

Bloomberg New Energy Finance Summit

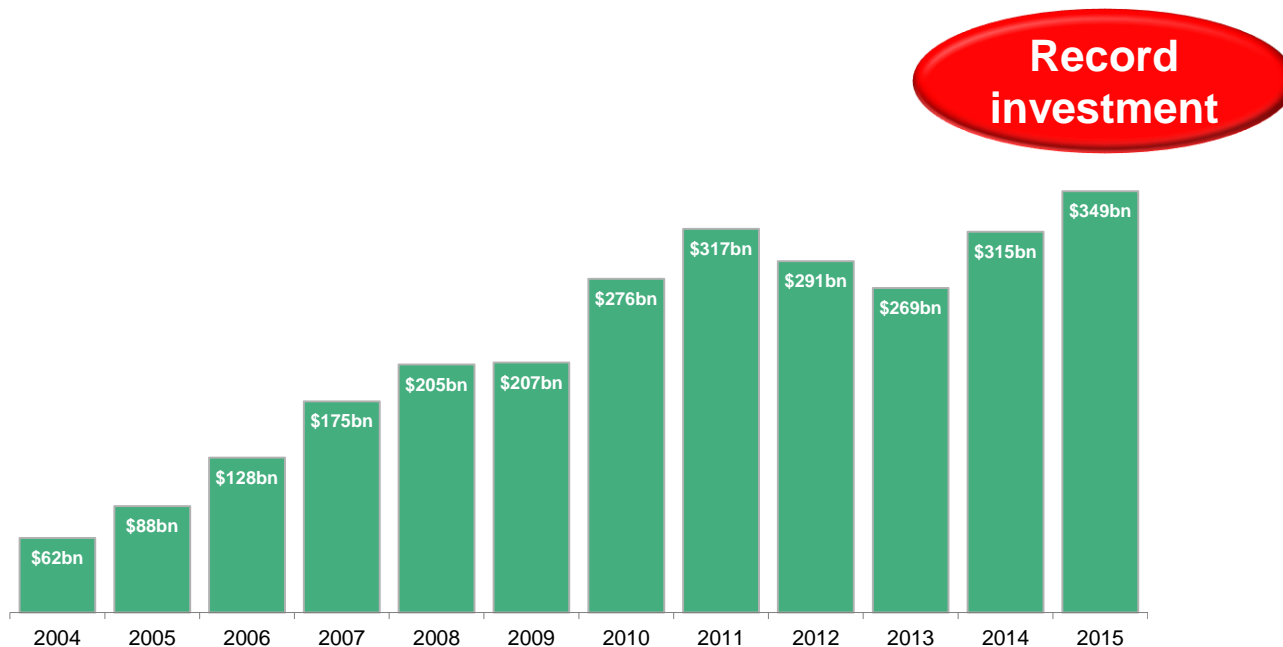
New York

Michael Liebreich
Chairman of the Advisory Board
Twitter: @mliebreich

25 April 2017

Bloomberg
New Energy Finance

Global new clean energy investment



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

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**

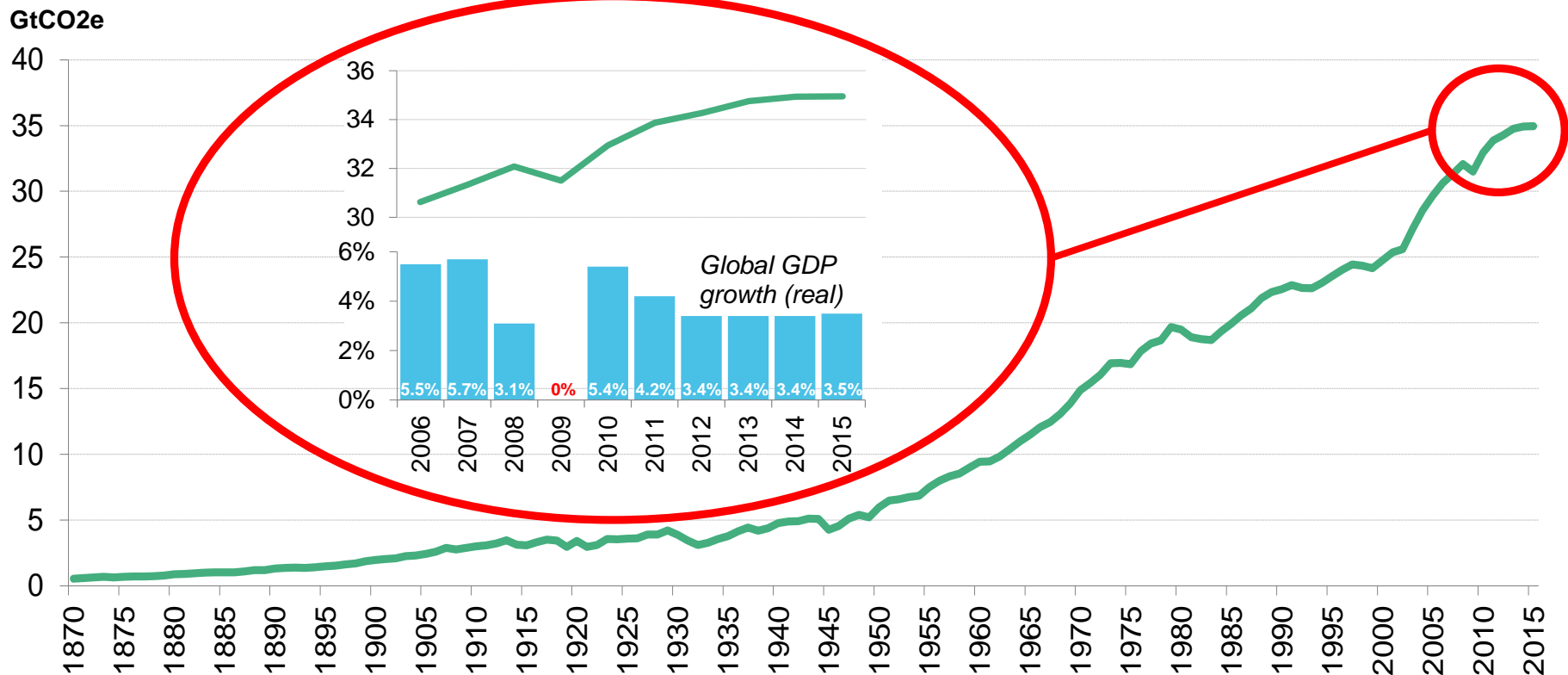
Offshore wind



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

