Discussion of long term energy transitions

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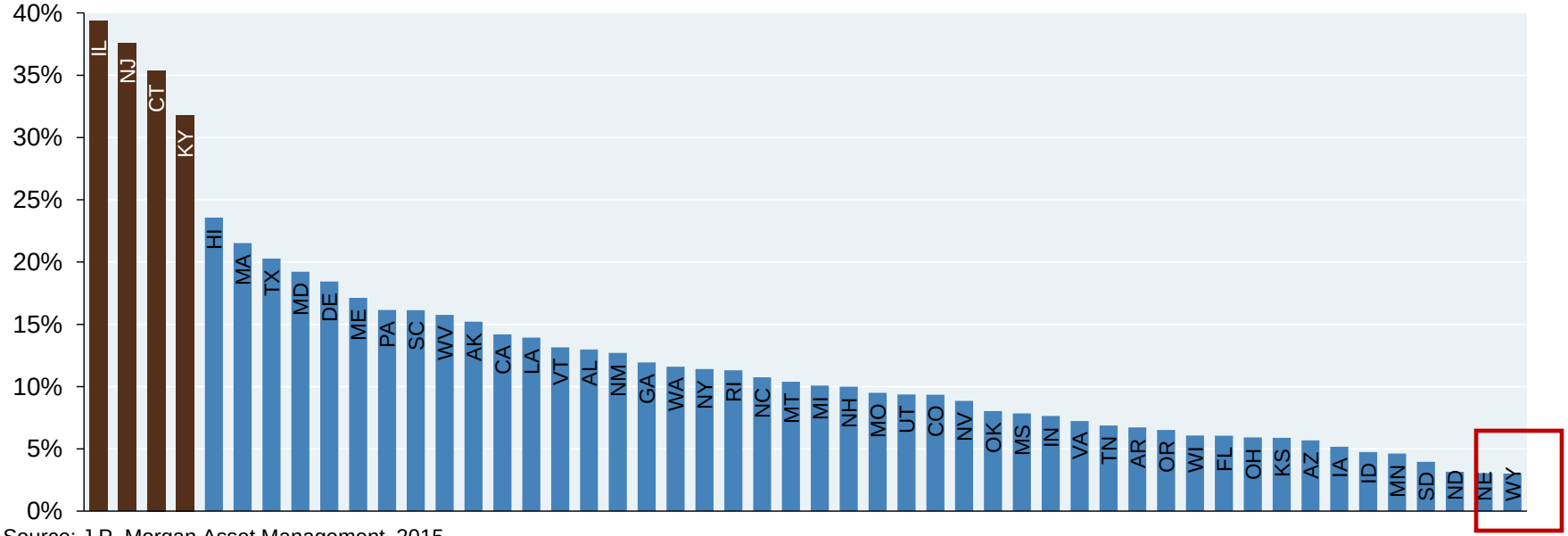
Wyoming

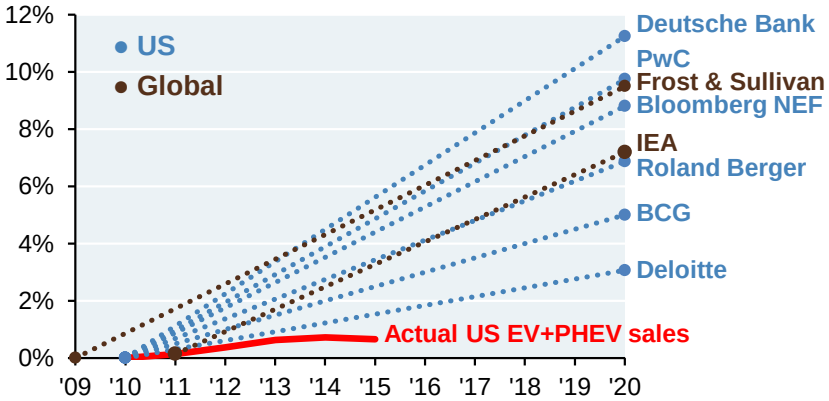
% of state revenue collections required to pay the sum of interest on bonds, the state's share of unfunded pension and retiree healthcare liabilities, and defined contribution plan payments



Source: J.P. Morgan Asset Management. 2015.

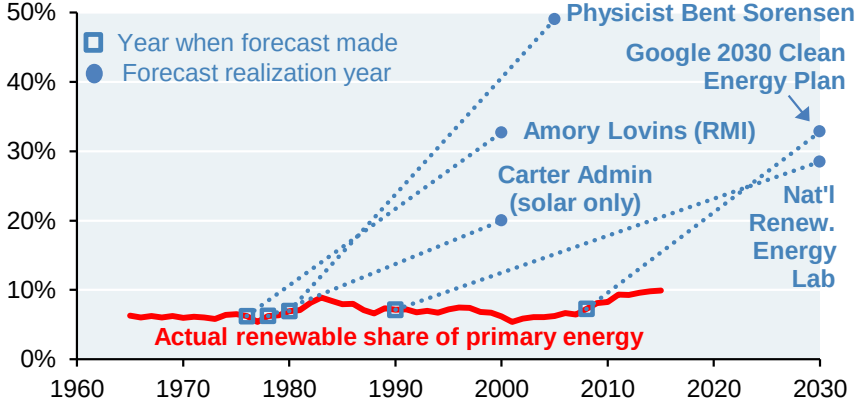
Wishful thinking

Another generation of electric car projections out of sync with reality, EV+PHEV sales as % of total car sales



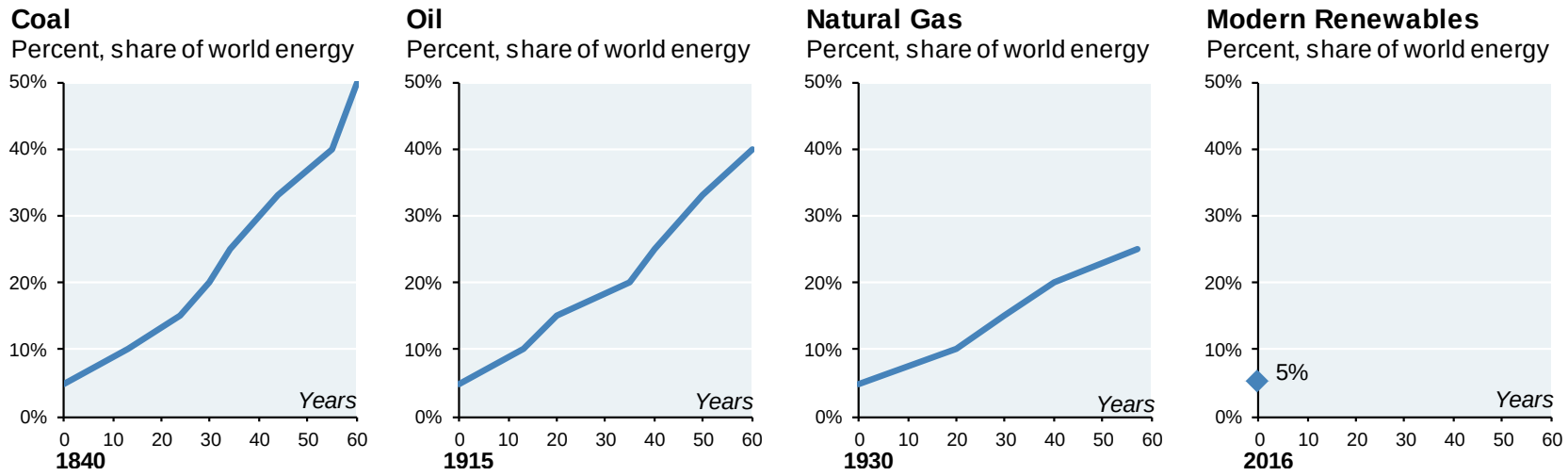
Source: DOE, BEA and listed organizations. 2015. Note: global EV+PHEV sales in 2015 were also around 0.6%.

