

# The development of low carbon energy sources

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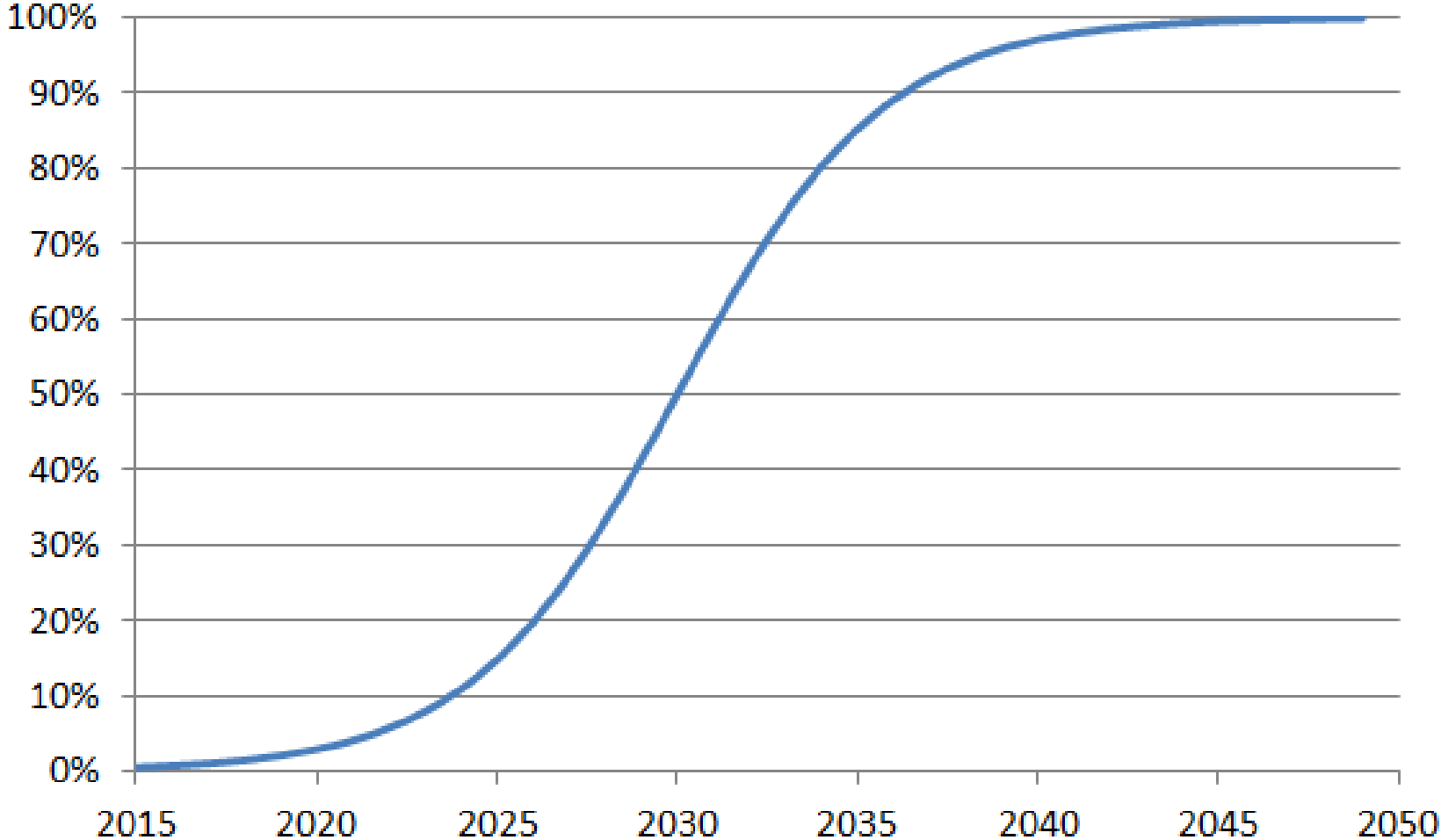
# Decarbonization

- 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) → electricity → ?

# 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

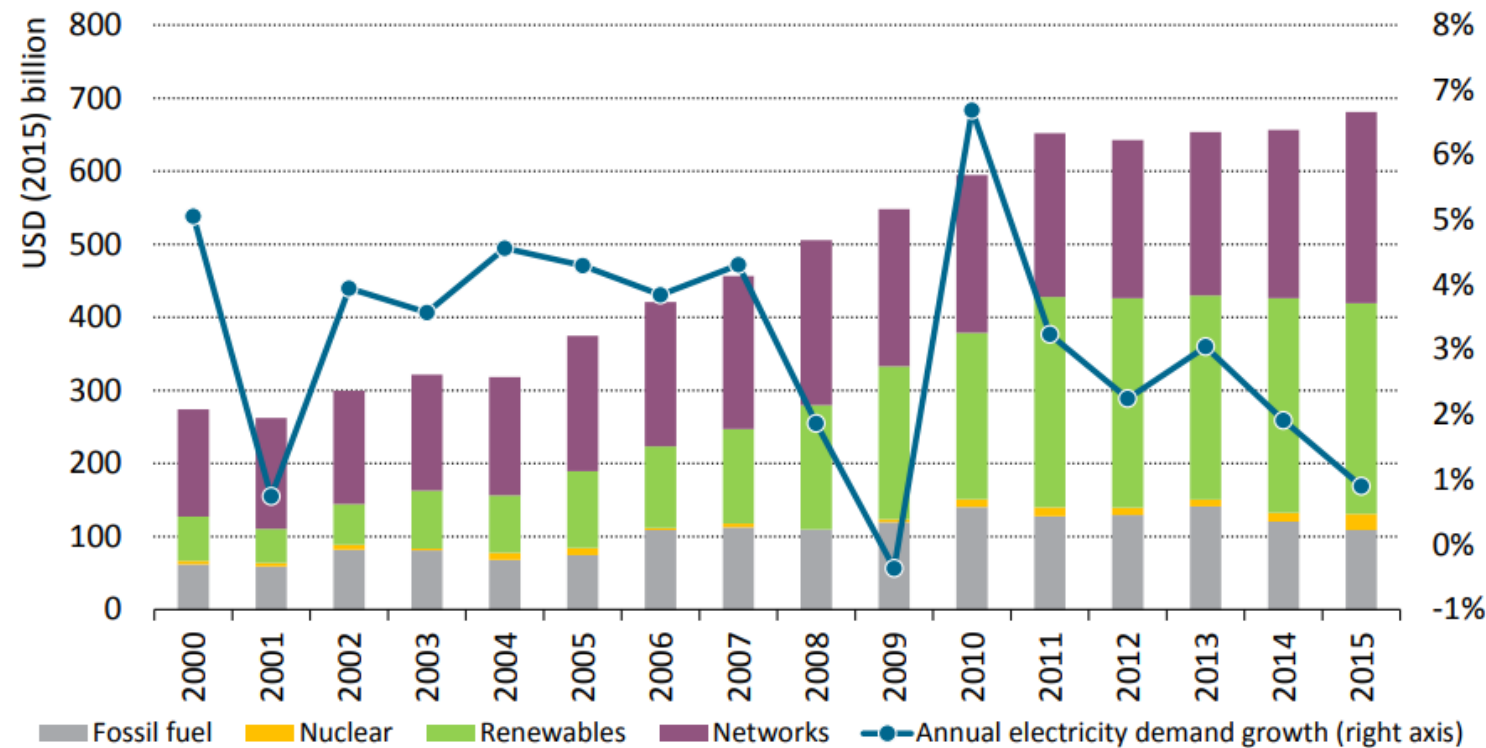


# Life cycle CO<sub>2</sub> equivalent of selected electricity supply technologies

<b>Technology</b>	<b>Median</b>	<b>Technology</b>	<b>Median</b>
Coal	820	Geothermal	38
Biomass co-fired 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

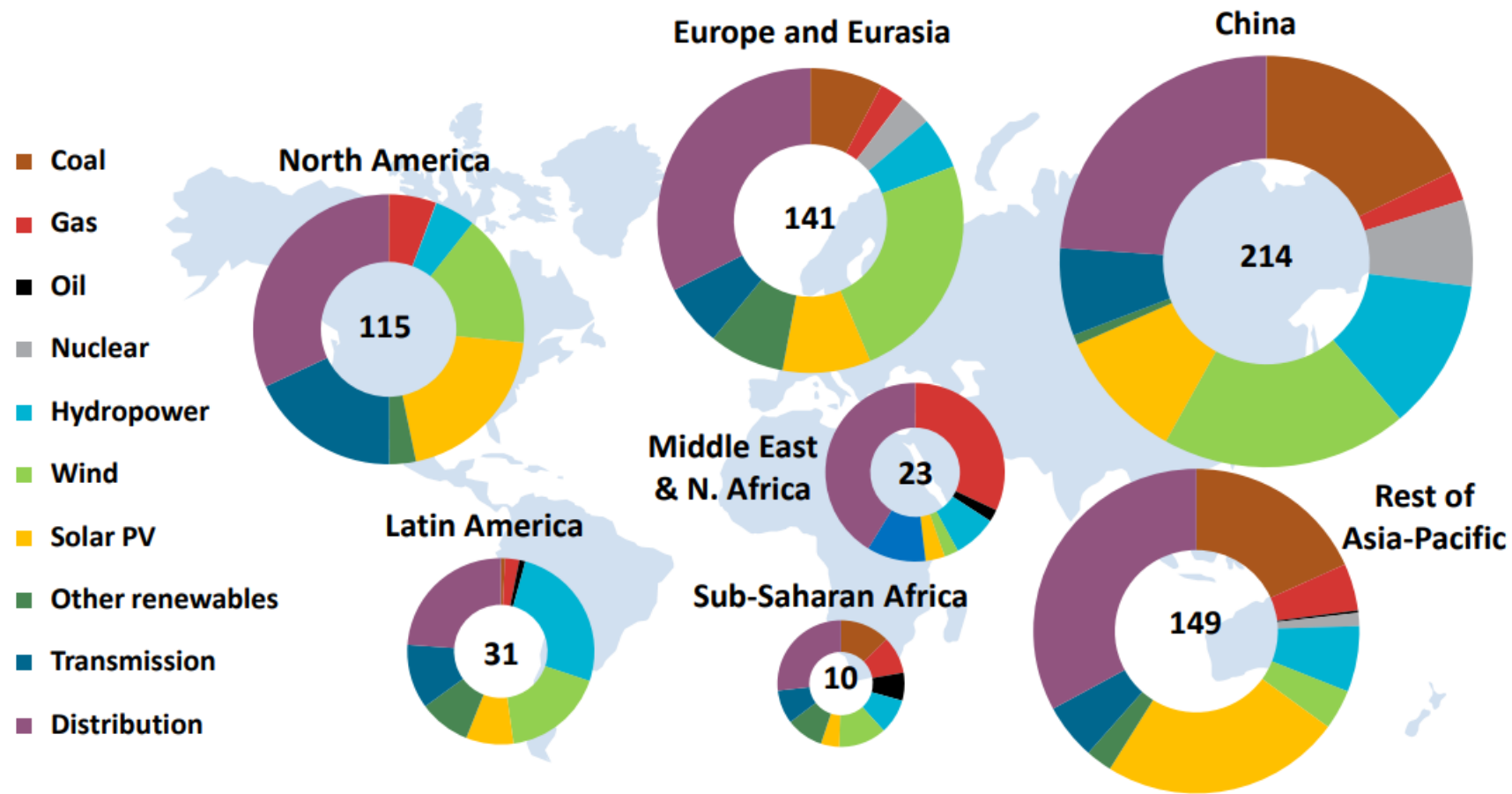
*Arranged by decreasing median values. In gCO<sub>2</sub>eq/kWh*

