

# The development of low carbon energy sources

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# Decarbonization

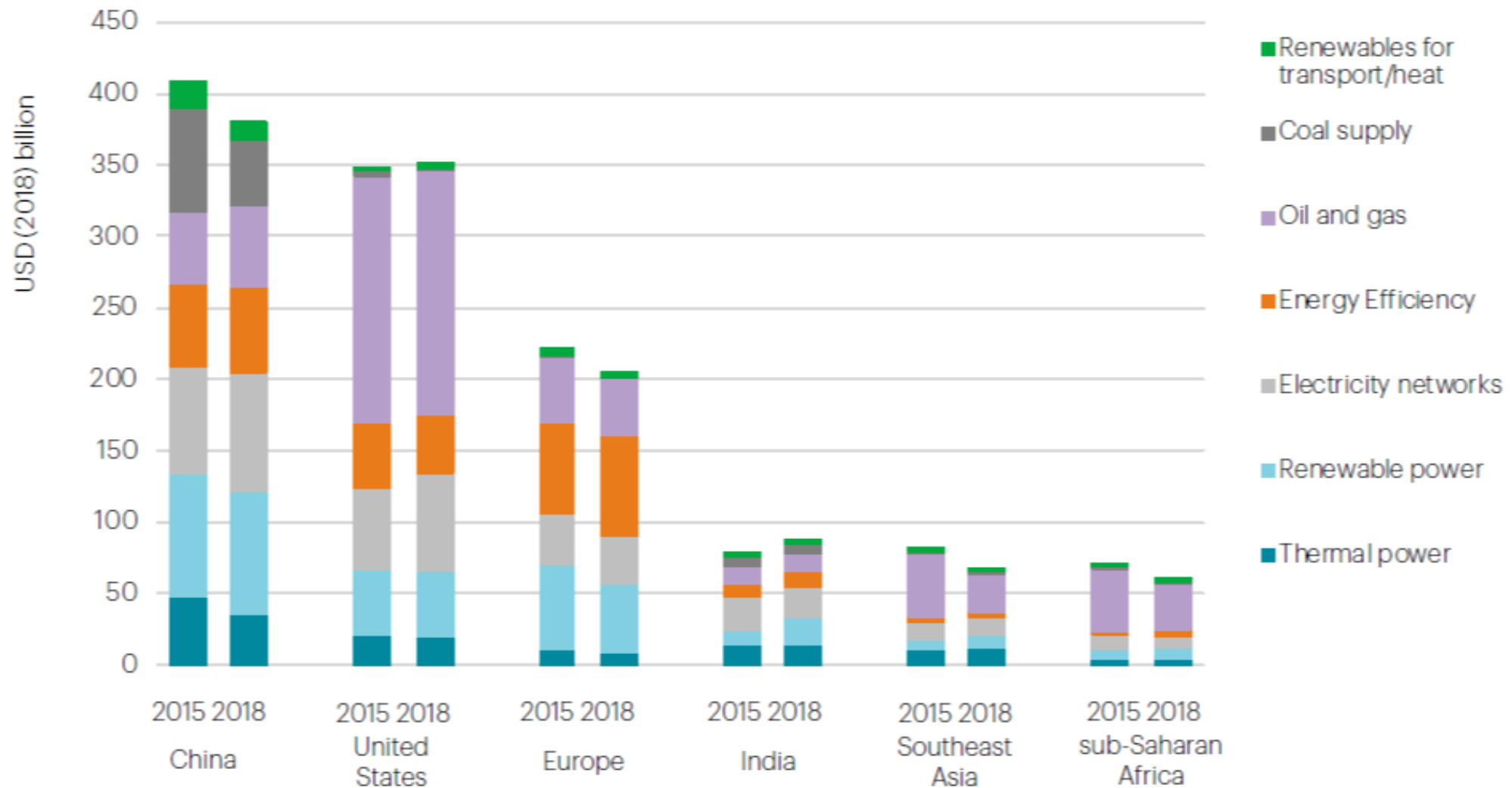
- Politically driven, with the climate change reasoning.
- Specified goal, in search for suitable technologies - vs. previous energy transitions.
  - Muscles + fire → draft animals → waterwheels and windmills → coal (oil, natural gas) → (coal) electricity → ?

# Life cycle CO<sub>2</sub> equivalent of selected electricity supply technologies

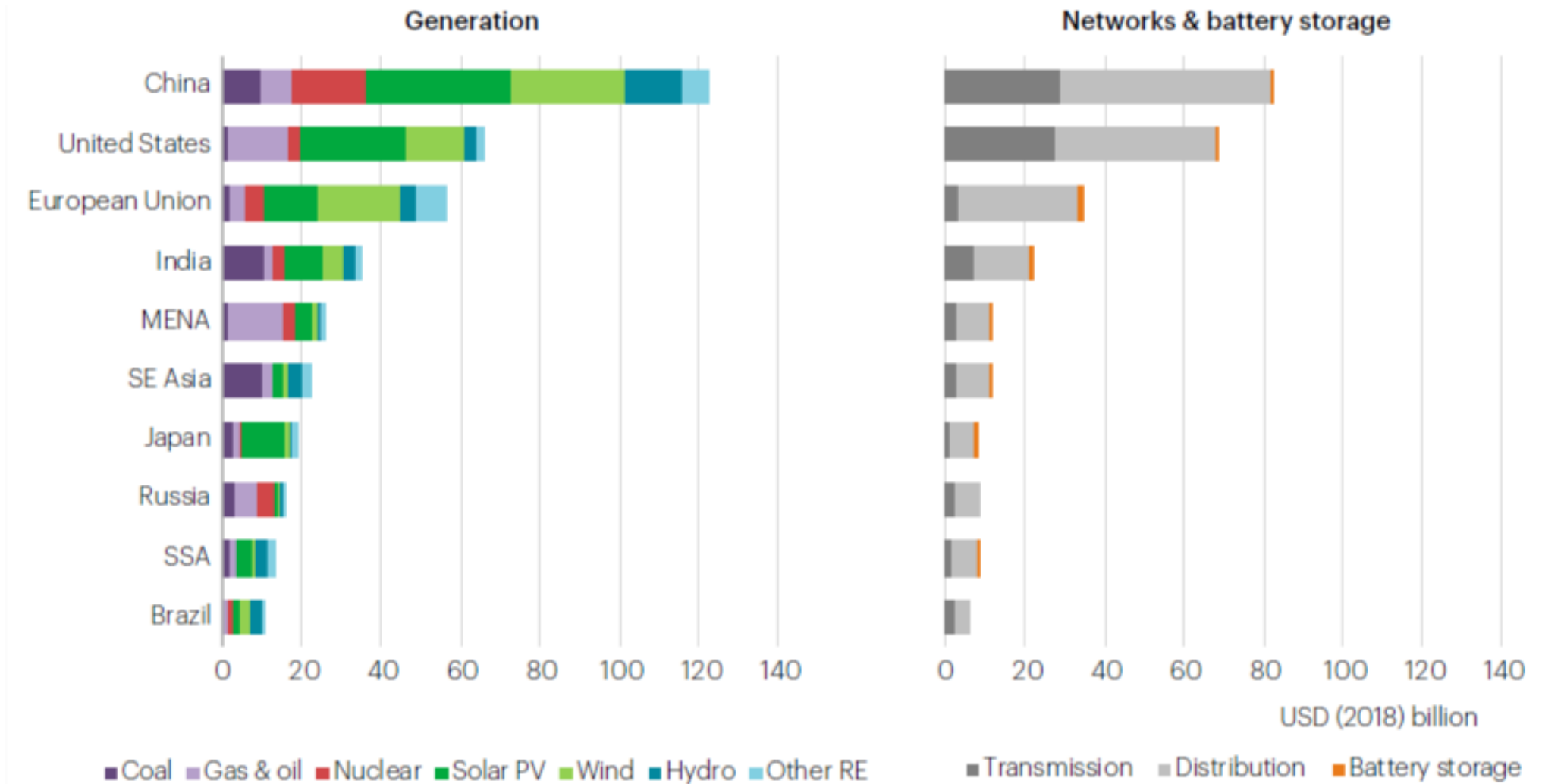
| <b>Technology</b>             | <b>Median</b> | <b>Technology</b>           | <b>Median</b> |
|-------------------------------|---------------|-----------------------------|---------------|
| Coal                          | 820           | Geothermal                  | 38            |
| Biomass co-fired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

*Arranged by decreasing median values. In gCO<sub>2</sub>eq/kWh*

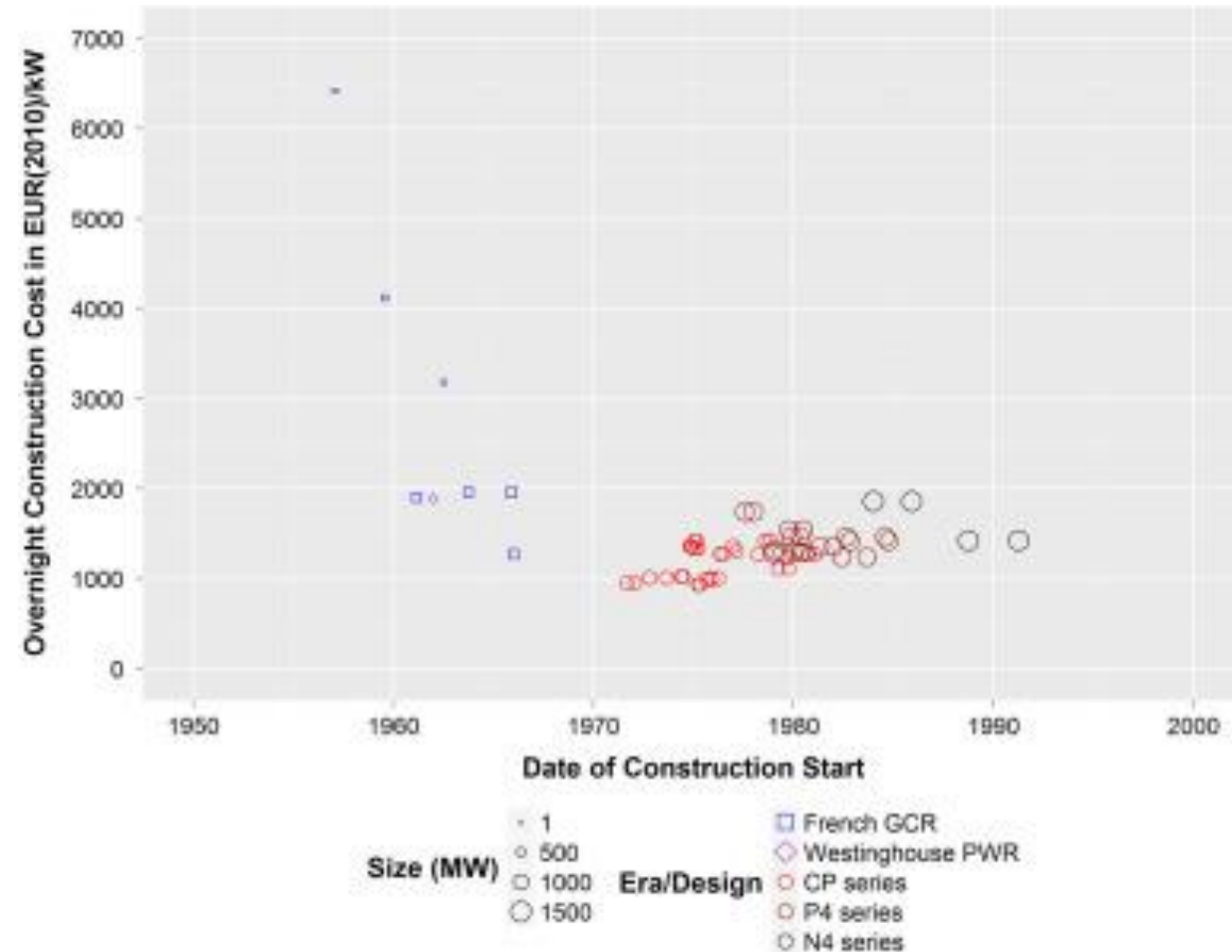
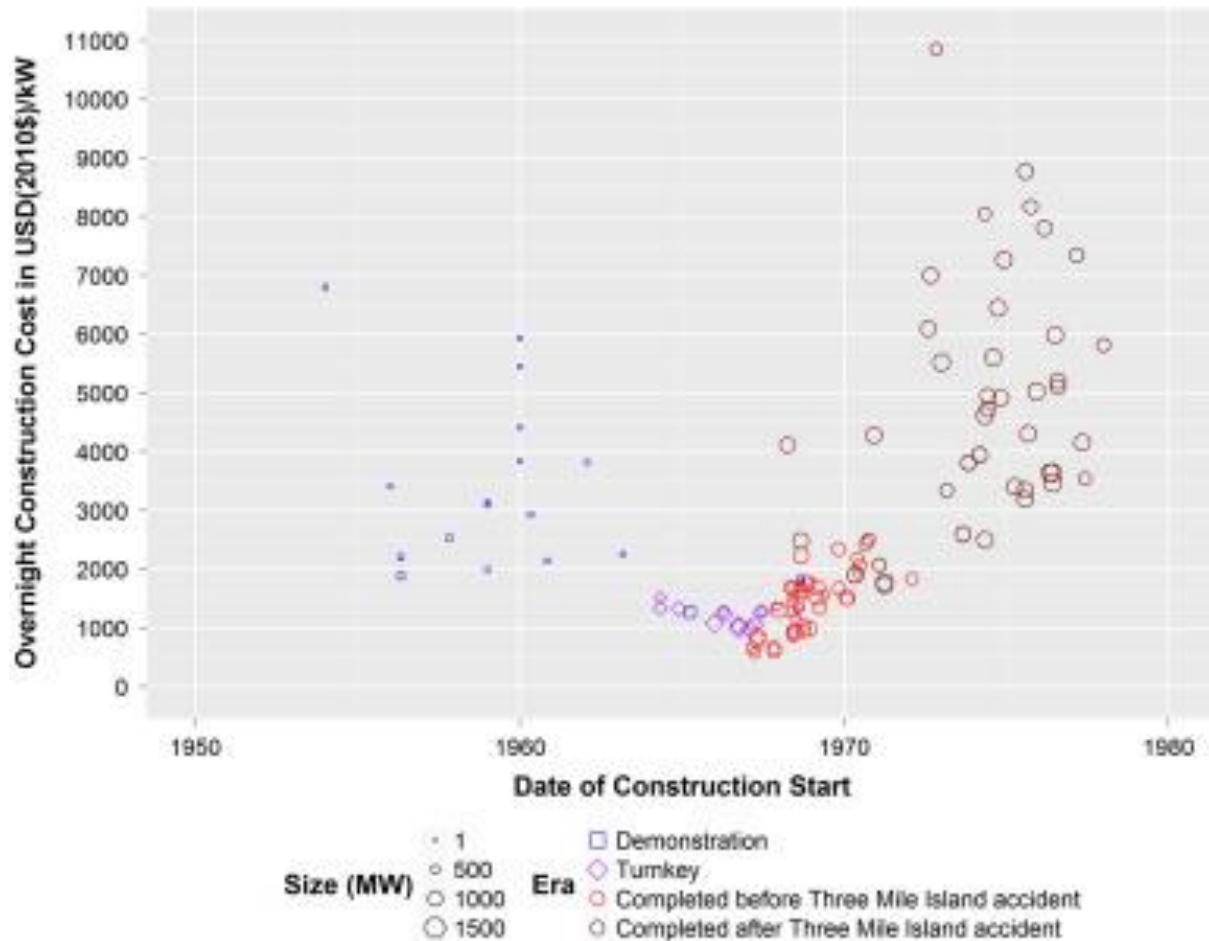
# Energy investments in selected regions, 2015 and 2018



