

Global Trends in Clean Energy and Electric Mobility

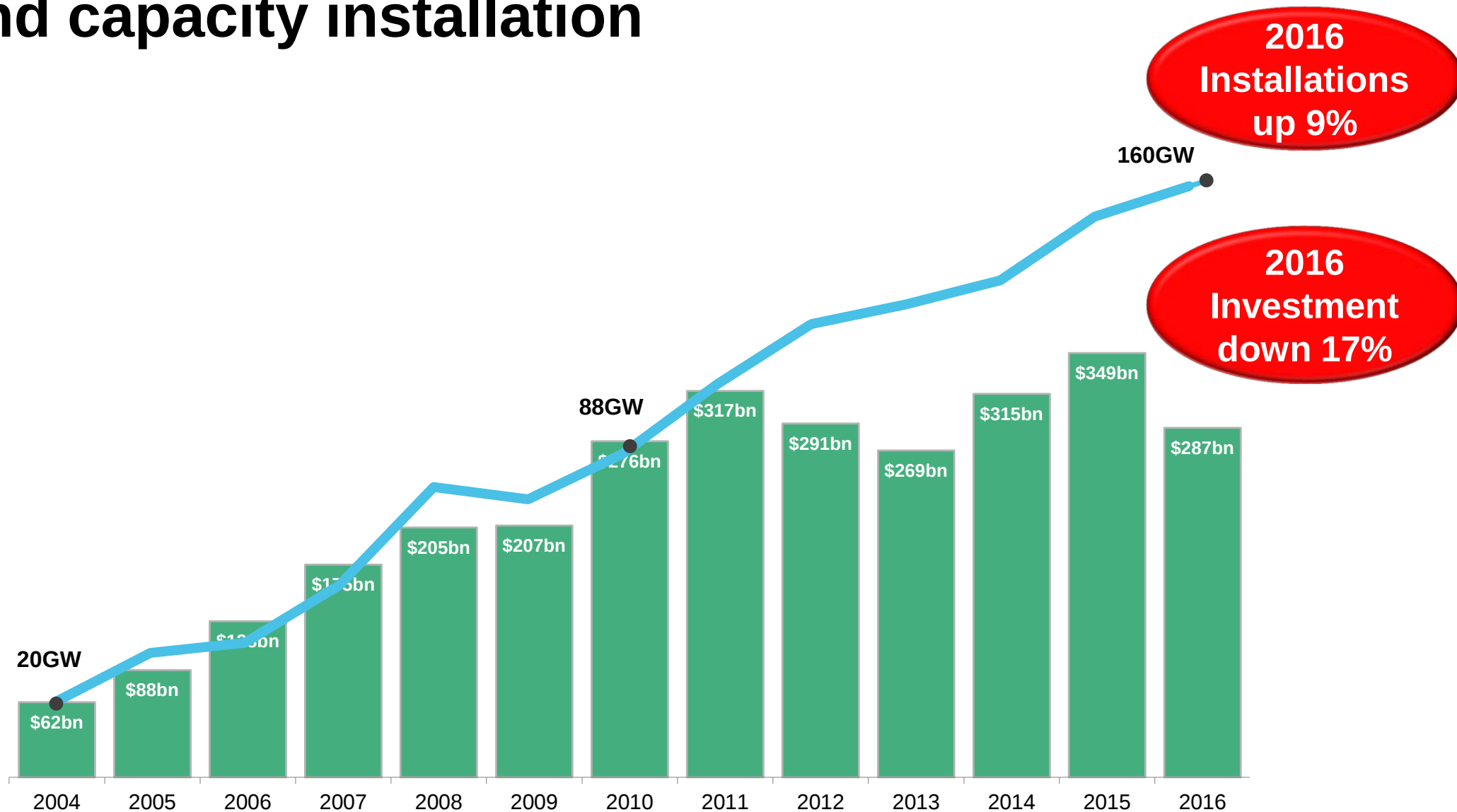
Berlin

Michael Liebreich
Chairman of the Advisory Board
Twitter: @mliebreich

10 May 2017

**Bloomberg
New Energy Finance**

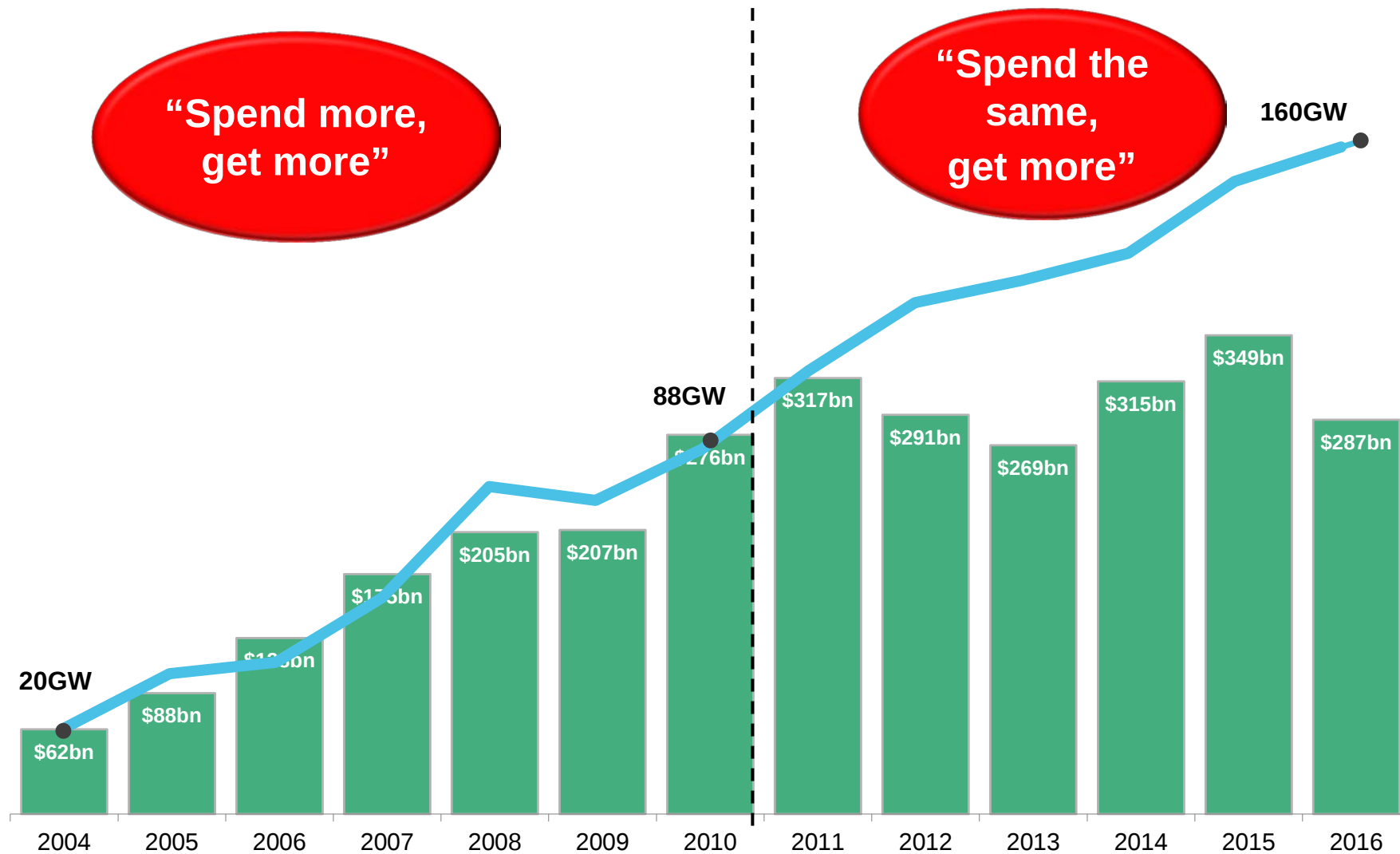
Global new clean energy investment and capacity installation



Note: Total values include estimates for undisclosed deals. Includes corporate and government R&D, and spending for digital energy and energy storage projects (not reported in quarterly statistics). Excludes large hydro.

Source: Bloomberg New Energy Finance

Global new clean energy investment and capacity installation



Note: Total values include estimates for undisclosed deals. Includes corporate and government R&D, and spending for digital energy and energy storage projects (not reported in quarterly statistics). Excludes large hydro.

Source: Bloomberg New Energy Finance

2011 unsubsidised clean energy World records

ONSHORE WIND



US\$ 6.2 cents/kWh

SOLAR PV



US\$ 17 cents/kWh

Source: Bloomberg New Energy Finance; ImagesSiemens; Wikimedia Commons

Unsubsidised clean energy world records April 2016

Solar PV



Country: Coahuila Mexico
Bidder: Enel Green Power
Signed: March 2016
Construction: 2019
Price: US\$ 3.60 c/kWh

Onshore wind



Country: Morocco
Bidder: Enel Green Power
Signed: January 2016
Construction: 2018
Price: US\$ 3.0 c/kWh

Offshore wind



Country: Denmark
Bidder: Vattenfall
Signed: Dec 2015
Construction: 2019
Price: US\$ 5.3 c/kWh

Source: Bloomberg New Energy Finance; ImagesSiemens; Wikimedia Commons

Unsubsidised clean energy world records since April 2016

Solar PV



Country: United Arab Emirates
Bidder: Masdar/DEWA
Signed: May 2016
Construction: 2018
Price: US\$ 2.99 c/kWh

Onshore wind



Country: Morocco
Bidder: Enel Green Power
Signed: January 2016
Construction: 2018
Price: US\$ 3.0 c/kWh

Offshore wind



Country: Denmark
Bidder: Vattenfall
Signed: Dec 2015
Construction: 2019
Price: US\$ 5.3 c/kWh

Source: Bloomberg New Energy Finance; ImagesSiemens; Wikimedia Commons

Unsubsidised clean energy world records since April 2016

Solar PV



Country: Chile
Bidder: Solarpack Corporation
Signed: August 2016
Construction: 2019
Price: US\$ 2.91 c/kWh

Onshore wind



Country: Morocco
Bidder: Enel Green Power
Signed: January 2016
Construction: 2018
Price: US\$ 3.0 c/kWh

Offshore wind



Country: Denmark
Bidder: Vattenfall
Signed: Dec 2015
Construction: 2019
Price: US\$ 5.3 c/kWh

Source: Bloomberg New Energy Finance; ImagesSiemens; Wikimedia Commons

Unsubsidised clean energy world records since April 2016

Solar PV



Country: Mexico
Bidder: X-Elio
Signed: September 2016
Construction: 2019
Price: US\$ 2.74 c/kWh

Onshore wind



Country: Morocco
Bidder: Enel Green Power
Signed: January 2016
Construction: 2018
Price: US\$ 3.0 c/kWh

Offshore wind



Country: Denmark
Bidder: Vattenfall
Signed: Dec 2015
Construction: 2019
Price: US\$ 5.3 c/kWh

Source: Bloomberg New Energy Finance; ImagesSiemens; Wikimedia Commons

Unsubsidised clean energy world records since April 2016

Solar PV



Country: Mexico
Bidder: FRV
Signed: September 2016
Construction: 2019
Price: US\$ 2.69 c/kWh

Onshore wind



Country: Morocco
Bidder: Enel Green Power
Signed: January 2016
Construction: 2018
Price: US\$ 3.0 c/kWh

Offshore wind



Country: Denmark
Bidder: Vattenfall
Signed: Dec 2015
Construction: 2019
Price: US\$ 5.3 c/kWh

Source: Bloomberg New Energy Finance; ImagesSiemens; Wikimedia Commons

Unsubsidised clean energy world records since April 2016

Solar PV



Country: Mexico
Bidder: FRV
Signed: September 2016
Construction: 2019
Price: US\$ 2.69 c/kWh

Onshore wind



Country: Morocco
Bidder: Enel Green Power
Signed: January 2016
Construction: 2018
Price: US\$ 3.0 c/kWh

Offshore wind

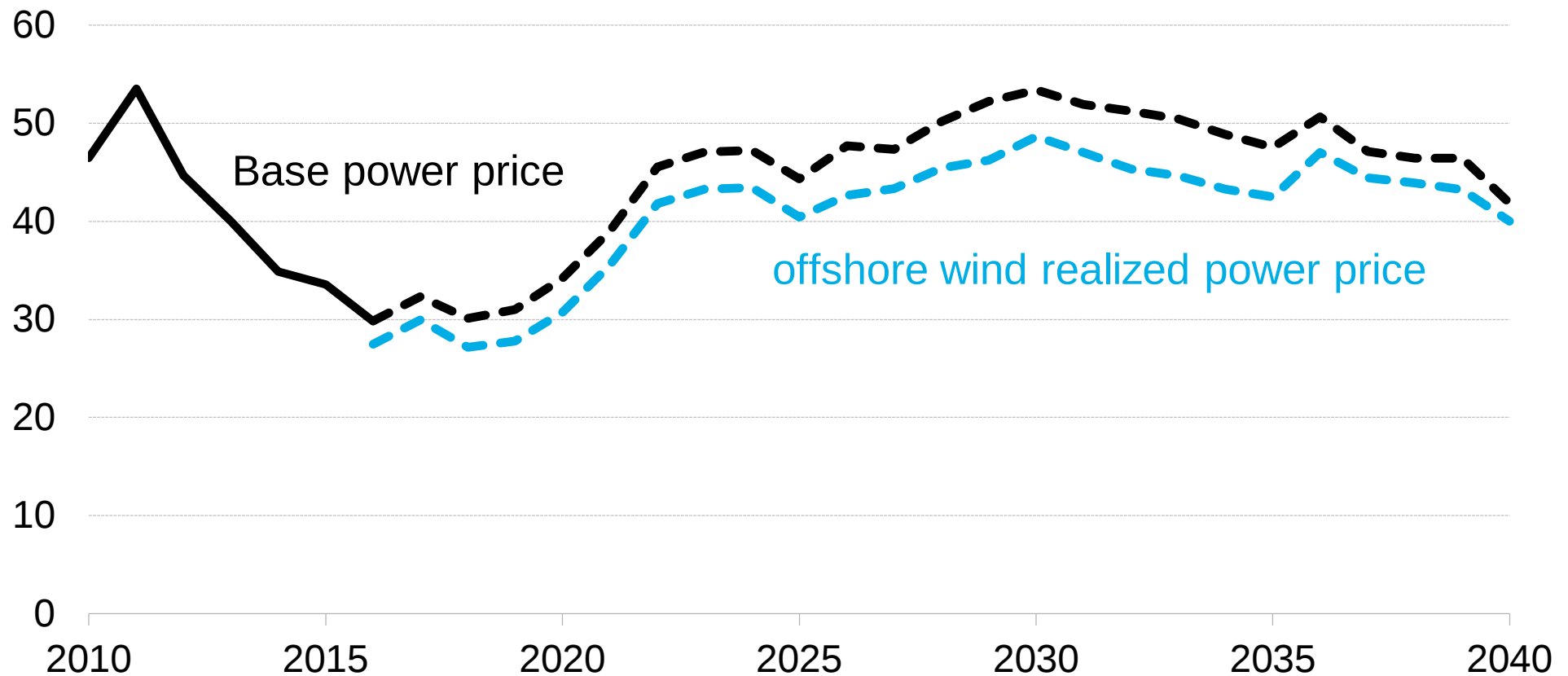


Country: Germany
Bidder: DONG/EnBW
Signed: April 2017
Construction: 2024
Merchant Price: US\$ 4.9 c/kWh

Note: The offshore wind merchant price is estimated based on project LCOE in real 2016 terms *Source: Bloomberg New Energy Finance; ImagesSiemens; Wikimedia Commons*