Source: Bloomberg New Energy Finance; ImagesSiemens; Wikimedia Commons

Global carbon emissions from fossil fuels



Note: Includes NGL and processing gain, but excludes biofuels

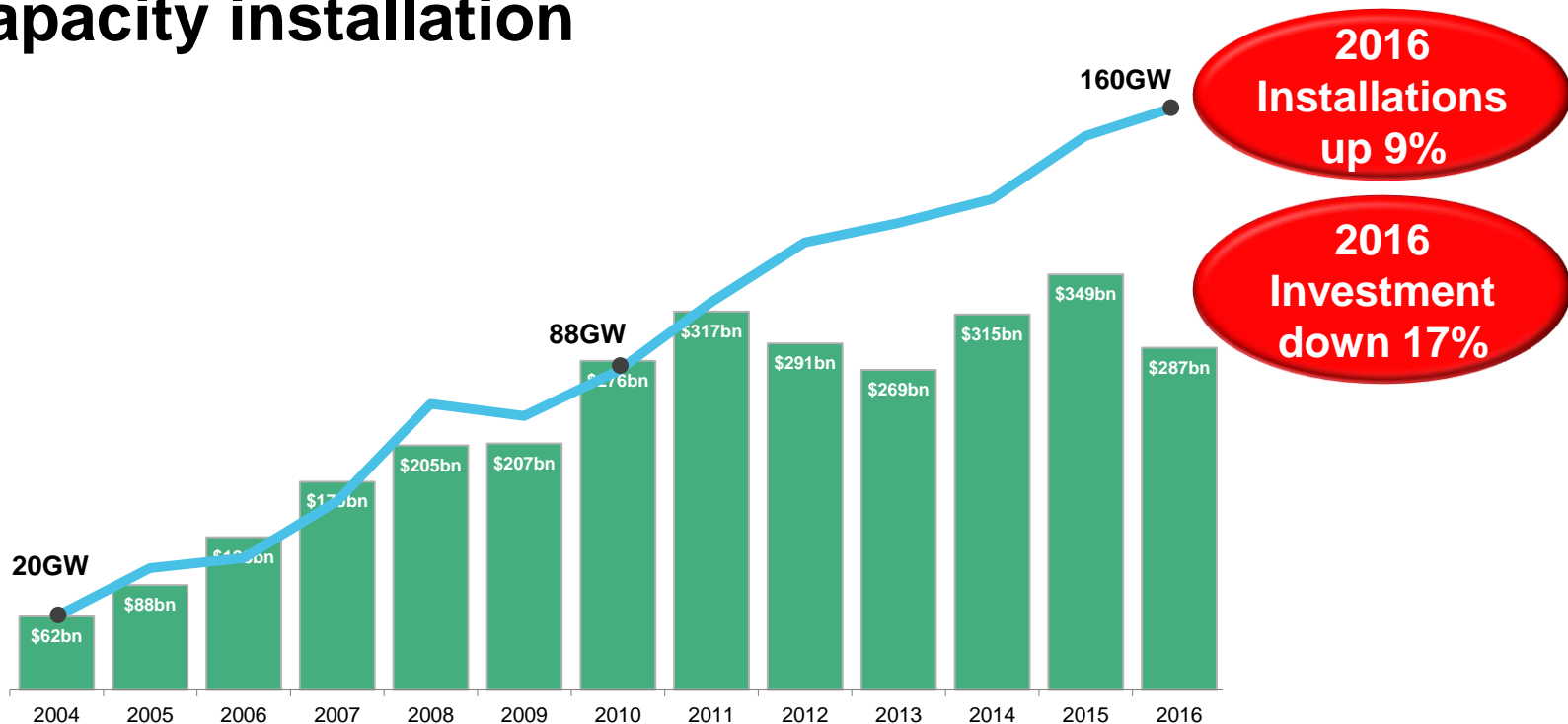
Source: IEA; CDIAC; BP; Bloomberg New Energy Finance

The 2016 election



Image: Skinbase; M Liebreich

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

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
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Construction: 2018
Price: US\$ 3.0 c/kWh