# Investments in power generation, 2018



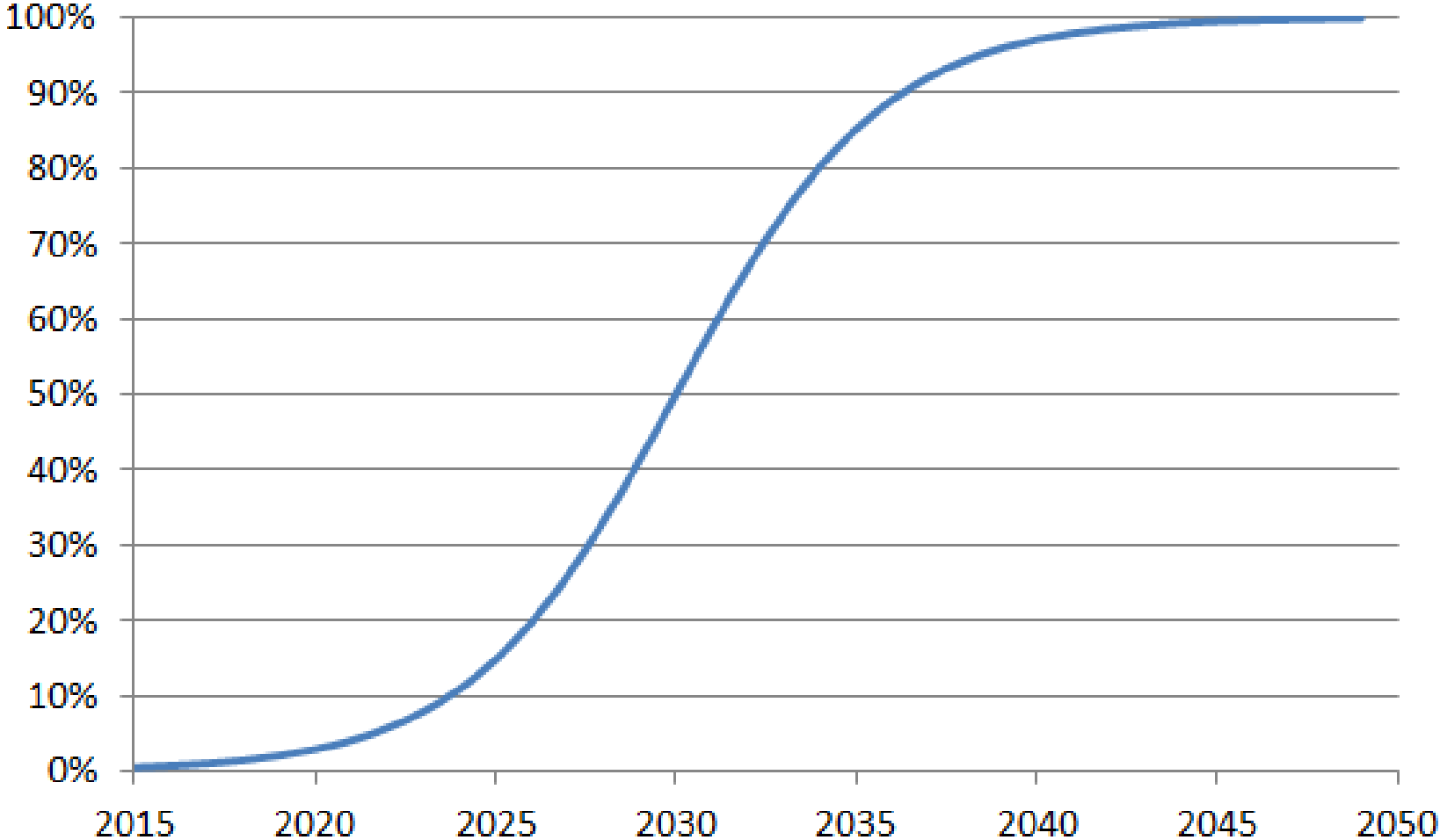
# Overnight construction costs (OCC) in 2015USD/kW, USA (left) and France (right)



# Learning curve

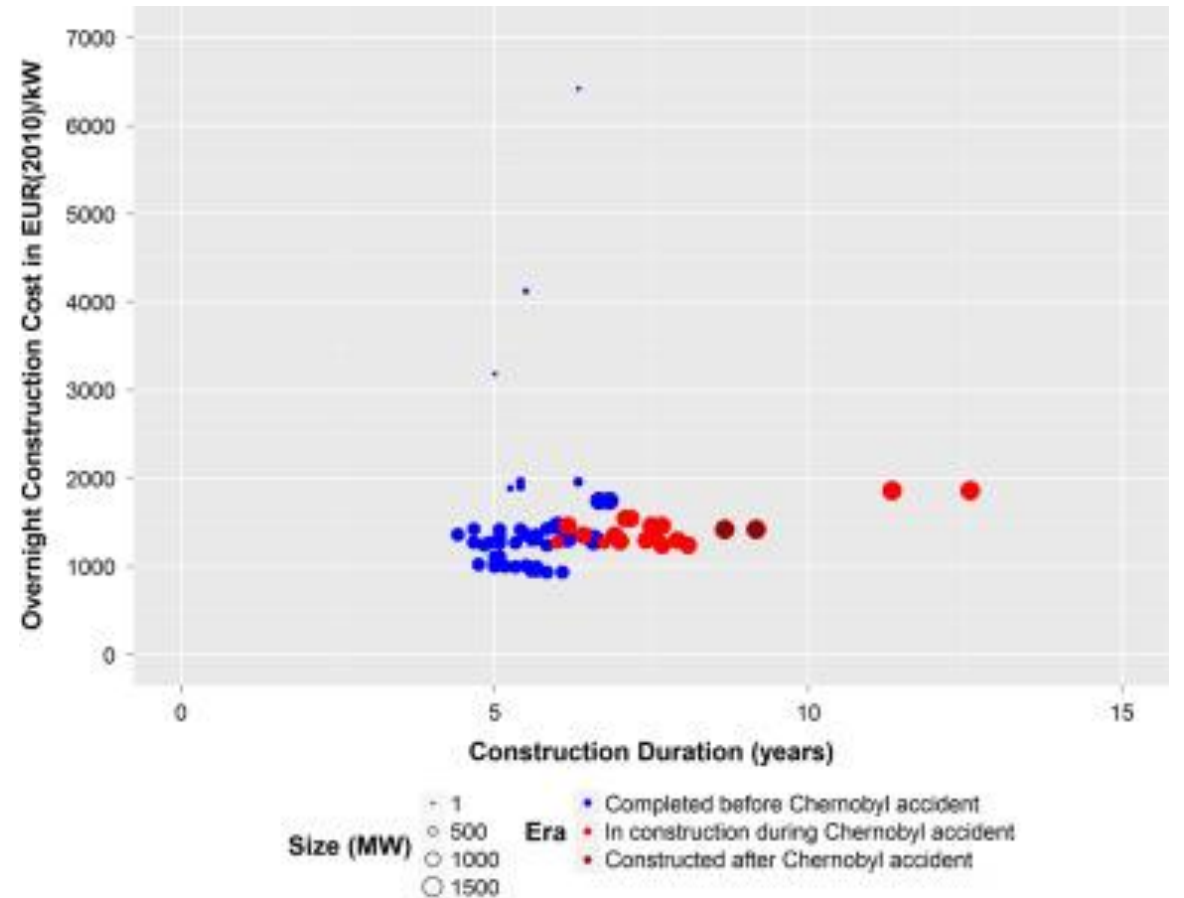
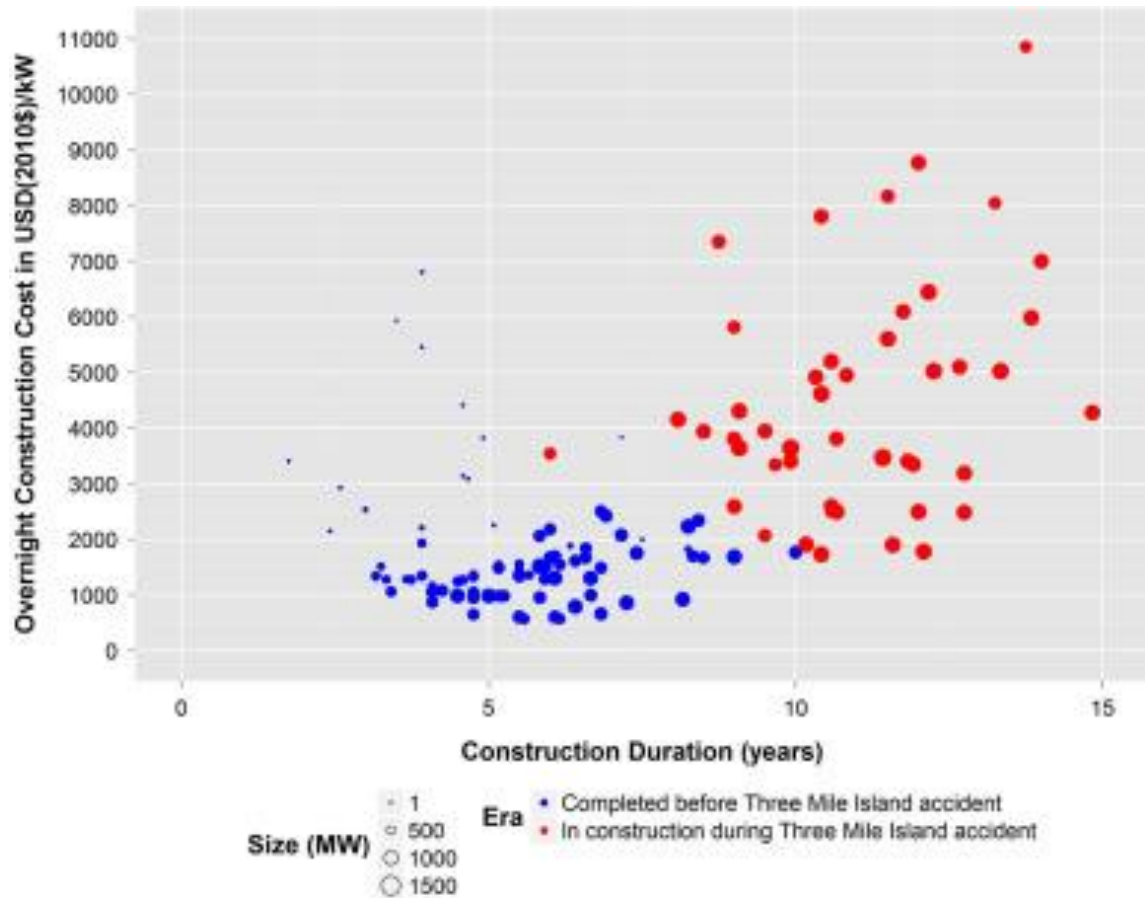
- Decreasing costs due to:
  - Research and development itself.
  - Learning by doing – a byproduct of manufacturing and deployment, with companies incrementally improving industrial operations, installation procedures, sales, and financing processes.
  - Economy of scale – companies and industries getting 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