Germany power price forecast

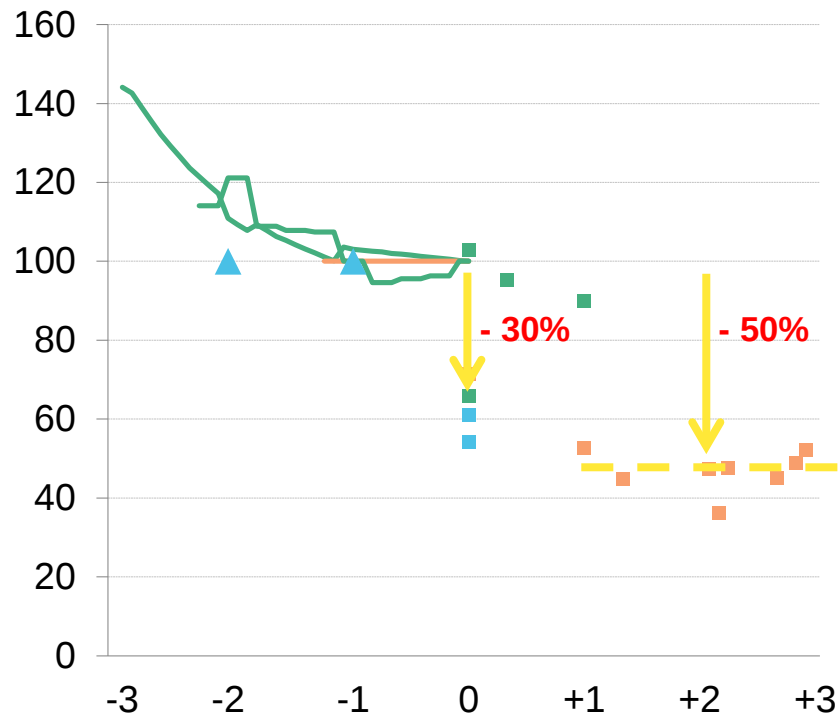
2016 euros/MWh



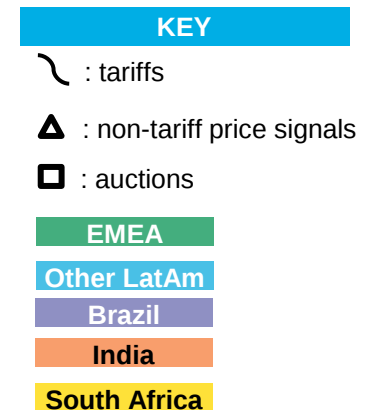
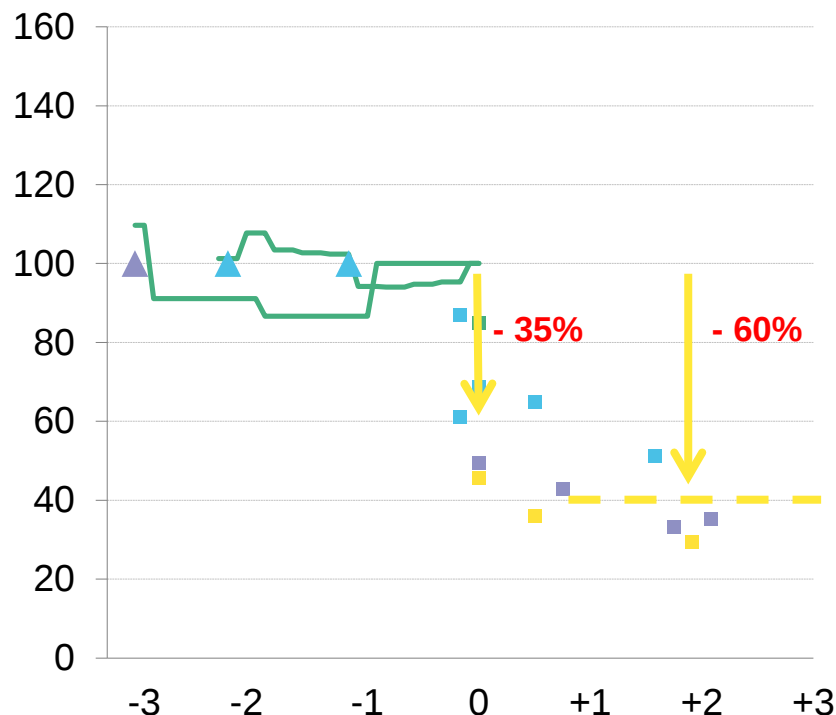
Source: Bloomberg New Energy Finance

Price impact of switch from FiT to auctions, selected countries (normalised)

Solar PV
(unit price normalised to 100 at date of first auction)

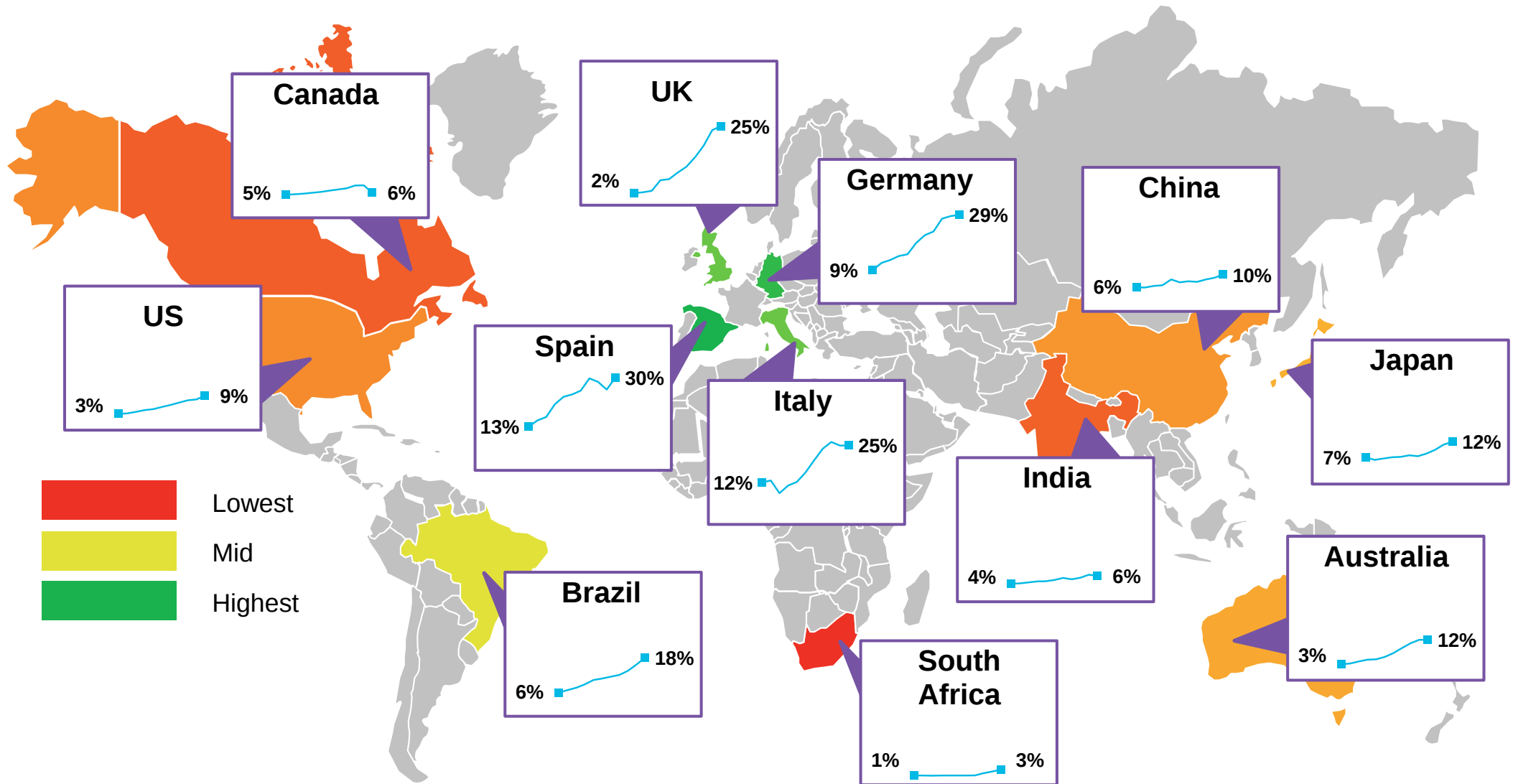


Onshore Wind
(unit price normalised to 100 at date of first auction)



Source: Bloomberg New Energy Finance

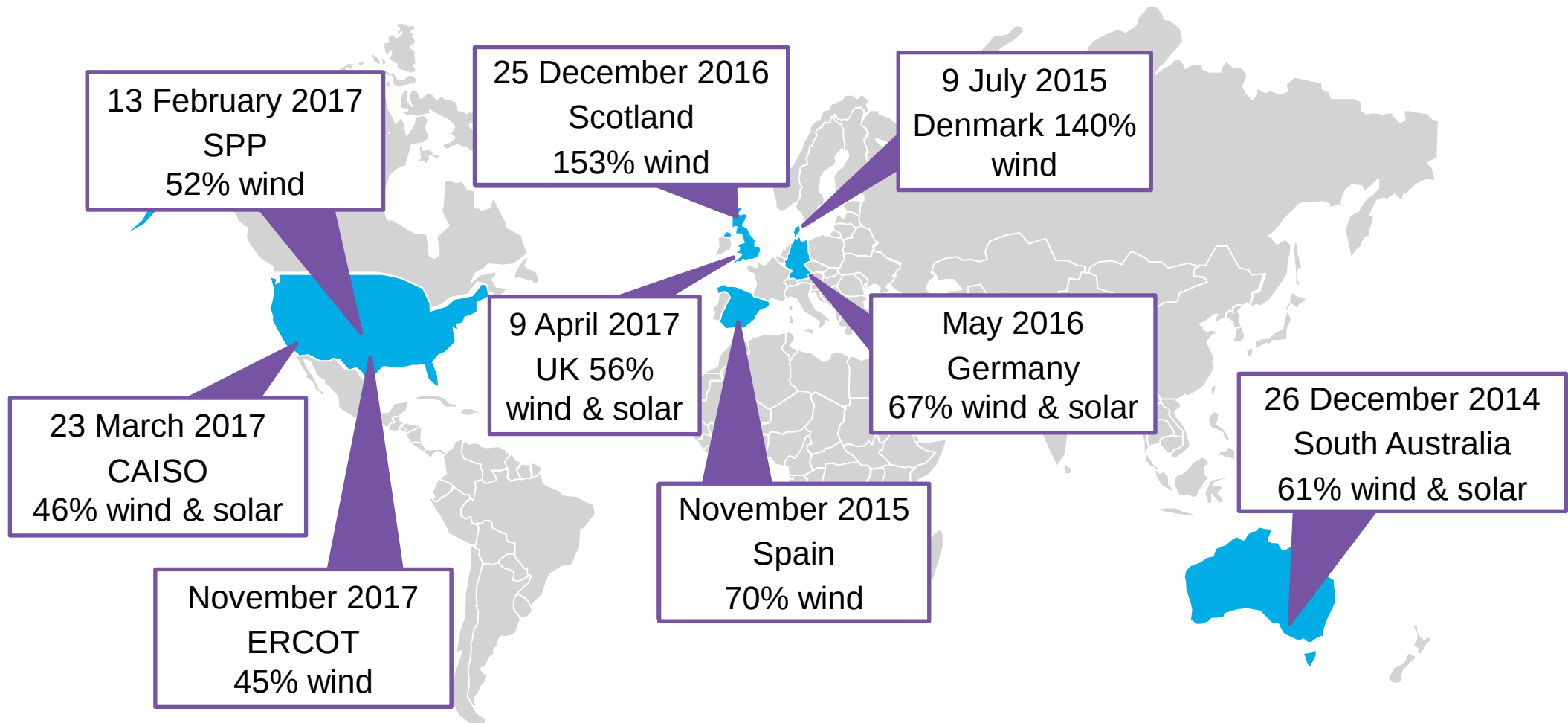
Renewable energy excl. large hydro, proportion of power generation, 2006-16



Note: Excludes large hydro

Source: Bloomberg New Energy Finance

Variable renewables high penetration

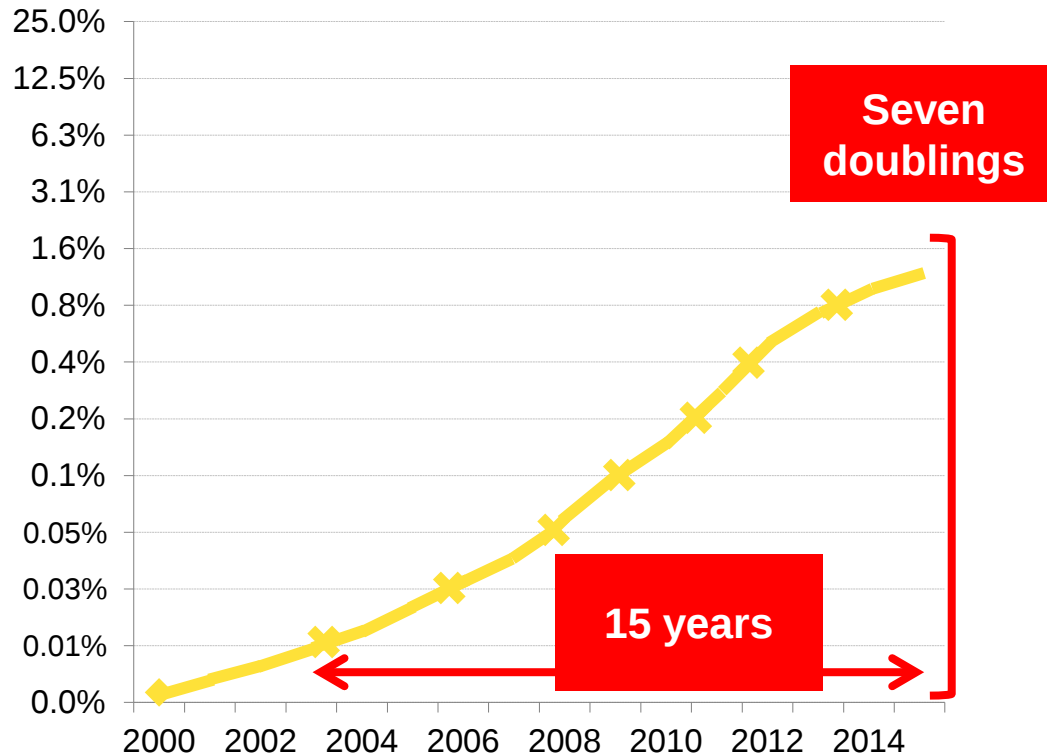


Source: Bloomberg New Energy Finance, various

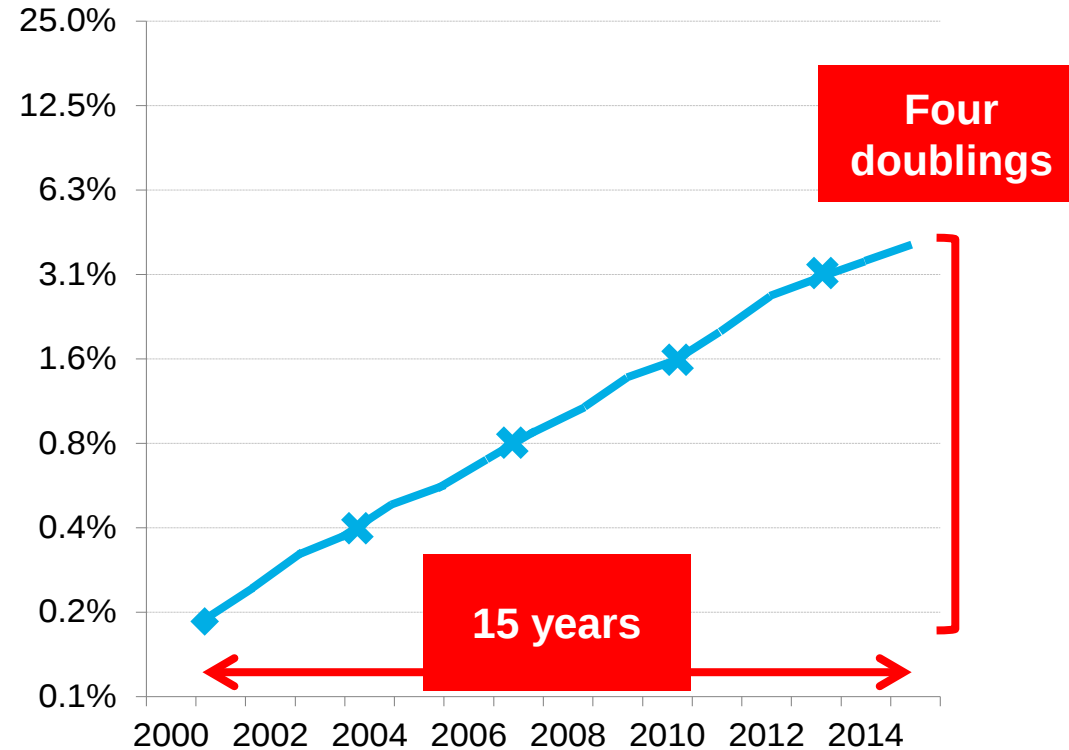
Renewables share of Generation, 2000–15

(% of system total)