The share of US primary energy coming from renewable sources, and some notable forecasts



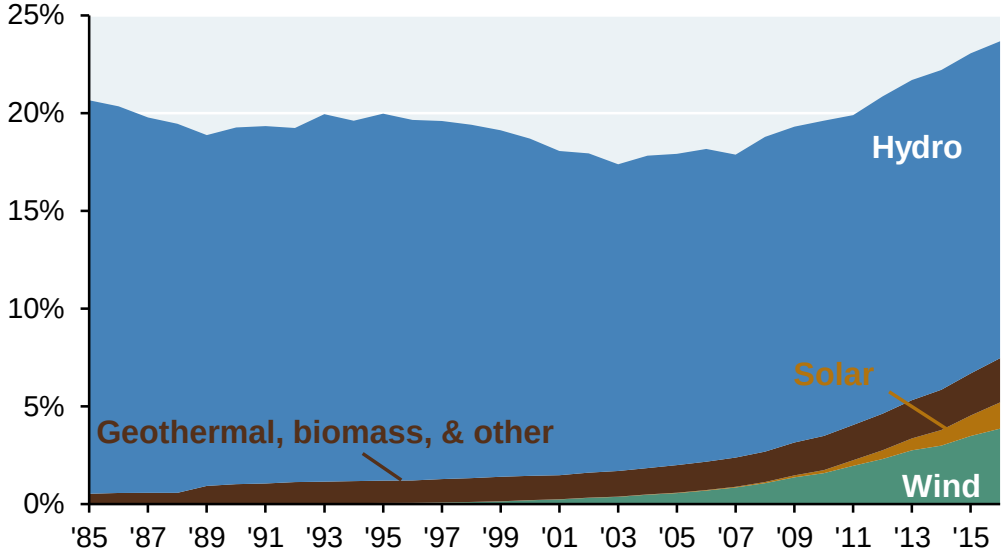
Source: EIA, listed authors, Vaclav Smil, JPMAM. 2015. Renewables include wind, solar, hydropower, geothermal, biomass, wood and waste.

Energy transitions



The modern renewable era: global

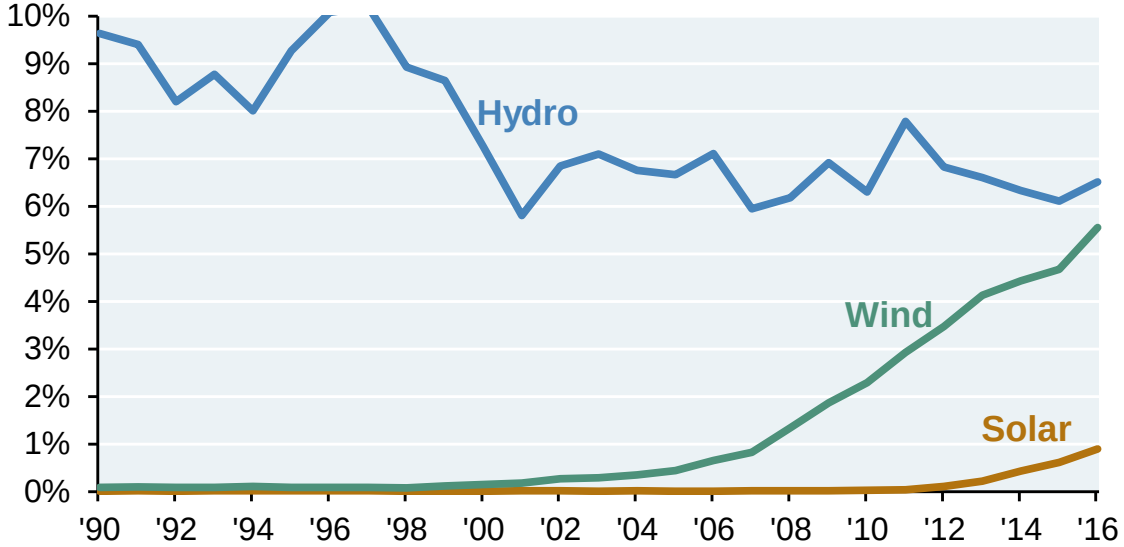
Global renewable electricity generation: still mostly a hydro-electric story, but wind rising, % of total generation



Source: BP Statistical Review of World Energy. 2016.

Modern renewable era: US

Wind, solar and hydroelectric shares of US electricity generation, %

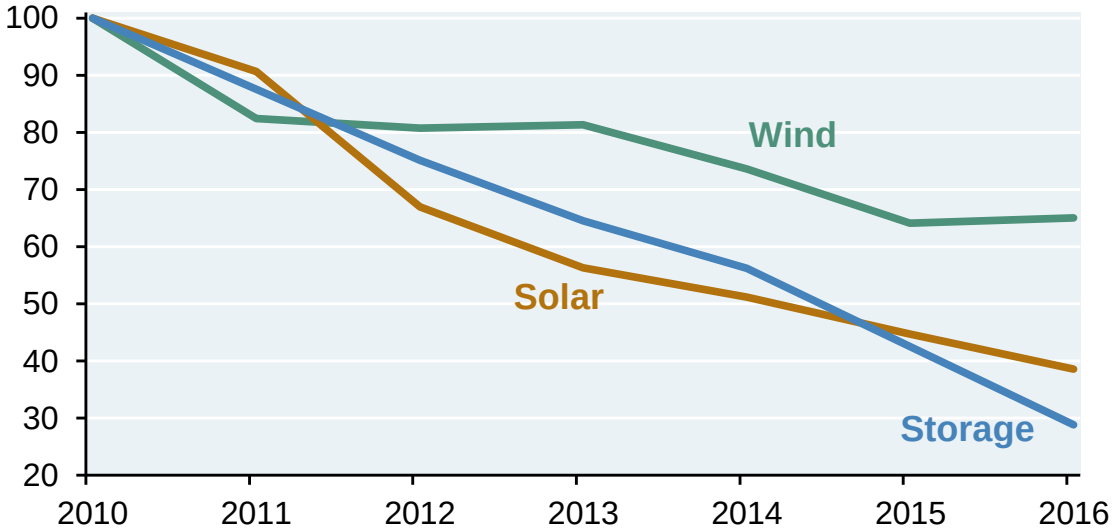


Source: Energy Information Administration. December 2016.