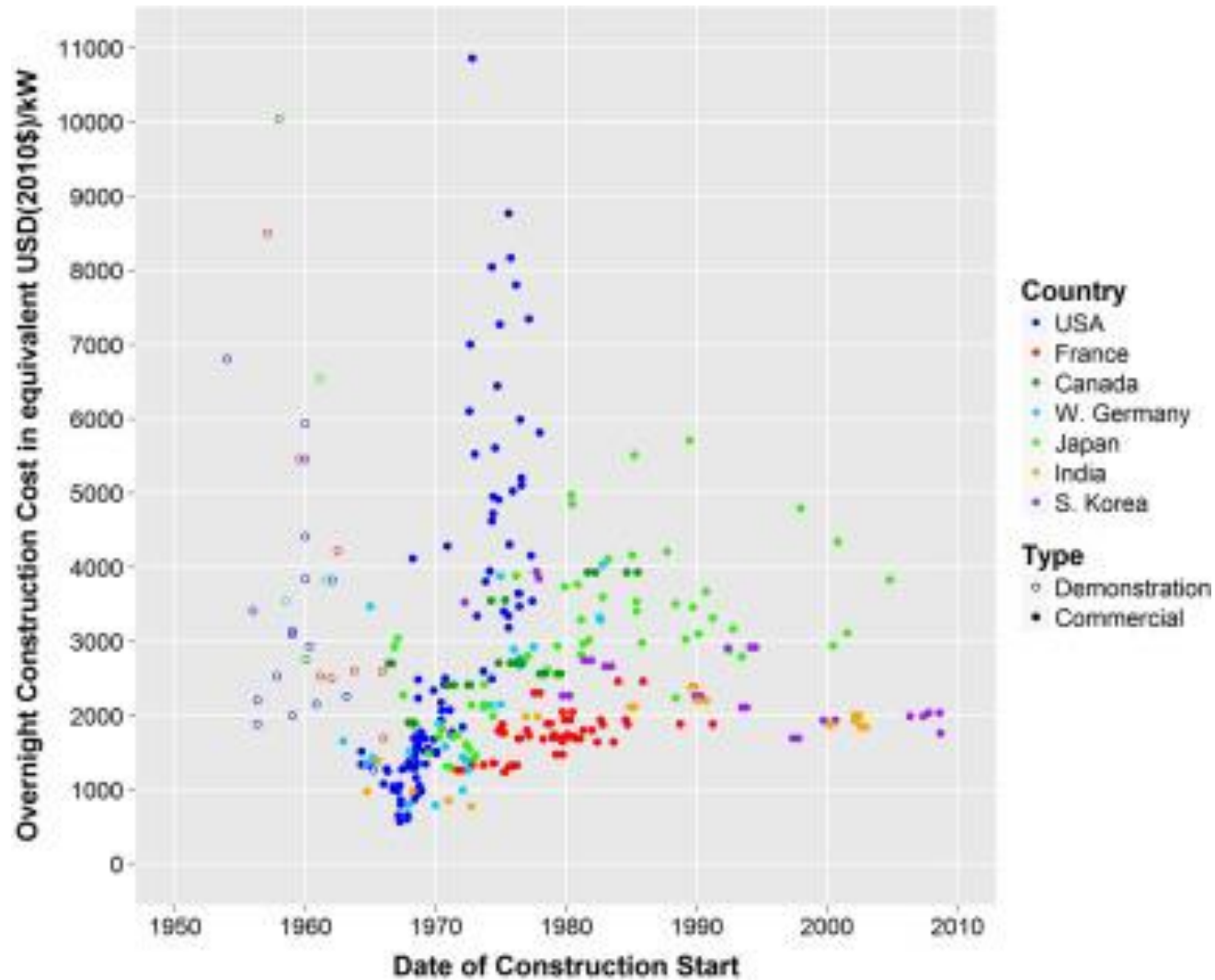




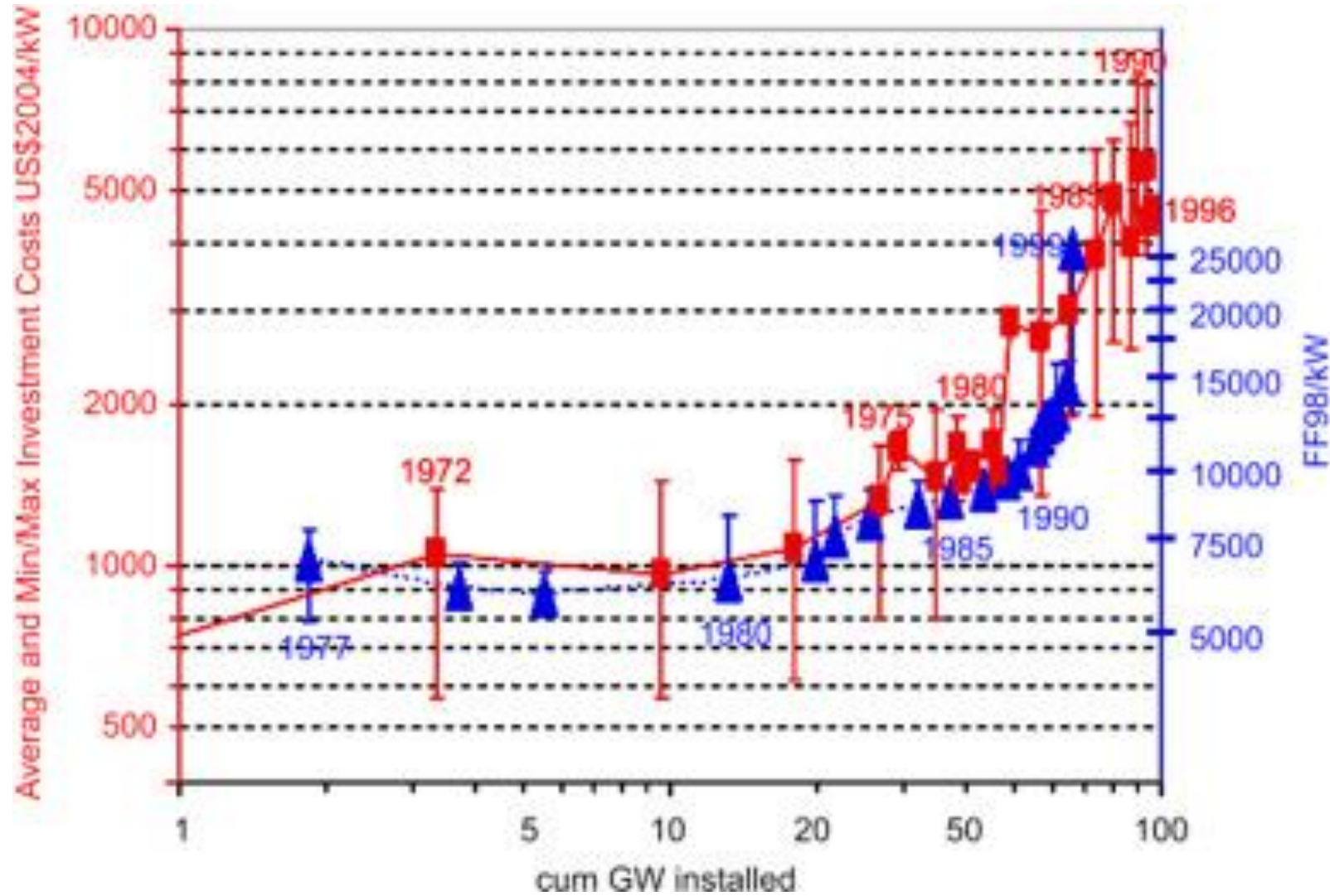
# Construction duration, USA and France



# OCC of global nuclear reactors in USD2010

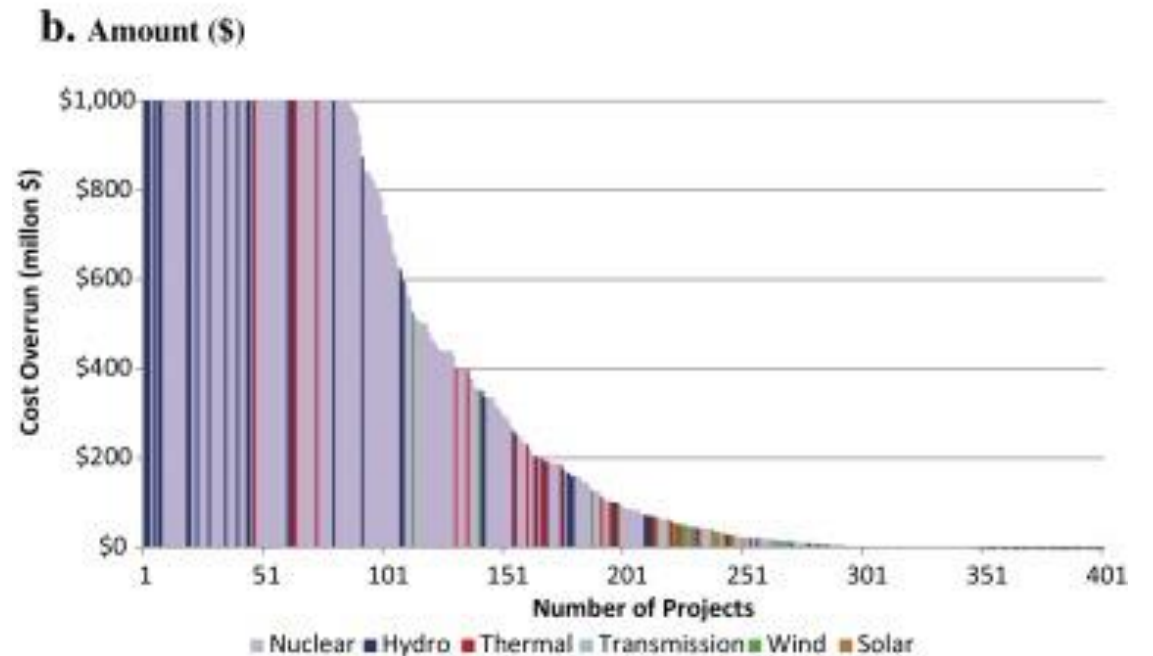
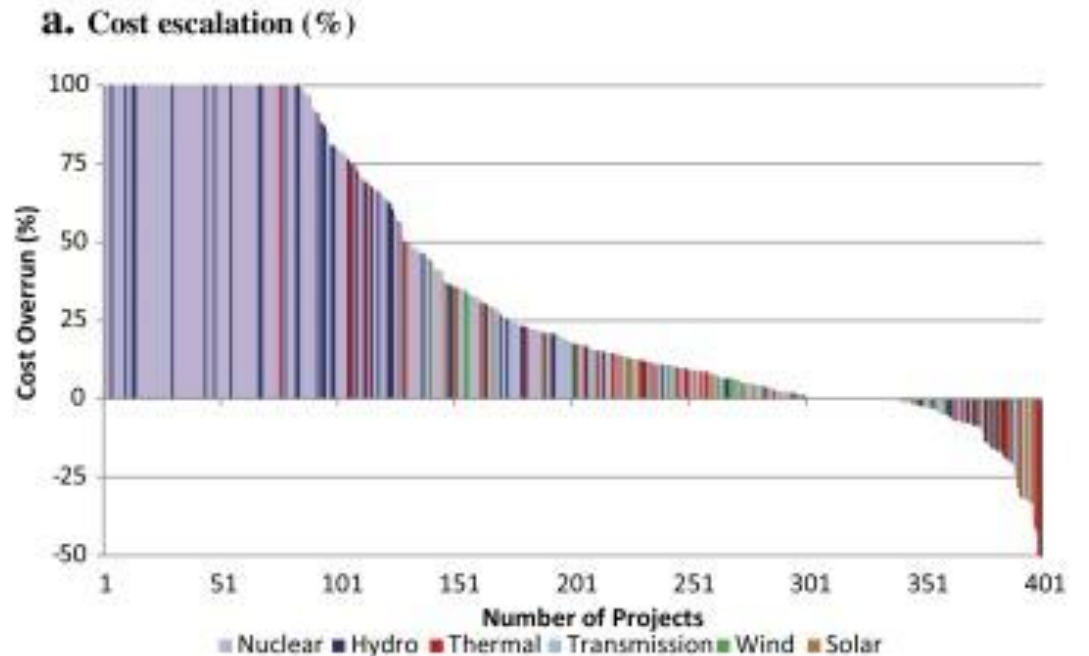