SOLAR



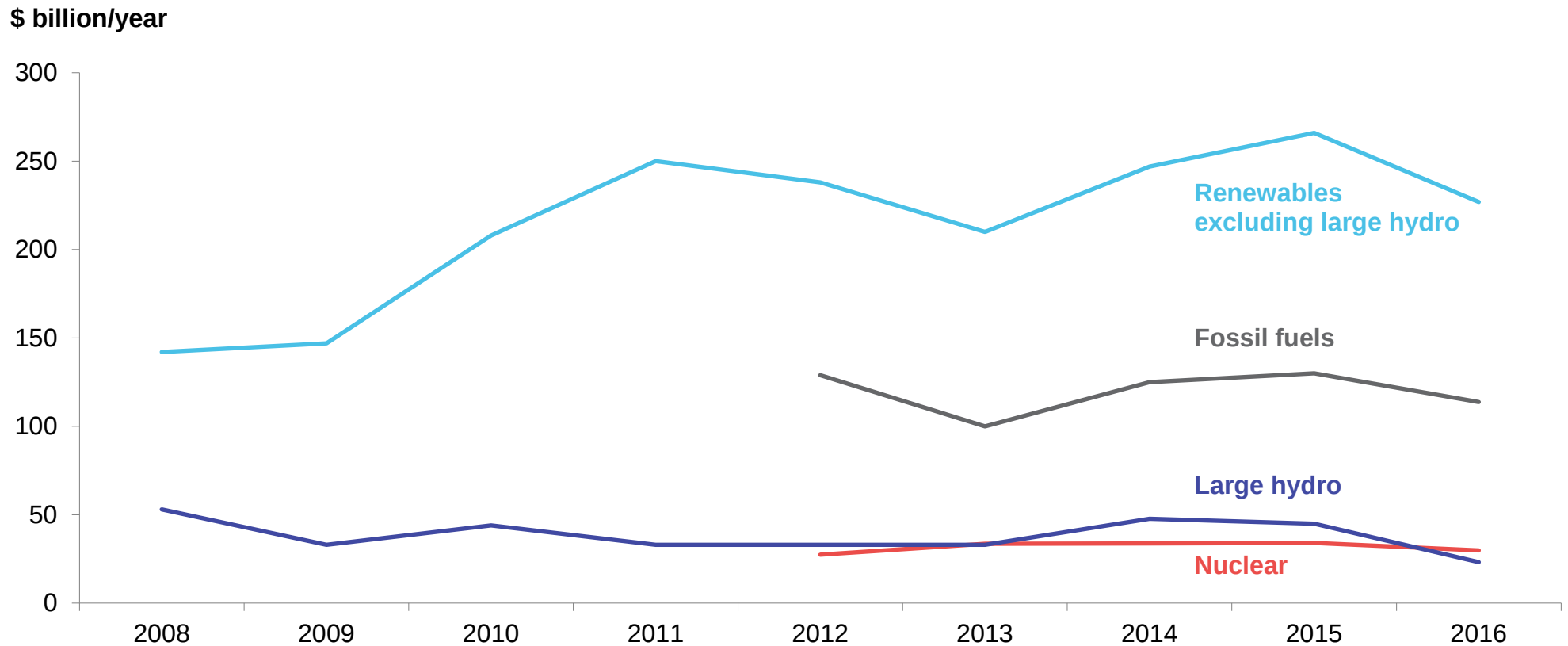
WIND



Source: Bloomberg New Energy Finance, BP, UNEP

Note: Y-axes are logarithmic with base 2

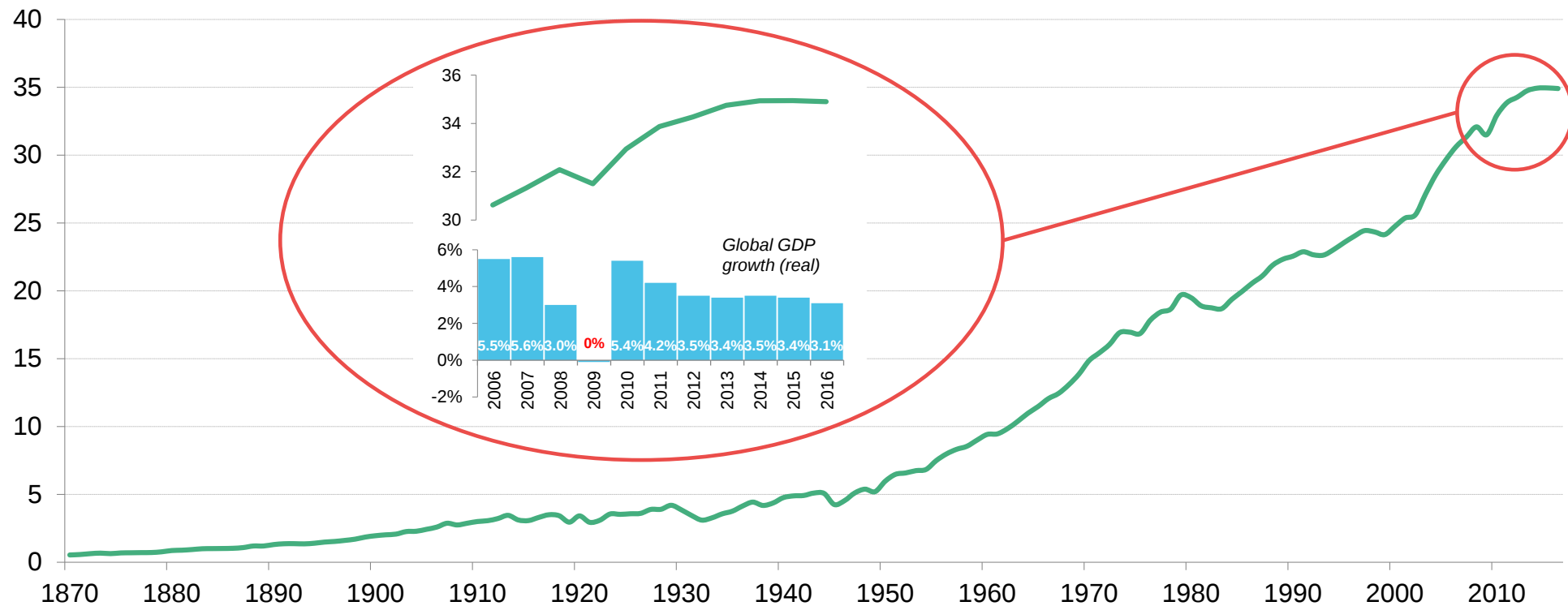
Investment in power capacity, by technology



Source: Bloomberg New Energy Finance, UNEP

Global carbon emissions from fossil fuels

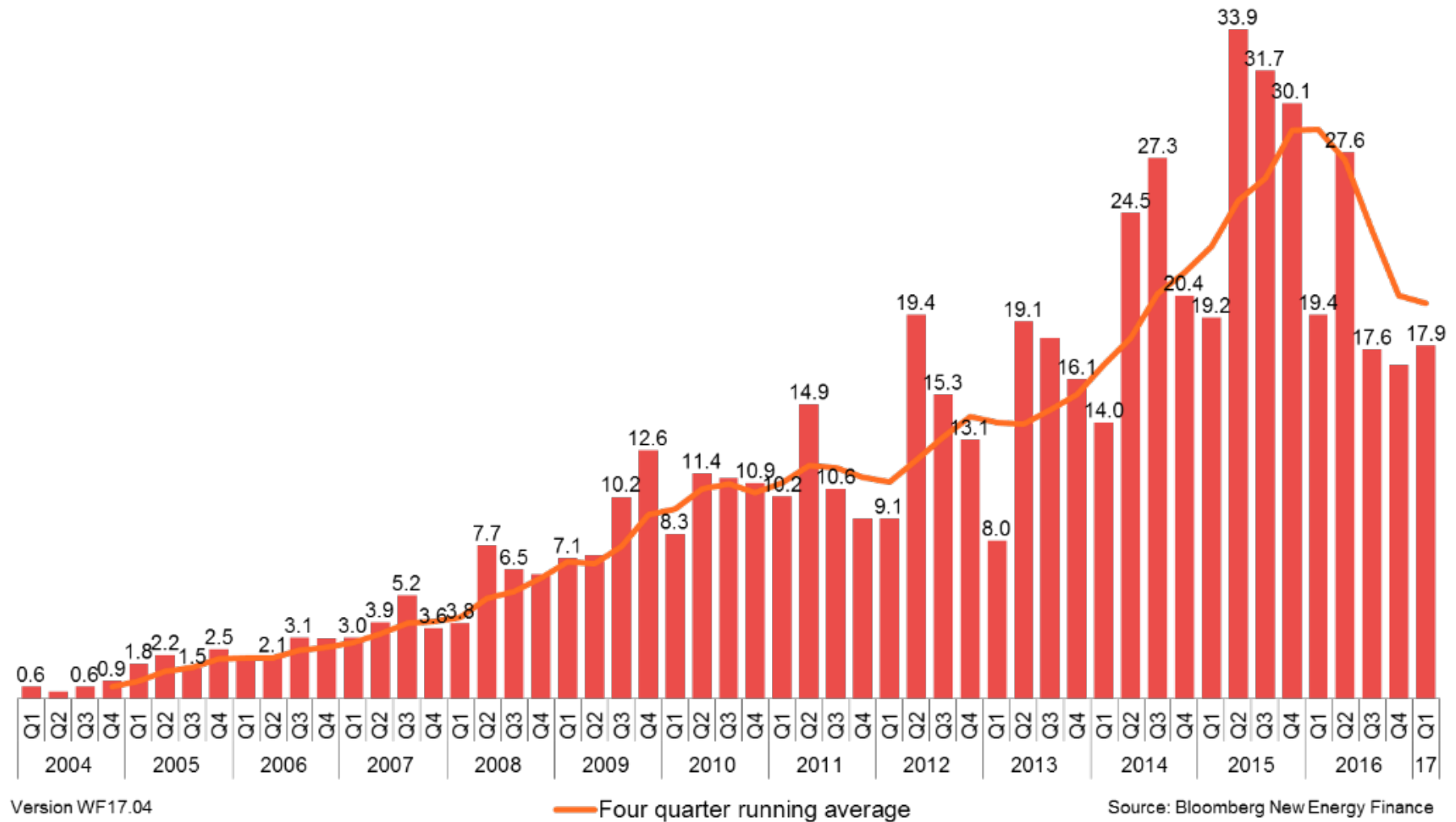
GtCO₂e



Source: IEA; CDIAC; BP; Bloomberg New Energy Finance

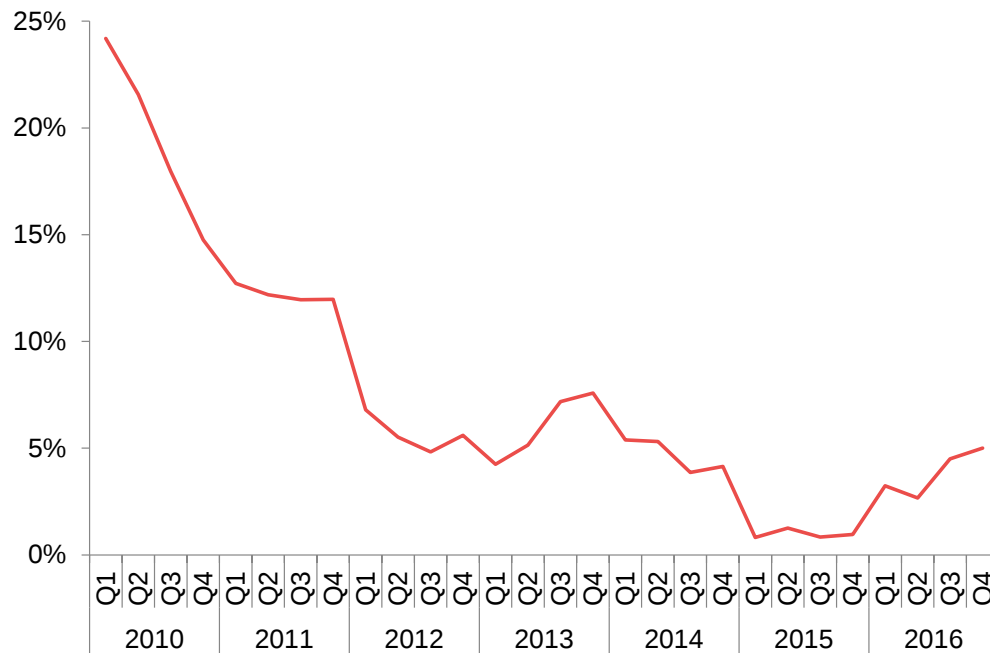
China new investment in clean energy

(\$ billion)

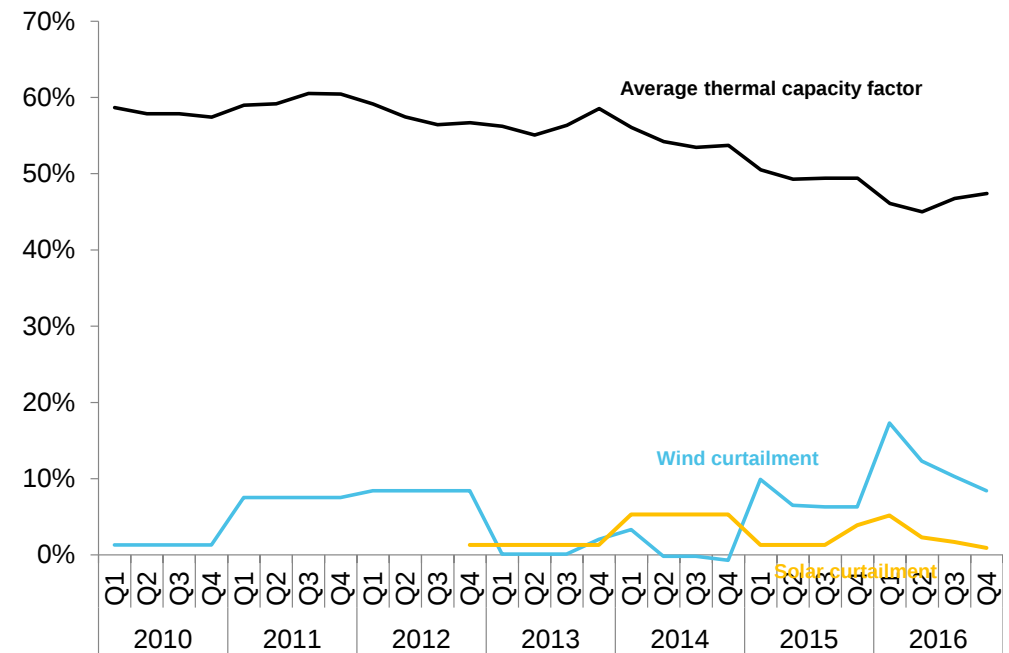


China snapshot

China yoy% growth in power demand



Thermal capacity factor and RE curtailment



Note: Thermal capacity factor includes all fossil fuel-fired thermal capacity. Wind and solar curtailment figures are not national averages, but refer to select provinces which exhibited the worst cases of curtailment nationally over the period

Source: Bloomberg New Energy Finance, China Electricity Council, National Energy Administration

Price of renewable energy in India

“

The cost of solar power is now cheaper than coal in this country.

”

*Piyush Goyal
Minister of State for Power, Coal, New &
Renewable Energy and Mines, India*

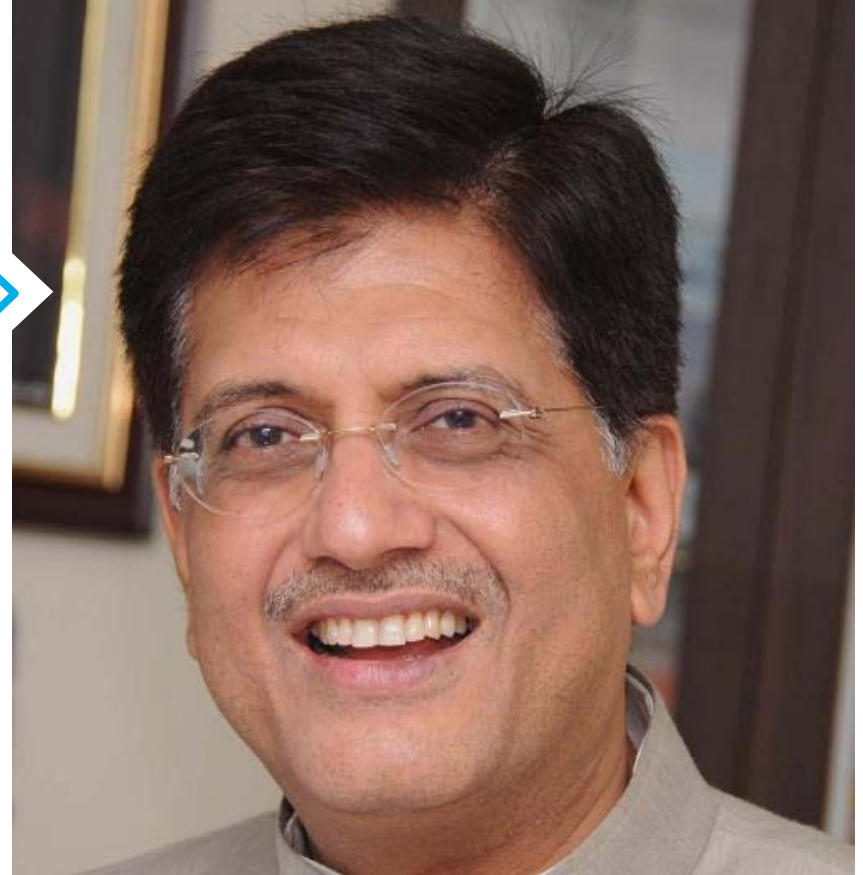
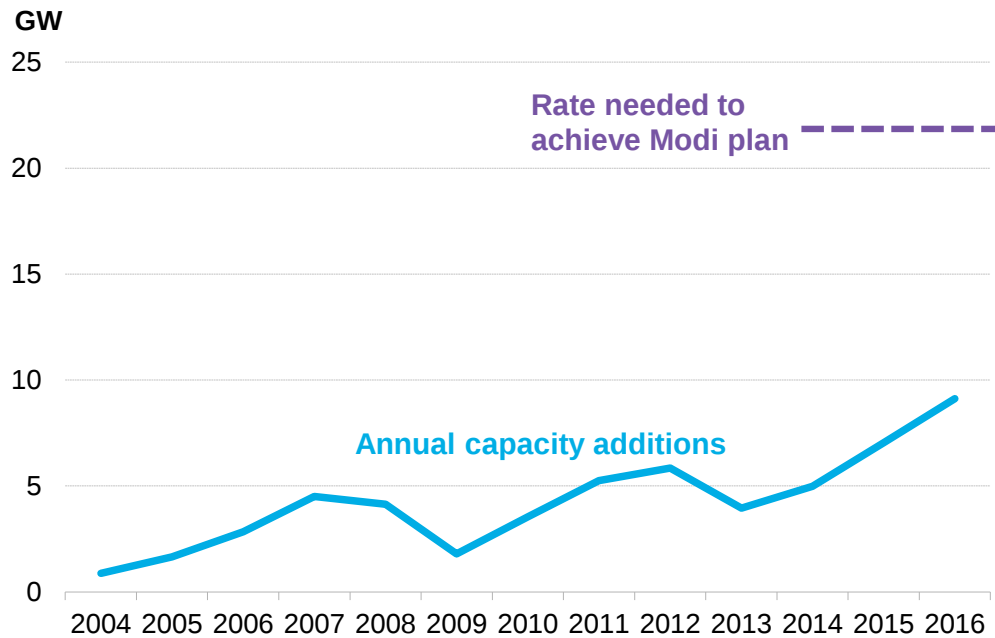