# Global investments in power generation, electricity networks and demand growth

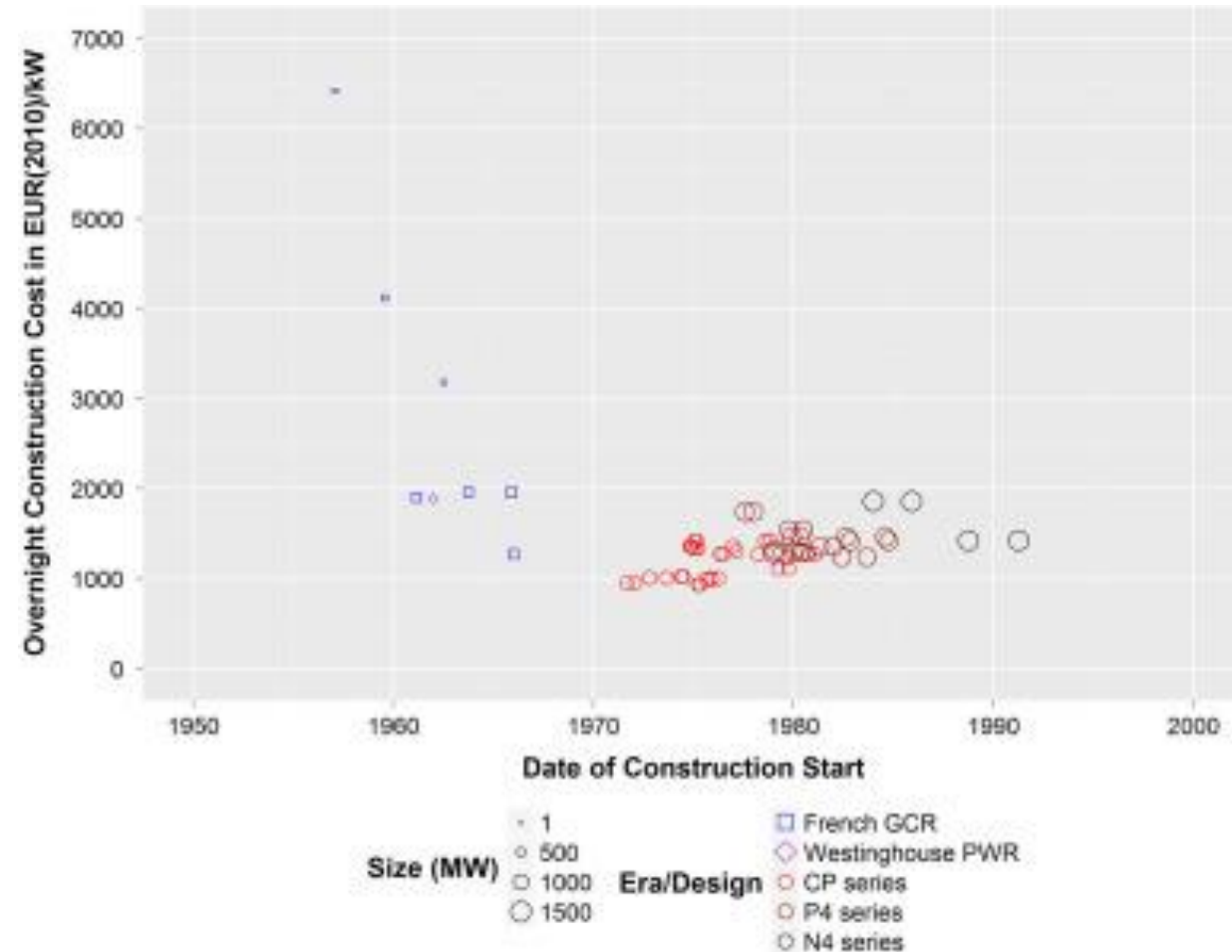
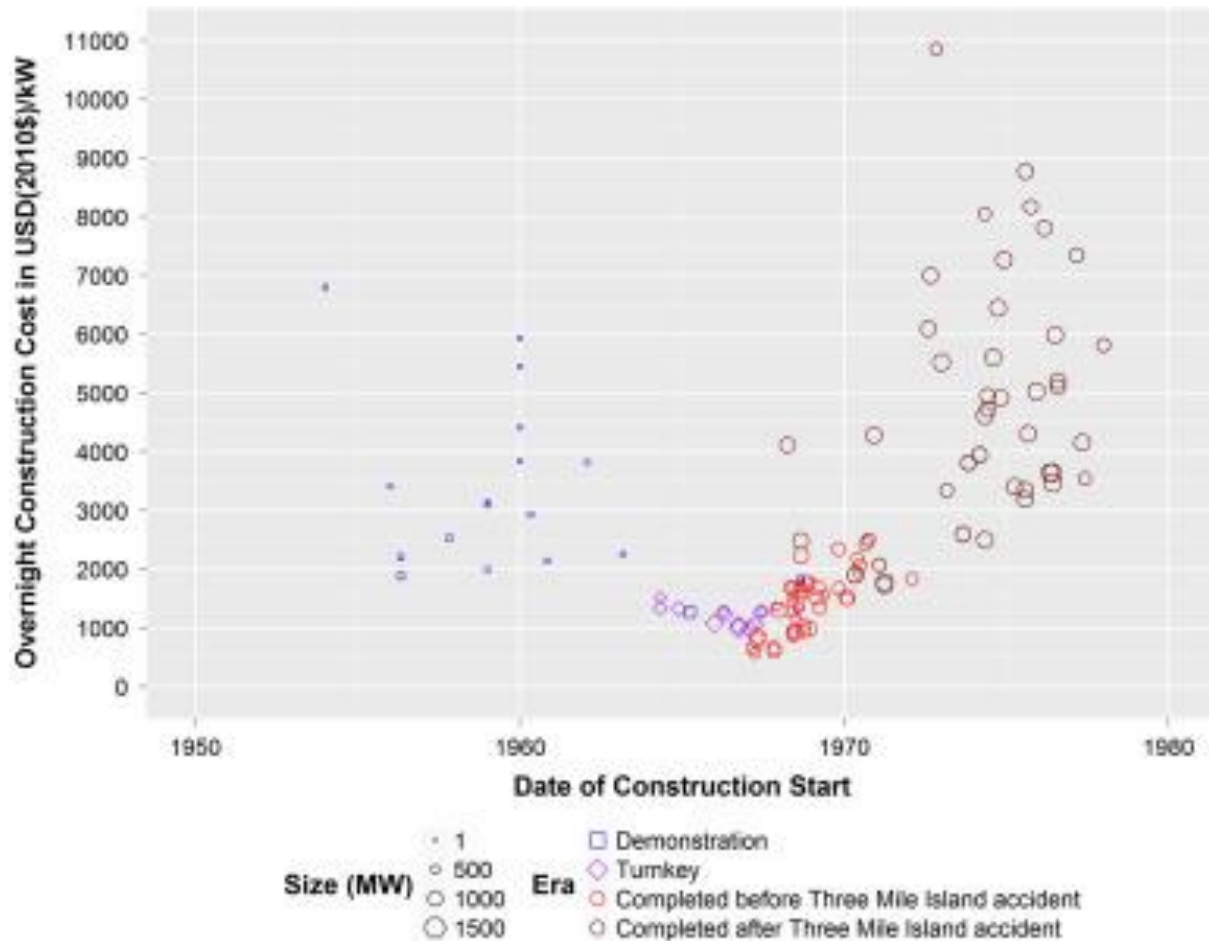


- In 2015 USD680 bn.
- 40% investments in low-carbon sources – cost deflation of wind and solar, easier financing, new business models, clearer long terms signals.
- Lowest investments in fossil fuel generation since 2008.
- Record investments into the grid and grid storage.

# Investments in the electricity generation and networks, 2015 (in USD2015 billions)

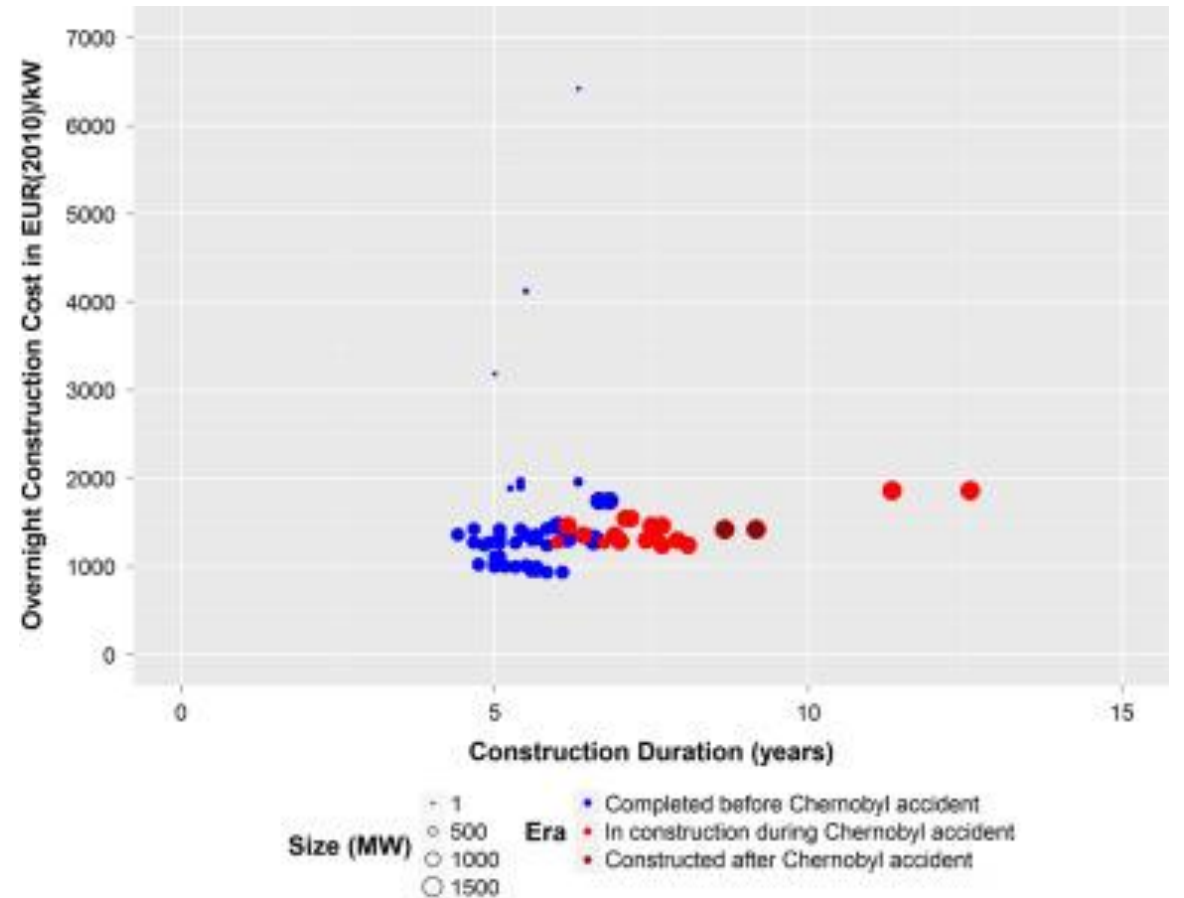
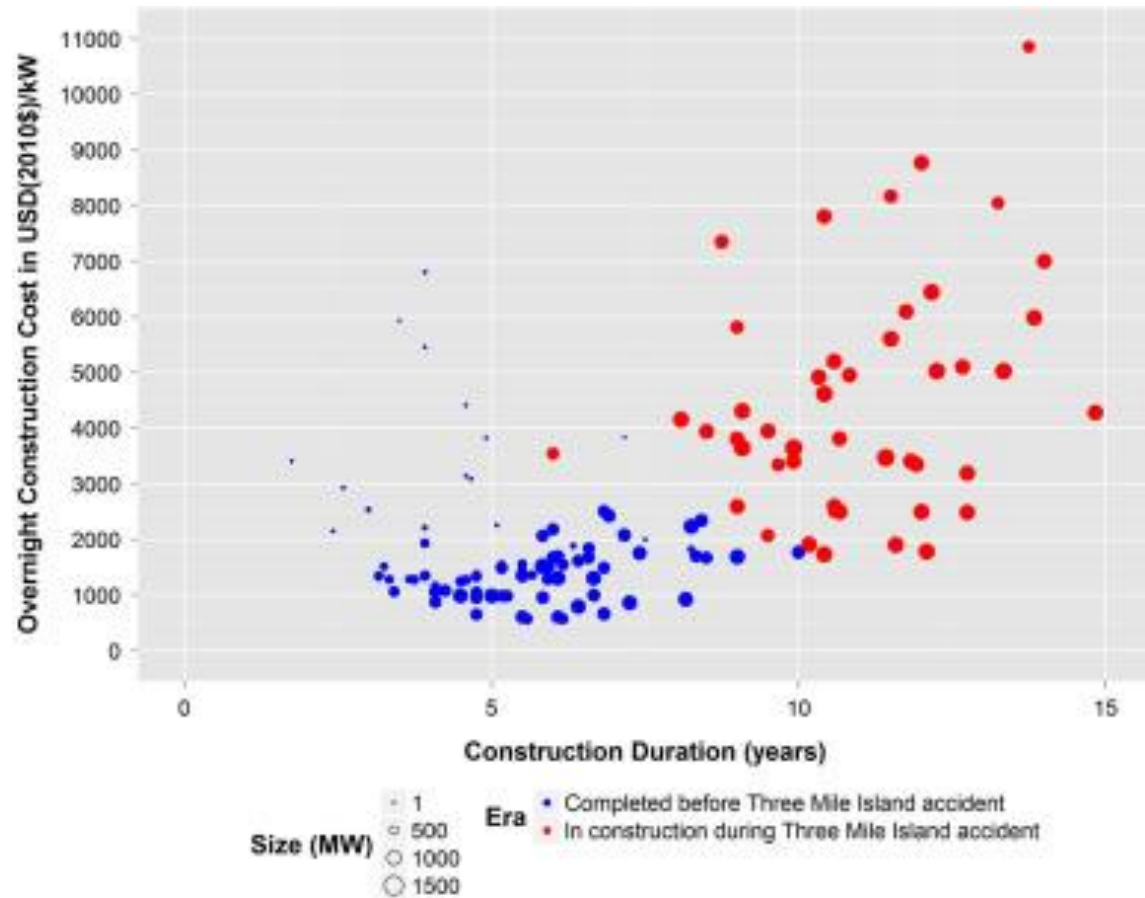