Offshore wind



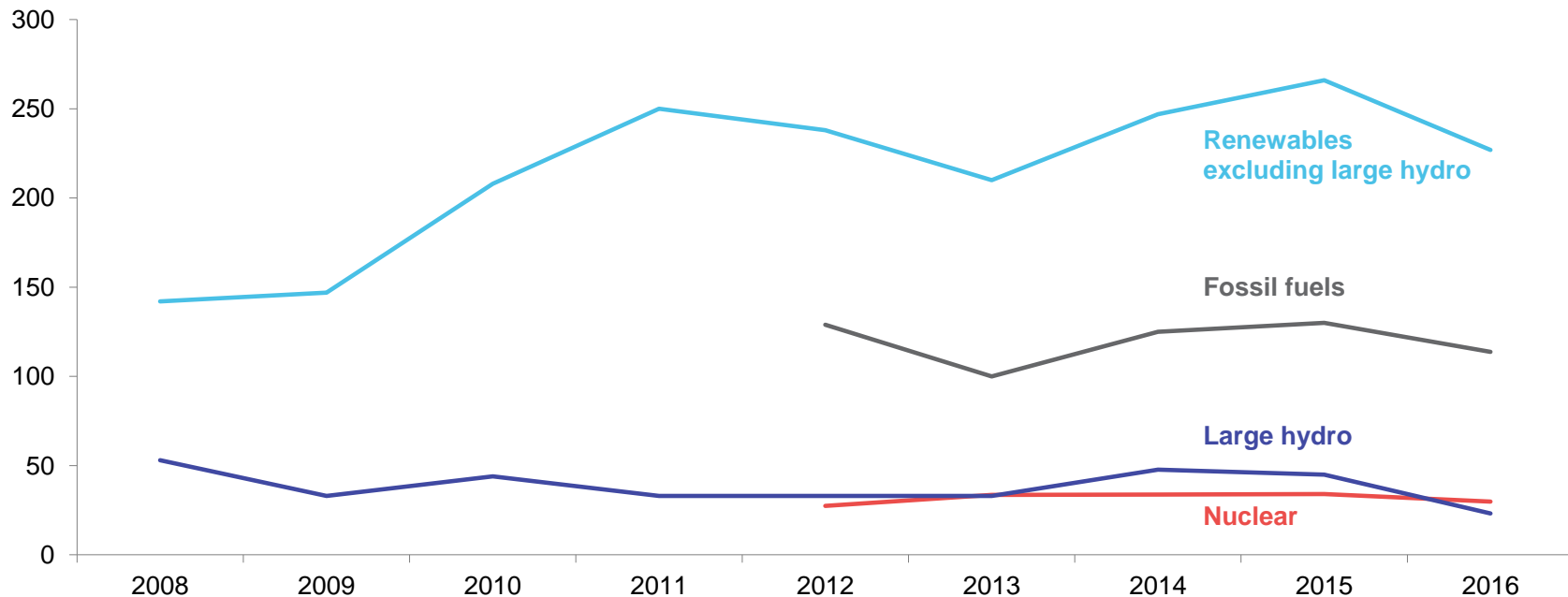
Country: Germany
Bidder: DONG/EnBW
Signed: April 2017
Construction: 2024
Merchant Price: US\$ 4.9 c/kWh

Note: The offshore wind merchant price is estimated based on project LCOE in real 2016 terms