Image: Twitter

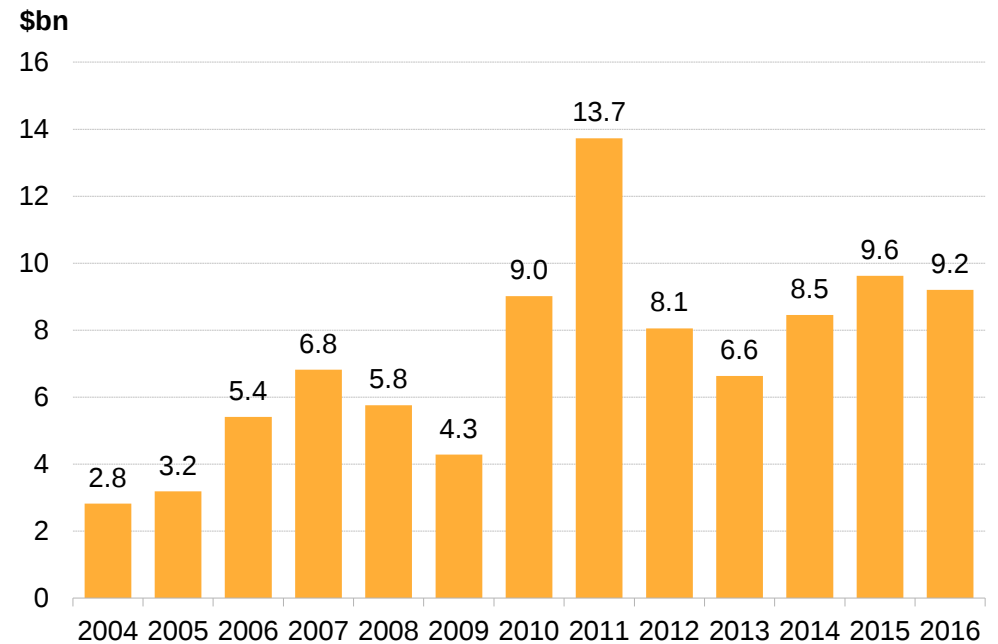
India snapshot

Annual capacity additions vs Modi plan



Note: Modi plan annual additions rate assumes linear trajectory to 175GW 2022 target. Figures exclude large hydro

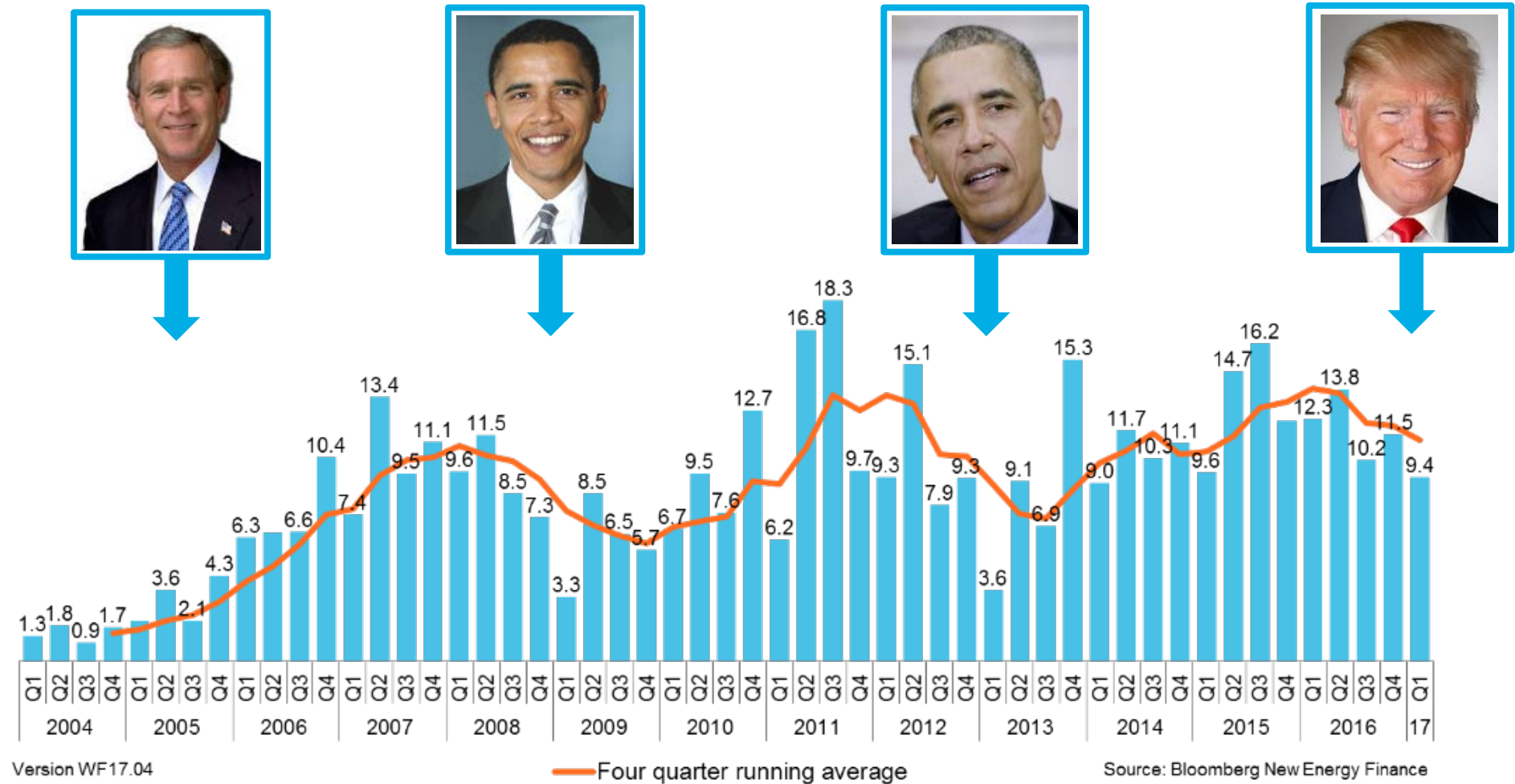
India clean energy investment



Source: Bloomberg New Energy Finance

US new investment in clean energy

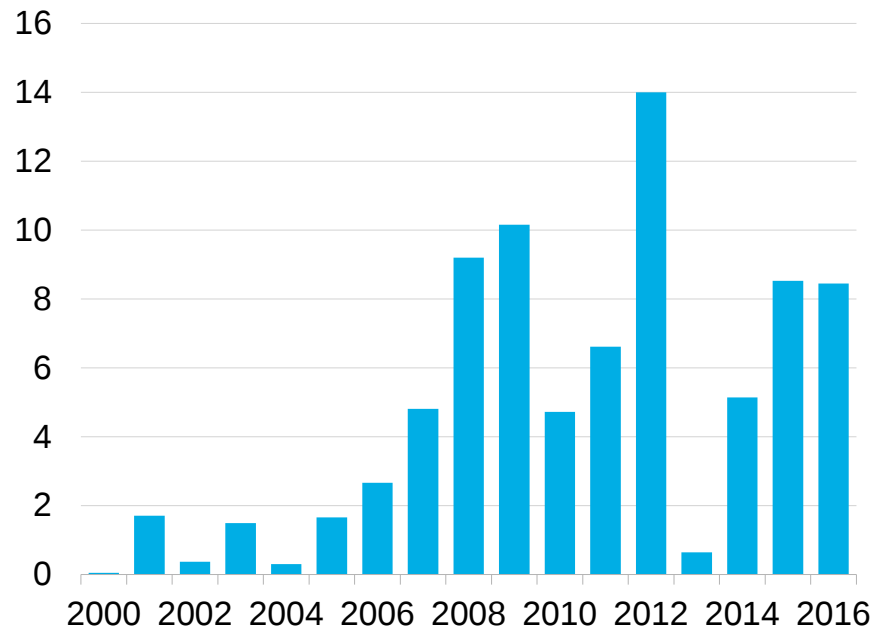
(\$ billion)