Productivity improvements

Declining upfront capital costs of wind, solar & storage

Index of upfront capital costs , 2010 estimates = 100

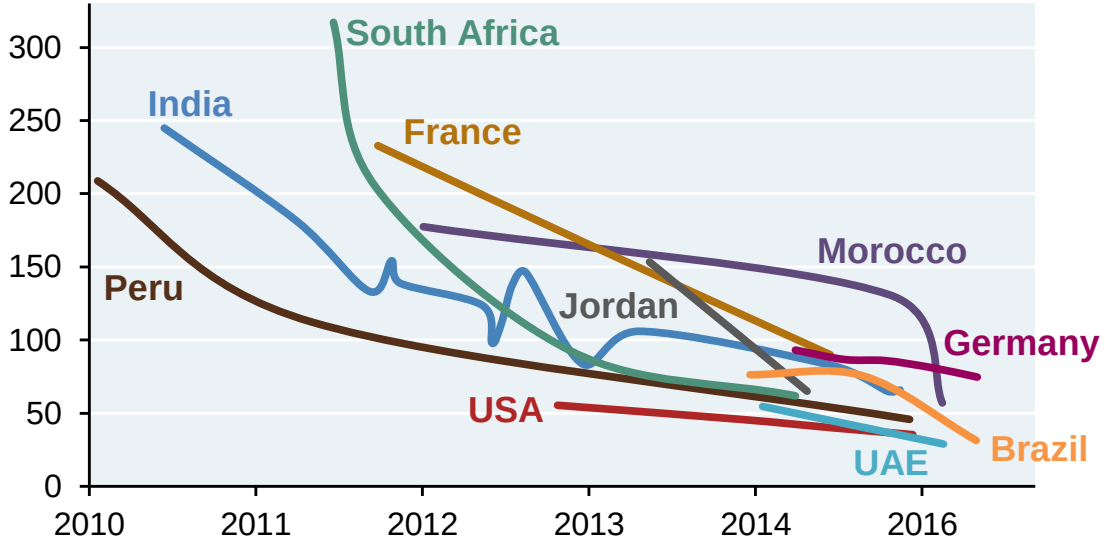


Source: EIA, NREL, Lazard, UBS, Nykvist, et. al. December 2016.
Storage proxied by electric vehicle battery packs.

Solar auction prices

Global solar auction prices converging below $100/MWh

US$/MWh

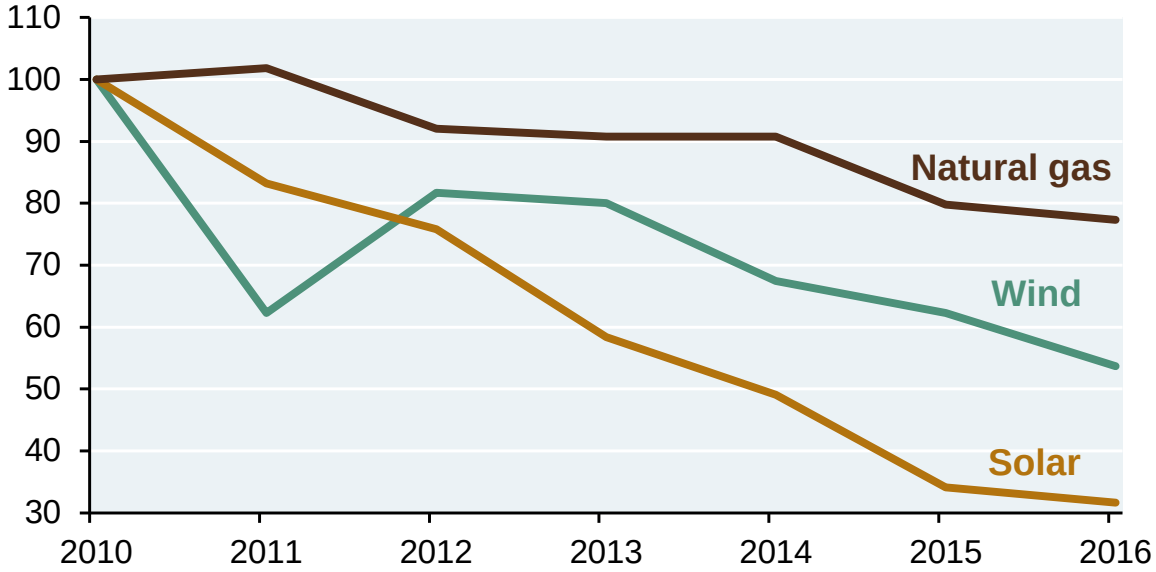


Source: International Renewable Energy Agency. 2017.

“Levelized cost”

Utility-scale solar PV, wind, and nat gas levelized cost

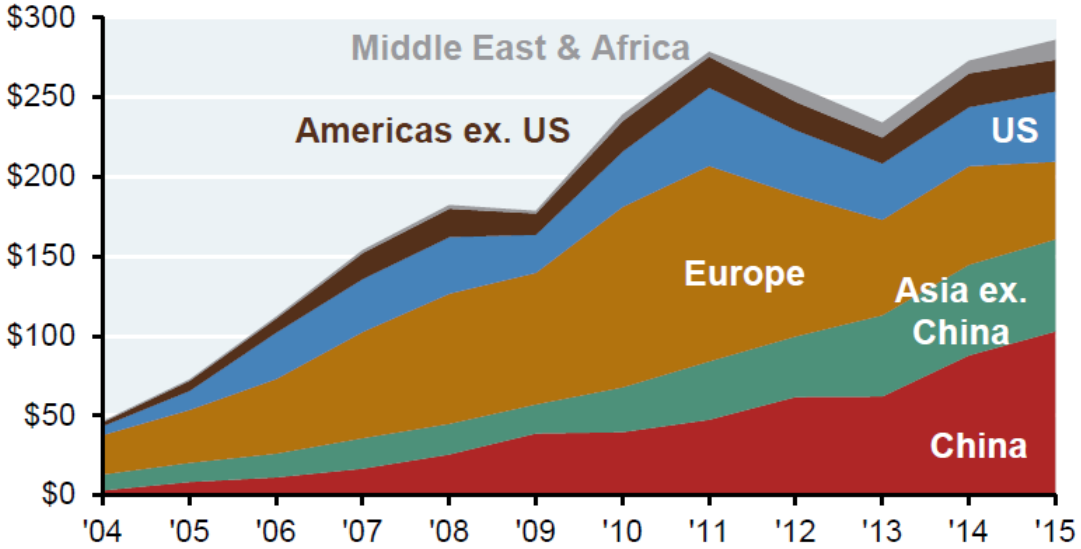
Index of levelized costs, 2010 estimates = 100



Source: Lazard. December 2016.