# Experience curve of USA/Fr NPPs

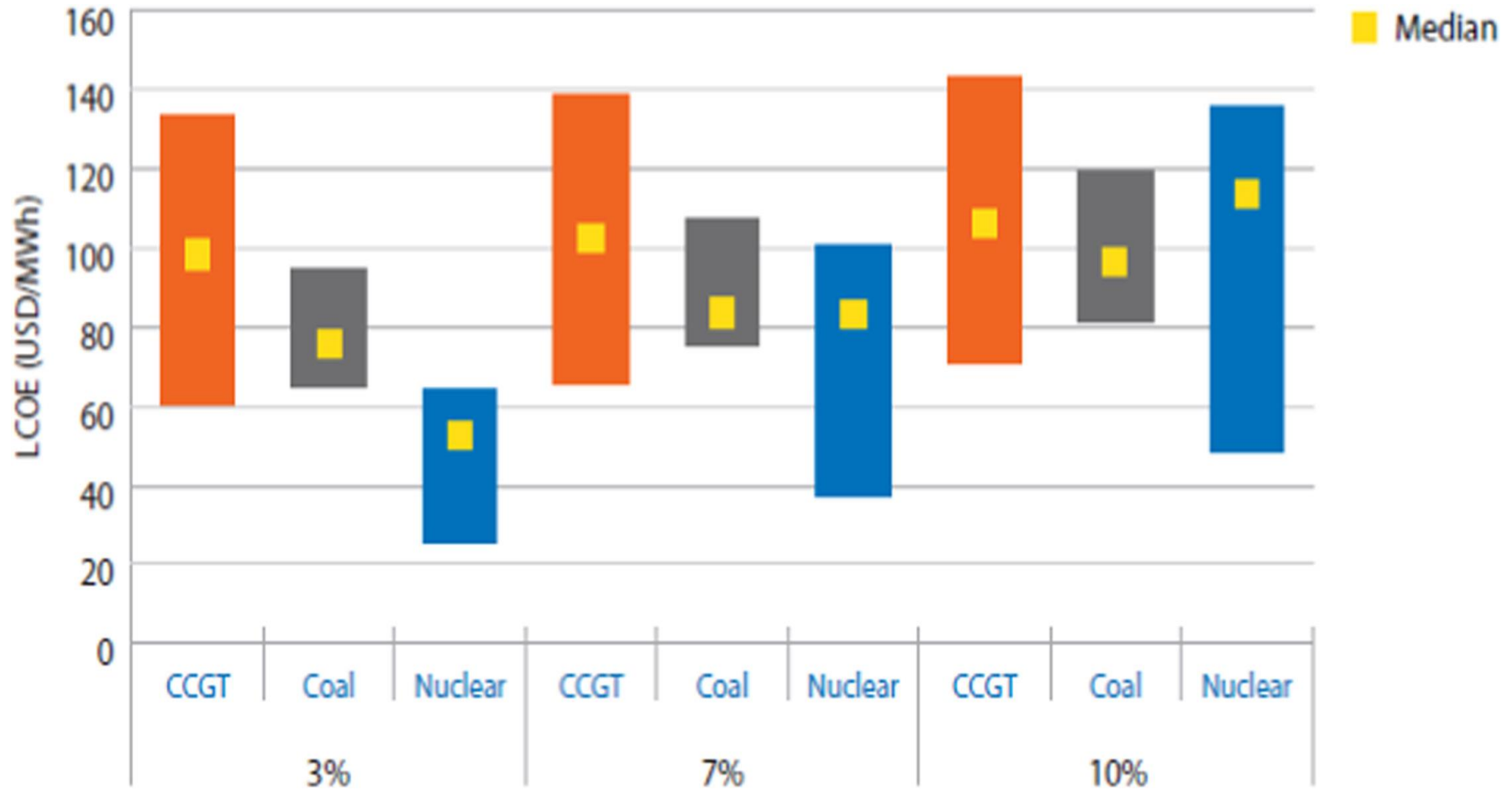


# Distribution of construction overrun costs by technology

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



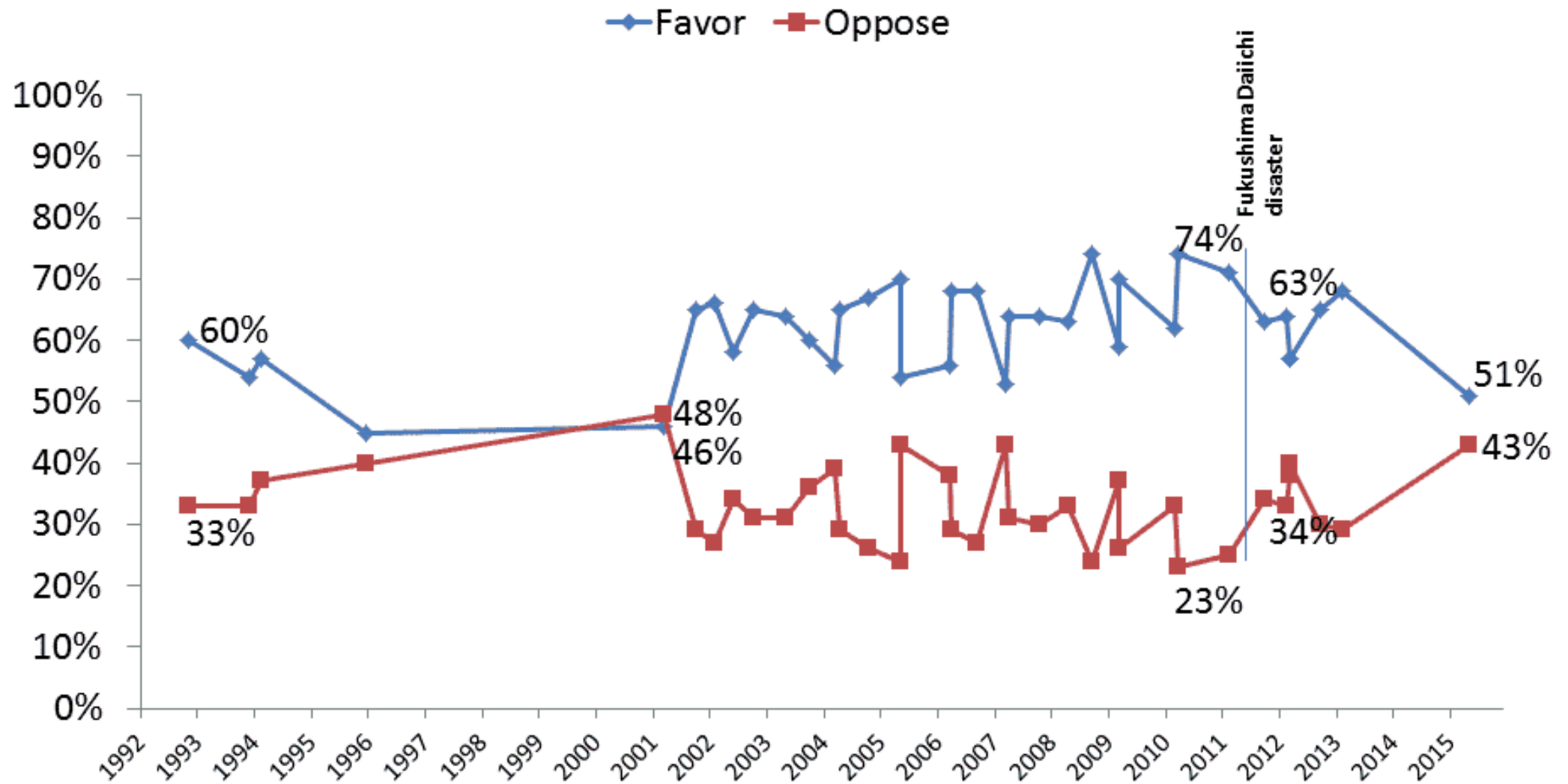
# LCOE for base load technologies, at different discount rates



# 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.

# Favor or oppose the use of nuclear energy as one of the ways to provide electricity in the United States



| Strongly positive  | Positive        | Neutral   | Rather negative | Strongly negative |
|--------------------|-----------------|-----------|-----------------|-------------------|
| Finland            | UK              | Luxemburg | Greece          | Ireland           |
| France             | The Netherlands | Denmark   | Sweden          | Germany           |
| Slovakia           | Estonia         |           | Belgium         | Austria           |
| Romania            | Portugal        |           |                 | Italy             |
| Bulgaria           | Poland          | -         | Latvia          | Malta             |
| The Czech Republic | Slovenia        | -         | Lithuania       | Cyprus            |
| Hungary            |                 |           | Spain           | -                 |
|                    |                 | -         | -               | -                 |