US wind installations

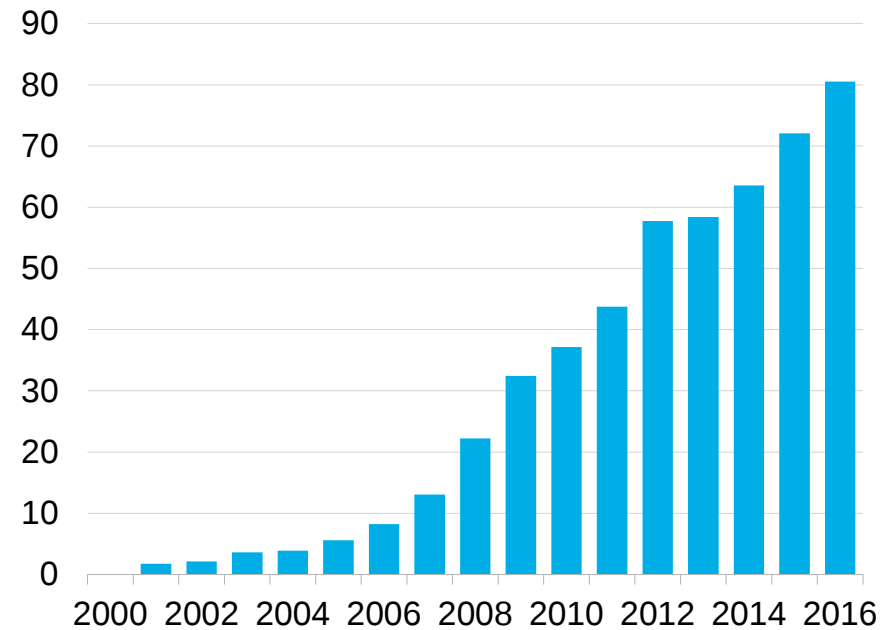
Annual

GW



Cumulative

GW



2008-16
Up 262%

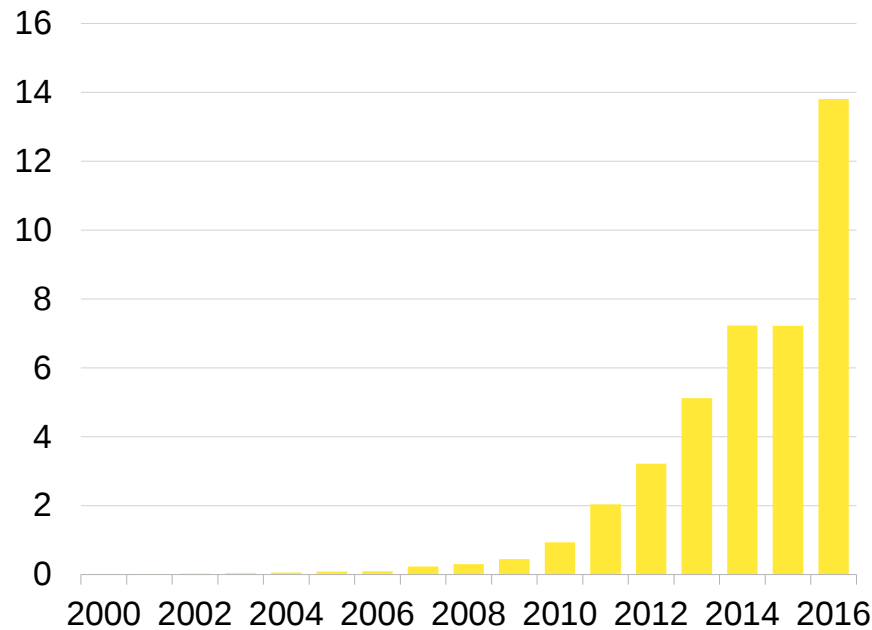
Note: Cumulative over 2000–16

Source: Bloomberg New Energy Finance

US solar installations

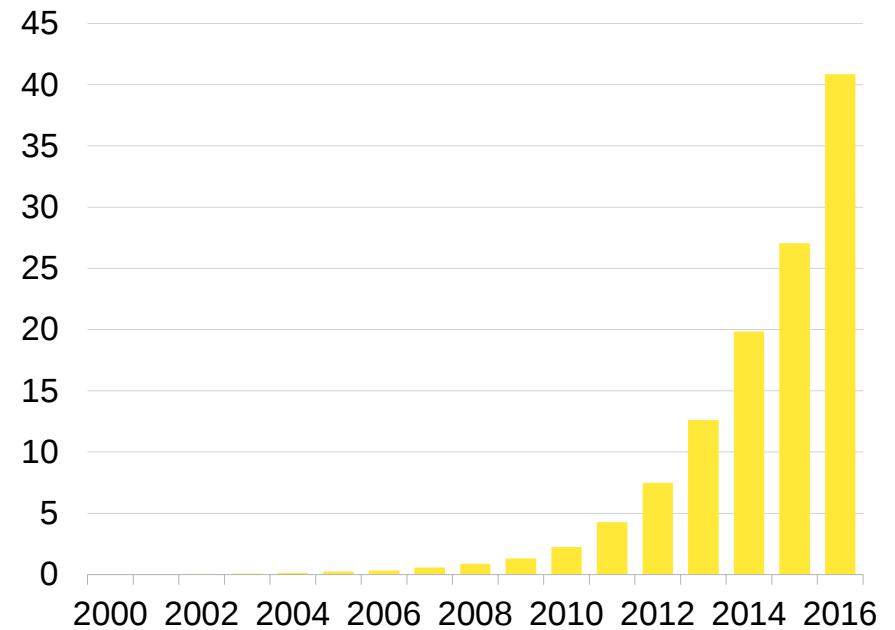
Annual

GW



Cumulative

GW



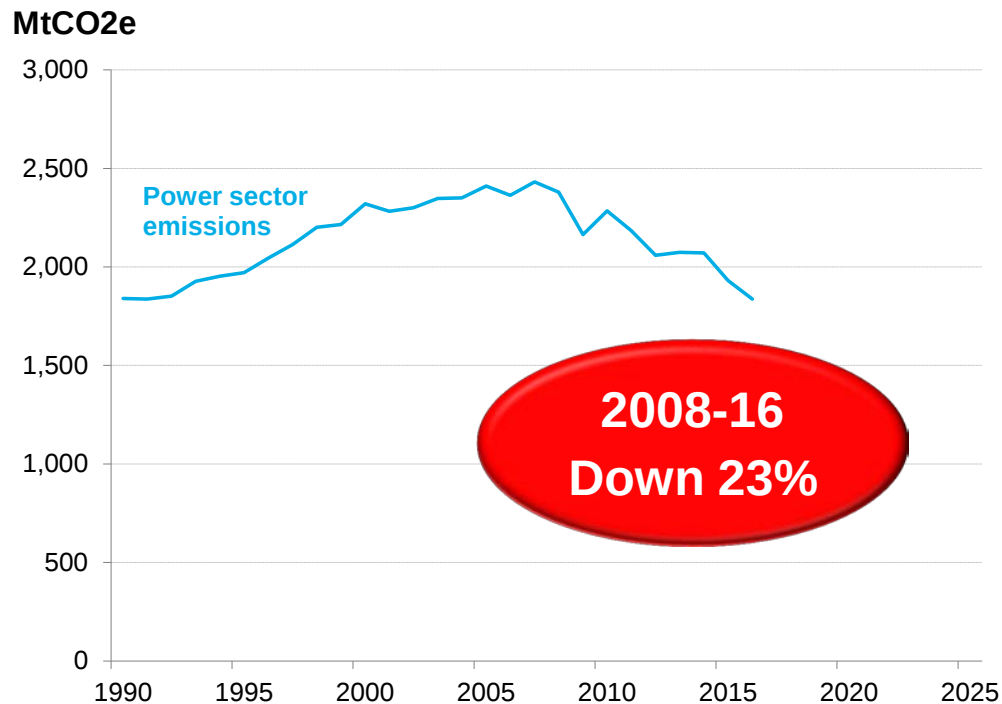
2008-16
Up 4,645%

Note: Cumulative over 2000–16

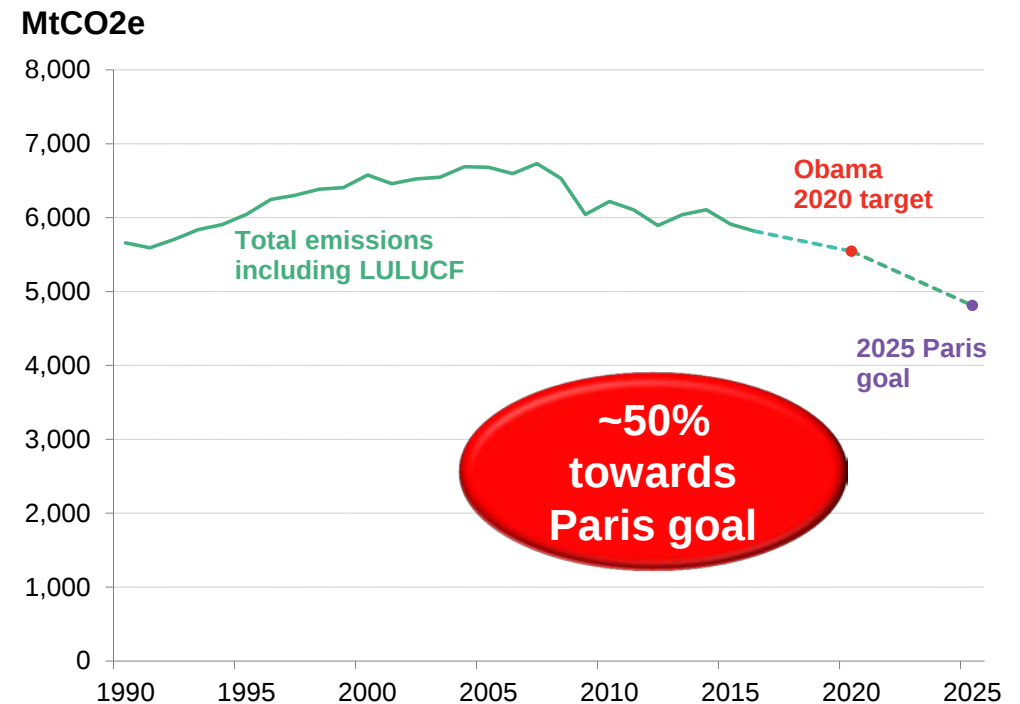
Source: Bloomberg New Energy Finance

Greenhouse gas emissions and progress towards targets

US power sector emissions



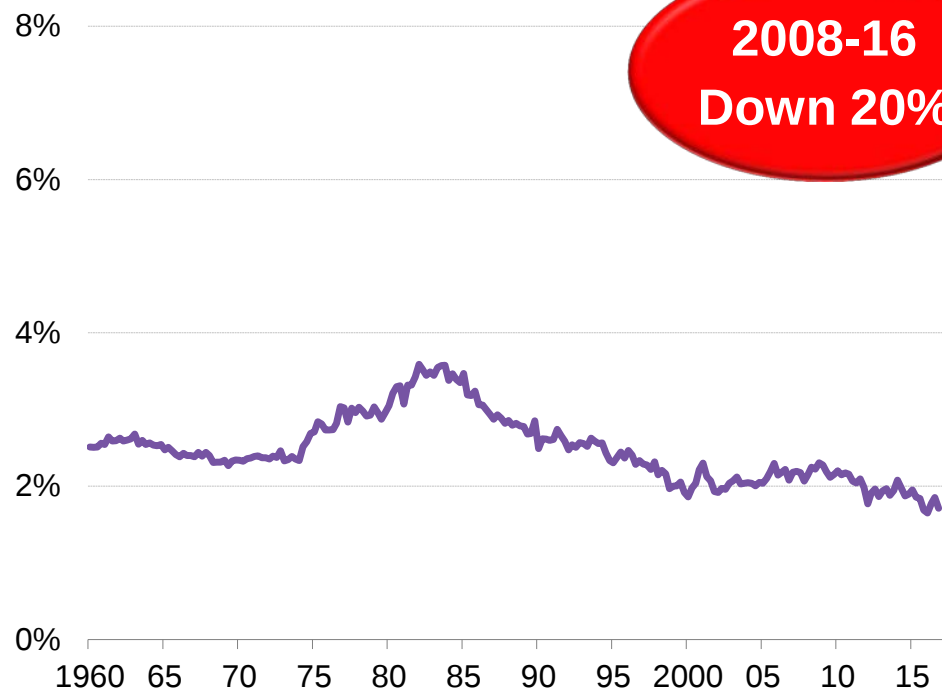
US total emissions



Source: Bloomberg New Energy Finance, EIA, EPA

Share of US personal expenditure on energy

Electricity & gas



Gasoline



Source: US Bureau of Economic Analysis, Bloomberg New Energy Finance

Making America Great Again?

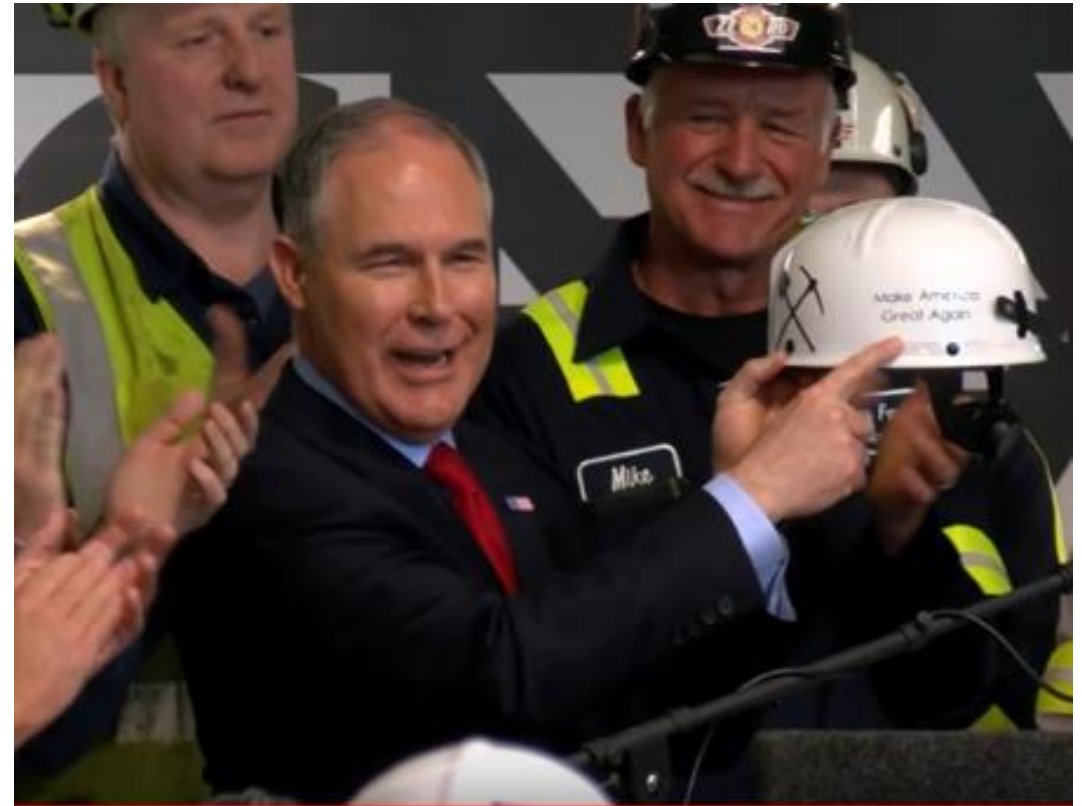
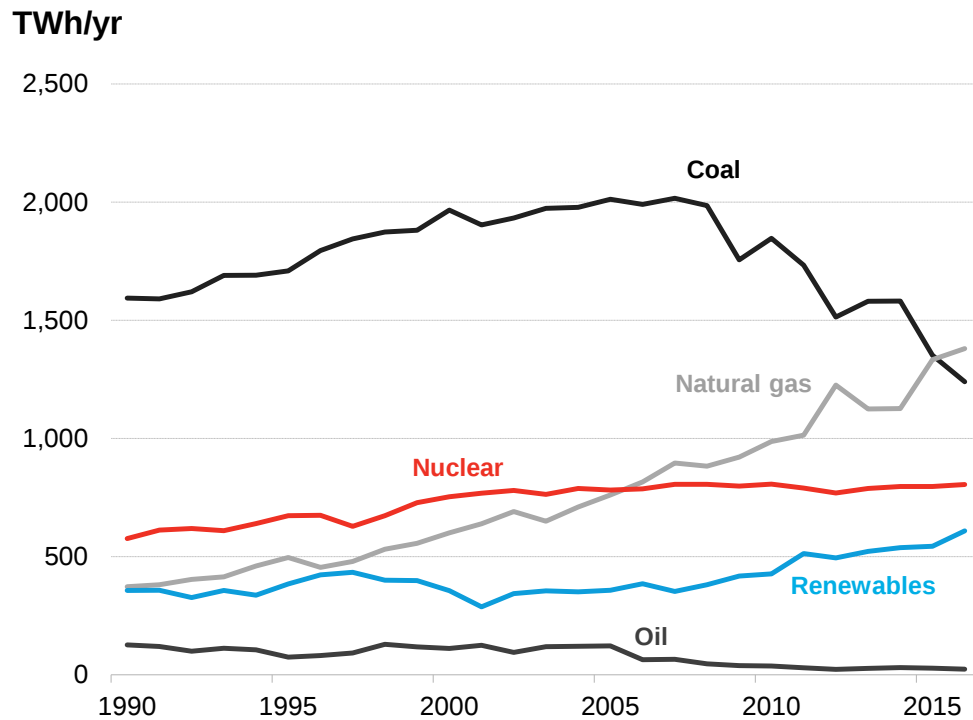


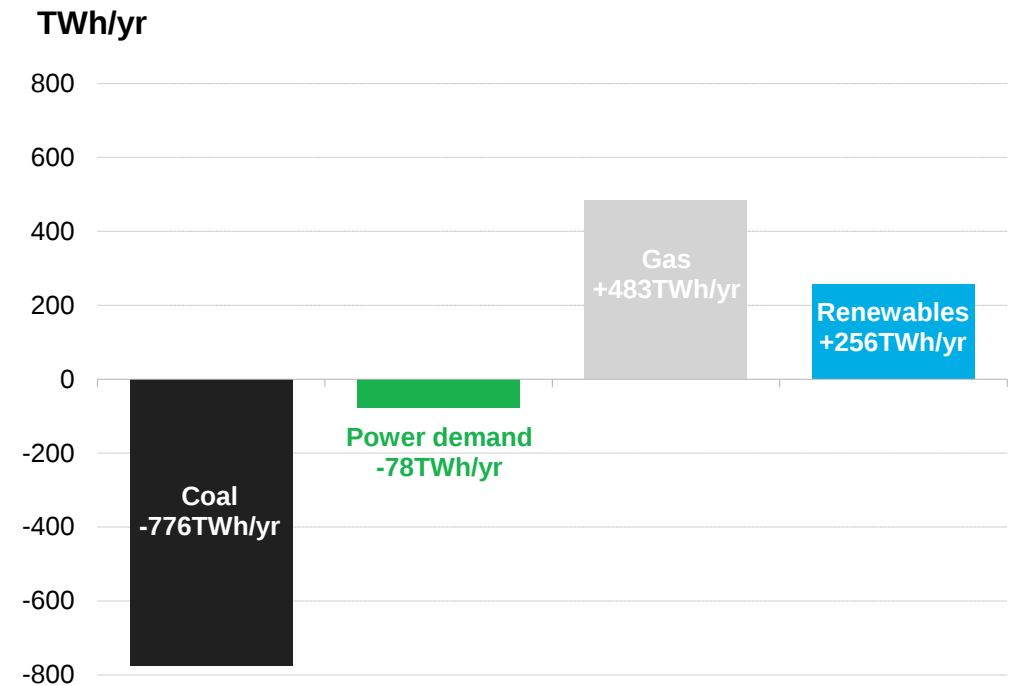
Image: White House; EPA

US power sector fuel mix

Generation by source

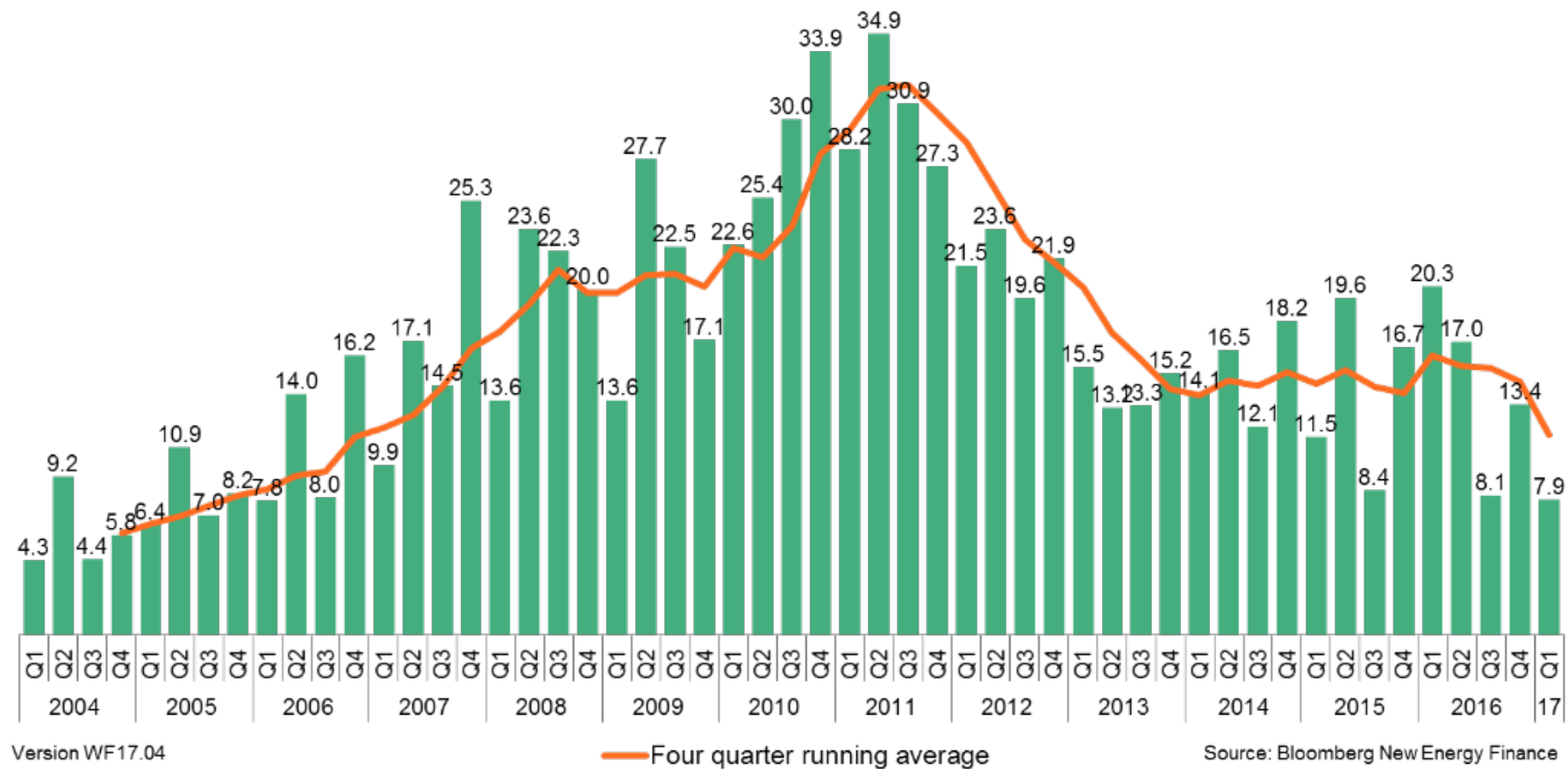


Change in generation 2007-16

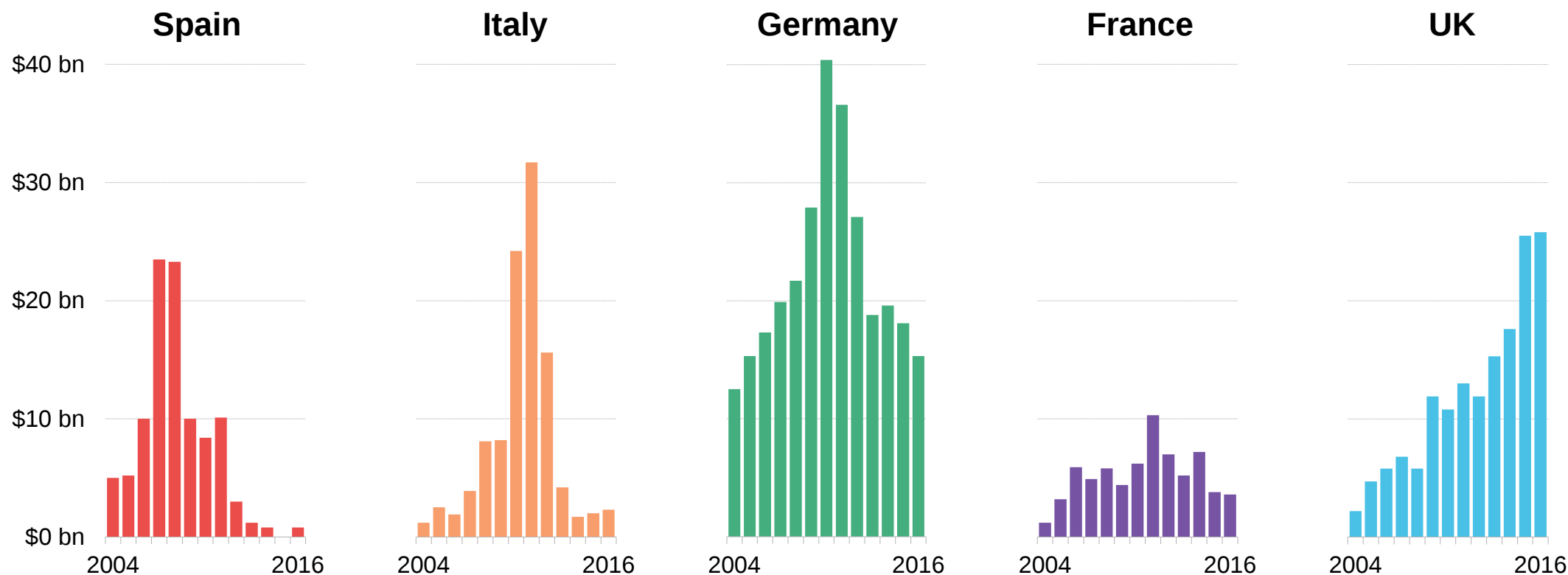


Source: EIA

Europe new investment in clean energy (\$ billion/quarter)

