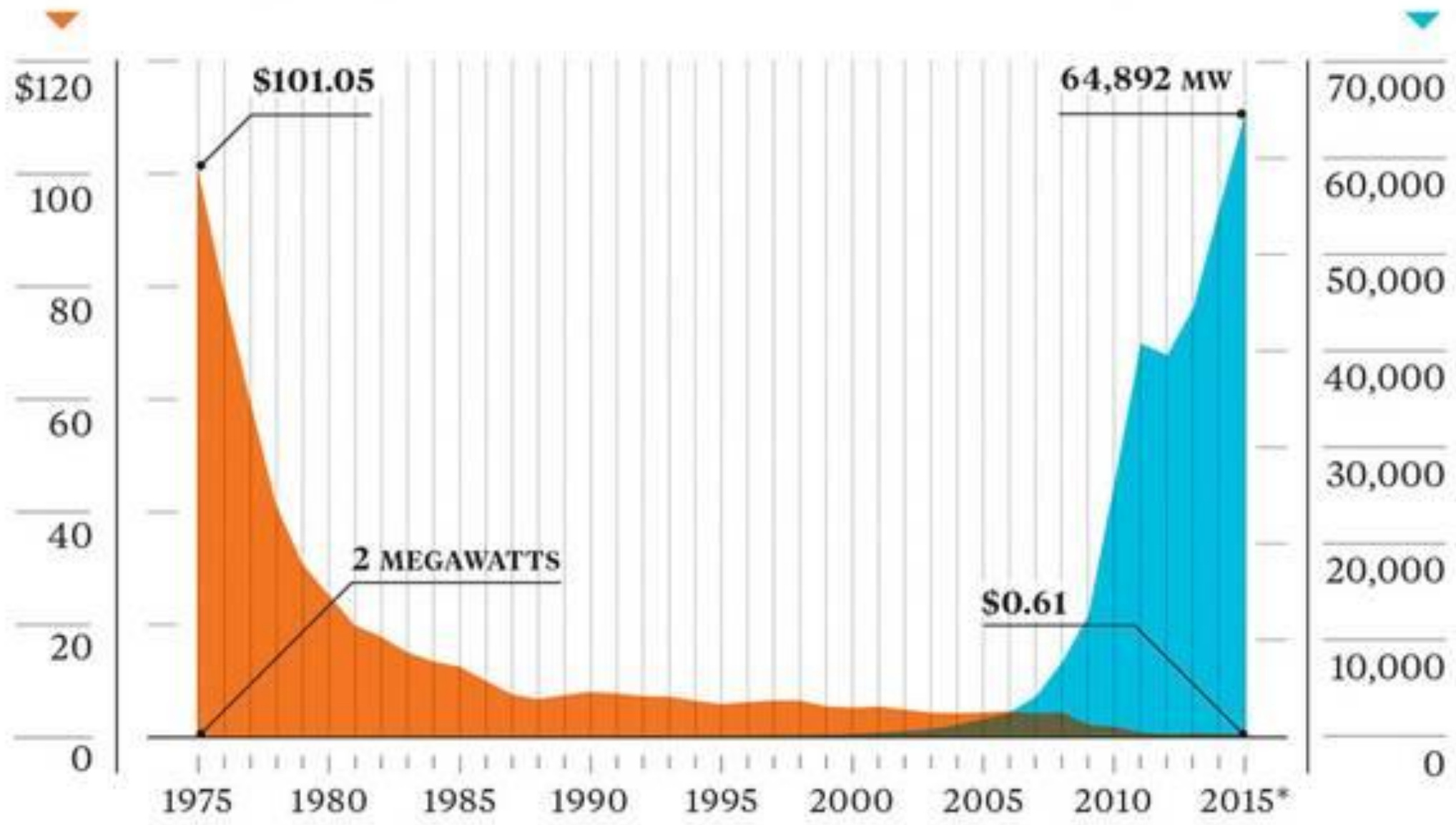
- Flamanville NPP – construction started in 2007, with scheduled commissioning in 2012 and planned costs €3,3bn. Last information (from 2015) – commissioning in 2022 for €10,5bn.
- Olkiluoto NPP – construction started in 2005, with scheduled commissioning in 2010 and planned costs of €3bn. Commissioning expected in 2020 for €8,5-10bn+.
- Mochovce NPP – construction re-started in 2009, with scheduled commissioning in 2012 and 2013 and planned costs of €2,775bn. Commissioning expected in 2020 and 2021 for €3,8bn.