Source: Bloomberg New Energy Finance; ImagesSiemens; Wikimedia Commons

Investment in power capacity, by technology

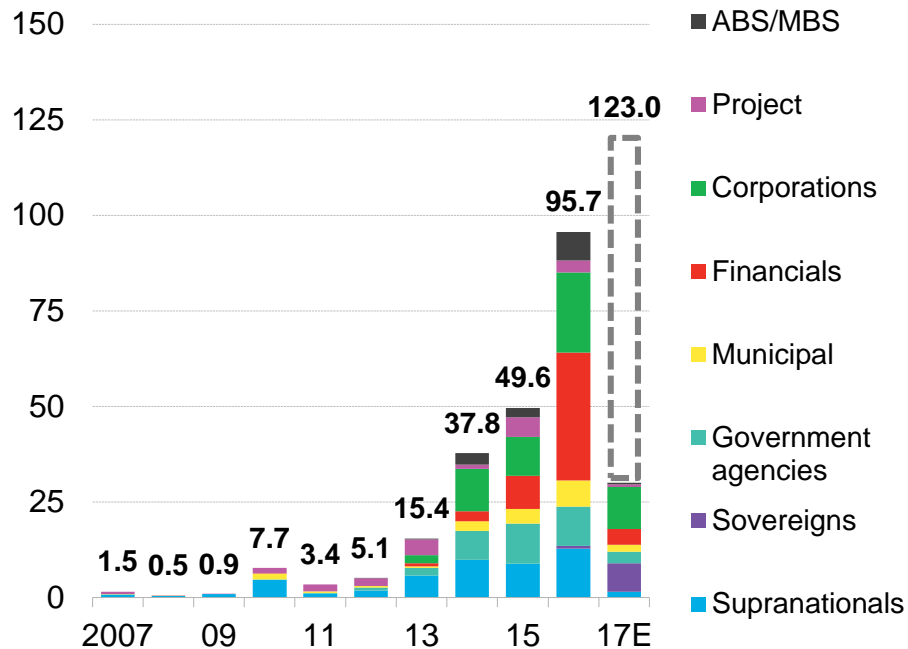
\$ billion/year



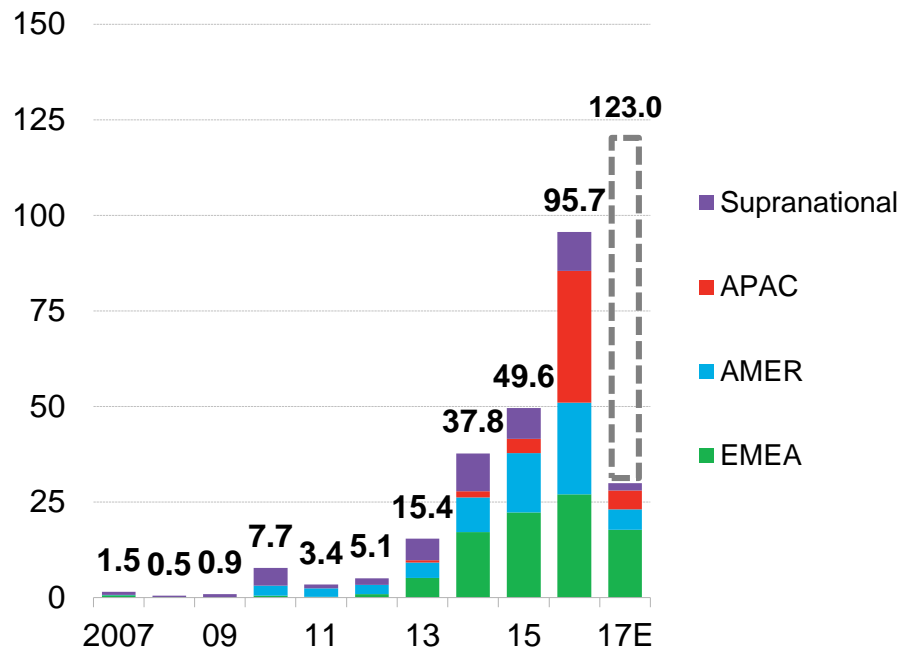
Source: Bloomberg New Energy Finance, UNEP

Green bond issuance

Issuance by category (\$ billion)



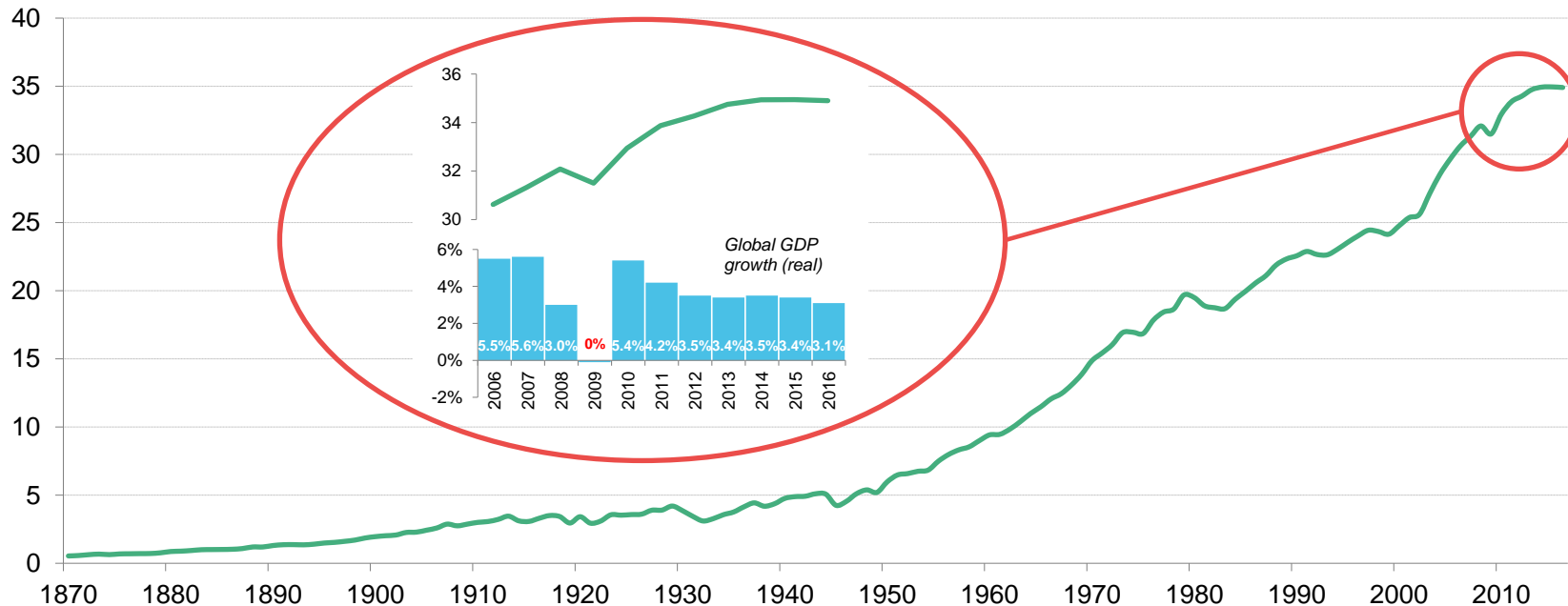
Issuance by geography (\$ billion)



Note: 1Q 2017 issuance was \$30 billion. 2017 estimate is based on growth on previous years Source: Bloomberg New Energy Finance, Bloomberg Terminal