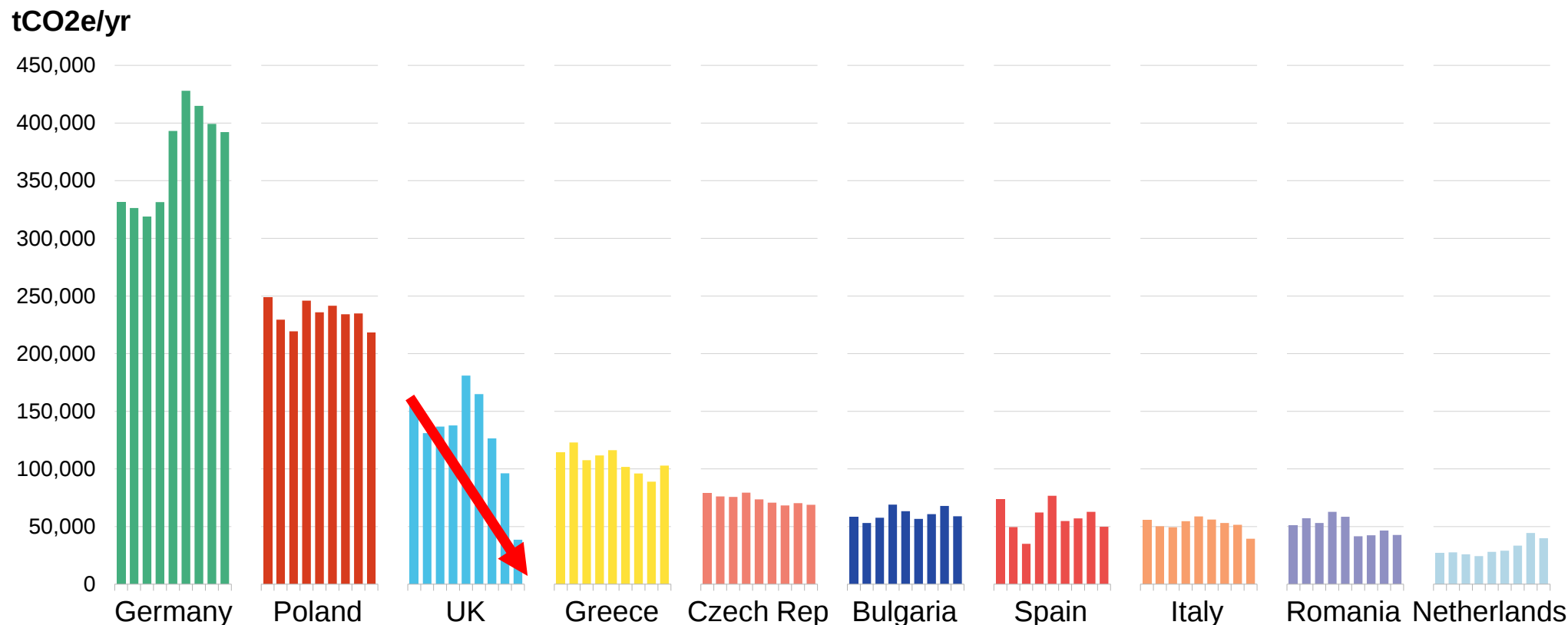


European clean energy investment 2004-2016 (\$bn)



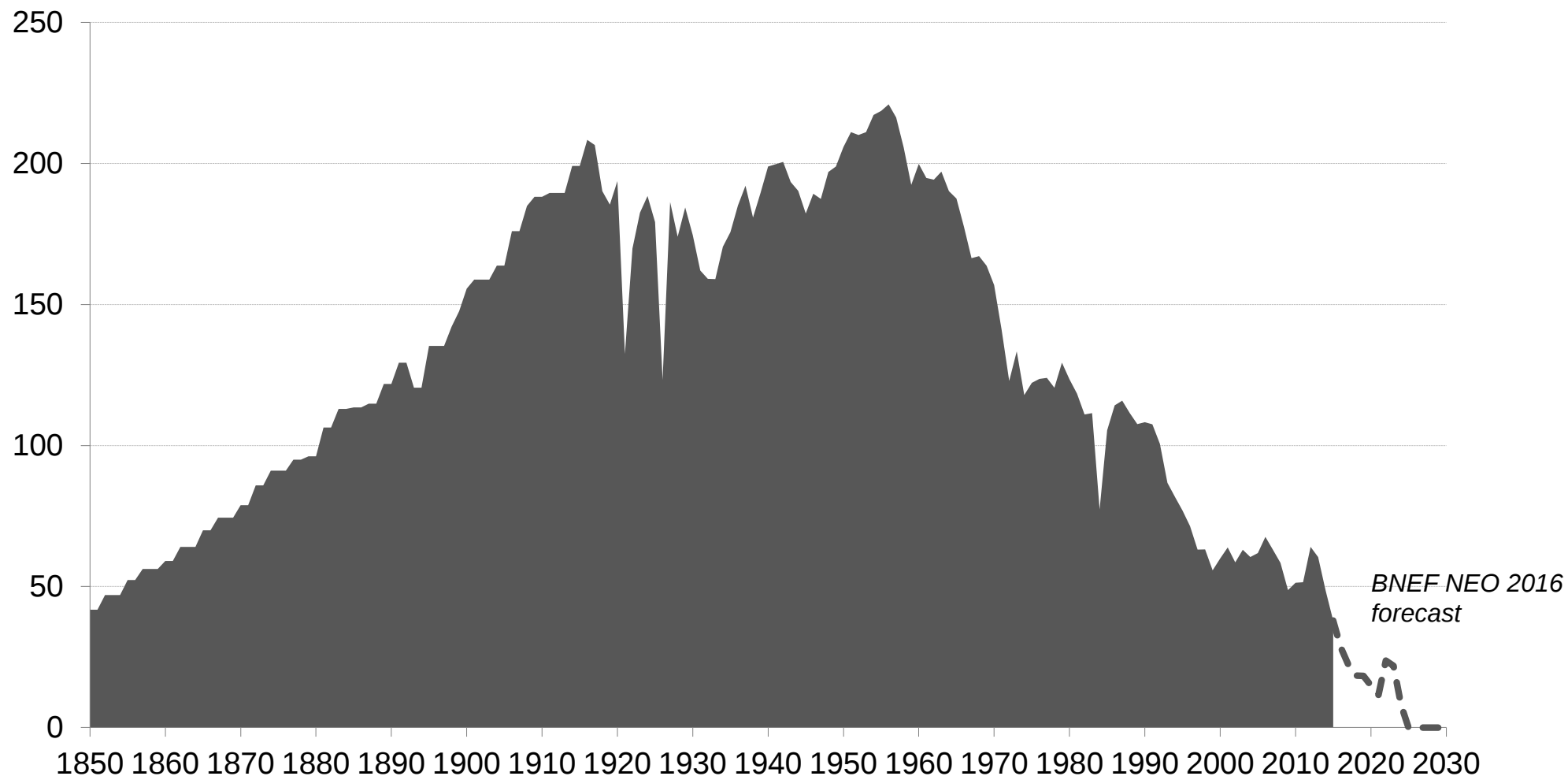
Source: Bloomberg New Energy Finance

Emissions from coal-fired power, 2008-16



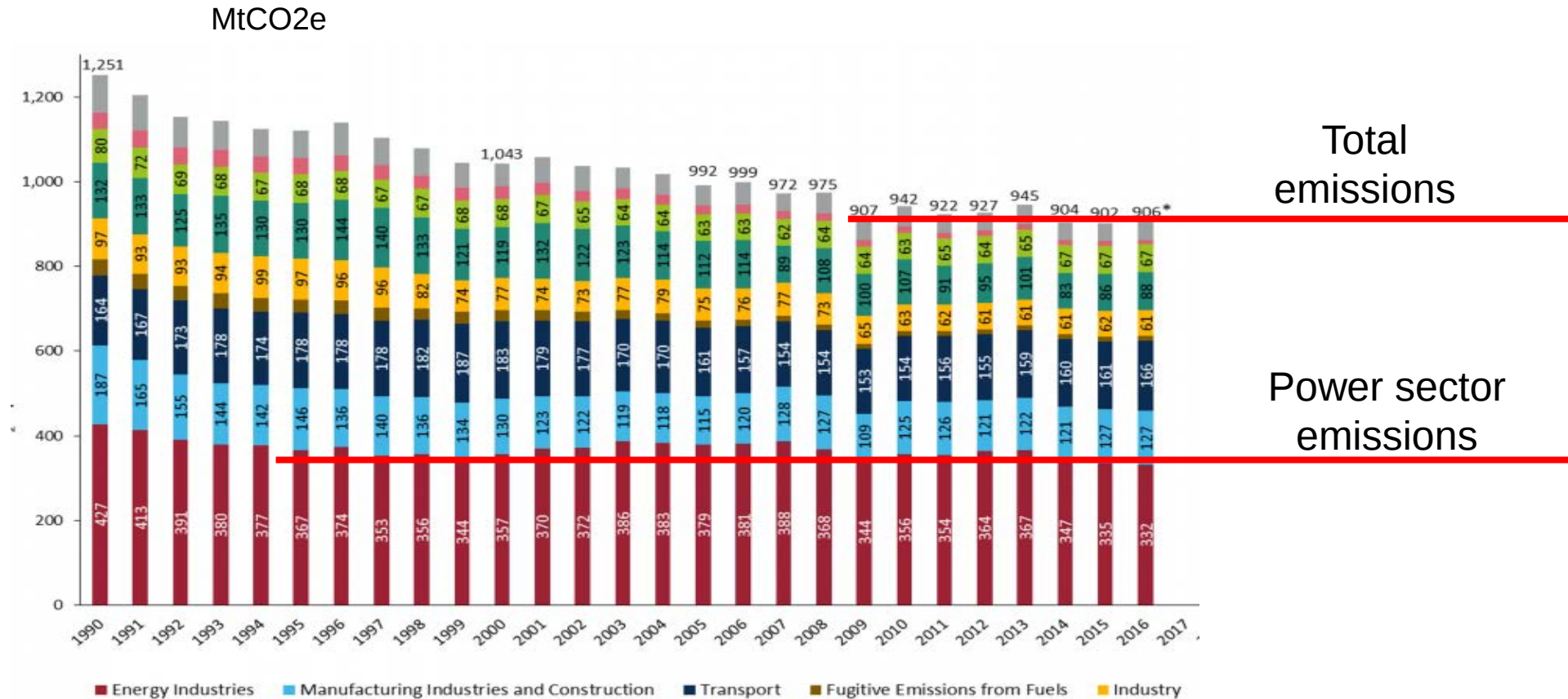
Source: Bloomberg New Energy Finance, Eurostat

UK coal consumption 1850-2030 (mt/yr)



Source: BEIS, Prof. David Rutledge,
Bloomberg New Energy Finance

Germany CO2 emissions



Source: UBA; BNEF

Bloomberg New Energy Finance Summit, New York, 25 April 2017

“

Don't make all these speeches about how good you're doing, when the fact is you're not. I want to stay in the Paris Accord but renegotiate - and my concern is that other parties, mainly the EU, are not doing enough.

”

*Rick Perry
US Secretary of Energy*



Image: Bloomberg

Bloomberg New Energy Finance Summit, New York, 25 April 2017

“

At the G7 meeting, we're out in the public and [the Europeans] are giving all these speeches about the Paris Accord, and all the things they're going to do. And we get into private meetings and it's like "How do we get that LNG?"

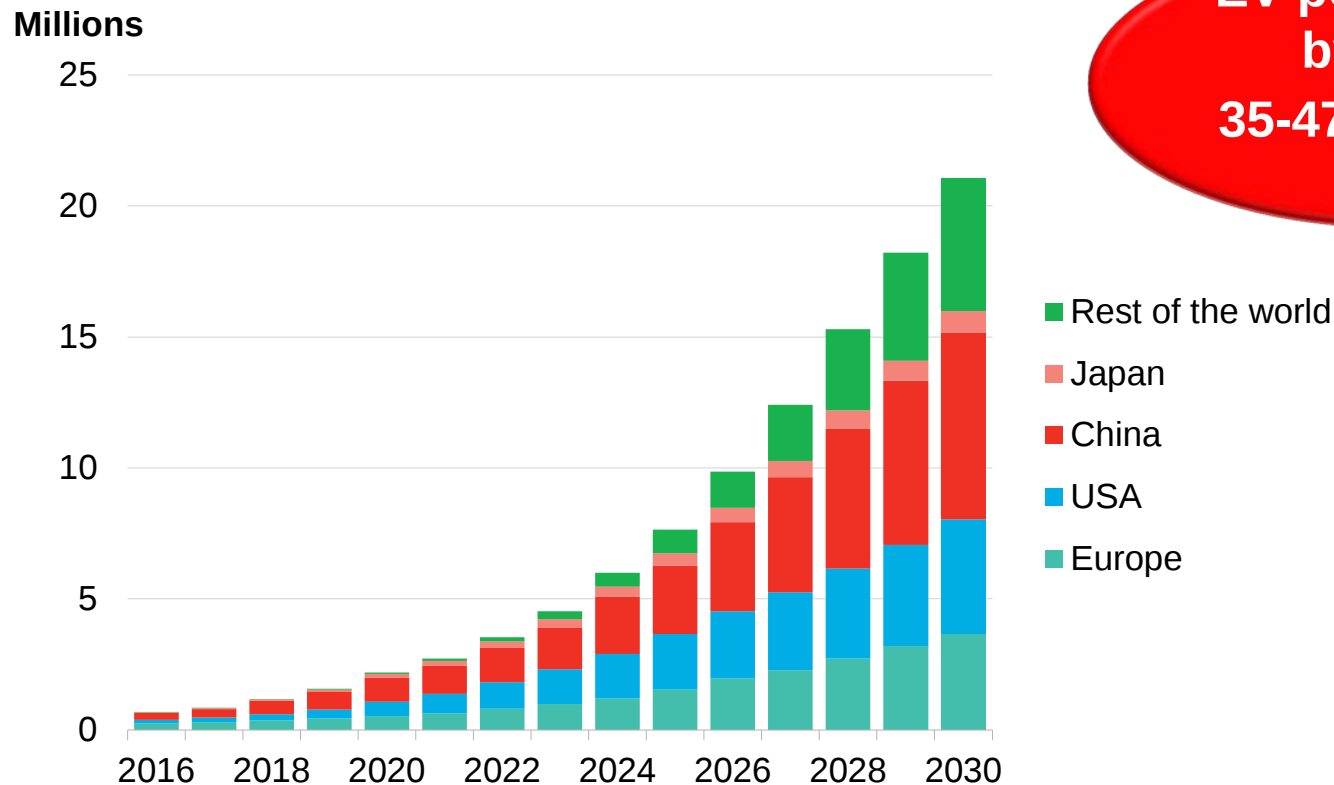
”

*Rick Perry
US Secretary of Energy*



Image: Bloomberg

BNEF global EV sales forecast by region



**EV penetration
by 2040
35-47% of new
cars**

Note: Forecast uses Gasoline and electricity prices from EIA's 2015 Annual Energy Outlook 'Low Oil Price' scenario (ranging from \$50 to \$65 per barrel between 2015 and 2025).