# Overnight construction costs (OCC) in 2015USD/kW, USA (left) and France (right)

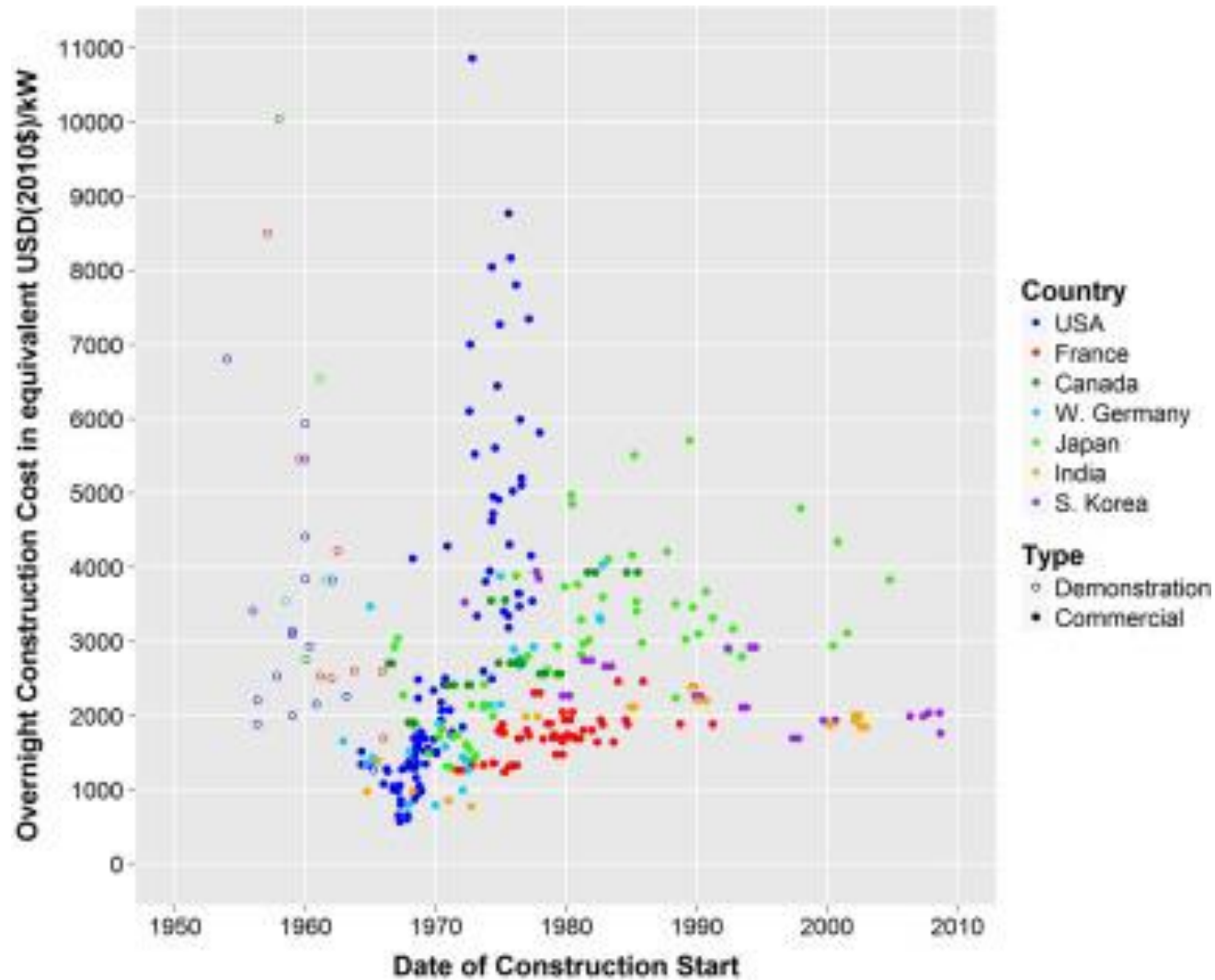




# Construction duration, USA and France

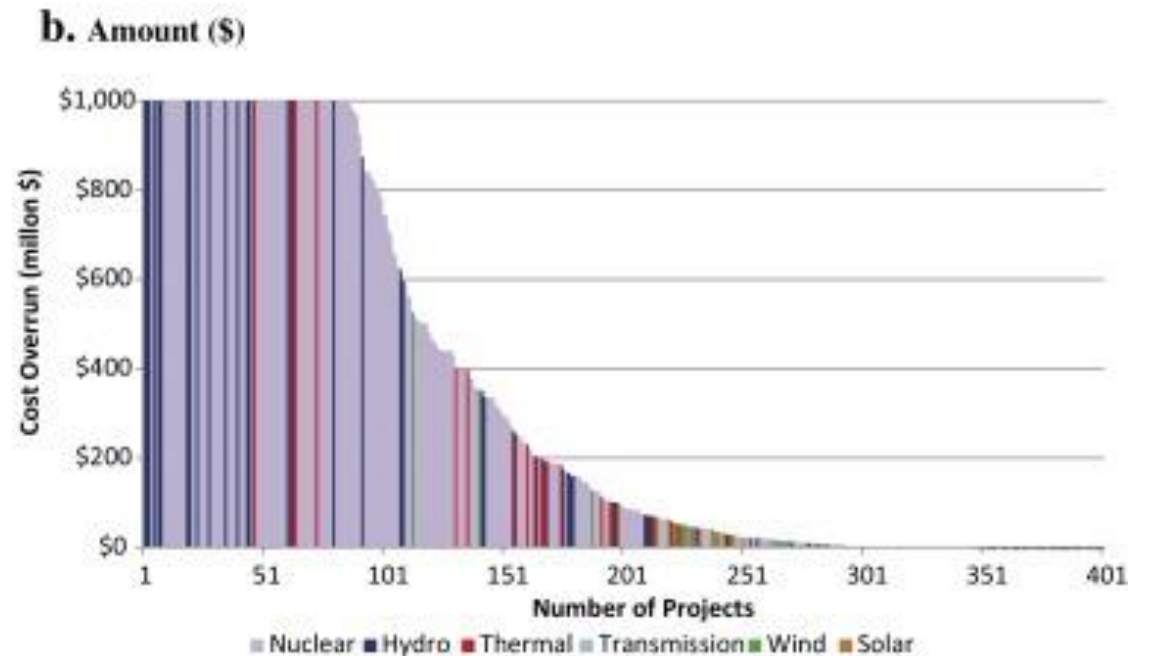
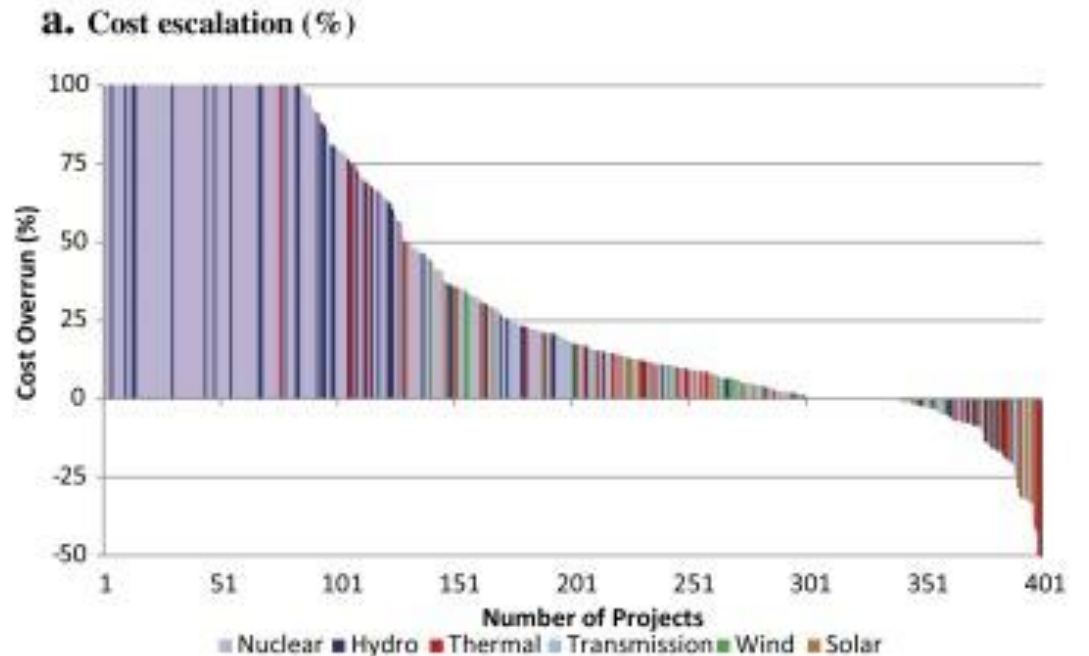