# Nuclear phase-outs

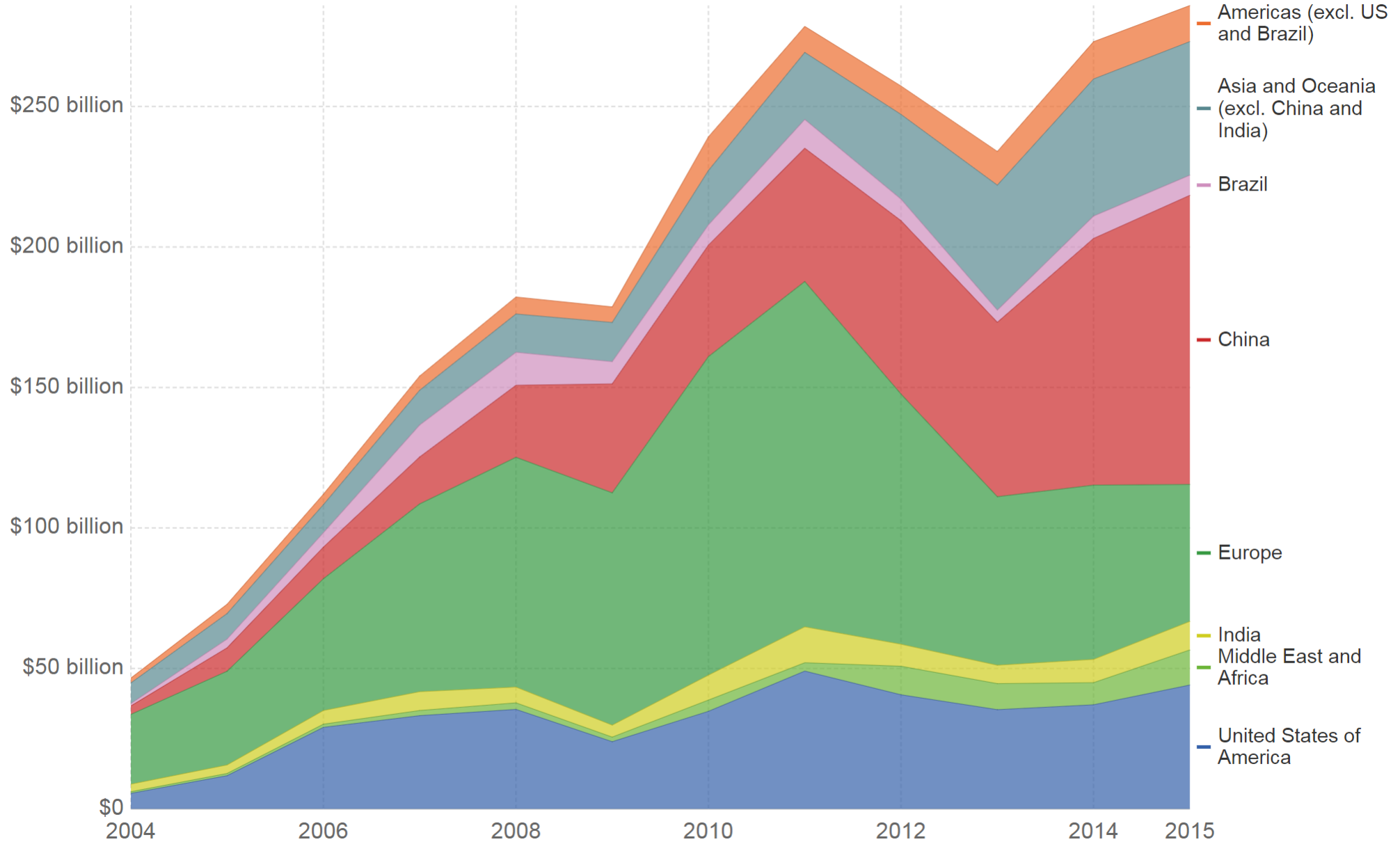
- Austria – 1997
- Germany – 2011
- Italy – 1987 (after Chernobyl)
- Sweden - 1980 (after Three Mile Island), renounced in 2010.
- New Zealand – 1987
- ...
- ...

# Position of nuclear in the EU

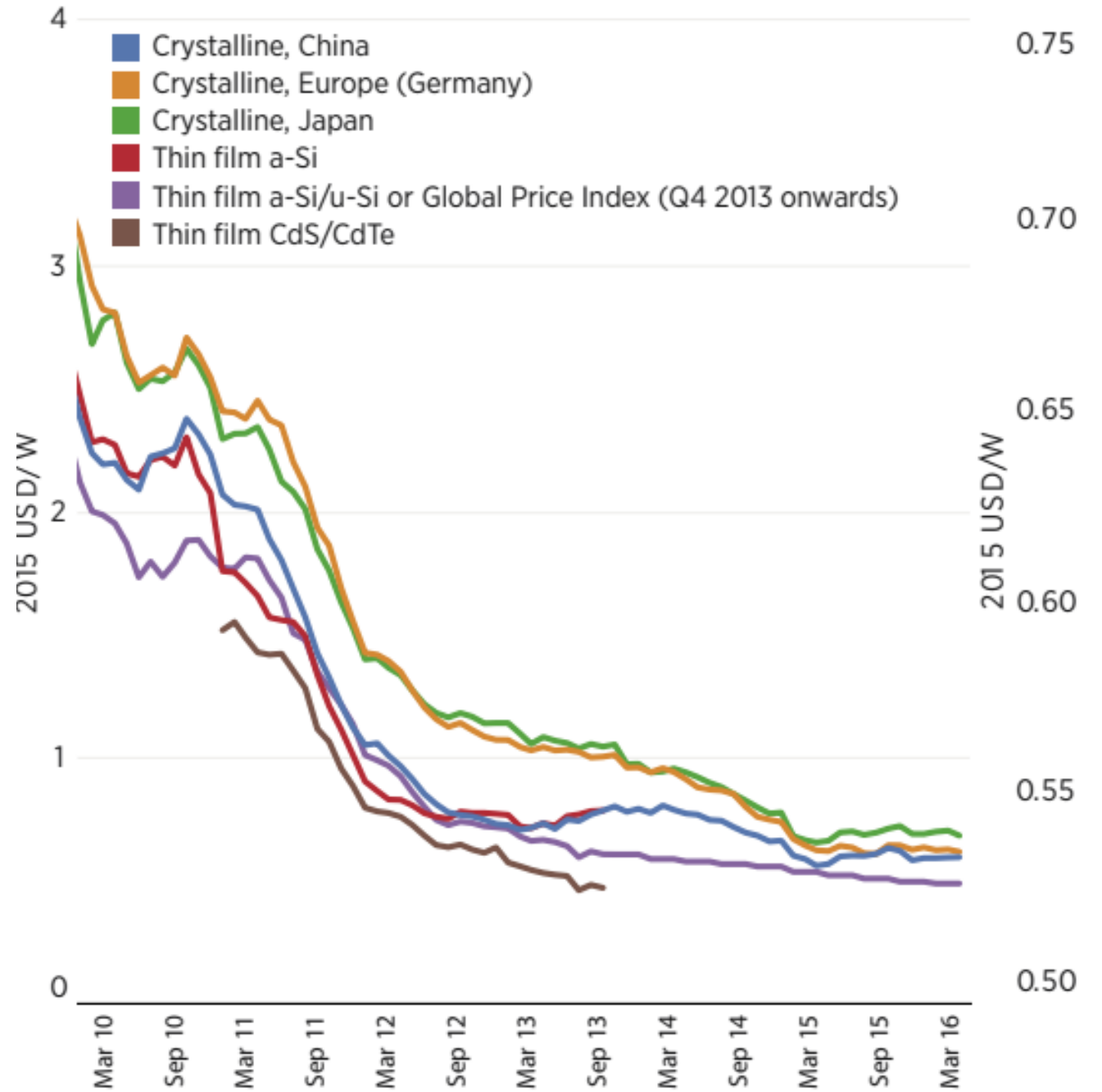
- Liberalized market emphasizes less risky and shorter investments.
- Limited role of the governments in energy.
- Public scepticims on the nuclear technology.
- Pricing of elektricity not able to valuate the reliability and predictability of sources.
- European companies (AREVA/EdF) absent in global investments.
  
- Vs. some investment in developing world.

# Renewable Energy Investment

Investment in renewable energy technologies per year in billion US dollars by region.