Global carbon emissions from fossil fuels

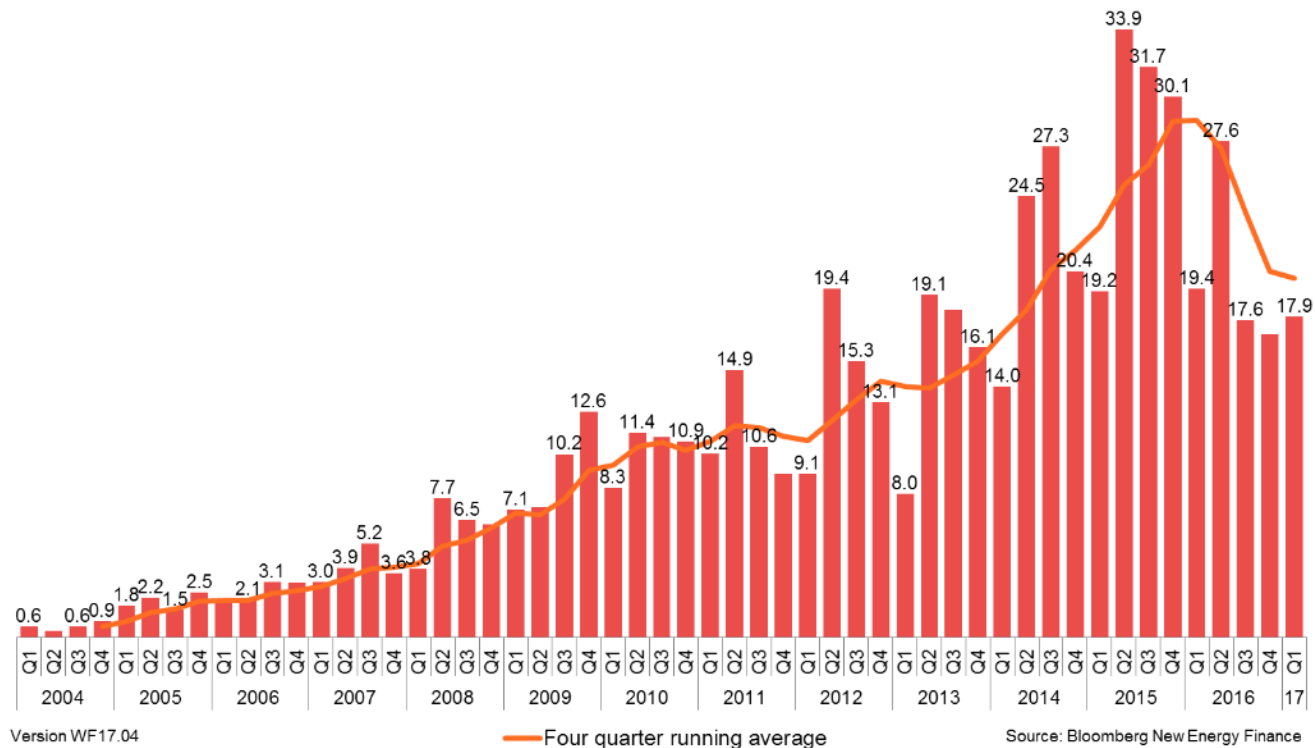
GtCO₂e



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

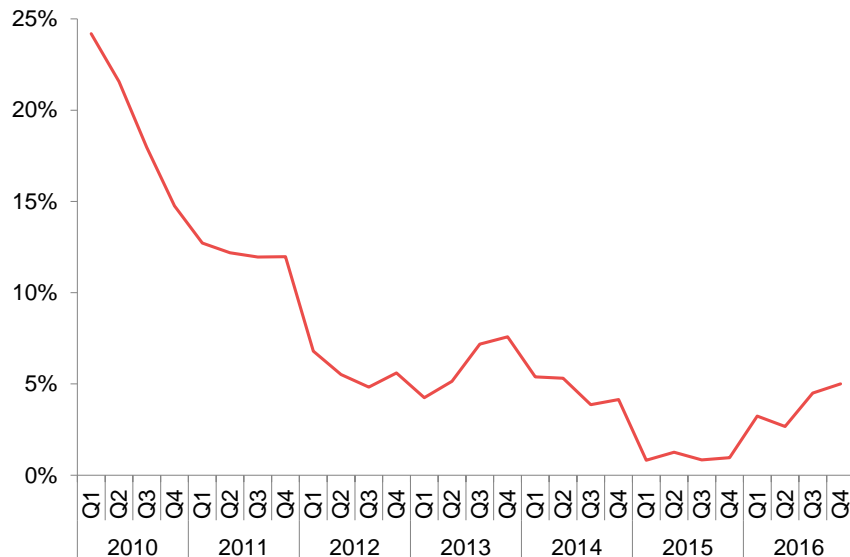
China new investment in clean energy

(\$ billion)



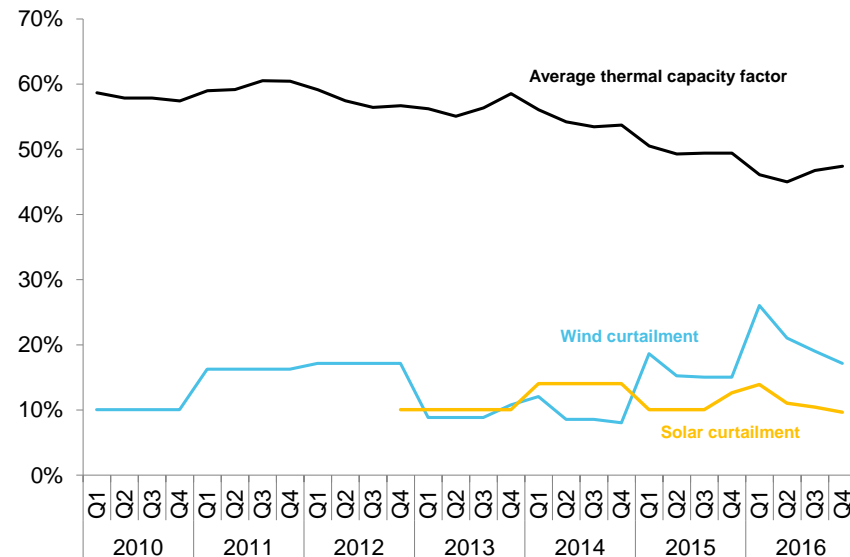
China snapshot

China yoy% growth in power demand



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

Thermal capacity factor and RE curtailment



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.