# OCC of global nuclear reactors in USD2010

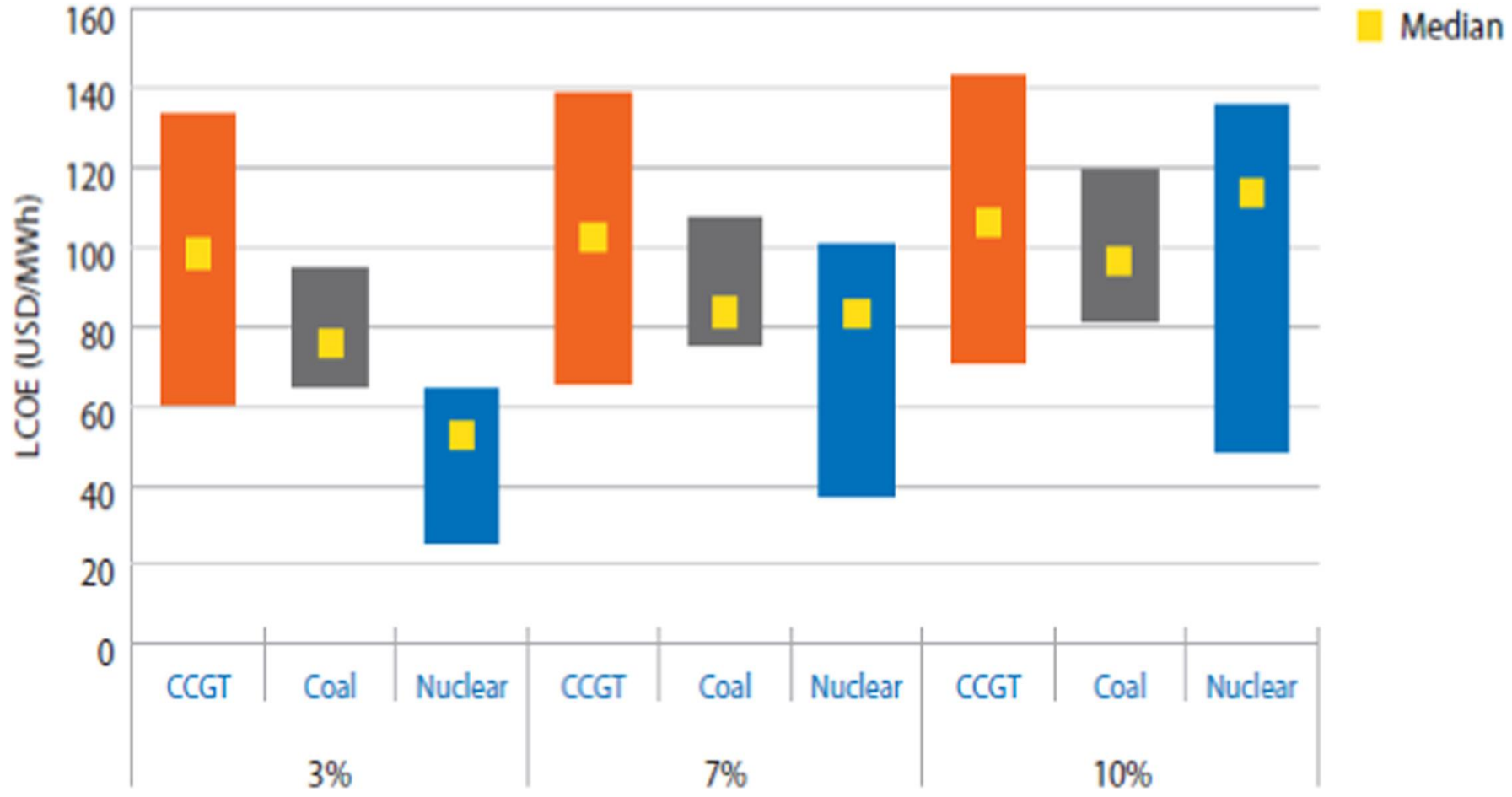


# Distribution of construction overrun costs by technology

- 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.



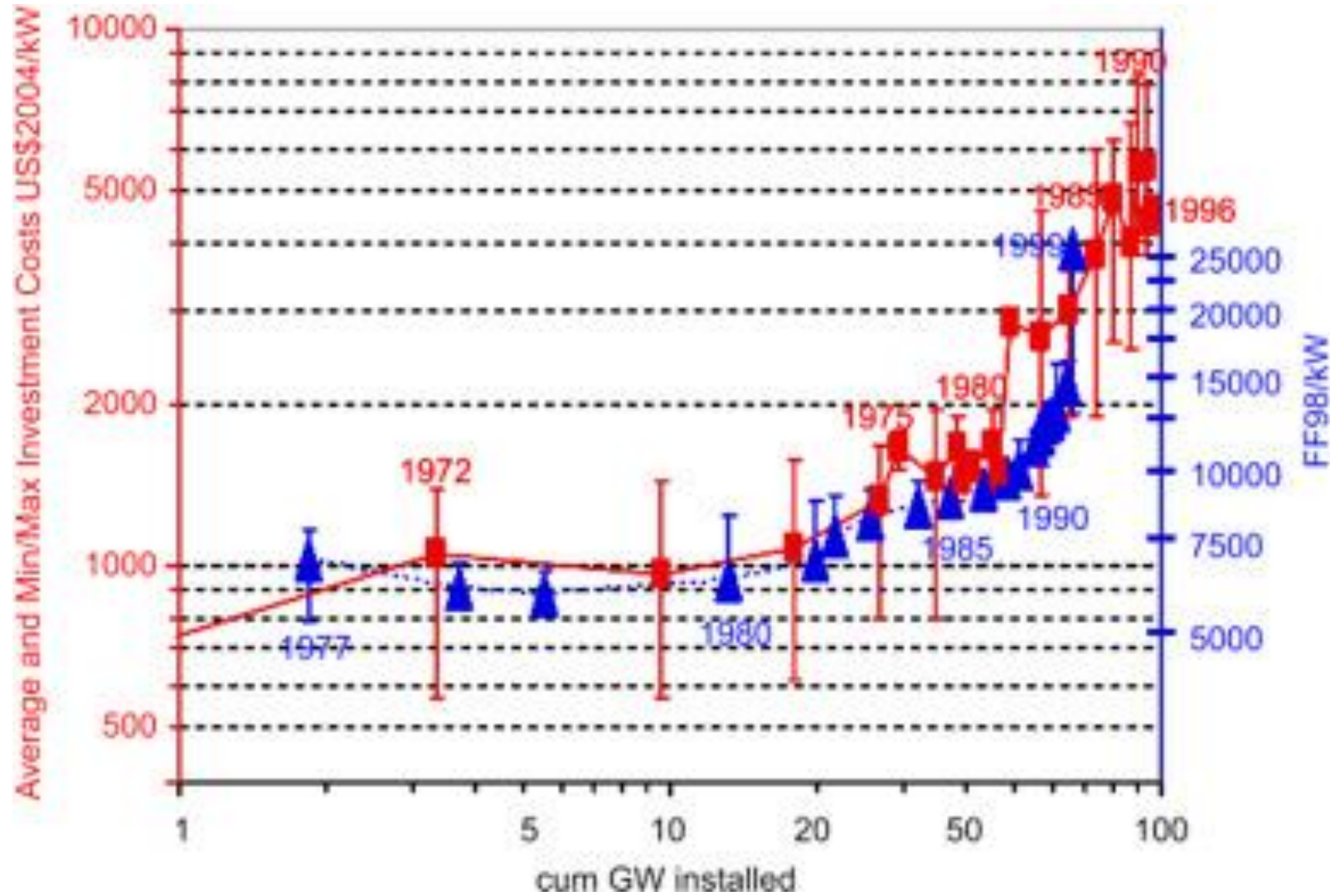
# LCOE for base load technologies, at different discount rates



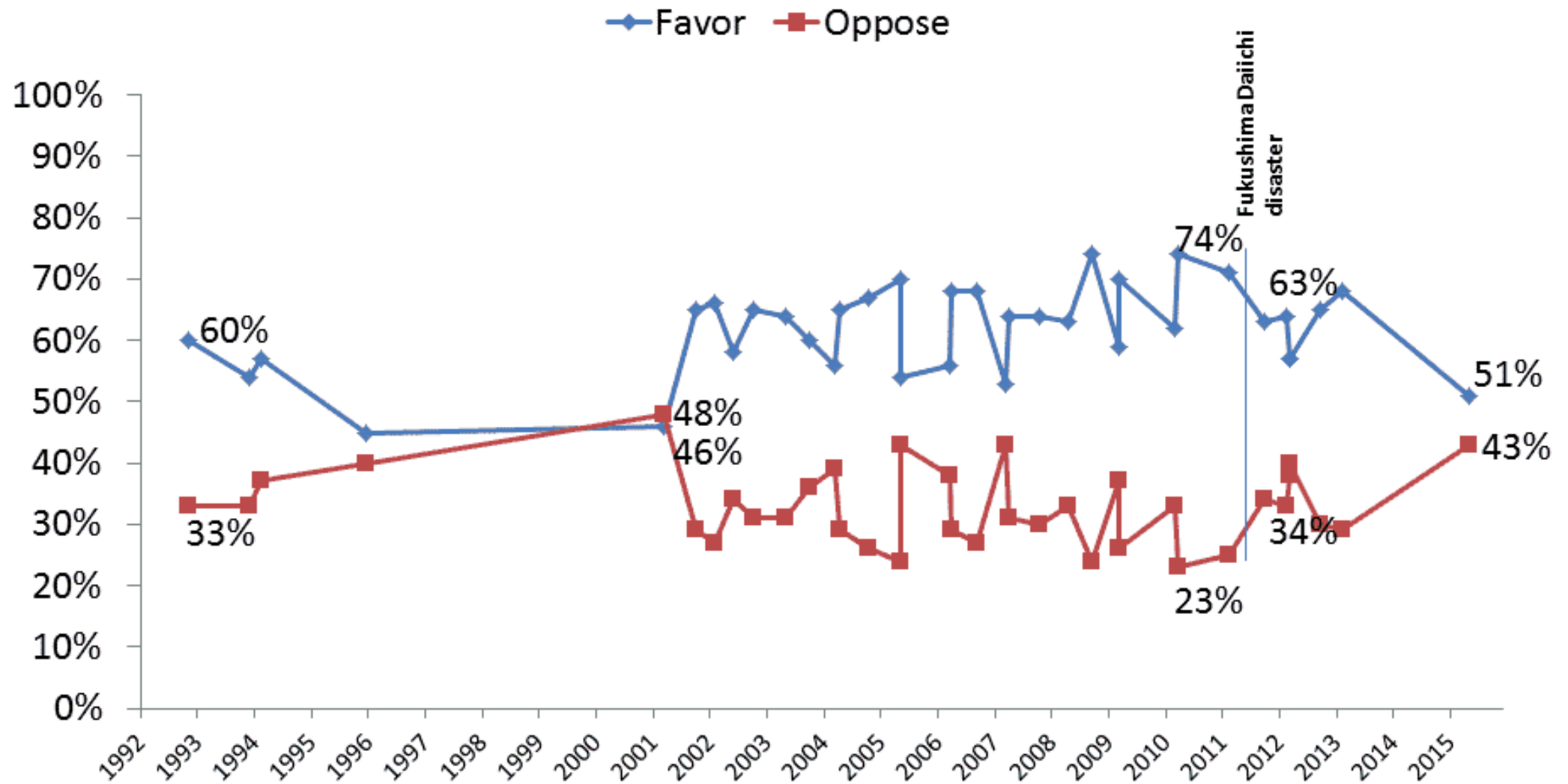
# NPP in the EU in progress

- Flamanville NPP – construction started in 2007, with scheduled commissioning in 2012 and planned costs €3,3bn. Last information (from 2015) – commissioning in 2018 for €10,5bn.
- Olkiluoto NPP – construction started in 2005, with scheduled commissioning in 2010 and planned costs of €3bn. Last information (from 2017) – commissioning in 2018 for €8,5-10bn+.
- Mochovce NPP – construction re-started in 2009, with scheduled commissioning in 2012 and 2013 and planned costs of €2,775bn. . Last information (from 2017) – commissioning in 2018-2019 for €3,8bn.