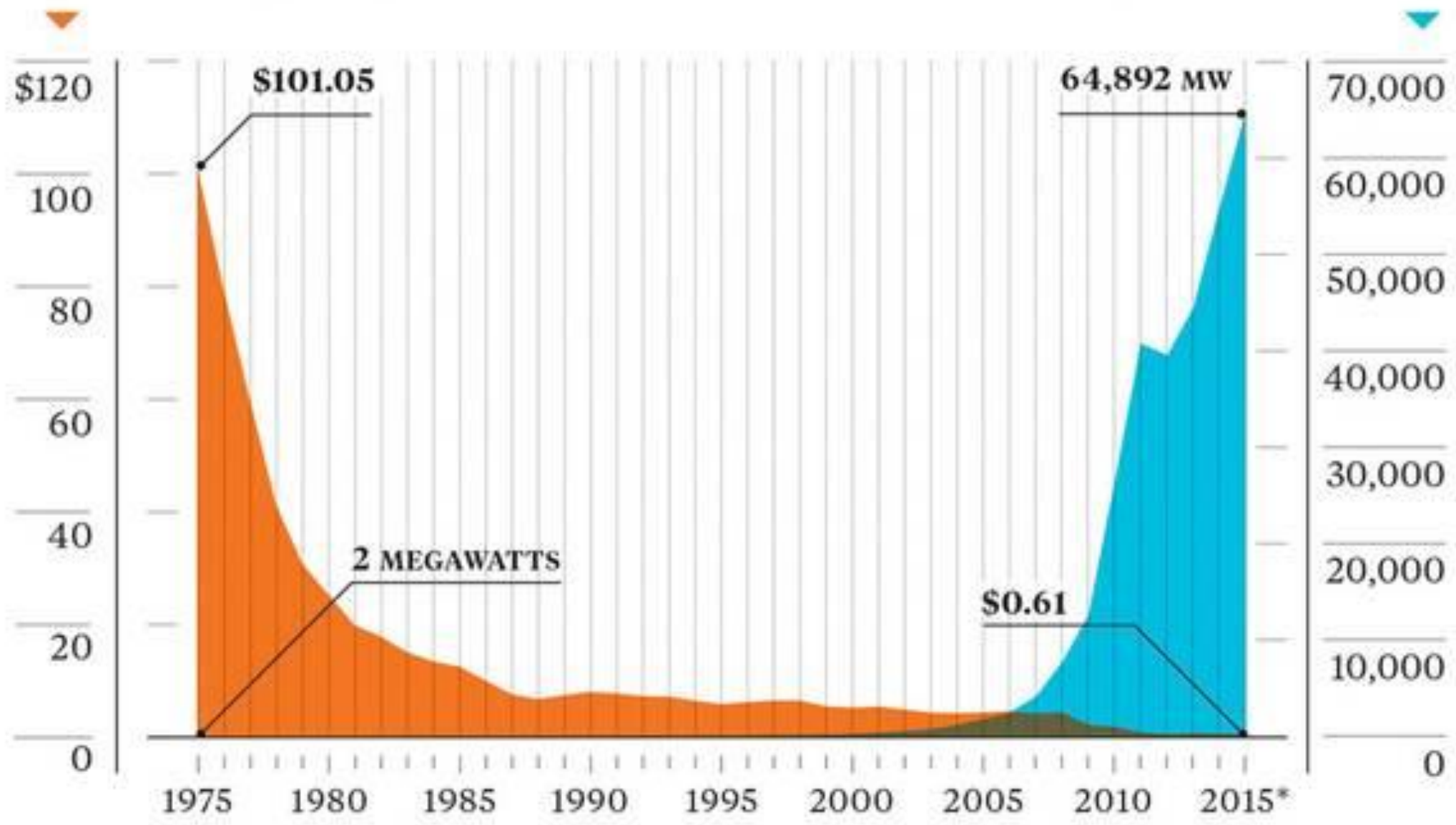


# Global PV module price trends 2009-2016

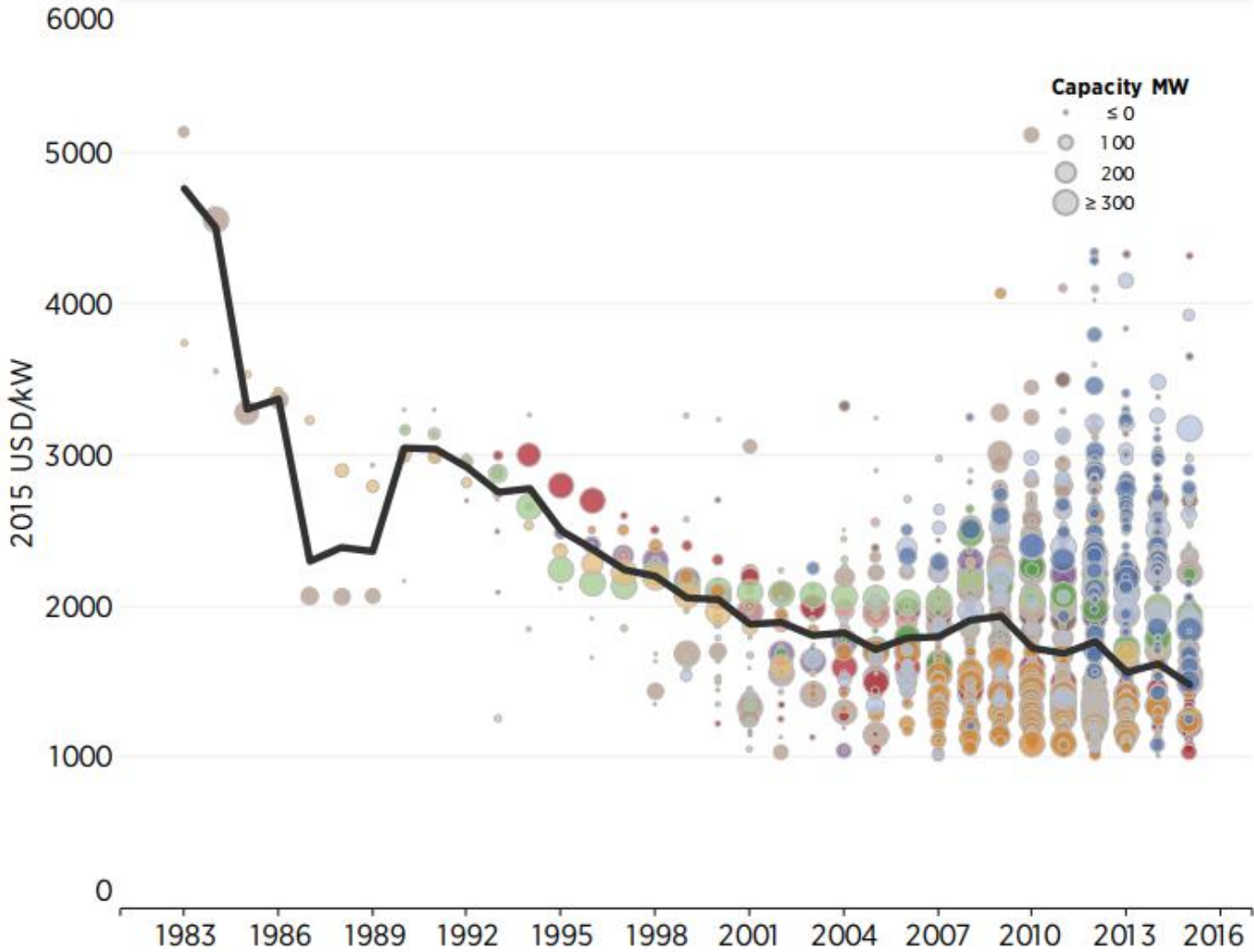


Price of a solar panel per watt

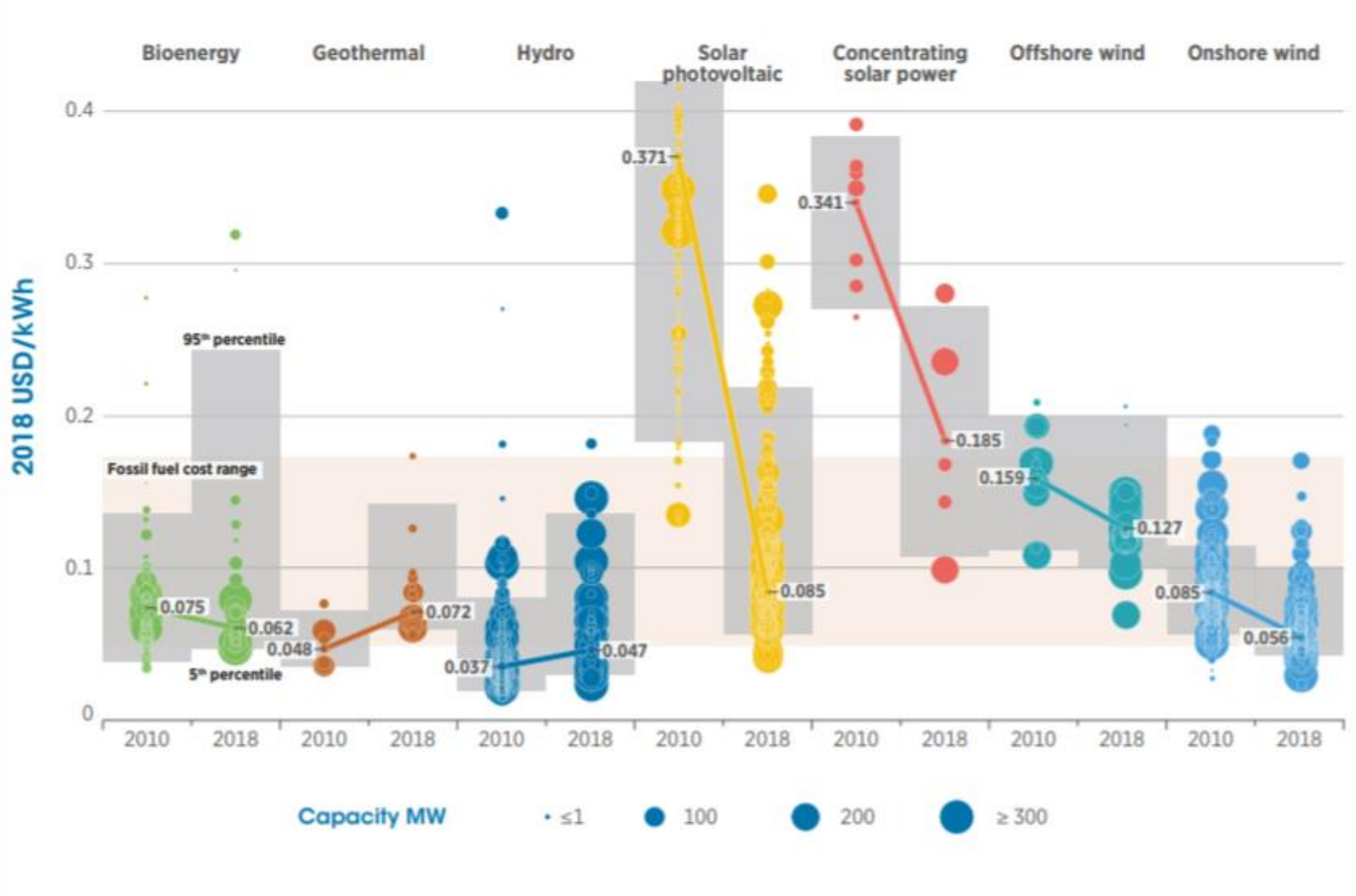
Global solar panel installations



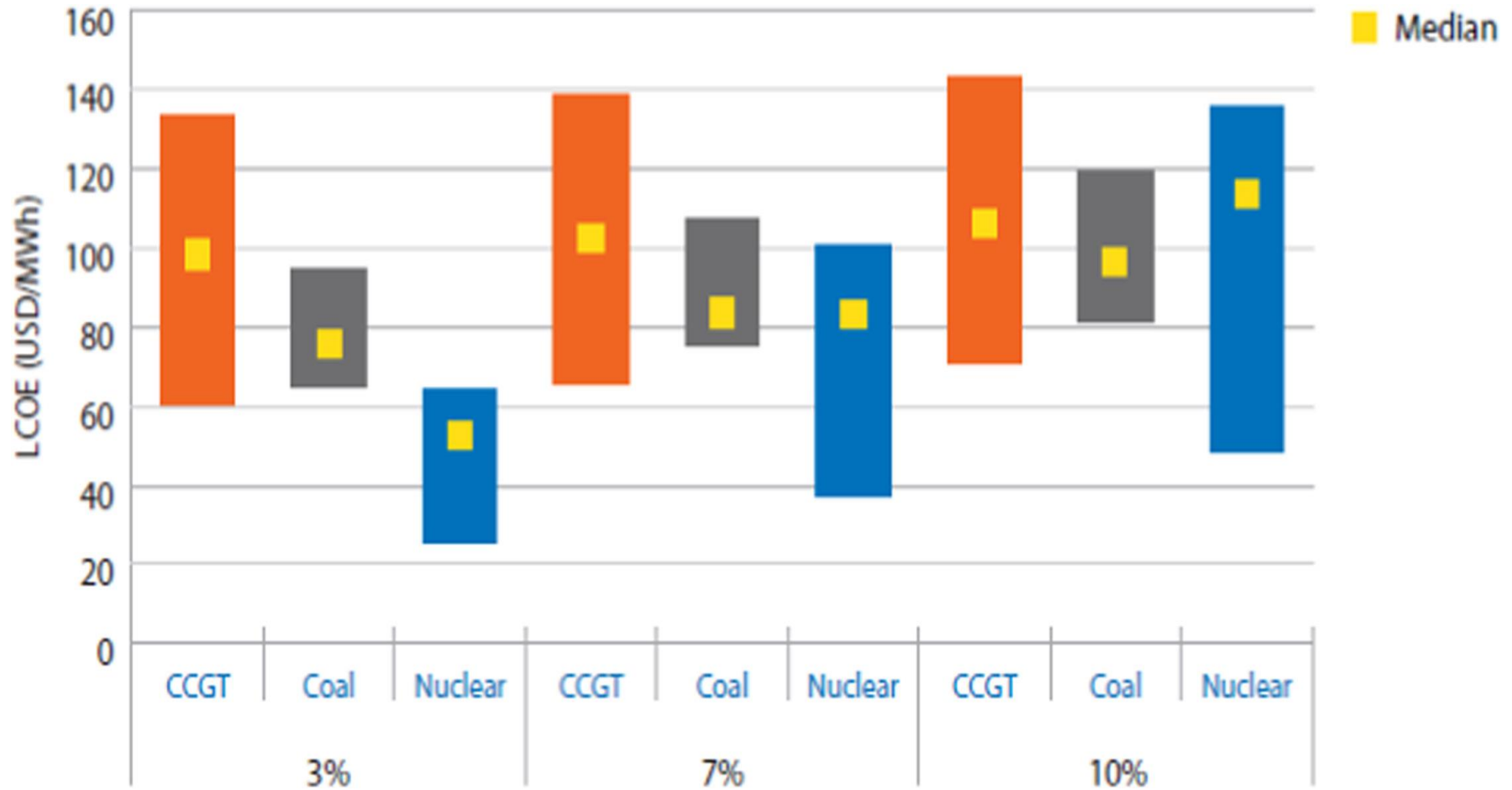
# Total installed costs of onshore wind by country 1983-2014