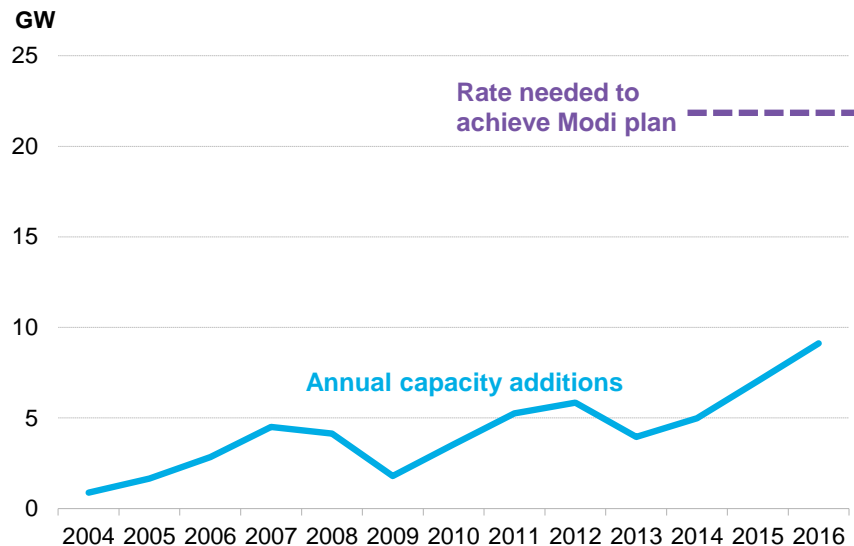
*Piyush Goyal
Minister of State for Power, Coal, New &
Renewable Energy and Mines, India*



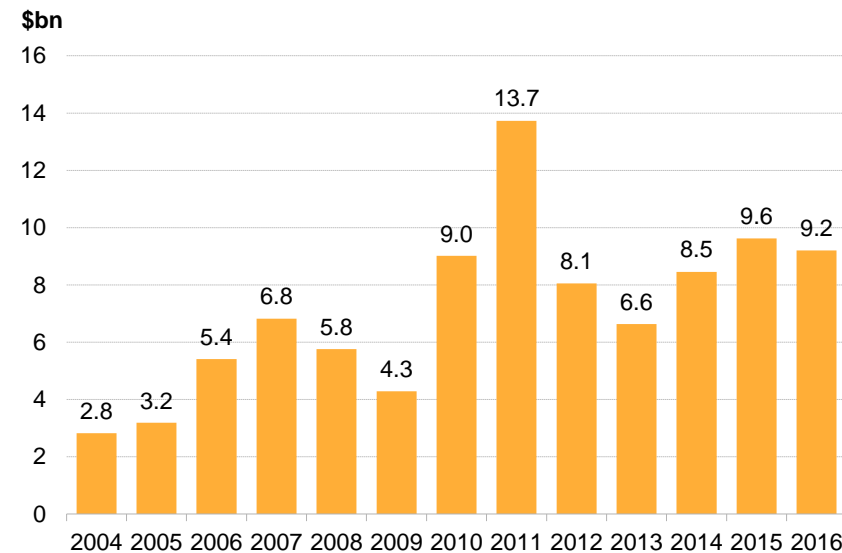
Image: Twitter

India snapshot

Annual capacity additions vs Modi plan



India clean energy investment

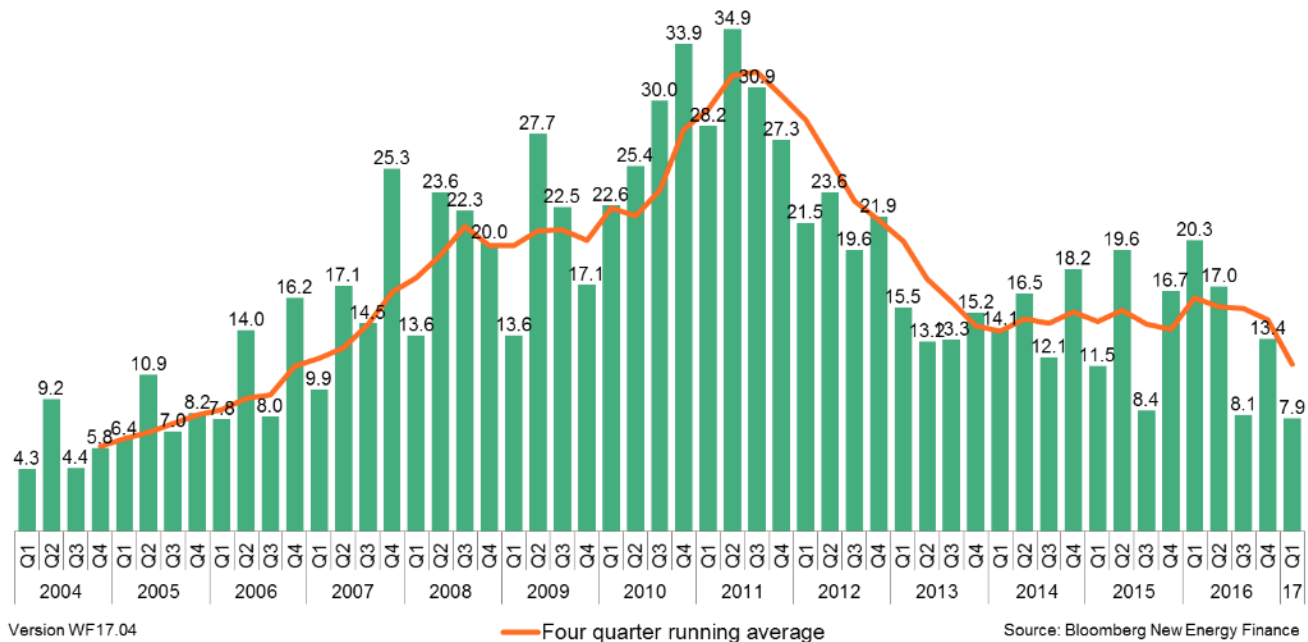


Note: Modi plan annual additions rate assumes linear trajectory to 175GW 2022 target. Figures exclude large hydro