# Experience curve of USA/Fr NPPs



# 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
	Estonia	Malta	Belgium	Austria
Romania	Portugal	Cyprus		Italy
Bulgaria	Poland	-	Latvia	-
The Czech Republic	Slovenia	-	Lithuania	-
Hungary			Spain	-
Slovakia		-	-	-

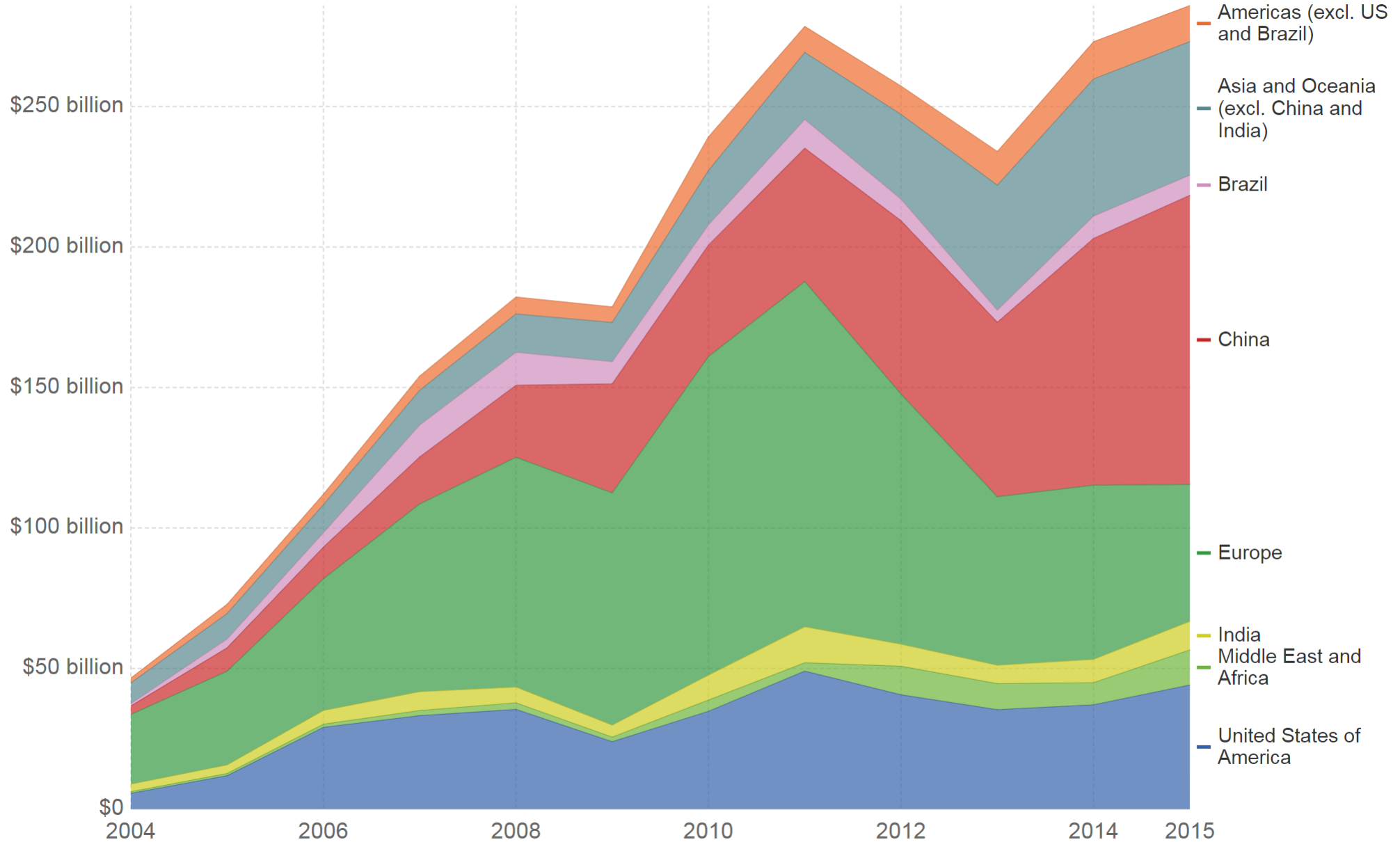


# Nuclear phase-outs

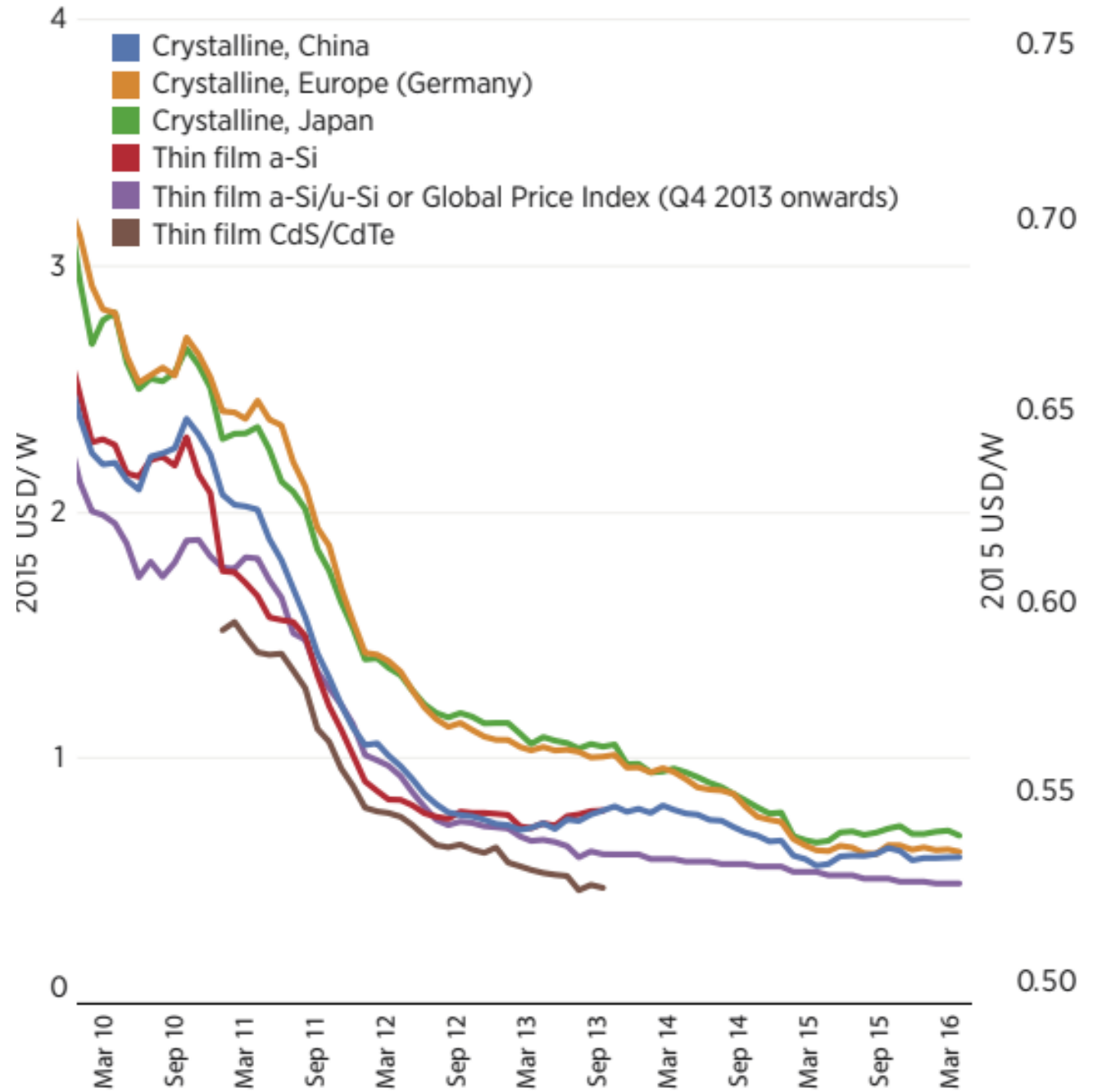
- Austria – 1997
- Germany – 2011
- Italy – 1987 (after Chernobyl)
- Sweden - 1980 (after Three Mile Island), renounced in 2010.
- New Zealand – 1987
- ...
- ...