Investment

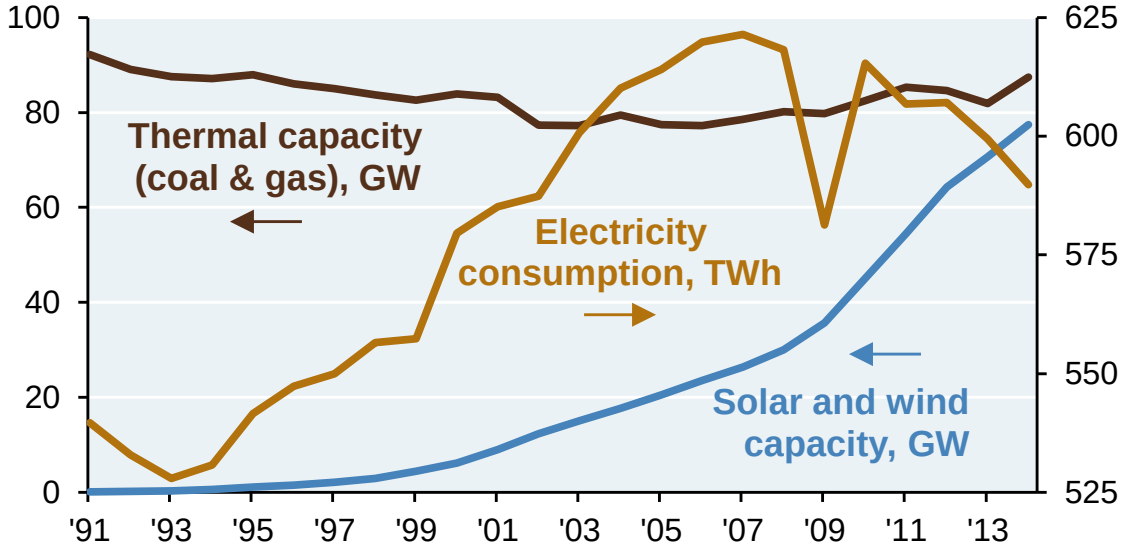
Annual global investment in renewable energy
USD billions



Source: UNEP, Bloomberg New Energy Finance. 2015.

Intermittency

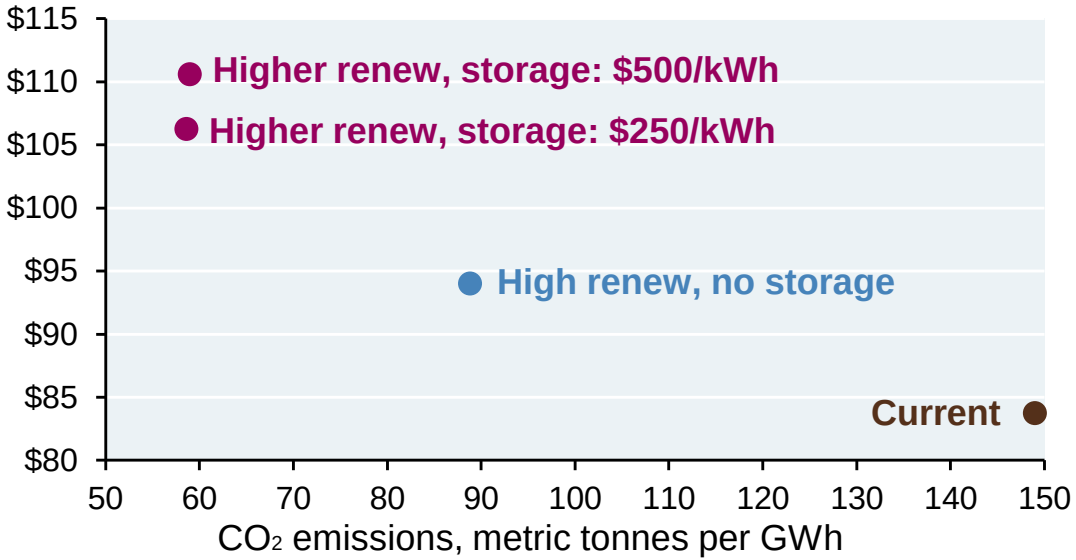
Despite a large renewable energy build-out in Germany, almost no reduction in natural gas and coal capacity



Source: German Federal Ministry for Economic Affairs and Energy. 2014.

Costs and emissions

California electricity cost-emission tradeoffs,
US$ system cost per MWh



Source: CAISO, EIA, JPMAM. 2017.

Realities of energy transitions

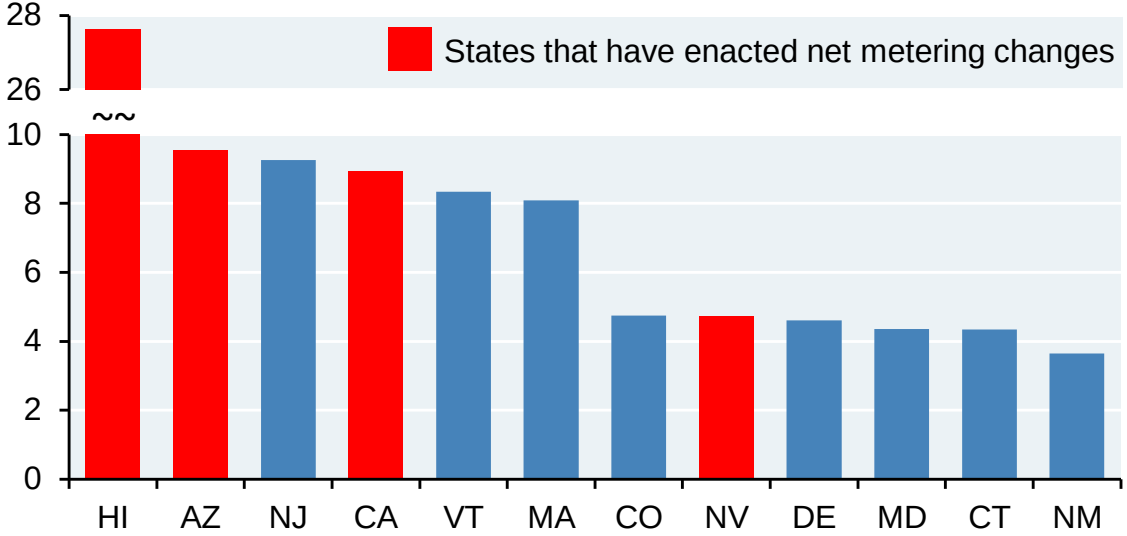
- Our estimates include the cost of connecting facilities to the grid, but do not include costs of building high voltage transmission lines. Their costs could add another $15-$20 per MWh to wind and solar costs, over and above the $2-$4 per MWh assumed by the EIA for grid interconnection

- The Plains & Eastern Clean Line (Texas panhandle to Memphis) is the first long-distance US HVDC transmission line built in more than 20 years, at annual cost of $15-$20 per MWh. If finished on time, it will have taken **11 years to complete**, and required the Dep't of Energy to invoke Section 1222 of the Energy Policy Act on eminent domain

- Electricity consumption in the 8 Midwestern and Northwestern states with high wind capacity factors (> 36%) and low population density (below 60 people per square mile, leaving plenty of room for wind farm construction) is only 6% of total US electricity consumption.