Source: Bloomberg New Energy Finance

Europe new investment in clean energy

(\$ billion)





NG Control Room

@NGControlRoom

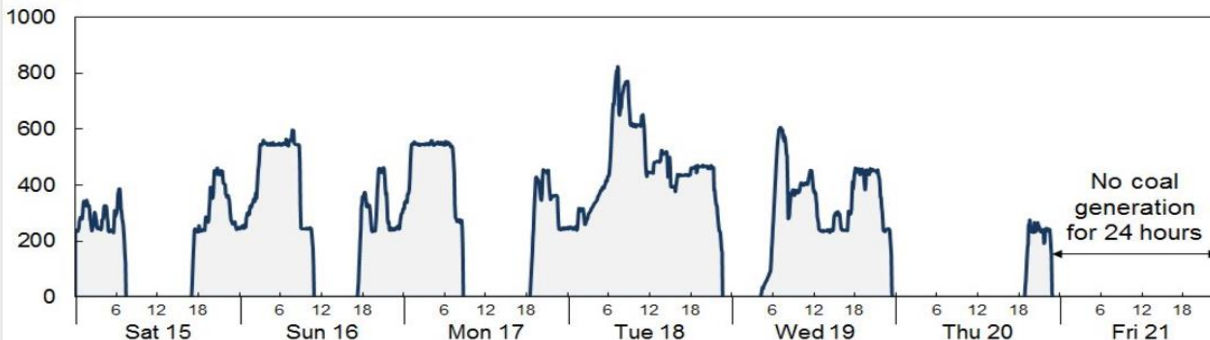
Following

National Grid can confirm that for the past 24 hours, it has supplied GB's electricity demand without the need for **#coal** generation.

Great Britain goes without Coal Generation for 24 hours

Friday 21st April 2017 was the first 24-hour period since the 1880s where Great Britain went without coal-fired power stations.

Coal Generation (MW)

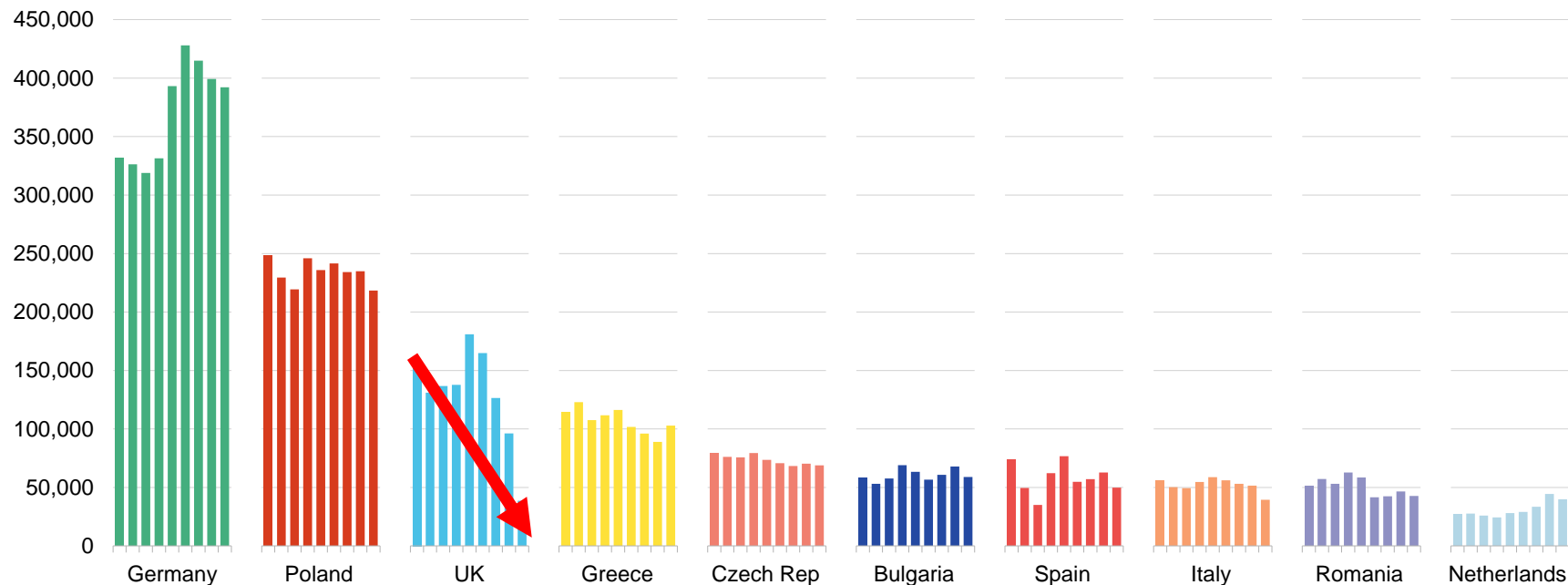


[nationalgrid | nationalgrid.com/uk/](http://nationalgrid.com/uk/)