# Renewable Energy Investment

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

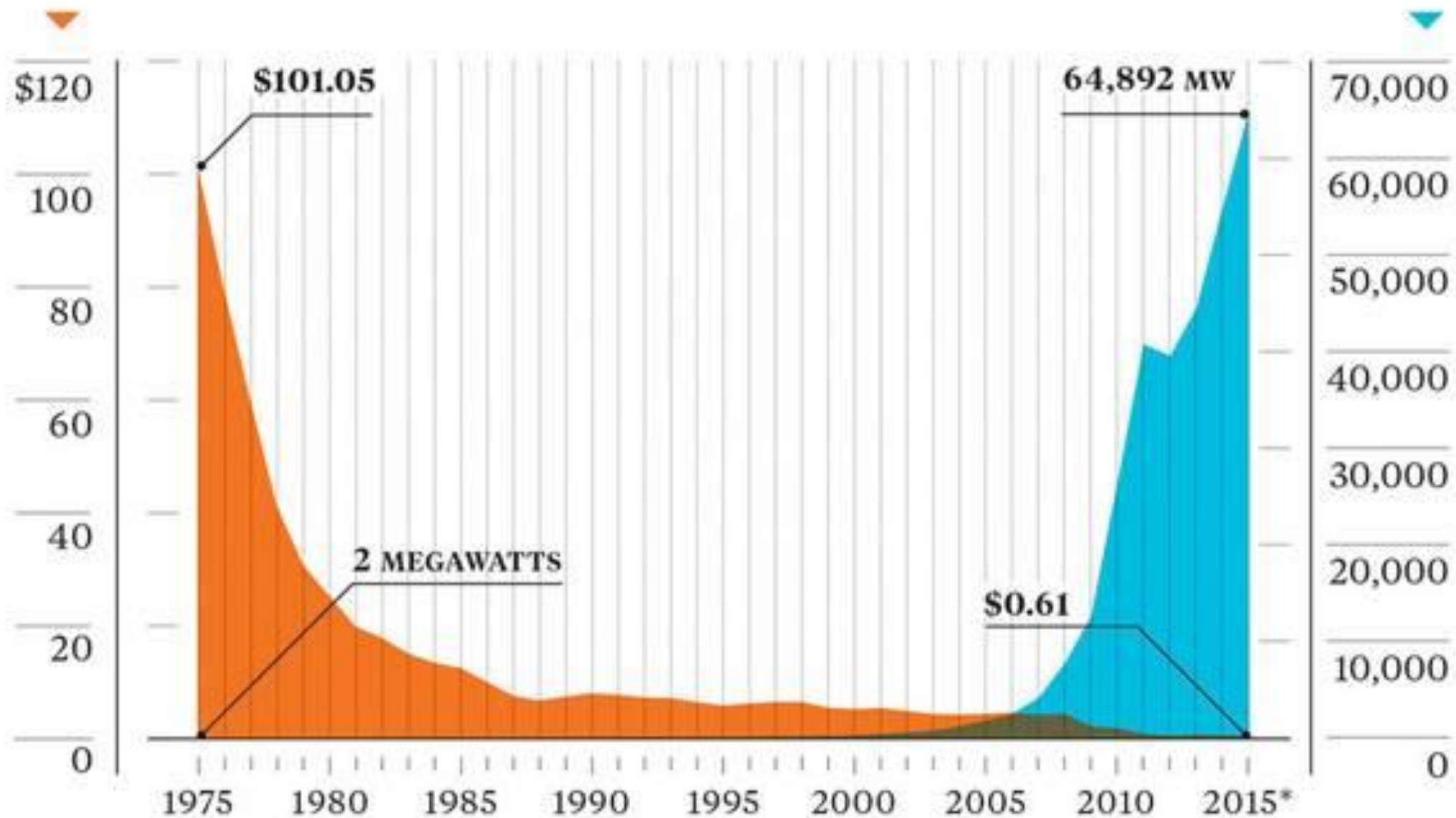


# Global PV module price trends 2009-2016

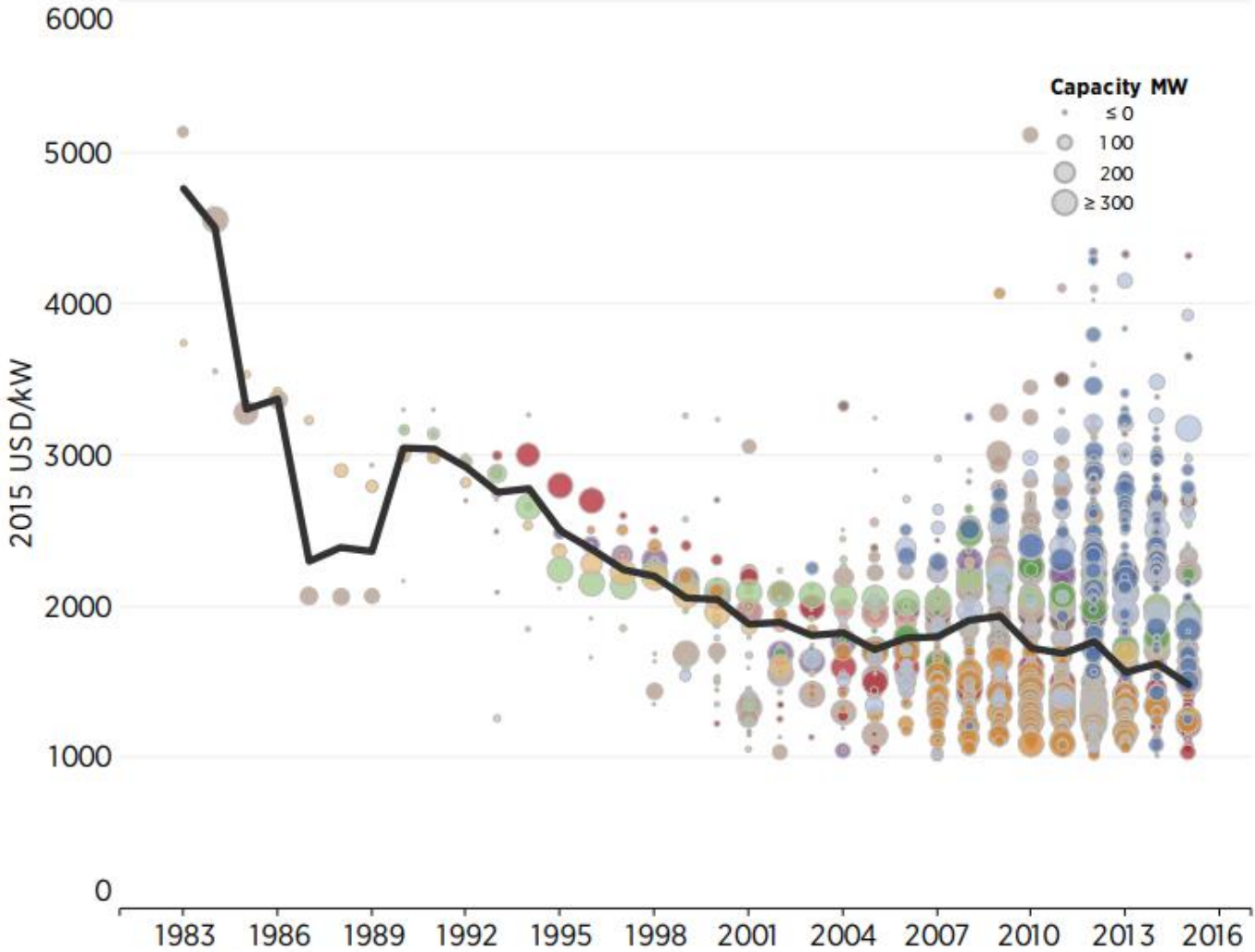


### Price of a solar panel per watt

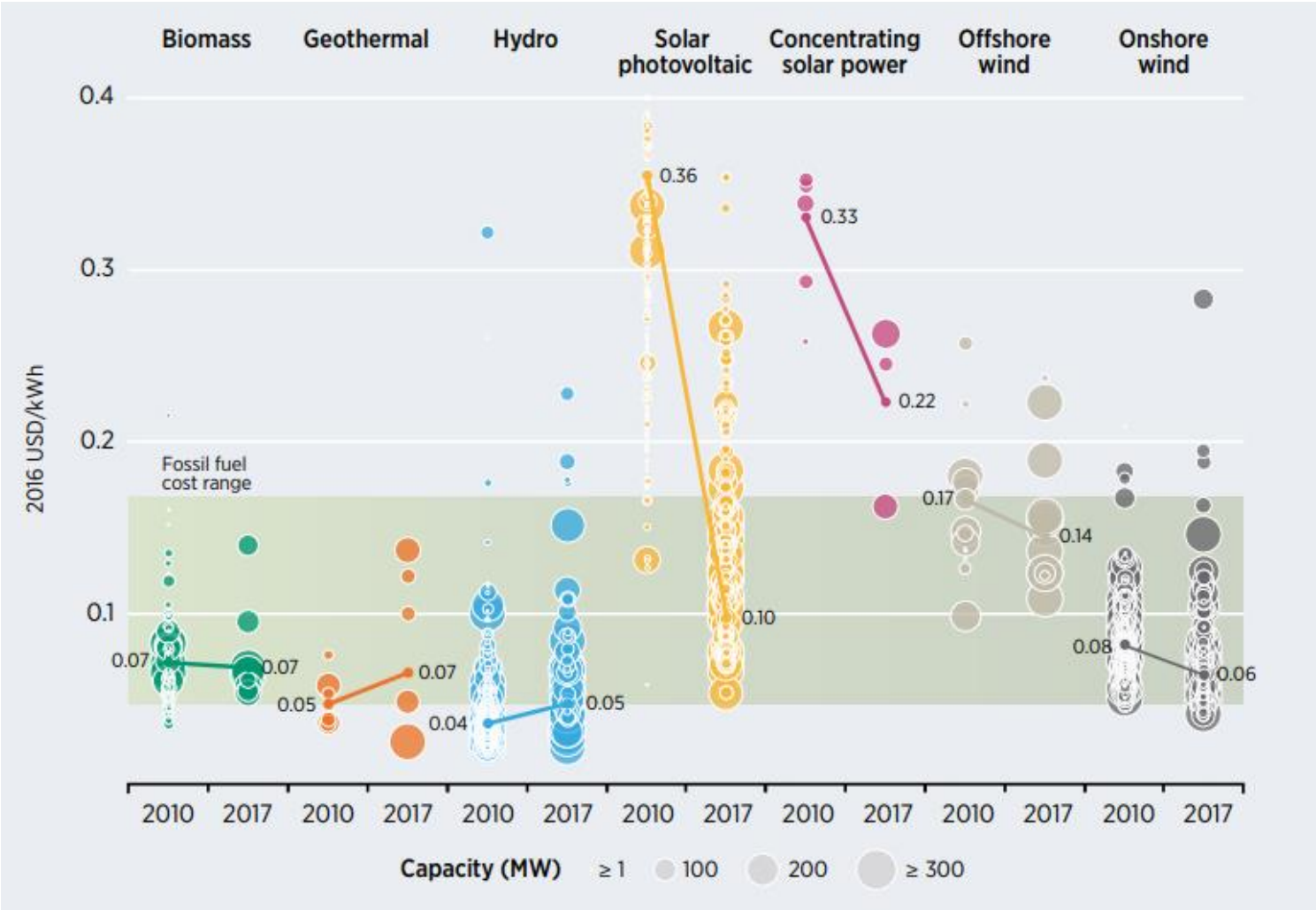
### Global solar panel installations



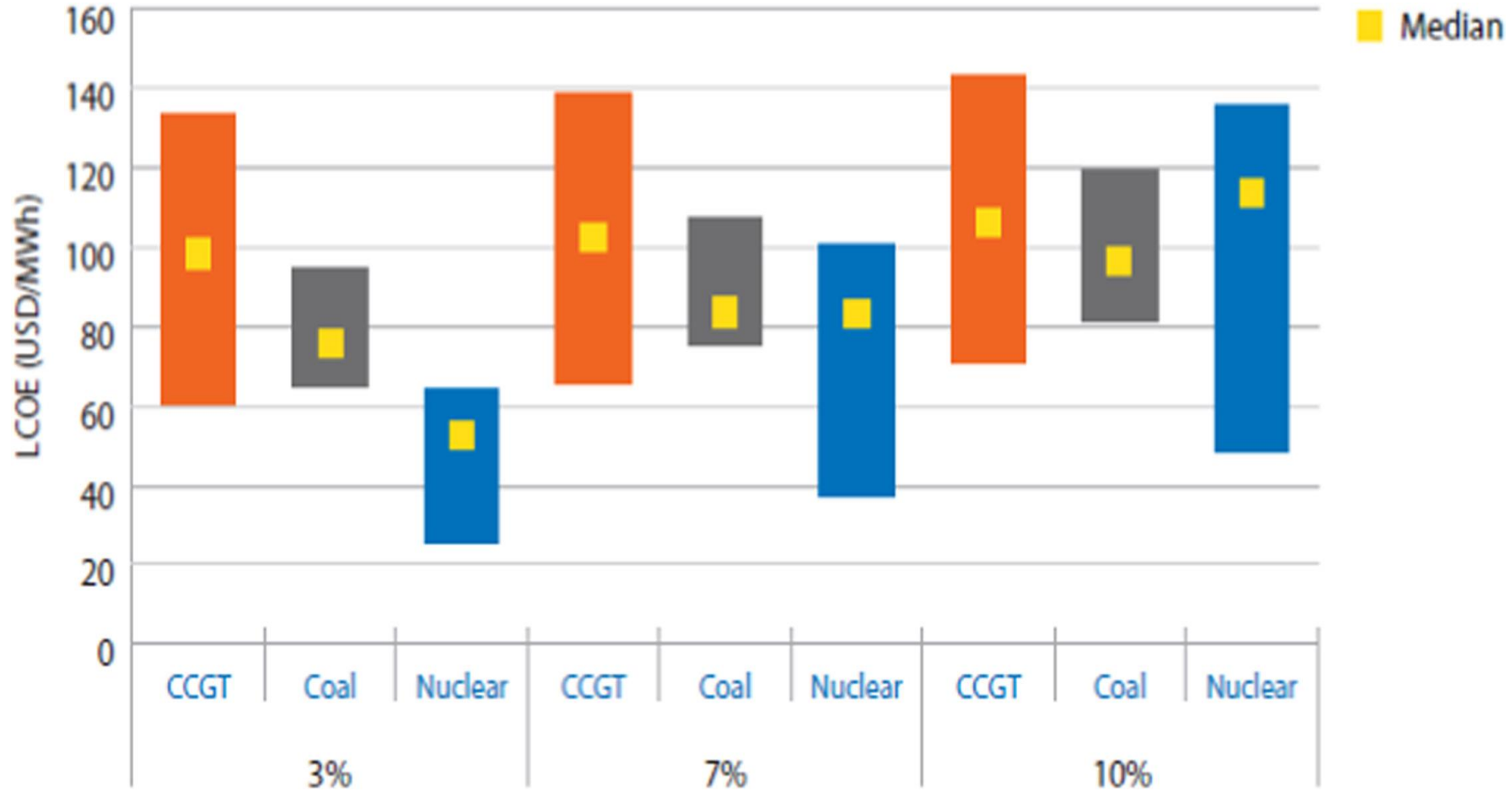
# Total installed costs of onshore wind by country 1983-2014



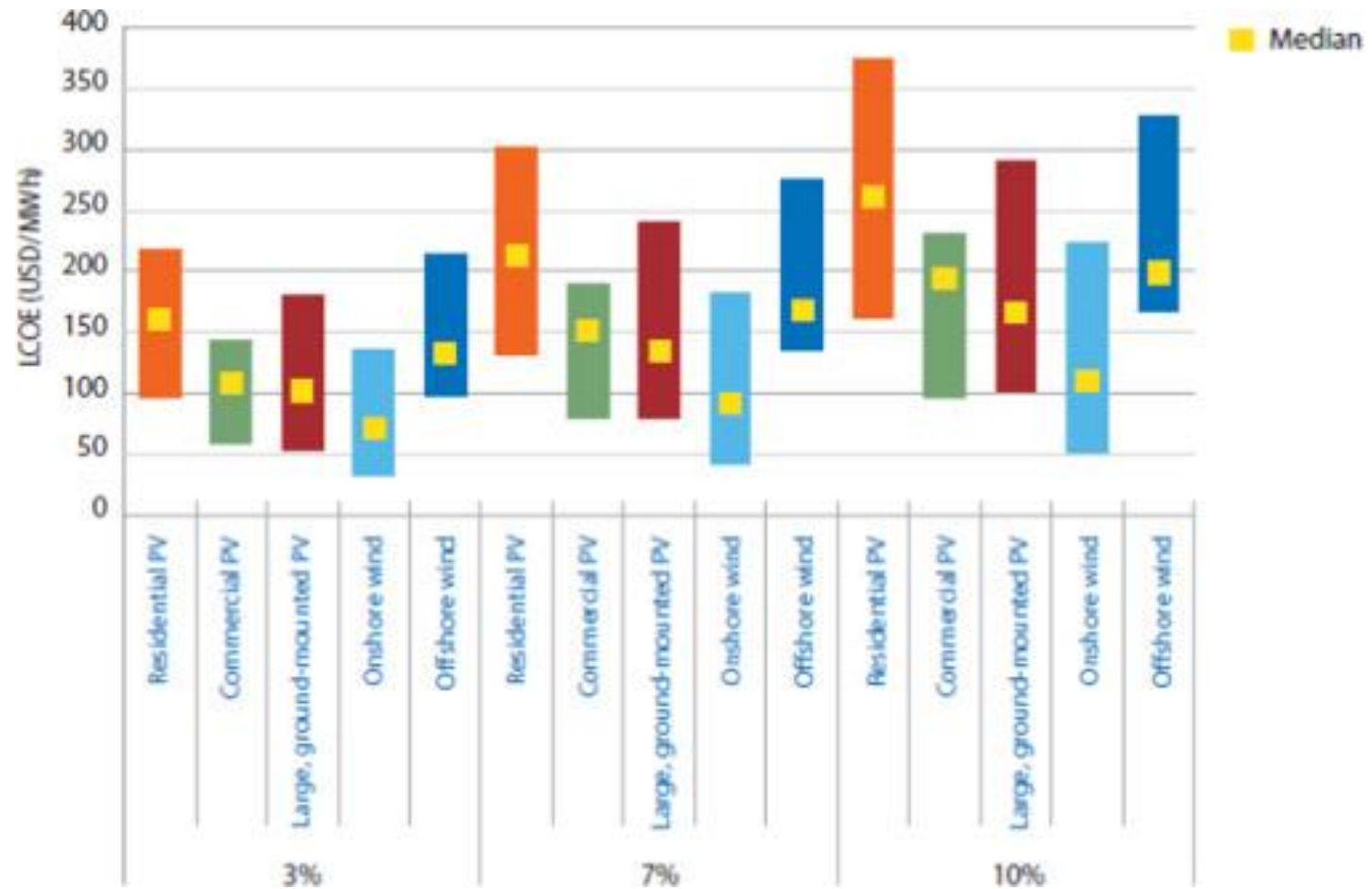
# Global levelised costs of electricity from utility-scale RES technologies, 2010 - 2017