Utilities changing the rules

States with high distributed solar PV and net-metering changes, Distributed solar MW per 100,000 people

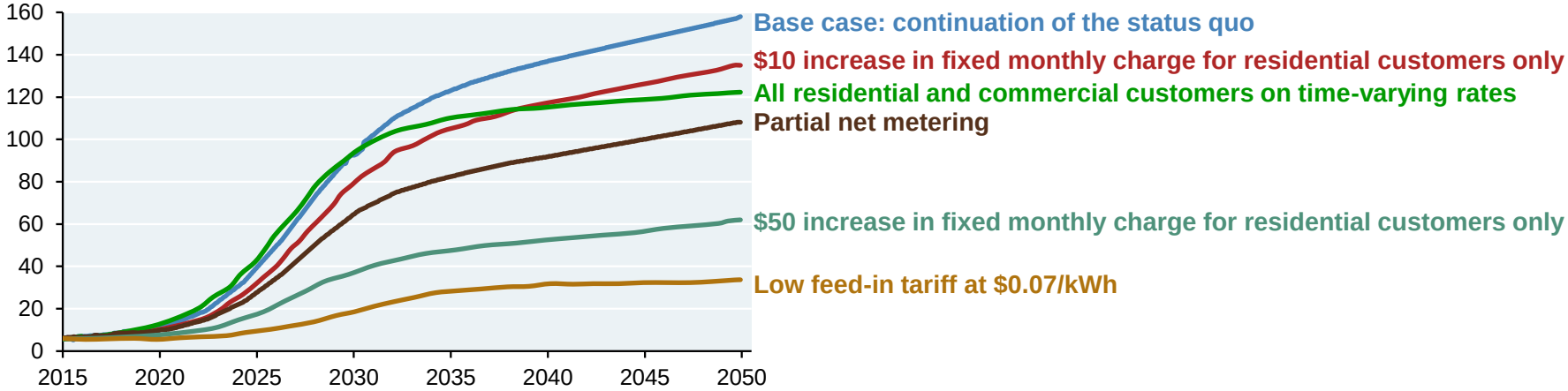


Source: EIA, US Census Bureau. January 2016. States shown are those with more than 3 MW per 100,000 people.

Sensitivity of future outcomes to policy

National distributed solar PV deployment by scenario

GW

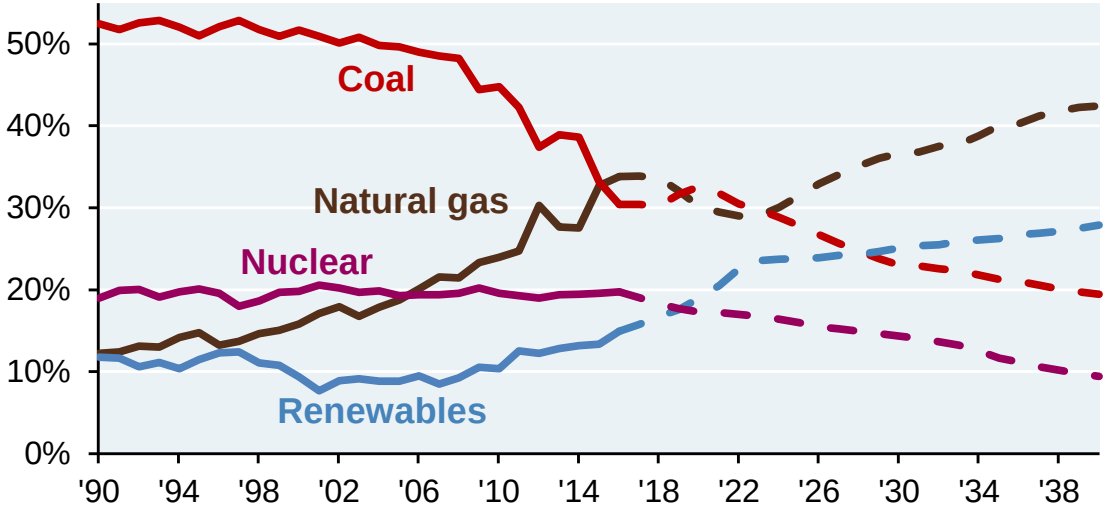


Source: Lawrence Berkeley National Laboratory. July 2015.

Decline of coal mostly a reflection of natural gas

US: natural gas could provide a pathway for more renewable energy, less coal and less nuclear

% of total electricity generation

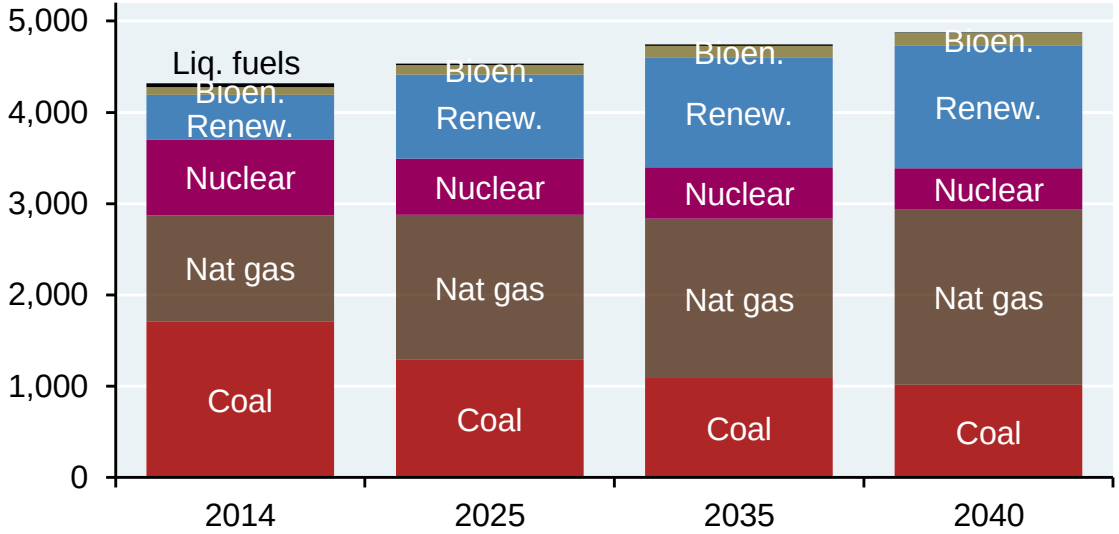


Source: Energy Information Administration, JPMAM. December 2016.