Source: Bloomberg New Energy Finance

ELECTRIC VEHICLES

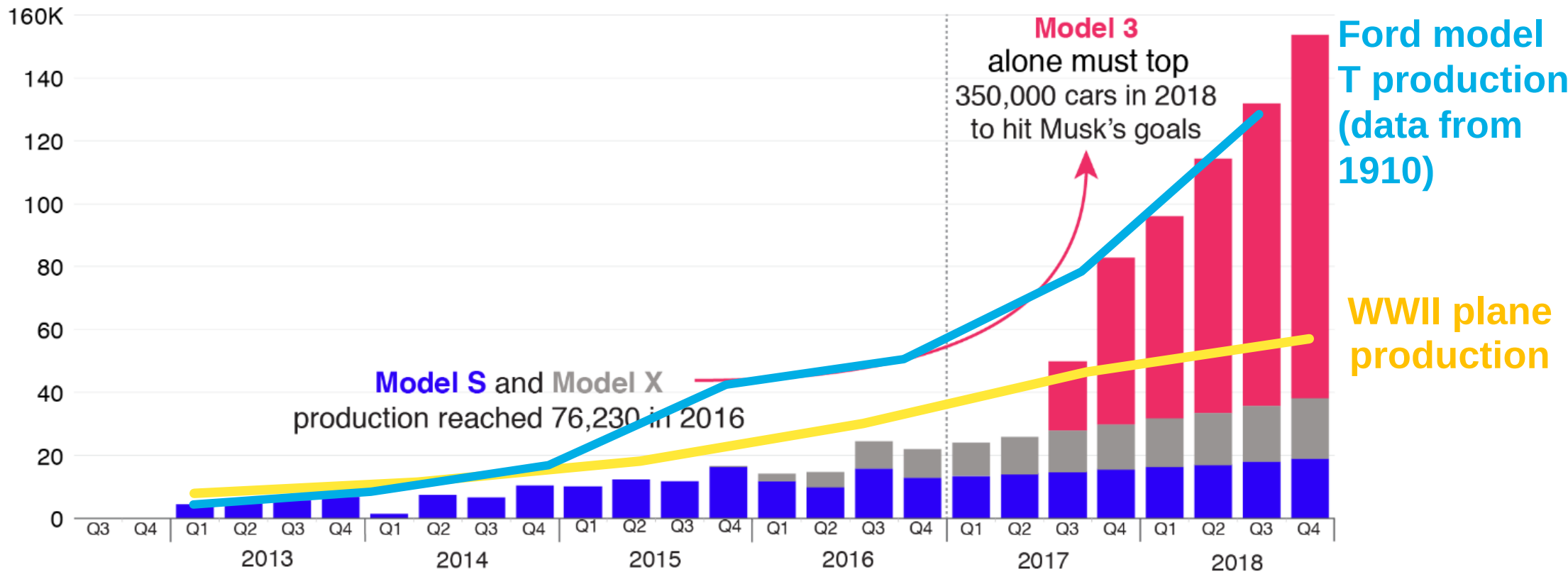
**CARS AND TRUCKS IN USE
WORLDWIDE, 2016
1.3 billion**



**ELECTRIC VEHICLES IN USE
WORLDWIDE, END 2016
1.8 million (to scale)**

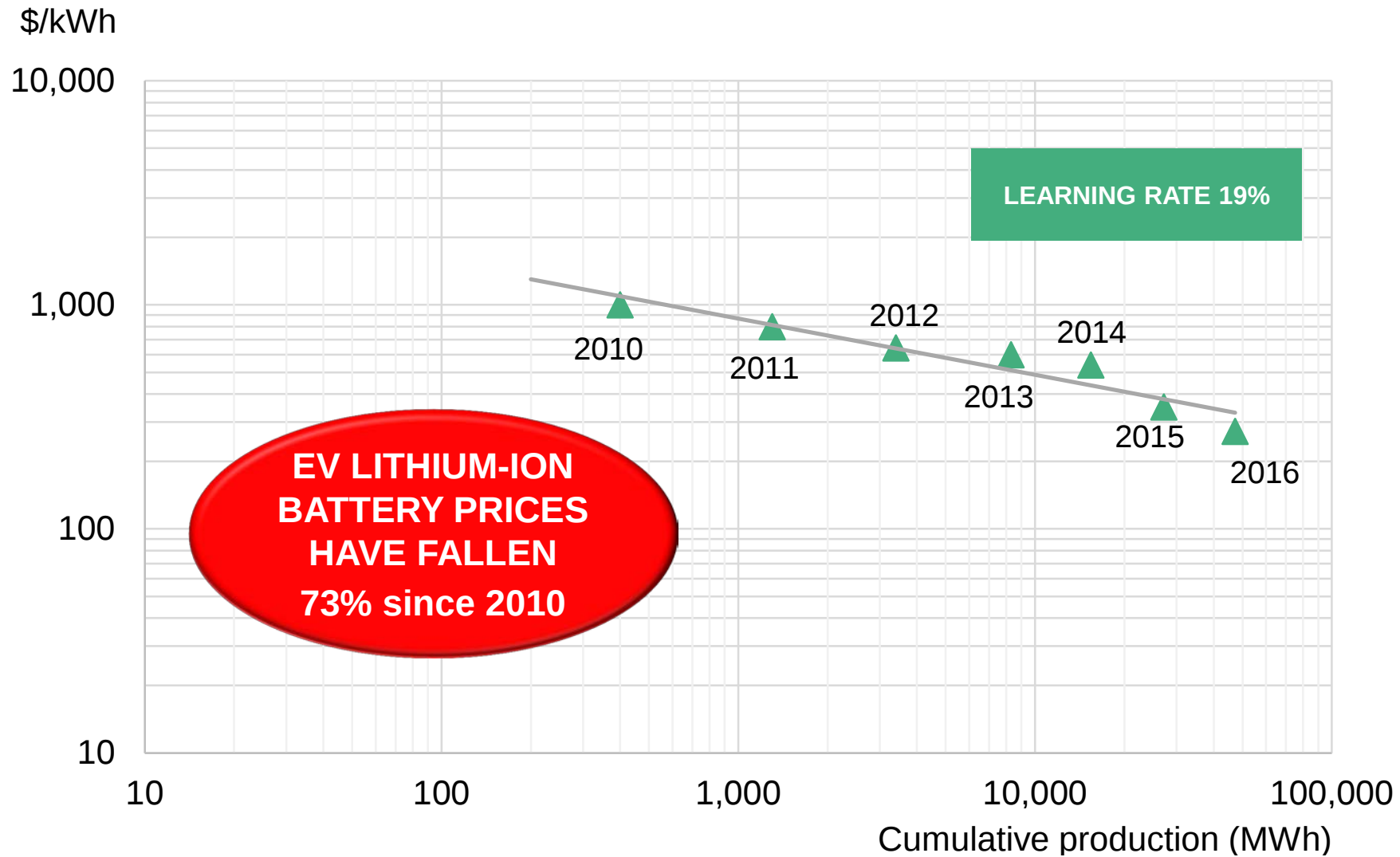
Source: Bloomberg New Energy Finance, International Organization of Motor Vehicle Manufacturers

Tesla's gamble



Source: Tesla; Bloomberg <https://www.bloomberg.com/news/articles/2017-03-27/tesla-model-3-ramp-up-aims-to-crush-bmw-and-mercedes>; Bloomberg New Energy Finance, Library of Congress WWII Companion

BNEF battery price learning rate 2013-2016 (\$ per kWh)



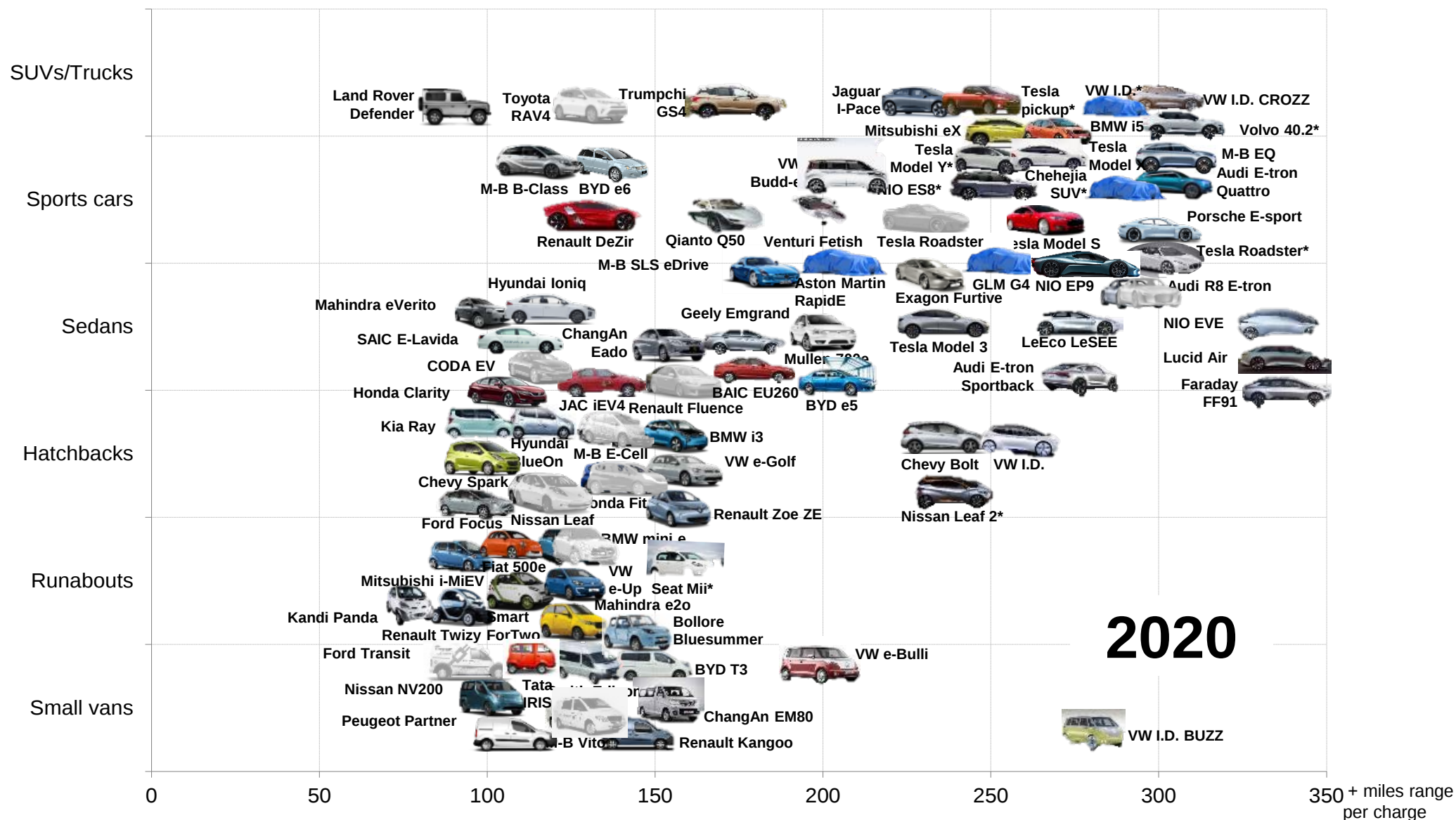
Notes: This includes cells plus pack prices. For years where there were two surveys, the data in this chart is an average for the year. Prices are nominal.

London, UK



Photo: HHRCA

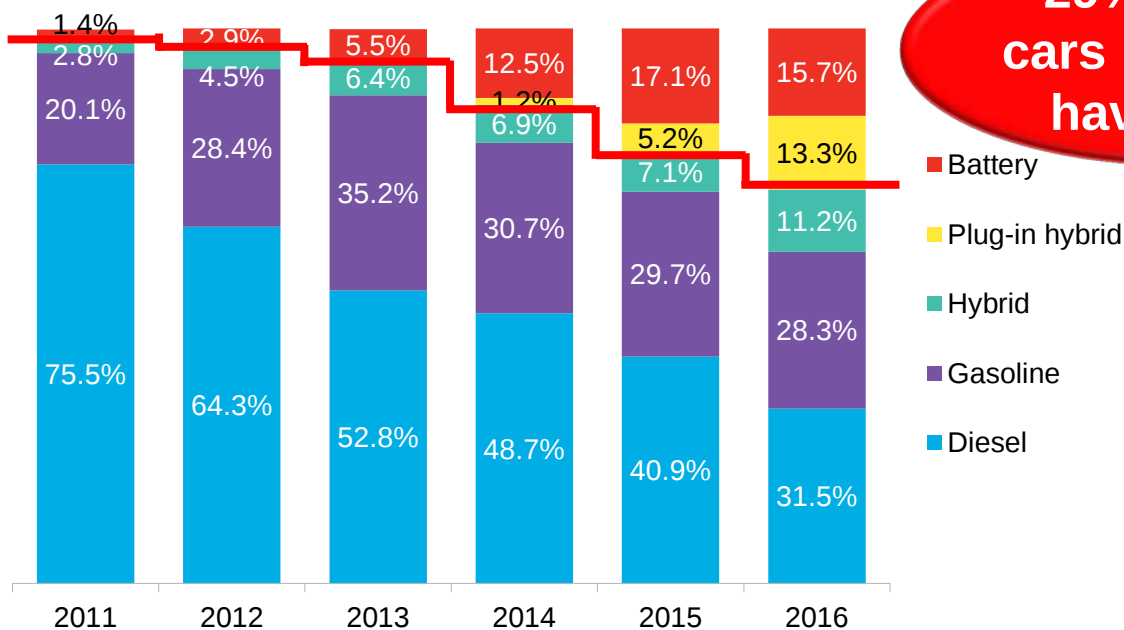
BEV model availability, 2008-20



Source: Bloomberg New Energy Finance, Images various. Notes: Not exhaustive. (*) Range is estimate

The Norwegian experience

Split of annual car sales by type



Vehicle choices



Audi A7 Q

Tesla S 60D

Price
(without tax):

\$44,392

\$75,117

Price
(with tax):

\$82,363

\$75,117

Source: Bloomberg New Energy Finance, Ofv.no

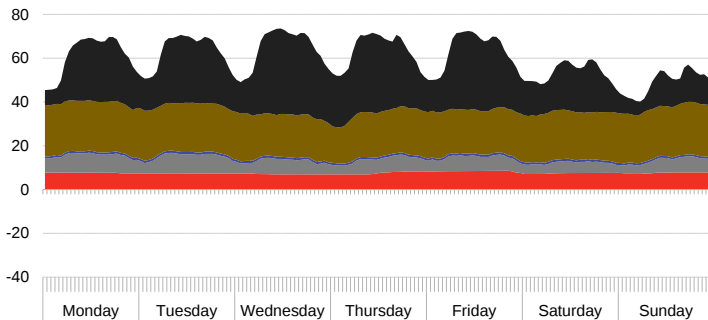
Evolving structure of power supply

Lots more variable renewables

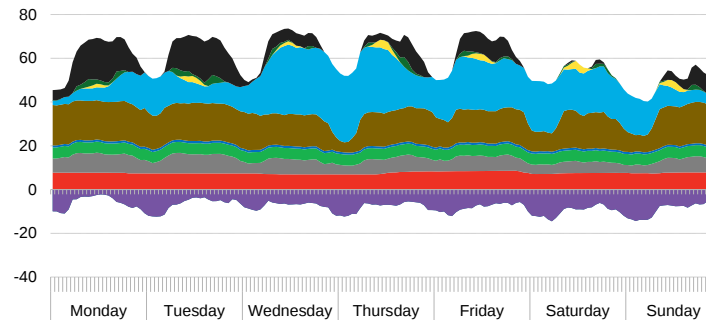
Added storage, interconnections

Reduced demand (exc. EVs)