# LCOE for base load technologies, at different discount rates

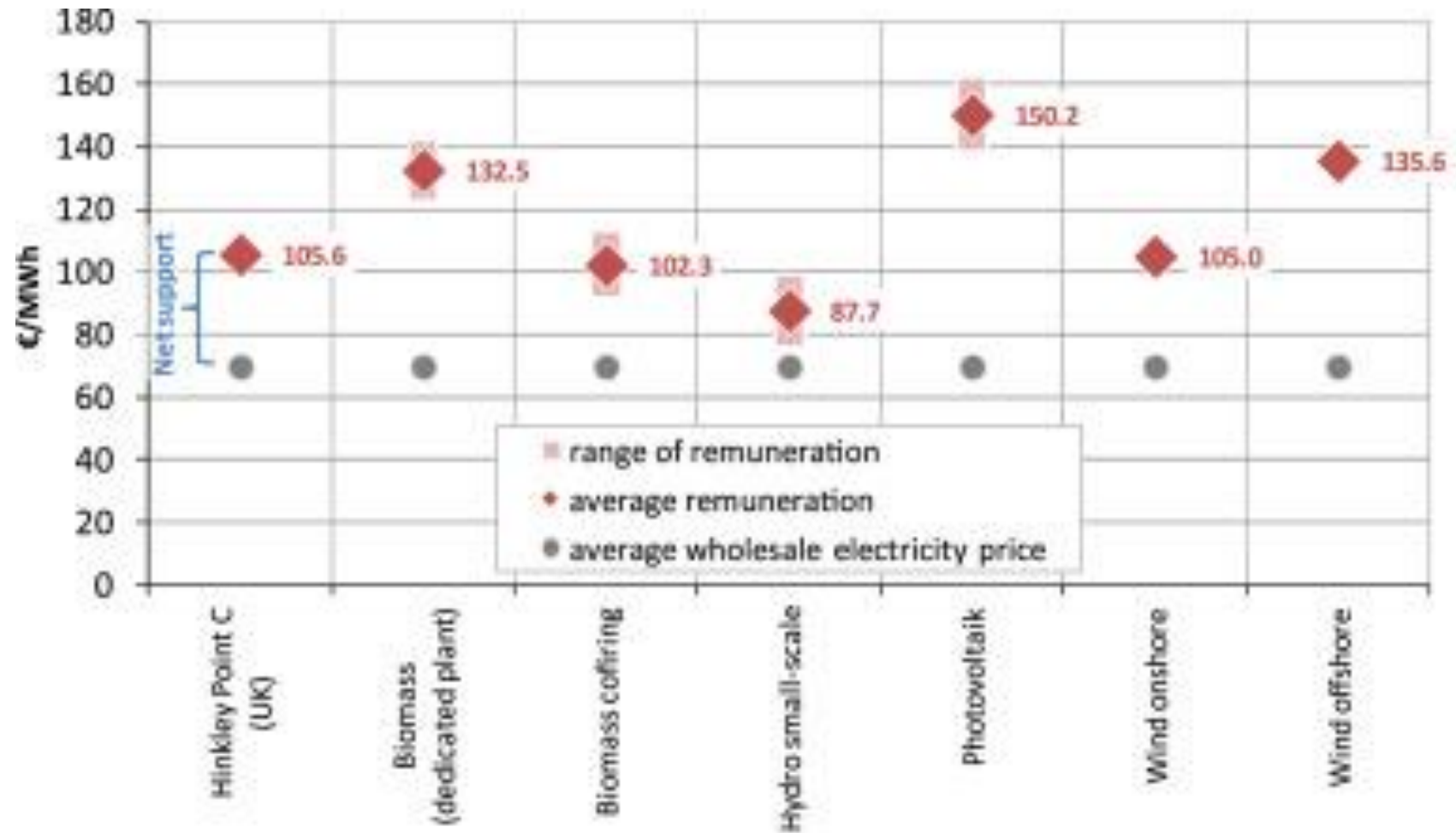


# LCOE for RES technologies, at different discount rates

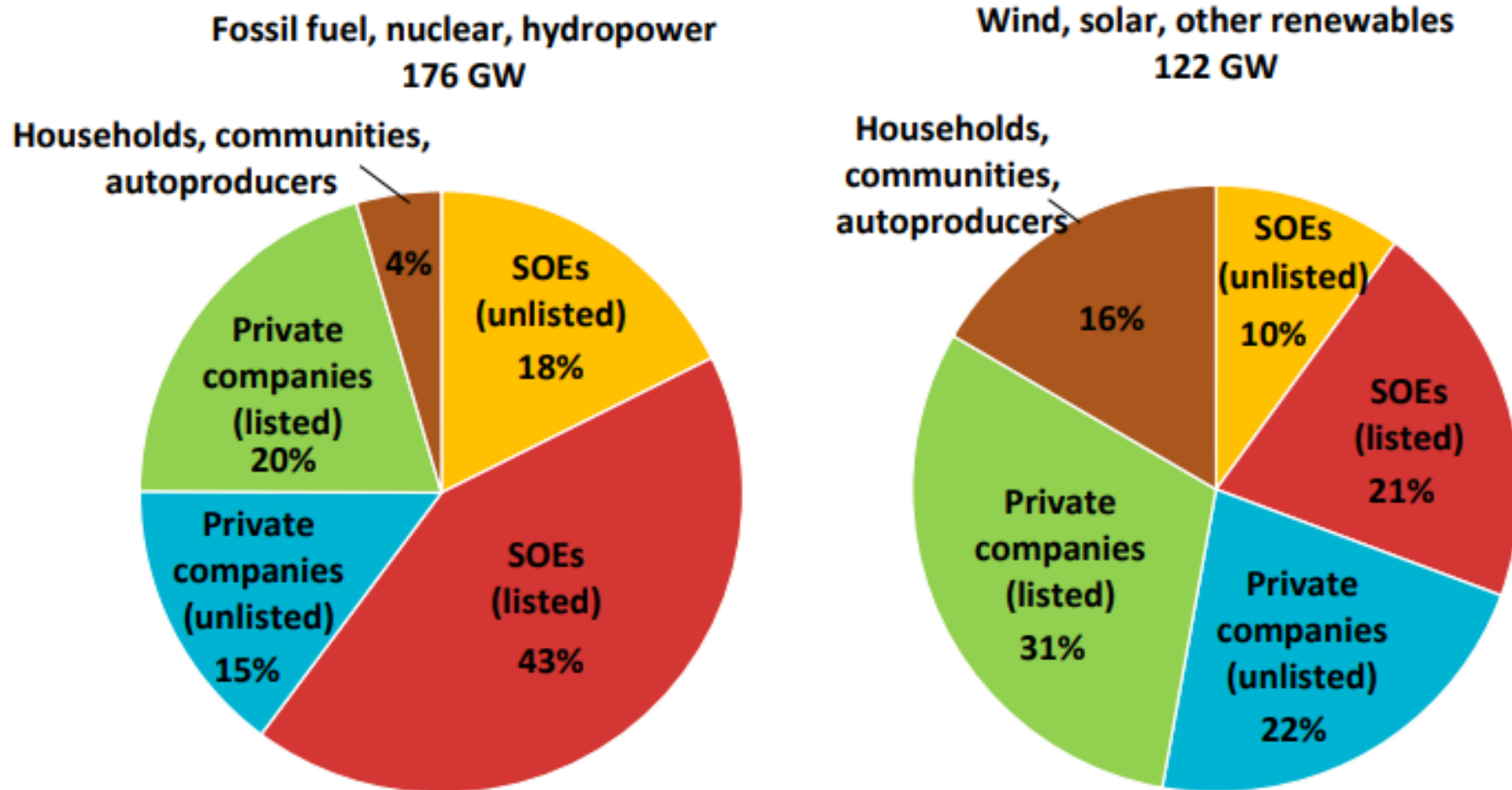




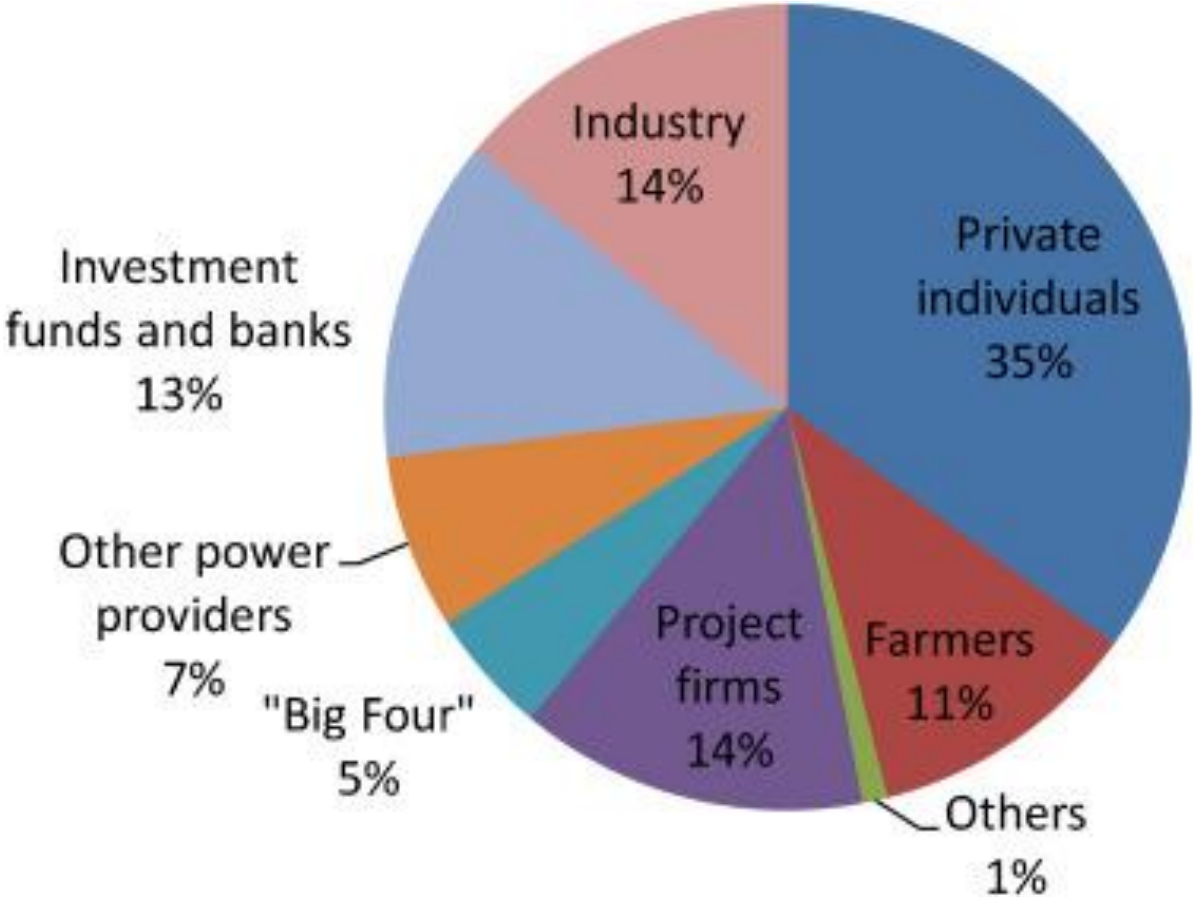
# Remuneration levels for nuclear and RE technologies in the UK