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

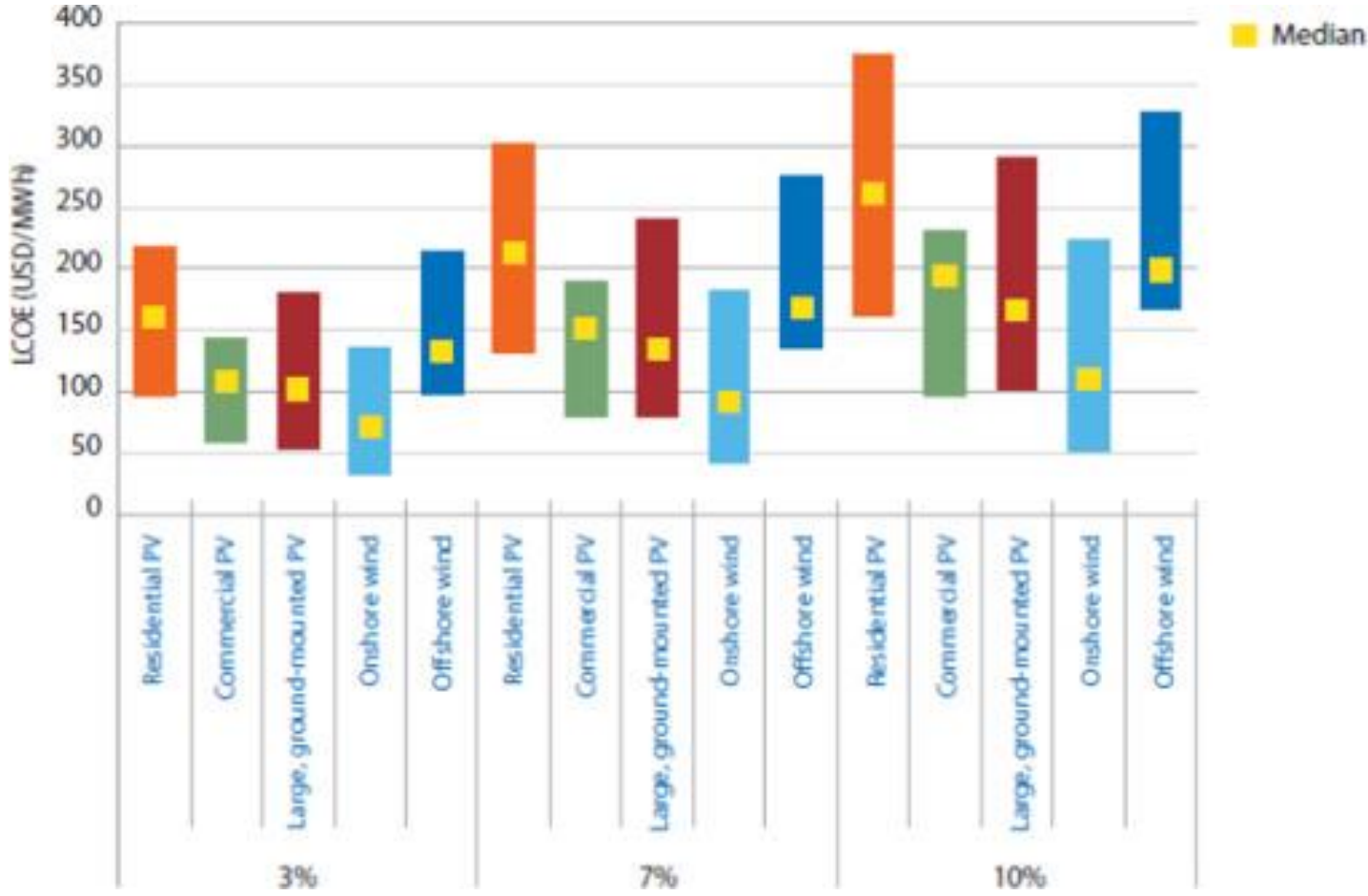


# LCOE for base load technologies, at different discount rates

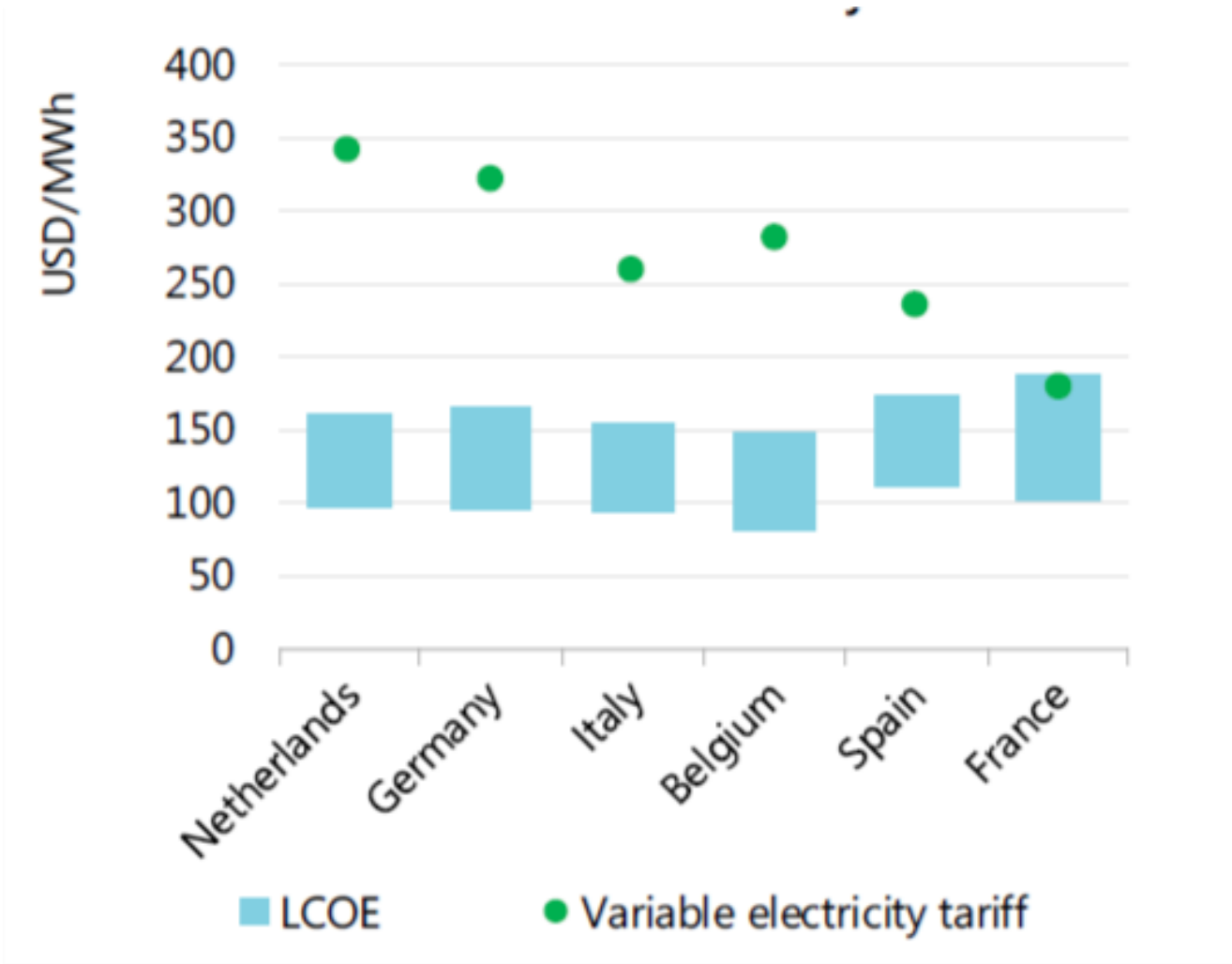




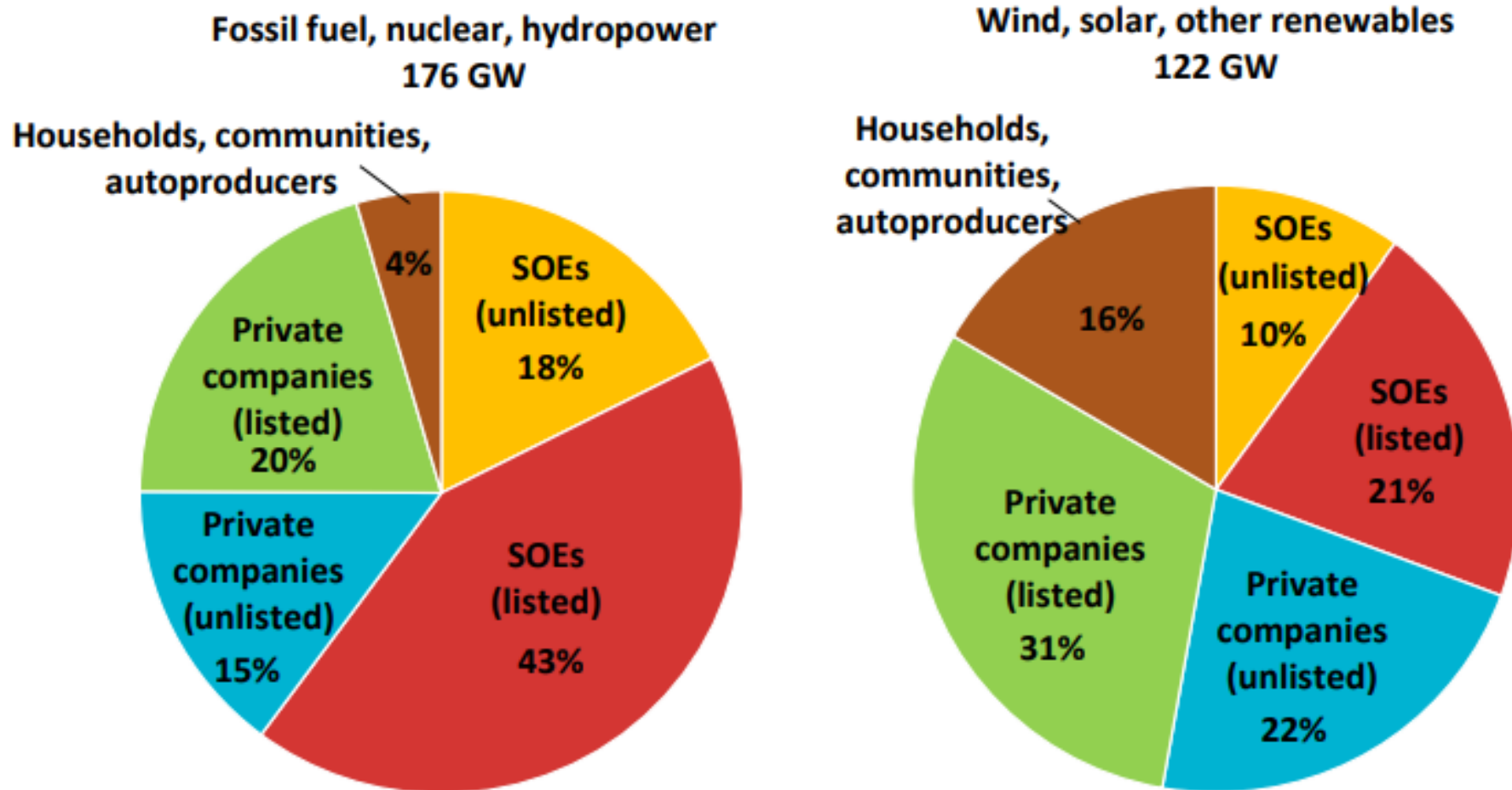
# LCOE for RES technologies, at different discount rates



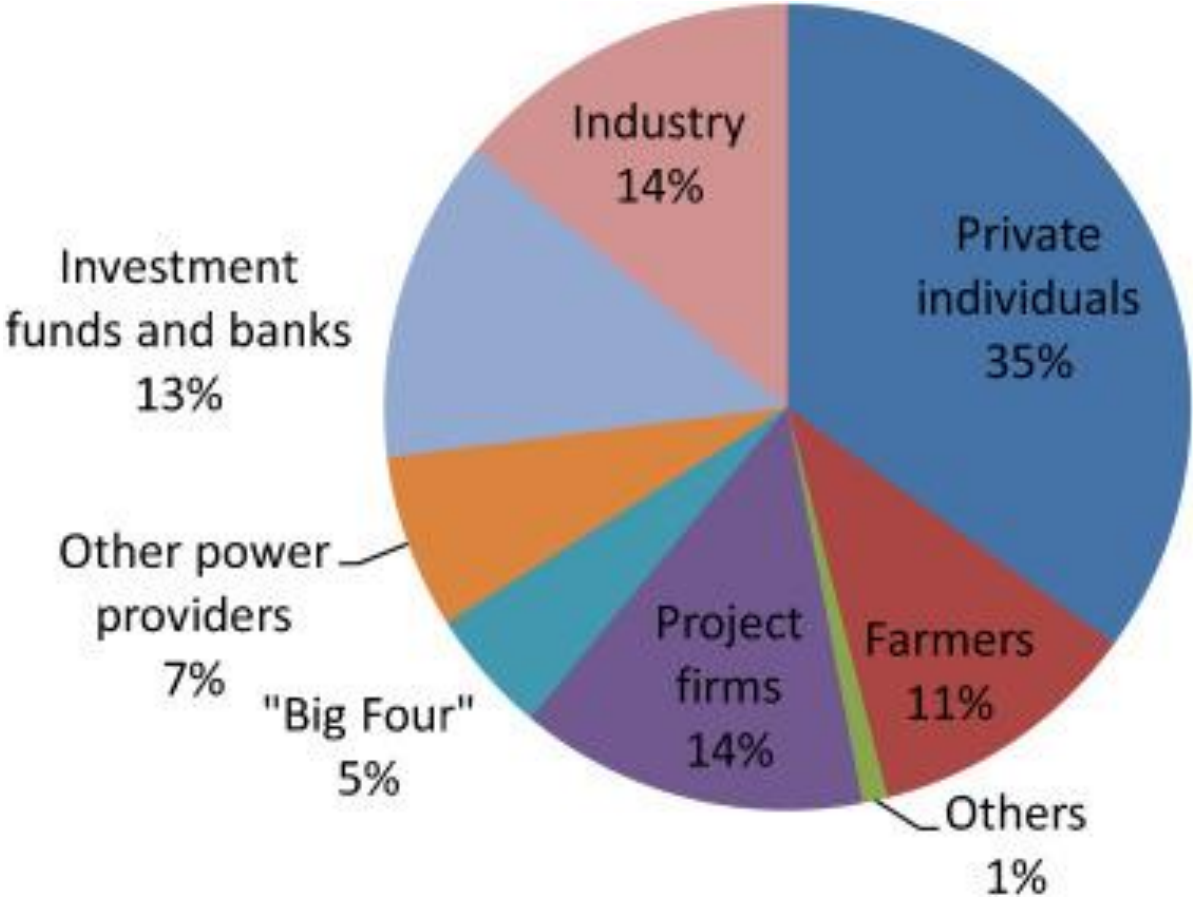
# LCOE vs. variable electricity household tariff