Global PV module price trends 2009-2016

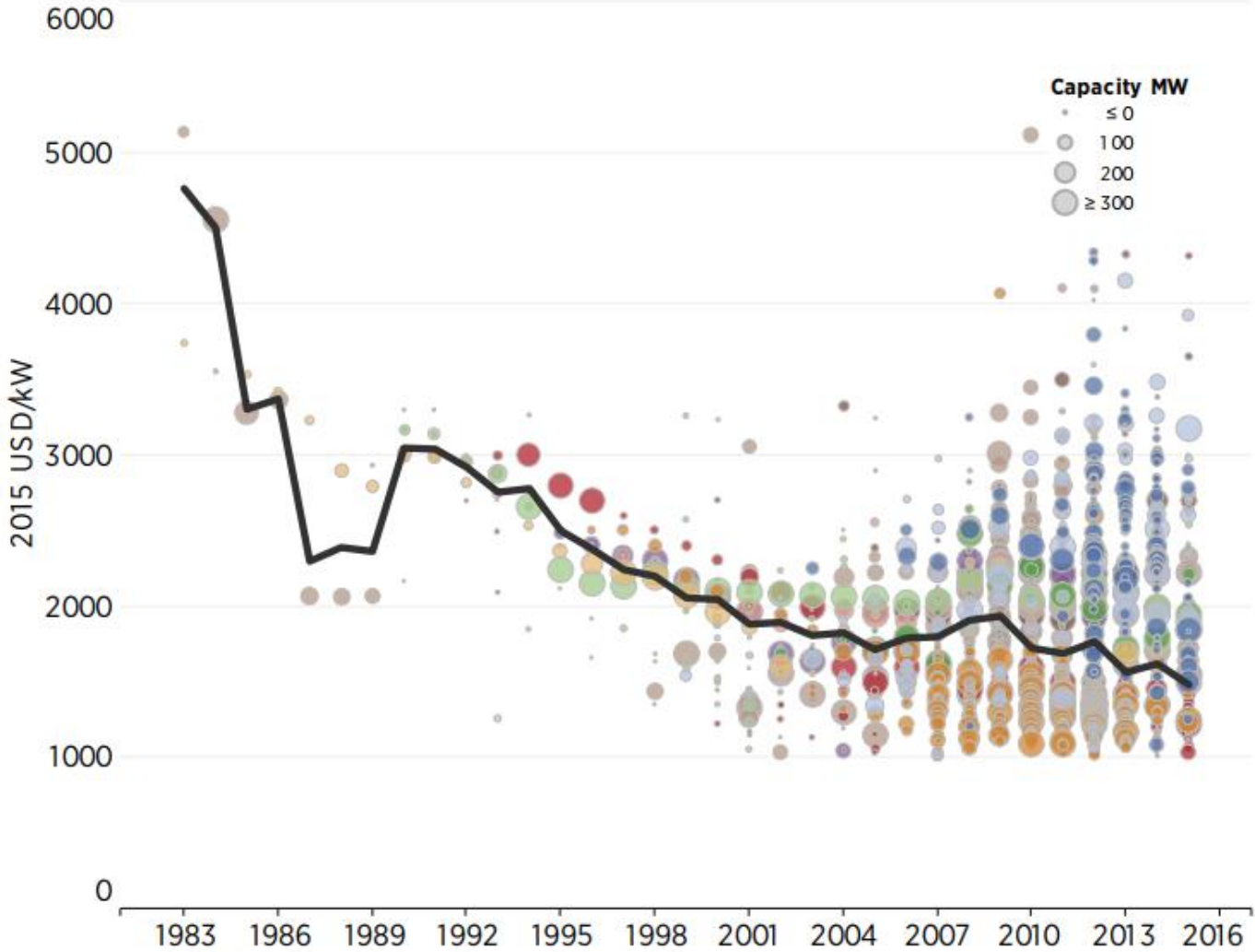


Price of a solar panel per watt

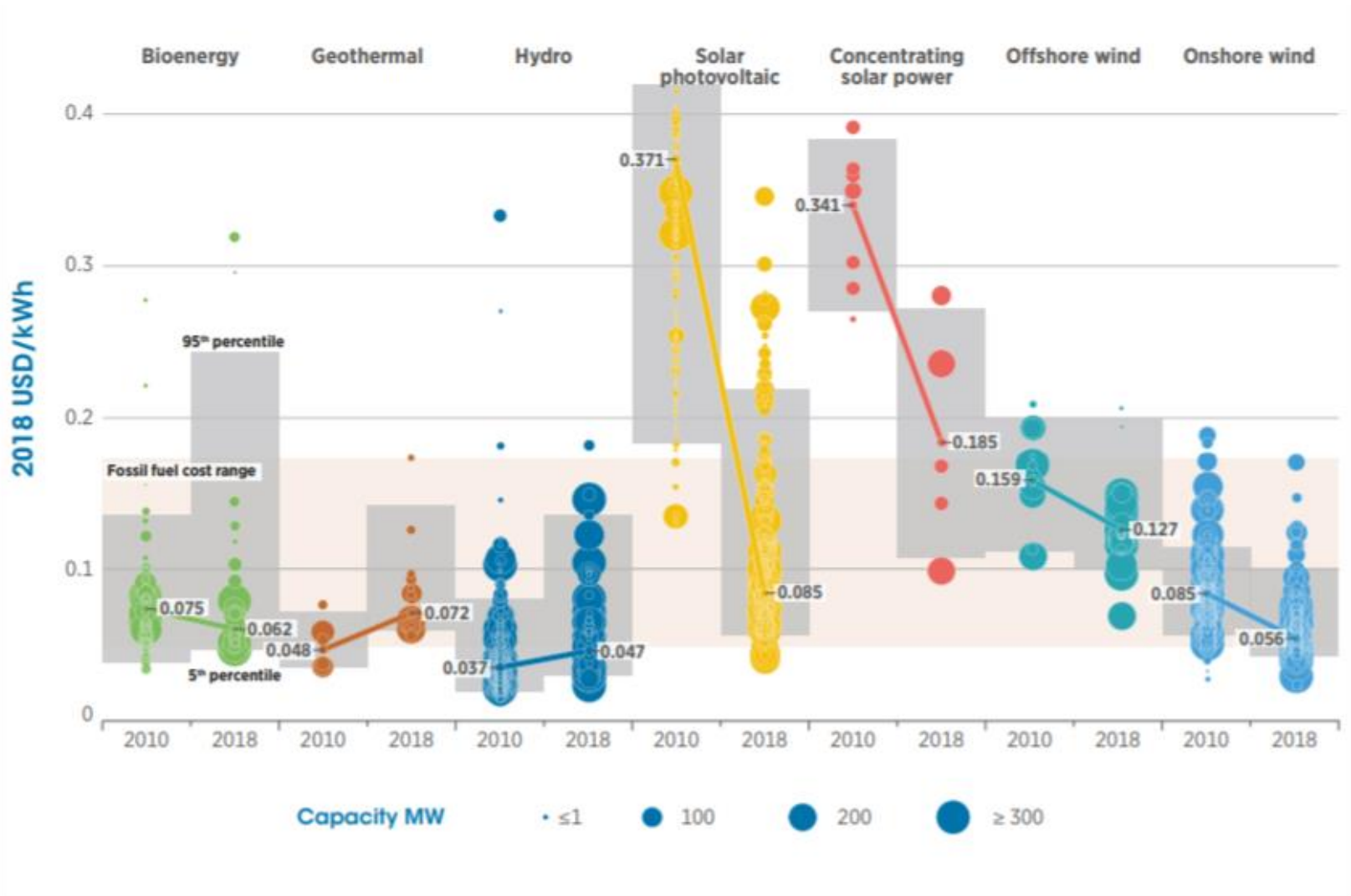
Global solar panel installations



Total installed costs of onshore wind by country 1983-2016



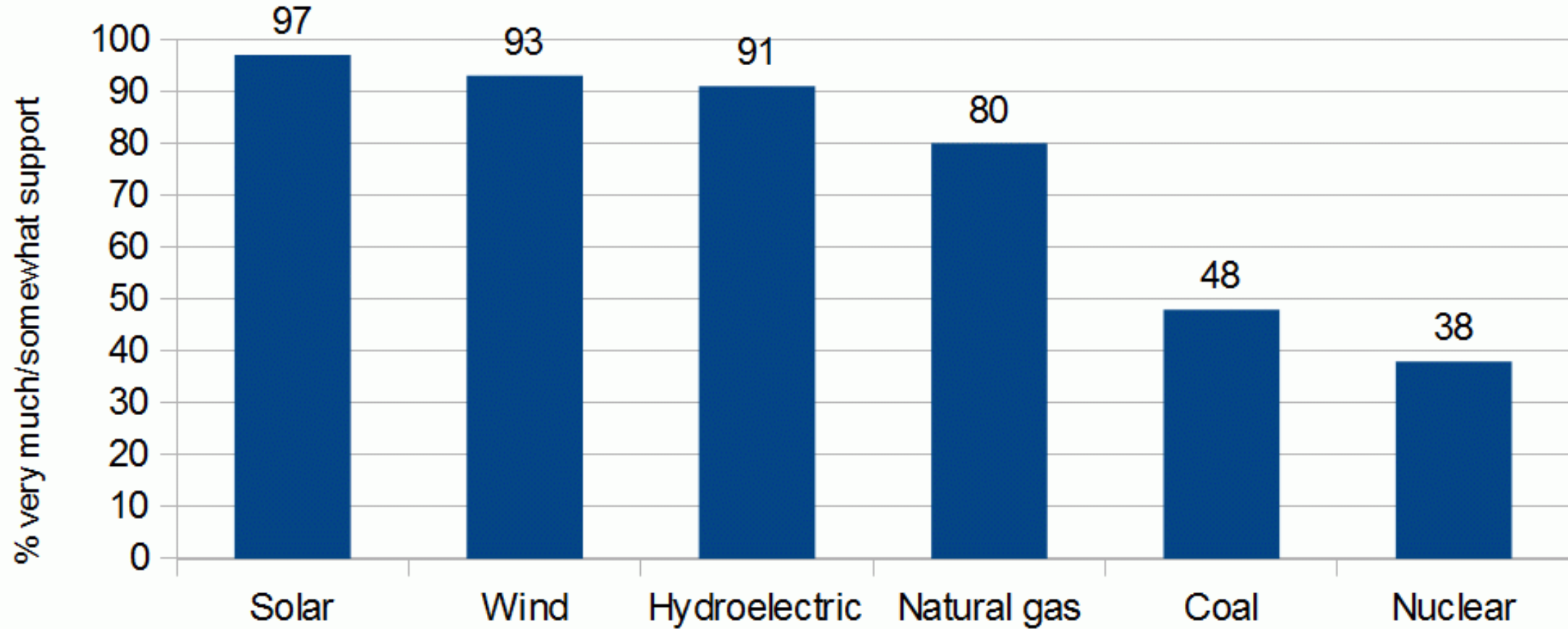
Global levelised costs of electricity from utility-scale RES technologies, 2010 - 2018



Public support and acceptance

Global public support for energy sources

"Please indicate whether you strongly support, somewhat support, somewhat oppose, or strongly oppose each way of producing energy"



Source: Ipsos, May 2011

Nuclear phase-outs

- Austria – 1997
- Germany – 2011
- Italy – 1987 (after Chernobyl)
- Sweden - 1980 (after Three Mile Island), renounced in 2010.
- New Zealand – 1987
- ...
- ...

Germany - Vernunftkraft

VERNUNFTKRAFT.
Bundesinitiative für vernünftige Energiepolitik

Euer „Ökostrom“ zerstört
Paradiese.



Bitte kommt zur Vernunft.

Dank unsinniger Subventionen werden zigtausende Windkraftanlagen in die Wälder gebaut. Naturparks werden zu Industriezonen, die letzten Rückzugsräume vernichtet.

» www.vernunftkraft.de



Dahl, Nordrhein-Westfalen

A power plant in your neighbourhood?