# Ownership of global power generation capacity commissioned in 2015

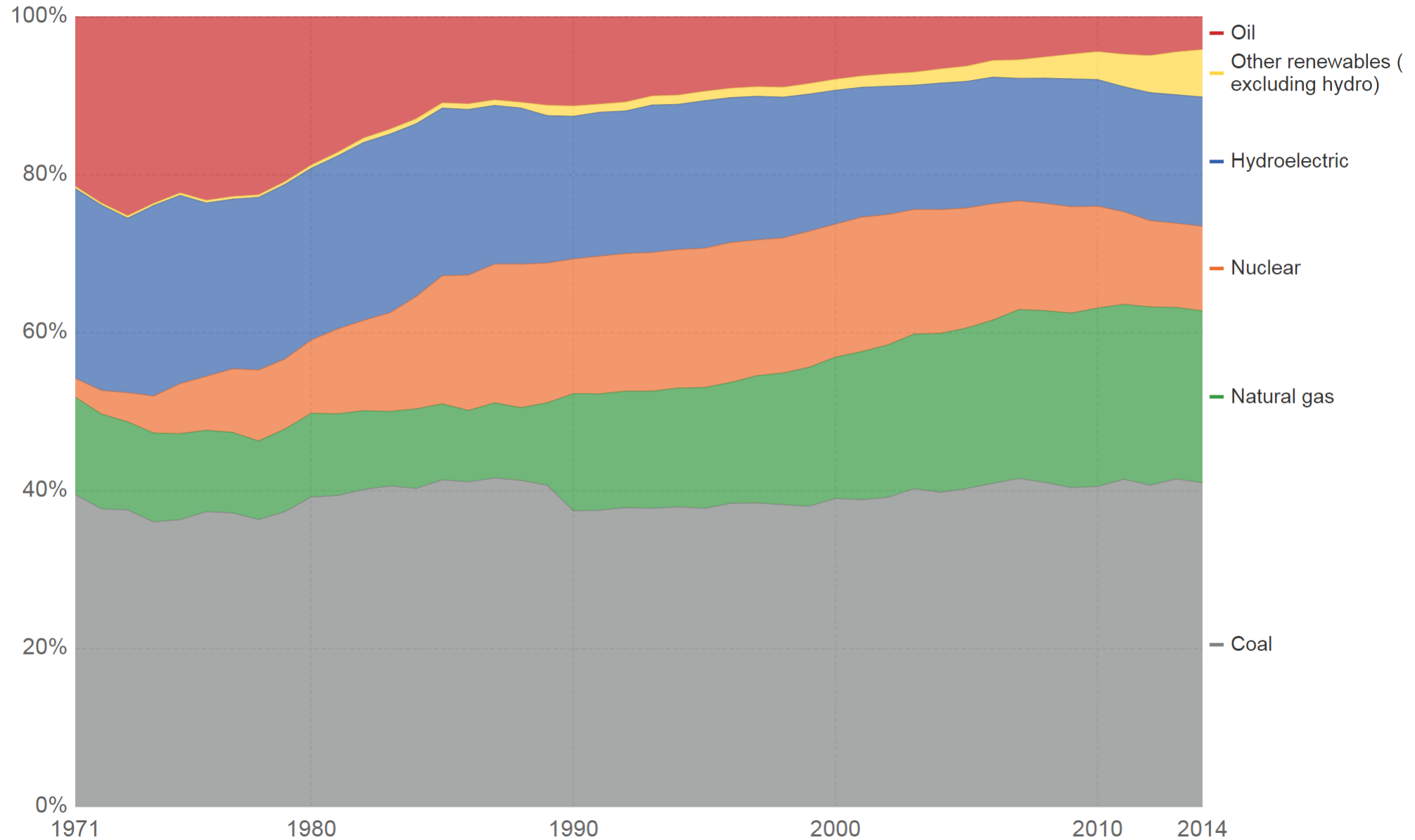


# Ownership of installed RE capacity in Germany (2012)



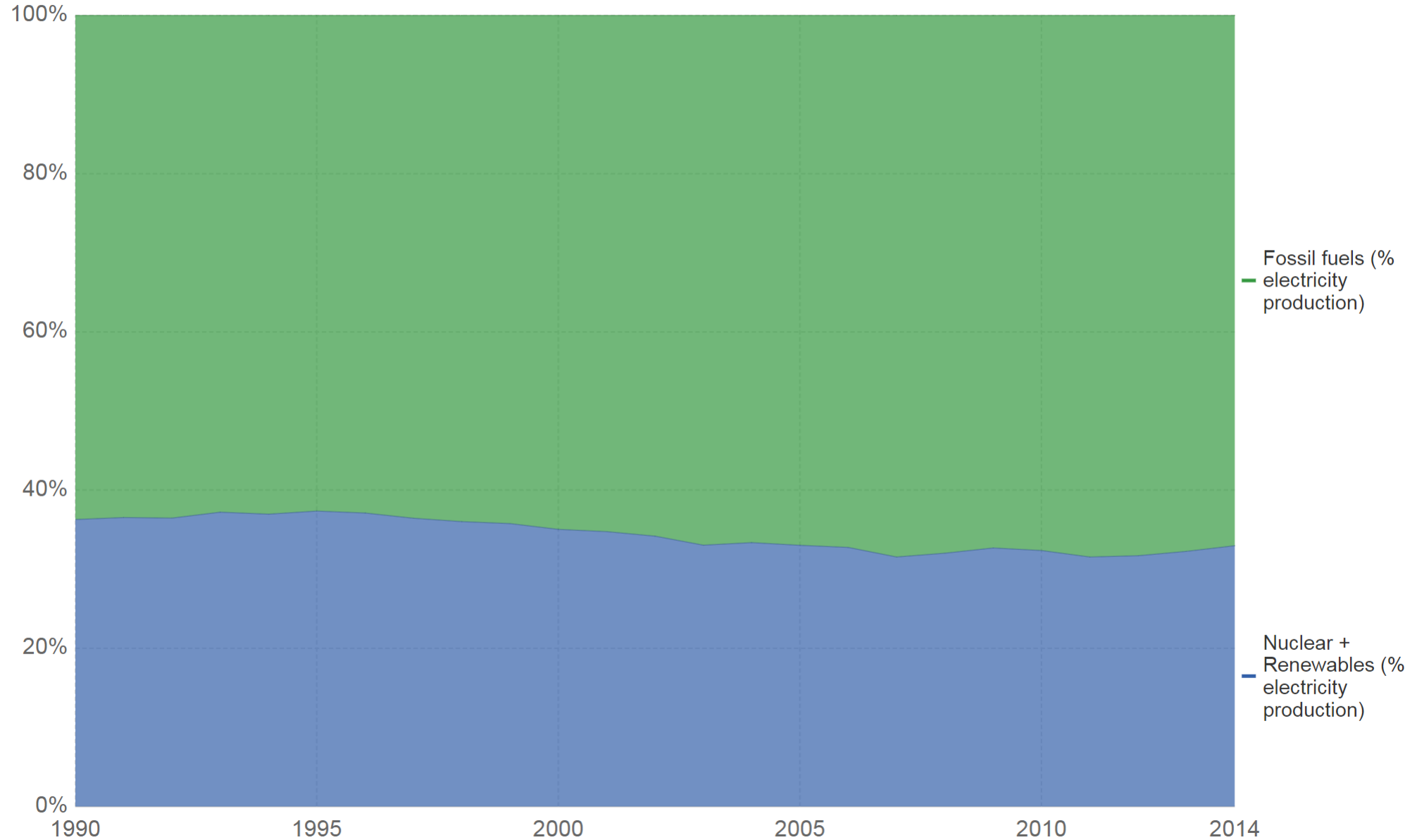
# Electricity share by fuel source, World

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.



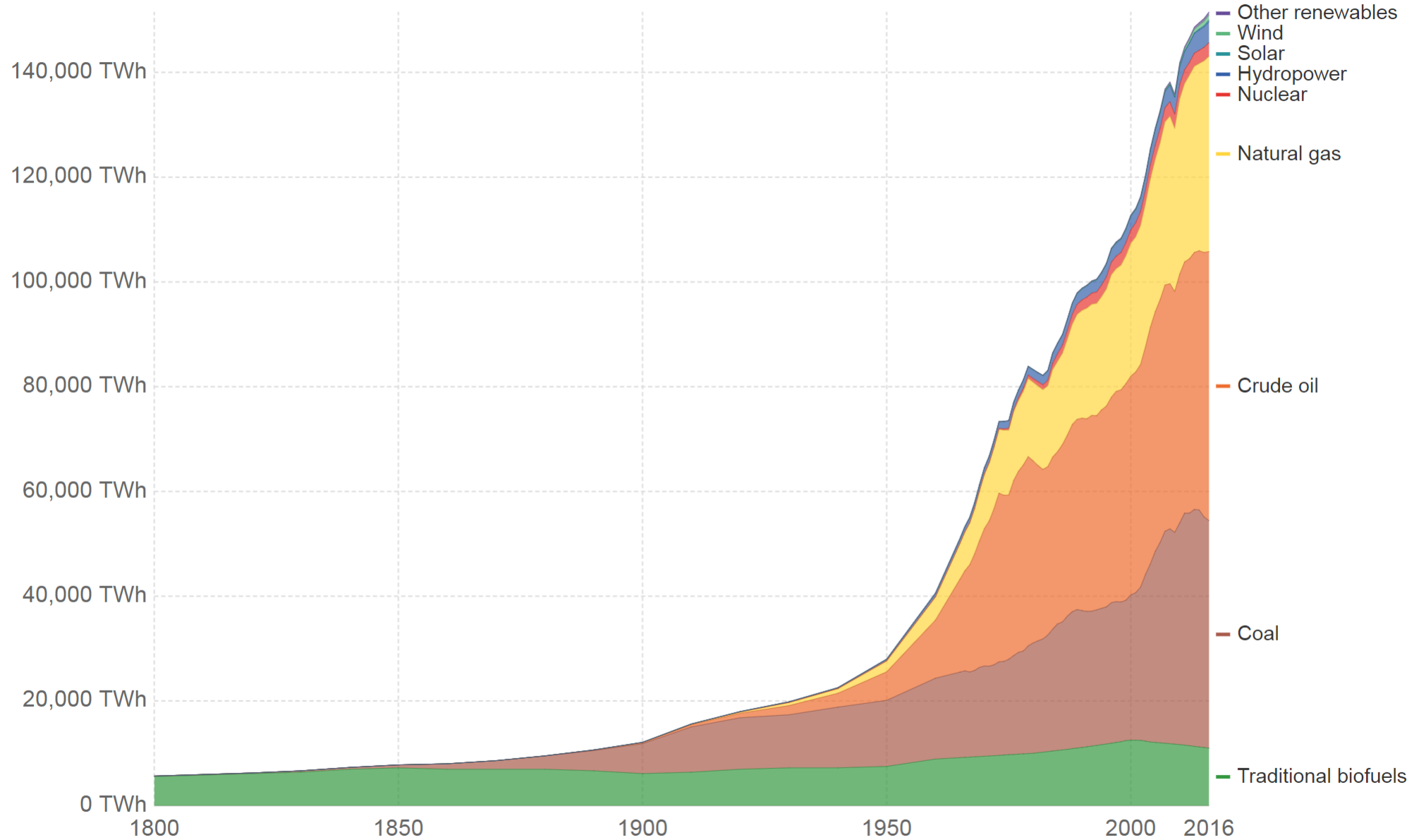
# Global electricity production by source

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

- Technology selection affected by
  - The structure of the market – liberalized vs. monopolized
  - Participation of the citizens on decision-making
  - Standardization of products
  - Environmental conditions
  - Energy intensity of the industry/economy
  - ...

# Discussion

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



# Sources

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