# Ownership of global power generation capacity commissioned in 2015



# Ownership of installed RE capacity in Germany (2012)

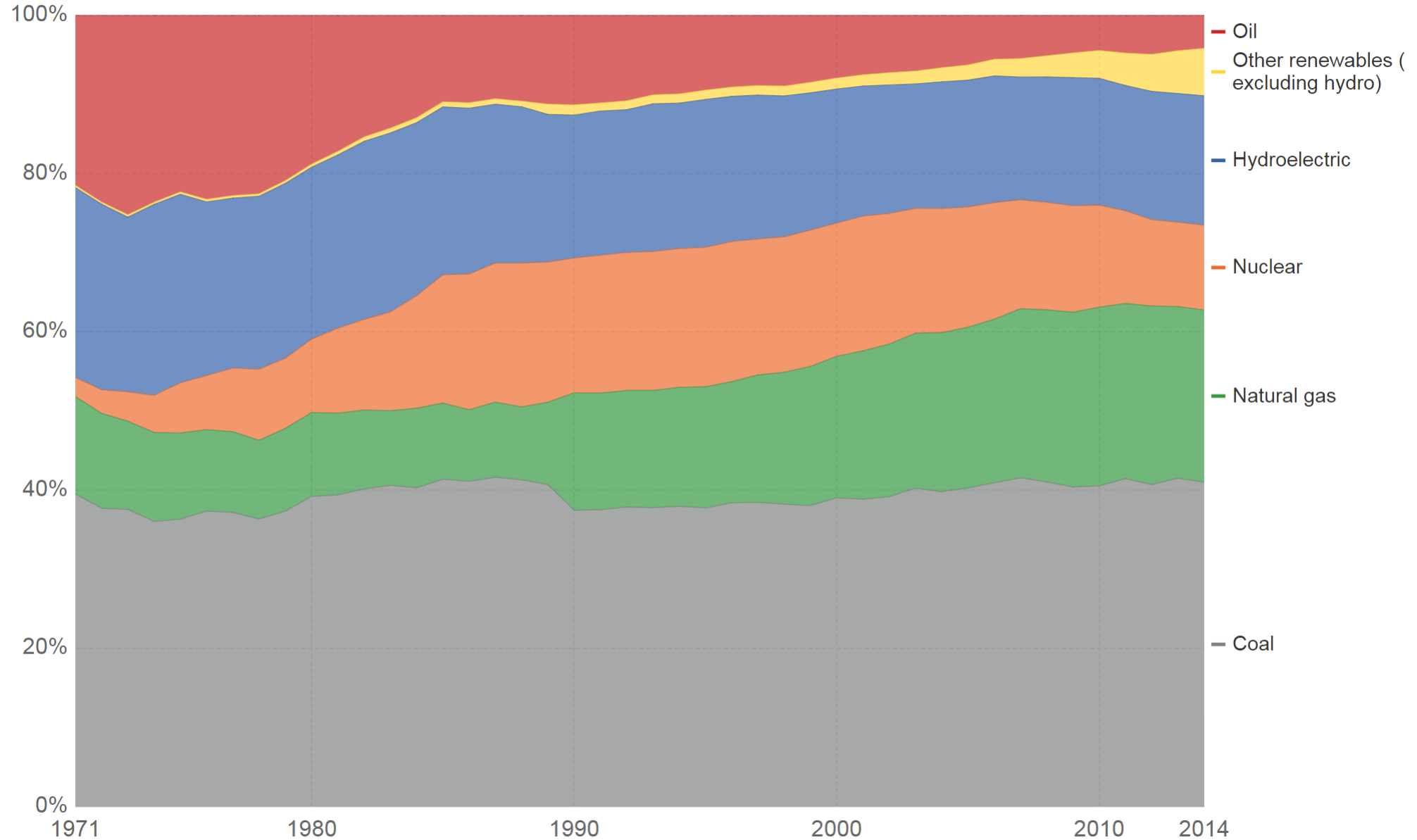


# RES position in the EU

- Smaller unit costs, mechanisms driving prices down (auctioning).
- Positive, albeit changing public acceptance.
- Prosumers.
- Current price mechanisms not capable to accommodate RES.
- Support mechanisms in line with the EU rules.
- Cannibalization of price
- Intermittent production.

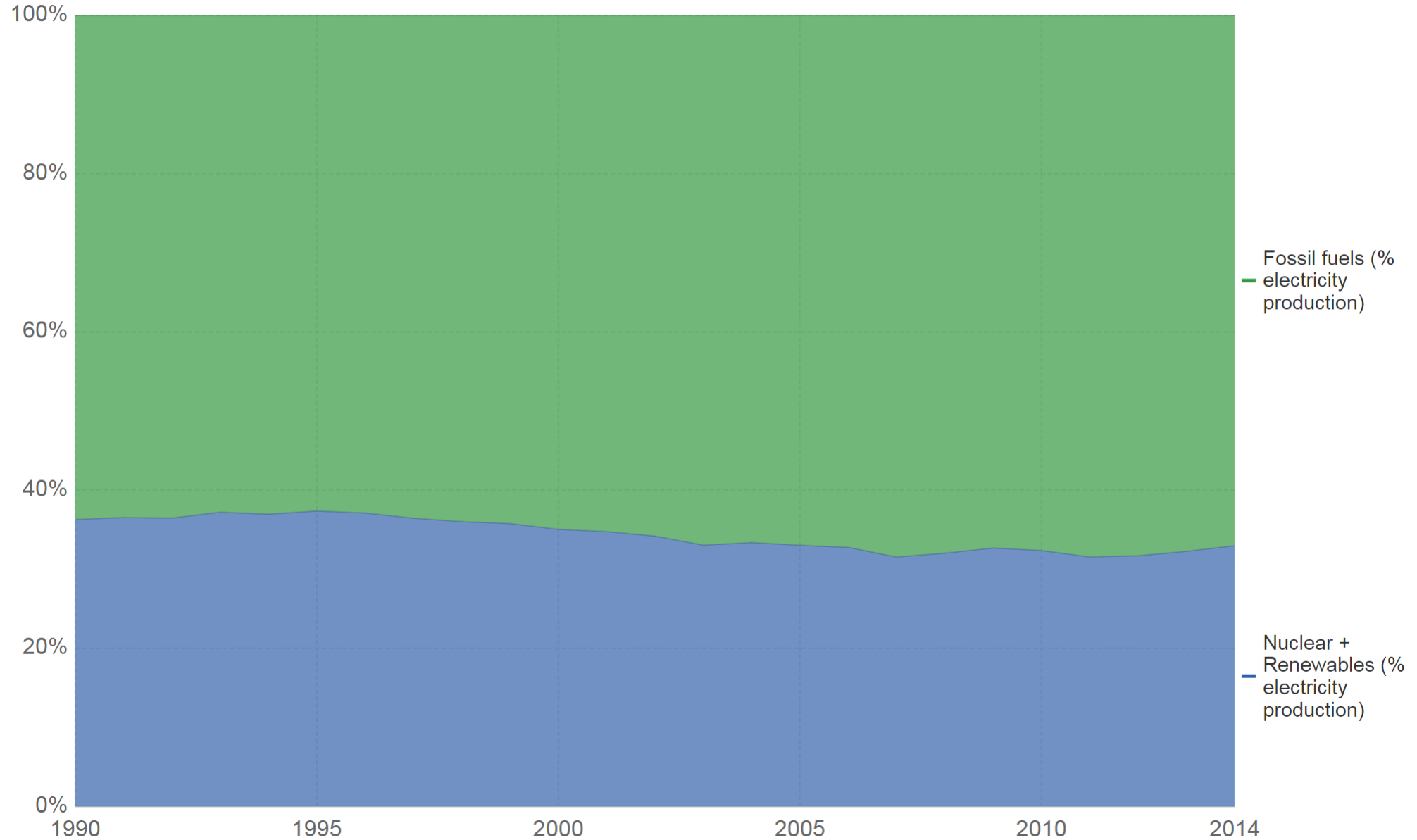
# Electricity share by fuel source, World

Electricity production (measured as the percentage of total electricity production) by source (coal, oil, gas, nuclear, hydroelectric power and other renewables). Other renewables in this definition includes biomass, wind, solar, geothermal, and marine power.



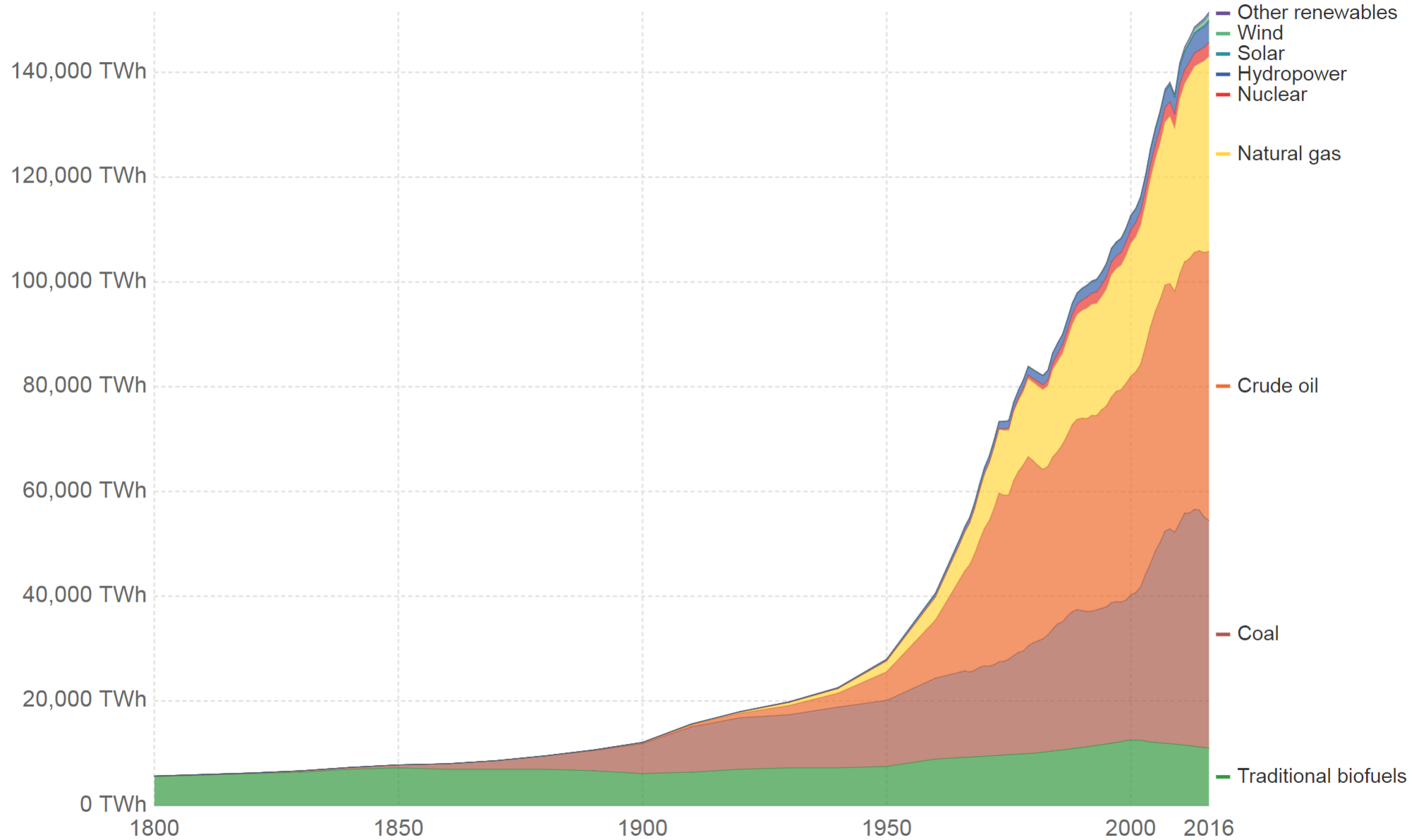
# Global electricity production by source

Global electricity production, measured as the percentage contribution from fossil fuels (coal, oil and gas) and low-carbon sources (nuclear, hydropower, biomass, wind, solar, geothermal and marine power)



# Global primary energy consumption

Global primary energy consumption by source, measured in terawatt-hours (TWh).



Source: Vaclav Smil (2017), Energy Transitions: Global and National Perspectives and BP Statistical Review of World Energy  
OurWorldInData.org/energy-production-and-changing-energy-sources/ • CC BY-SA



# Discussion

- Future of nuclear sources?
- Future of RES?
- Other options?

# Sources

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