Renewable growth meets future demand and lower nuclear; natural gas displaces coal

Scenario: natural gas could provide a pathway for more renewable energy, less coal and less nuclear

US electricity generation by source, terawatthours

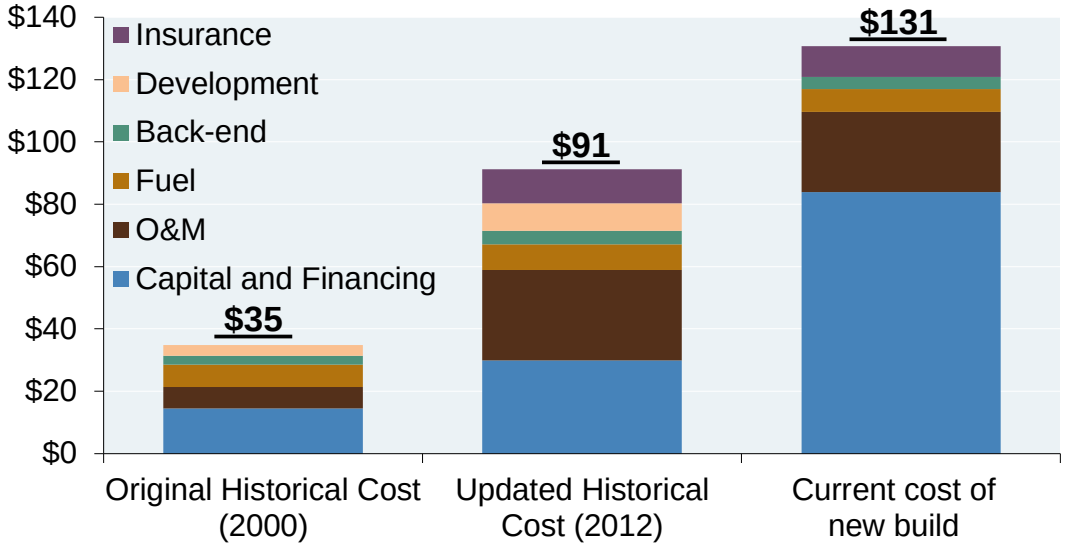


Source: International Energy Agency. JPMAM. 2016.

Nuclear costs

The rising cost of nuclear power in France

Levelized cost measured in 2010 $/MWh



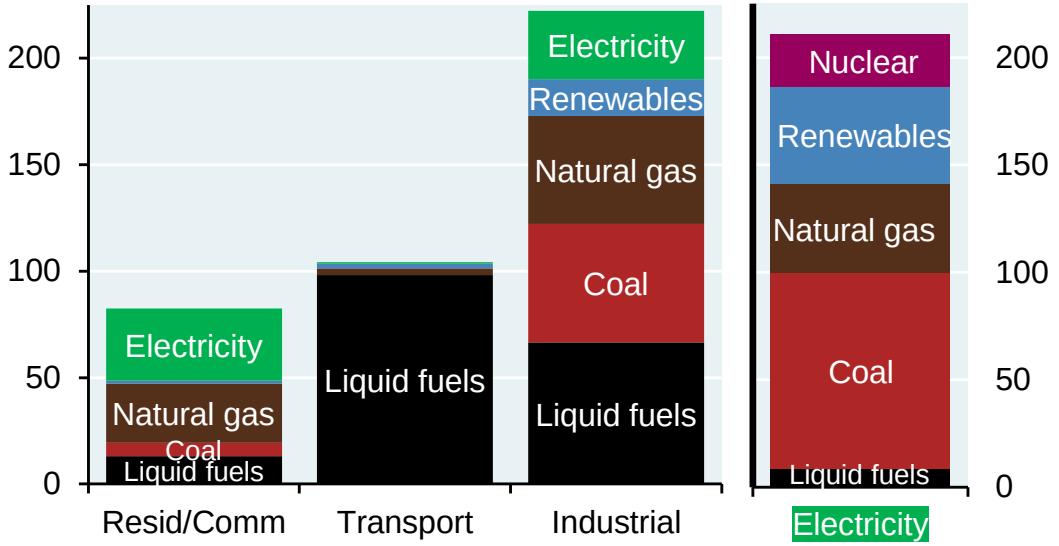
Source: N. Boccard, "*The cost of nuclear electricity: France after Fukushima",* Energy Policy Journal, December 2013.

- **US nuclear power plants scheduled to close** within the next decade include Pilgrim (MA), Diablo Canyon (CA), Three Mile Island (PA), Palisades (MI), Indian Point (NY) and Oyster Creek (NJ)

The resilience of natural gas demand: non-electricity usage

Renewables: so far, primarily impacting electricity

Global energy use by end-user and source, quadrillion BTU



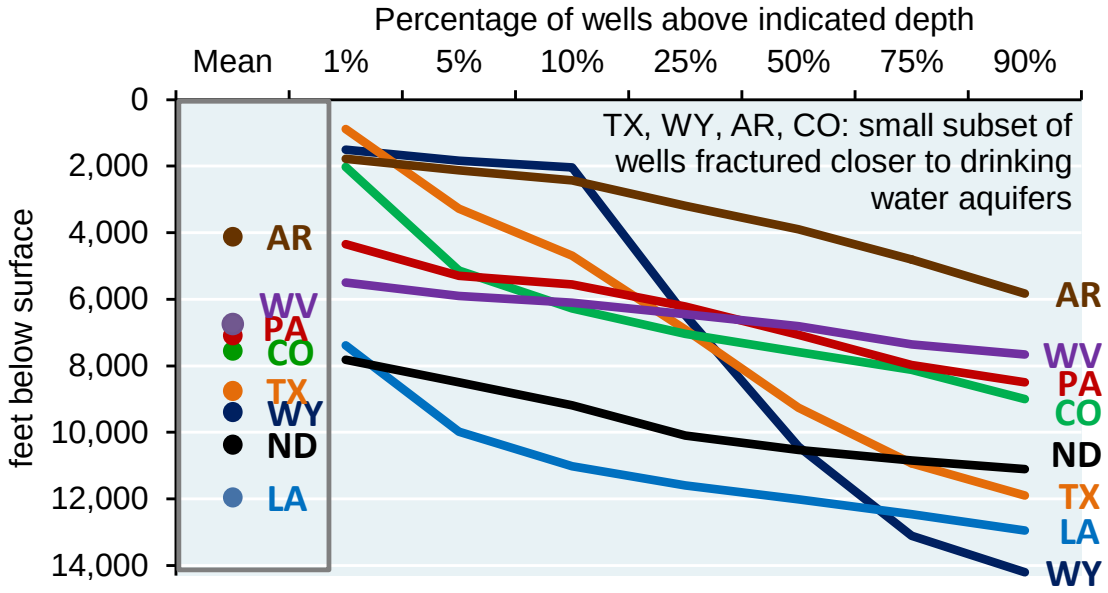
Source: Energy Information Administration, JPMAM. 2016.