Acceptance of installations near residential areas [in Germany 2016]



73% Solar power



52% Wind power



38% Biogas



19% Gas

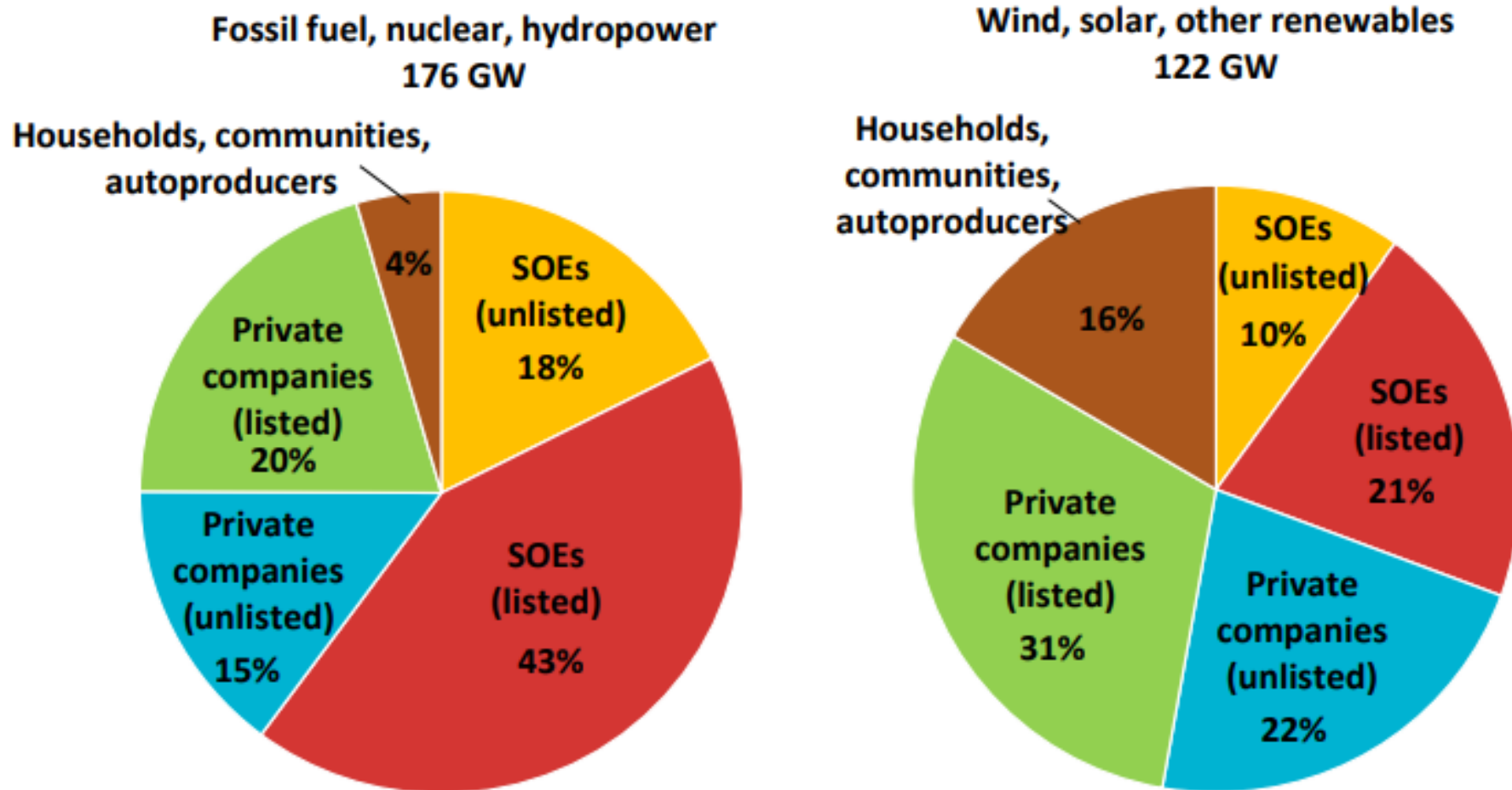


6% Coal



5% Nuclear

Ownership of global power generation capacity commissioned in 2015



+ Socio-energy system resilience

- Vested interests and sunk costs of the existing infrastructure.
- Status-quo actors vs. newcomers.
- Costs of rebuilding of the system.

+ Role of the government



Sources

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