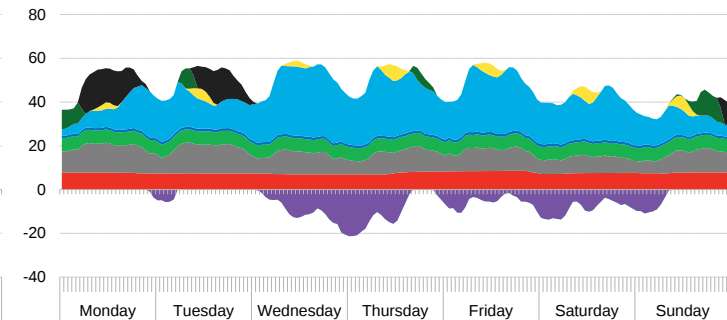
Past – winter



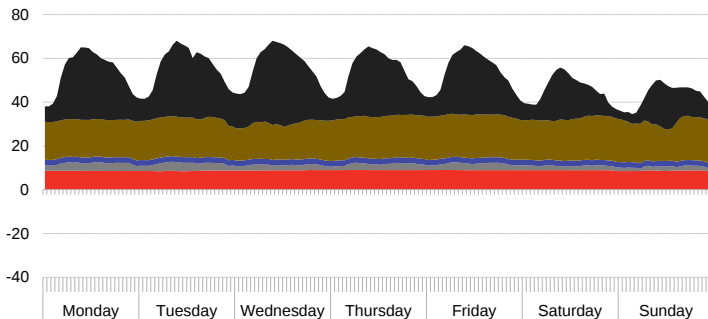
Current – winter



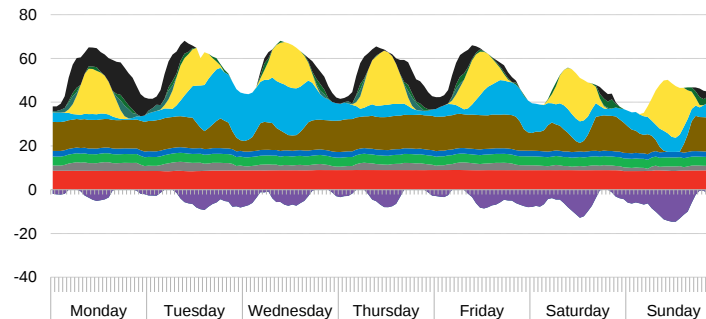
Future – winter



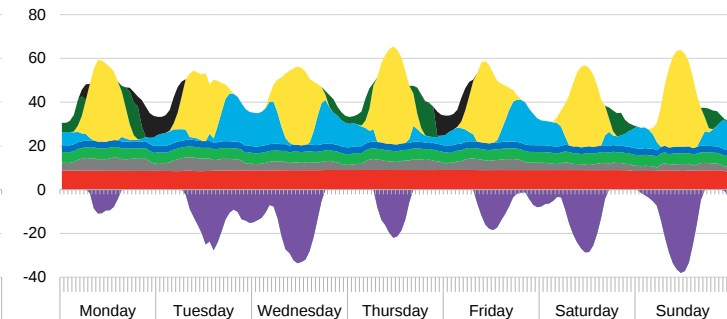
Past – summer



Current – summer



Future – summer



■ Peaking fossil ■ Baseload fossil ■ Nuclear ■ CHP ■ Hydro ■ Baseload RE ■ Solar ■ Wind ■ Pumped hydro generation/Storage ■ Imports ■ Exports/curtailment/DR

Source: Bloomberg New Energy Finance

Component 1: “base cost” renewables

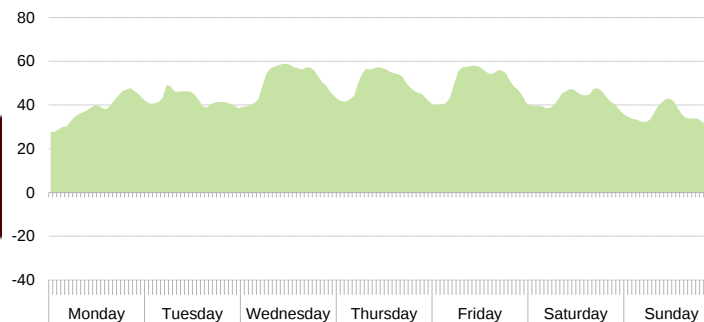
1. Very cheap wind & solar (“base cost renewables”)

2. Plus must-run CHP and nuclear (and CCS?)

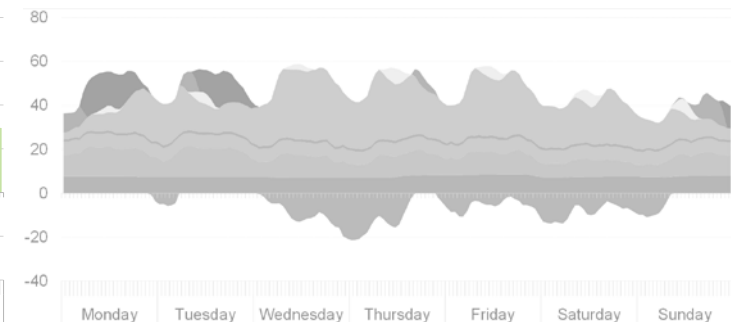
3. Zero mid-day power price every day in sunny countries and windy days

4. Dependent on flexible power to meet non-sunny, non-windy times

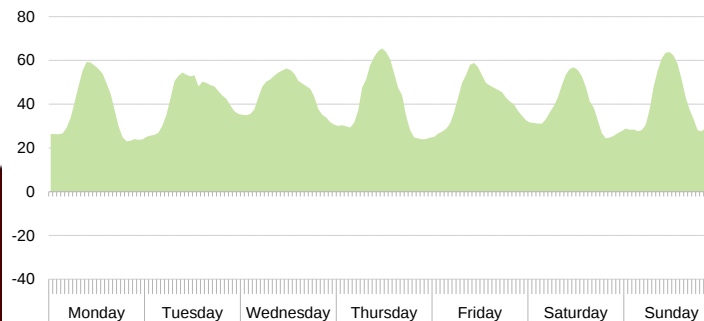
Low carbon generation – winter



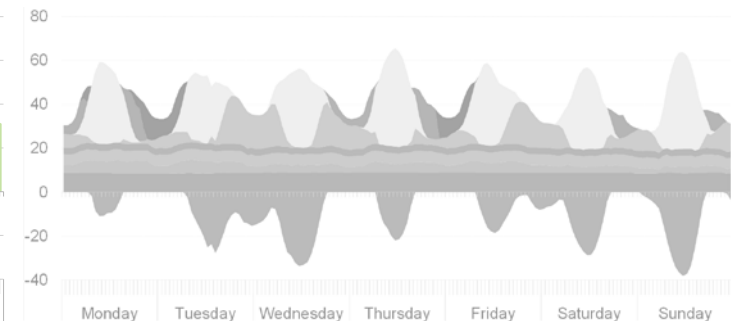
Future – winter



Low carbon generation – summer



Future – summer

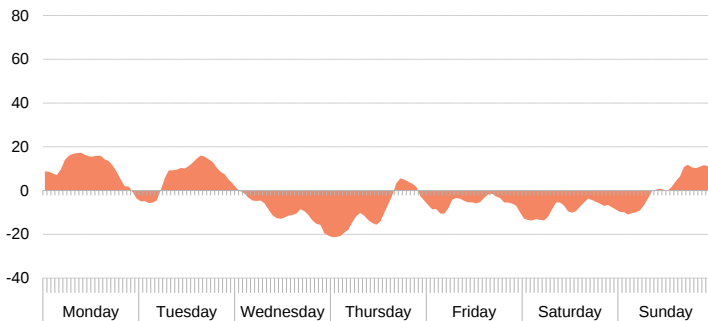


Source: Bloomberg New Energy Finance

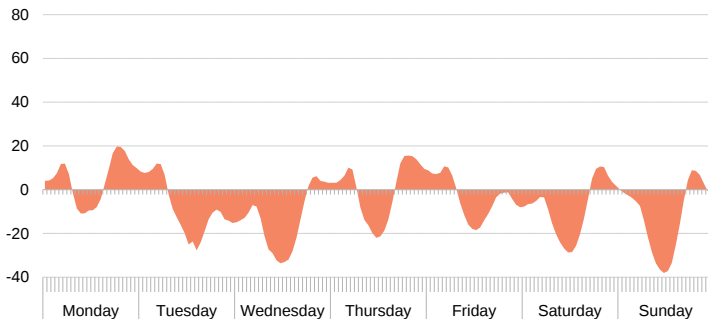
Component 2: Flexible power



Flexible generation – winter



Flexible generation – summer



1. Demand response is likely to be the cheapest

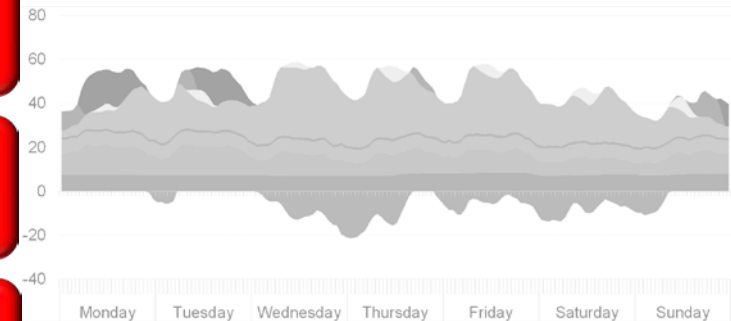
2. Storage

3. Interconnections

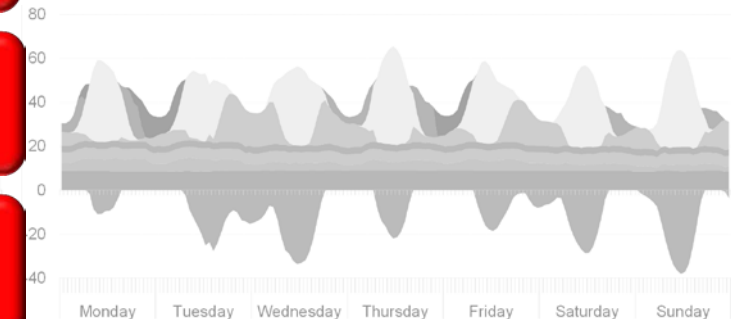
4. Fossil peakers

5. In case that's not enough, there will be curtailment

Future – winter



Future – summer



Source: Bloomberg New Energy Finance

Flexible power approaches

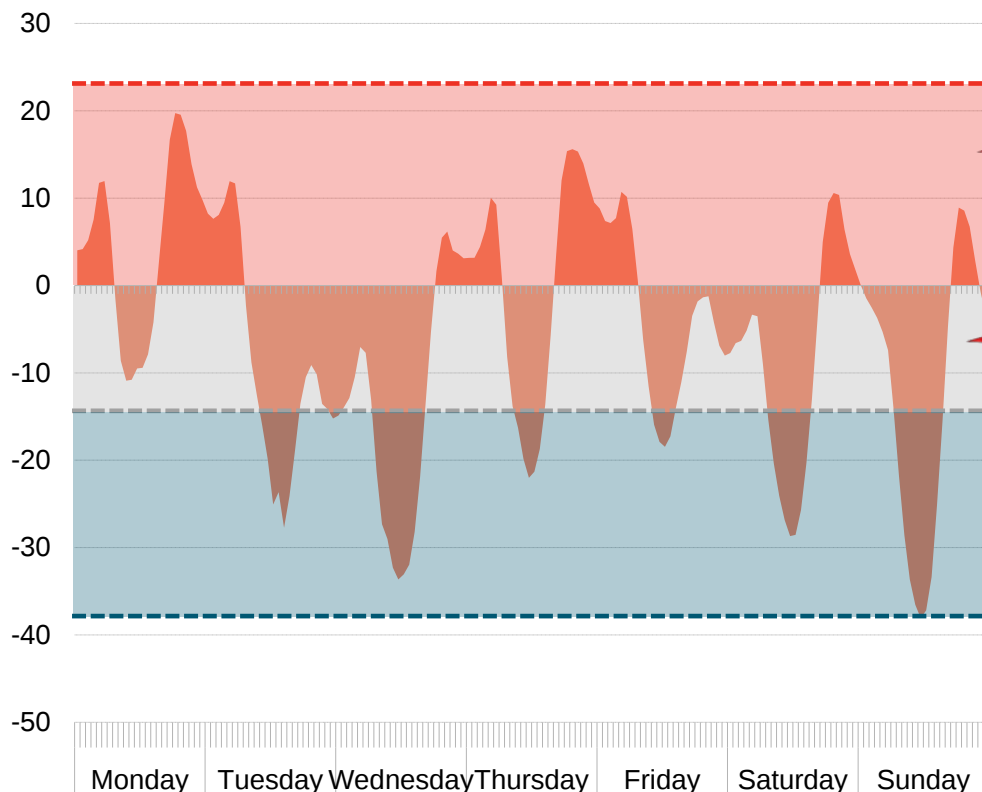
Option A: Capacity/Reserve (“Central Planning Lite”)

Risk of over-procurement:

- Inaccurate predictions of supply and demand
- Political risk aversion

Innovation suppressed by:

- Artificially-shaped demand
- Bias towards incumbents
- Picking of winners



Centrally designed capacity market, with regulated returns

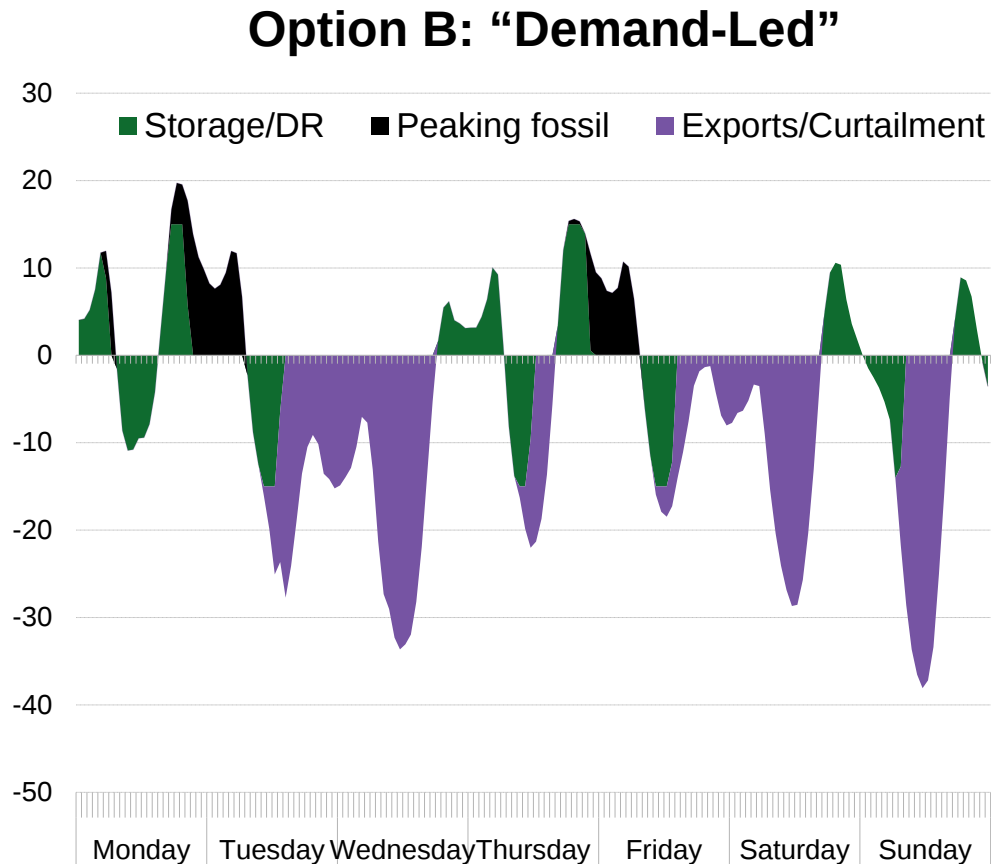
Centrally provisioned interconnections, with regulated returns

Curtailment

Source: Bloomberg New Energy Finance

Flexible power approaches

Option B: Demand-led flexible power market



1. Competitive, technology-neutral, liquid markets across location and time

2. Reliability standards at the retail level

3. Flexibility costs charged to those who cause them

4. Certificates of origin for imported power

5. Cost of stability-related ancillary services borne by TSOs and DSOs

**Carbon regulation via carbon tax or price, carbon intensity or retirement schedule.
“Remove the dirty, don’t push the clean”**

Source: Bloomberg New Energy Finance

Copyright and disclaimer

This publication is the copyright of Bloomberg New Energy Finance. No portion of this document may be photocopied, reproduced, scanned into an electronic system or transmitted, forwarded or distributed in any way without prior consent of Bloomberg New Energy Finance.

The information contained in this publication is derived from carefully selected sources we believe are reasonable. We do not guarantee its accuracy or completeness and nothing in this document shall be construed to be a representation of such a guarantee. Any opinions expressed reflect the current judgment of the author of the relevant article or features, and does not necessarily reflect the opinion of Bloomberg New Energy Finance, Bloomberg Finance L.P., Bloomberg L.P. or any of their affiliates ("Bloomberg"). The opinions presented are subject to change without notice. Bloomberg accepts no responsibility for any liability arising from use of this document or its contents. Nothing herein shall constitute or be construed as an offering of financial instruments, or as investment advice or recommendations by Bloomberg of an investment strategy or whether or not to "buy," "sell" or "hold" an investment.

Bloomberg New Energy Finance is a research firm that helps energy professionals generate opportunities. With a team of experts spread across six continents, BNEF provides independent analysis and insight, enabling decision-makers to navigate change in an evolving energy economy.

BNEF research and analysis is accessible via web and mobile platforms, as well as on the Bloomberg Terminal.

Coverage.

Renewable Energy

Power & Utilities

Gas

Carbon Markets & Climate Negotiations

Energy Smart Technologies

Storage

Electric Vehicles

Mobility and Autonomous Driving

Frontier Power

Emerging Technologies

sales.bnef@bloomberg.net

about.bnef.com

@BloombergNEF

Bloomberg
New Energy Finance