- Industrial sector requires carbon-based inputs as raw materials (for steel, ammonia, plastics and rubber), and also as sources of high and consistent heat for processing of construction materials and smelting (cement, iron ore and petrochemicals)

- 25% air, marine and rail
- 2 mm units in 2016…and 200 mm units in 2030 (IEA)?
- 70% of elect. from fossil fuels, 5% from wind/solar

Fracturing

Depths of hydraulic fracturing wells



Source: Env. Science & Technology, Jackson (Stanford) et al. 2015.

The EPA

Original 2015 EPA draft, from Exec Summary

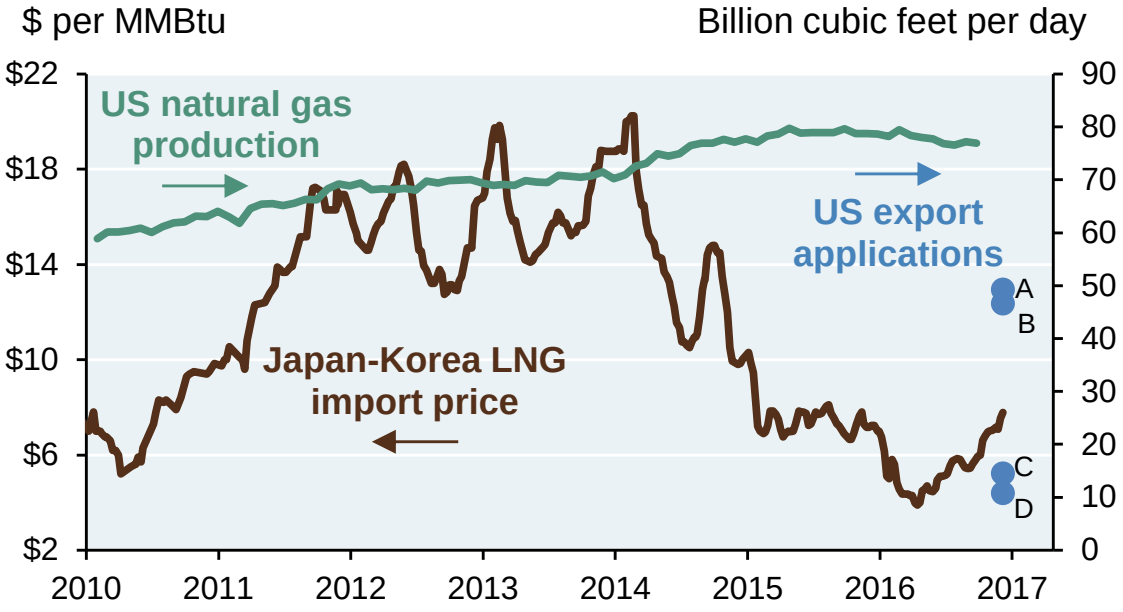
"We did not find evidence that these mechanisms have led to widespread, systemic impacts on drinking water resources in the United States"

Final EPA report January 2017, from Exec Summary

"This report describes how activities in the hydraulic fracturing water cycle can impact -- and have impacted -- drinking water resources and the factors that influence the frequency and severity of those impacts"

Rising US LNG exports unlikely to change US supply/demand equation

LNG: Asian import prices and US export applications



Source: DoE, EIA, FERC, J.P. Morgan Securities, JPMAM. Dec. 12, 2016.

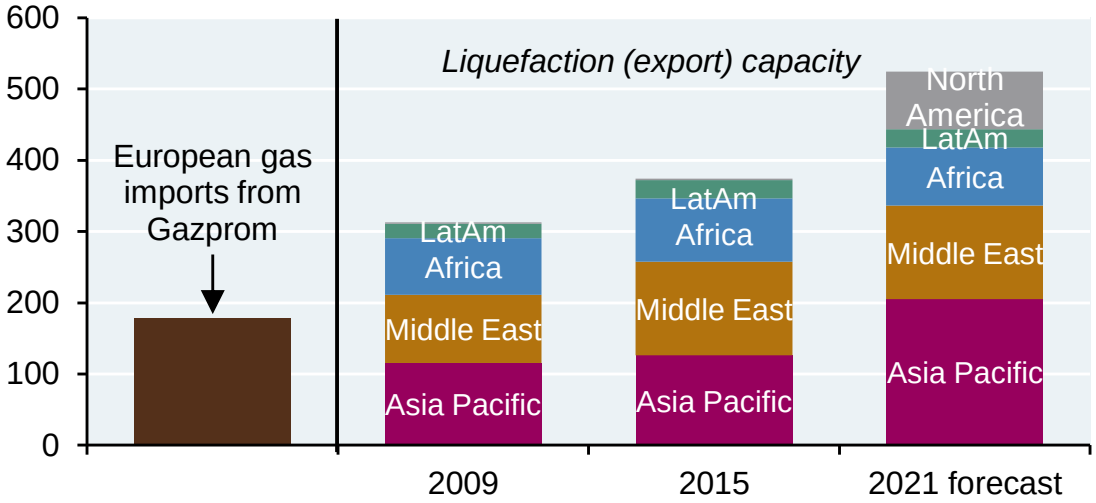
A: Applications approved by DoE to export LNG to FTA
B: Applications received by DoE to export LNG to non-FTA

C: Applications approved by DoE to export to non-FTA
(less contingent approvals)
D: LNG export facilities under construction

The cost of diversification for Europe

Potential gas counterparties for Europe

Billion cubic meters of natural gas per year

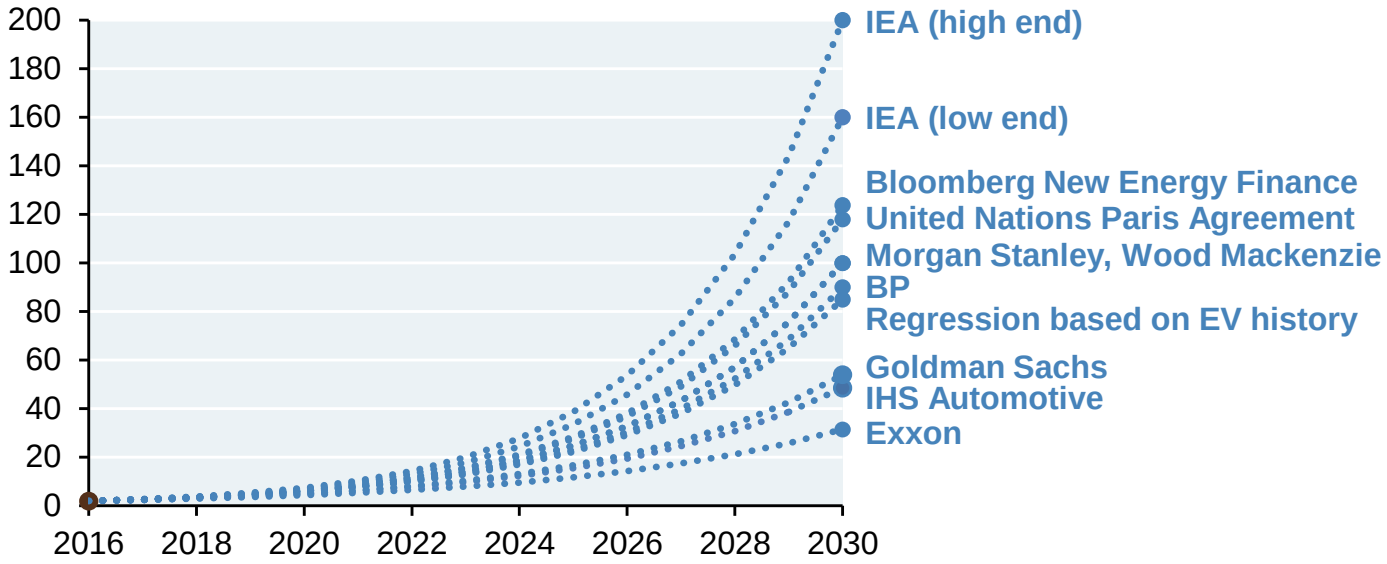


Source: International Gas Union, IHS. 2016. Capacity only refers to existing projects and projects under construction.

Electric vehicles

Electric vehicle projections vary widely

Global fleet size, million EVs

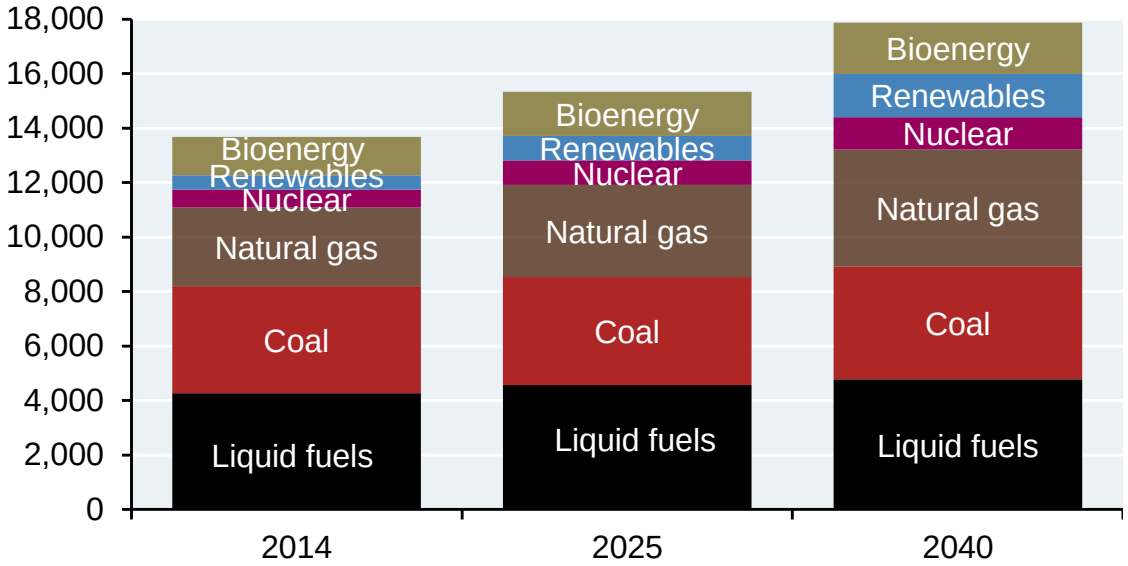


Sources: IEA, IHS, BNEF, MS, GS, UN, Wood Mackenzie, BP, Smil, Exxon. 2017.

Appendices

IEA: Renewables at 20% of primary energy by 2040

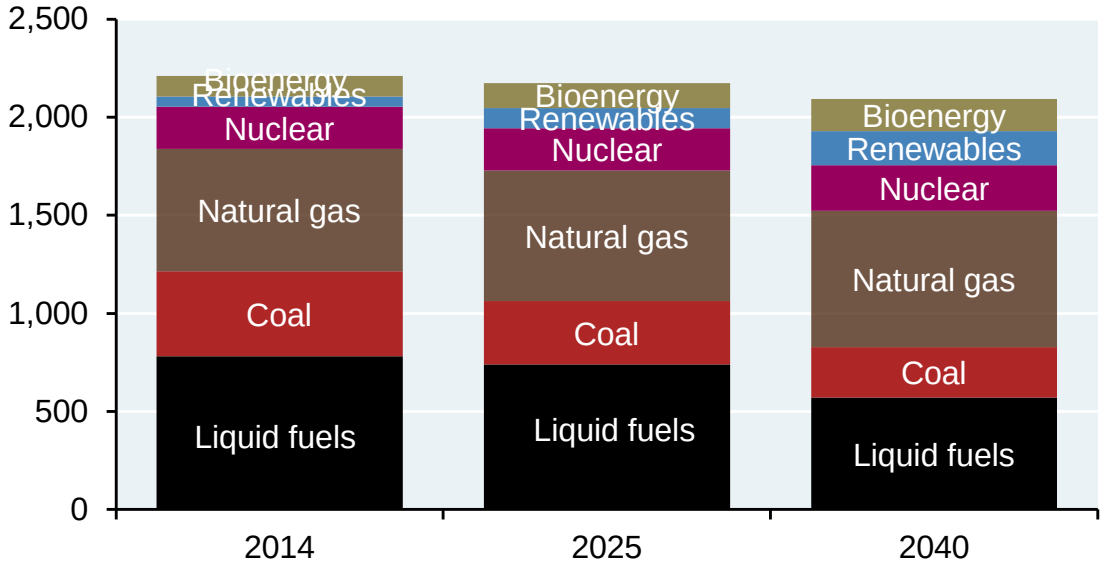
Global primary energy use by source, mm tonnes of oil equivalents



Source: International Energy Agency New Policies Scenario. 2016.

US energy demand by source

Primary energy, million tonnes of oil equivalents



Source: International Energy Agency New Policies Scenario. 2016.

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