April 2017
Source: National Grid

Emissions from coal-fired power, 2008-16

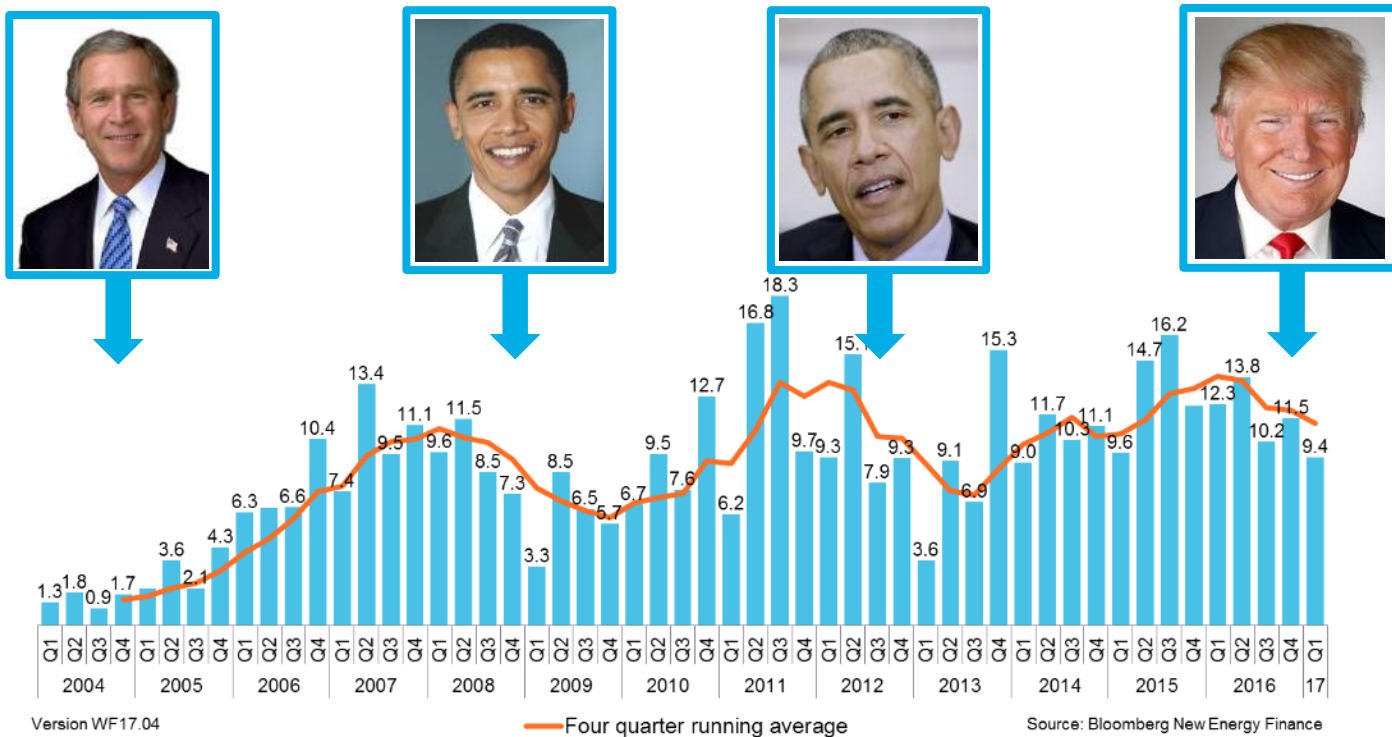
tCO₂e/yr



Source: Bloomberg New Energy Finance, Eurostat

US new investment in clean energy

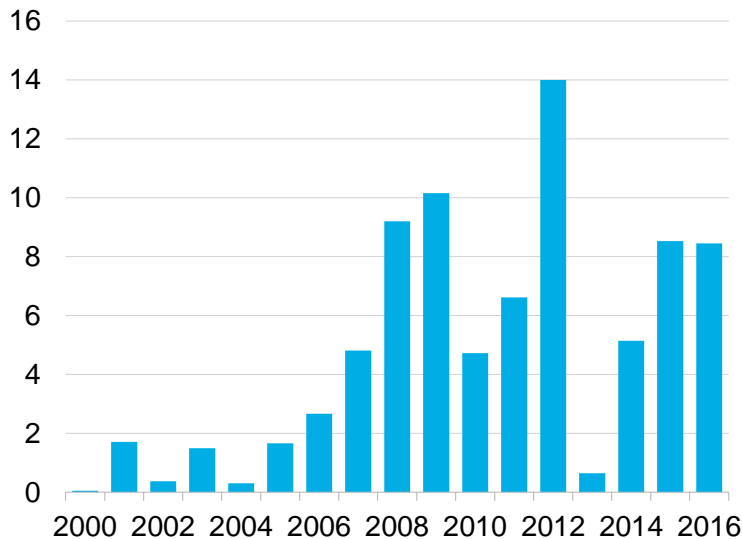
(\$ billion)



US wind installations

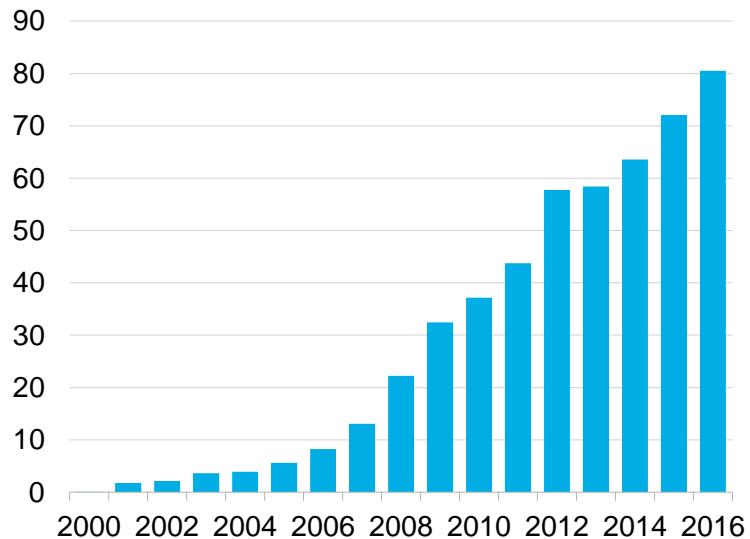
Annual

GW



Cumulative

GW



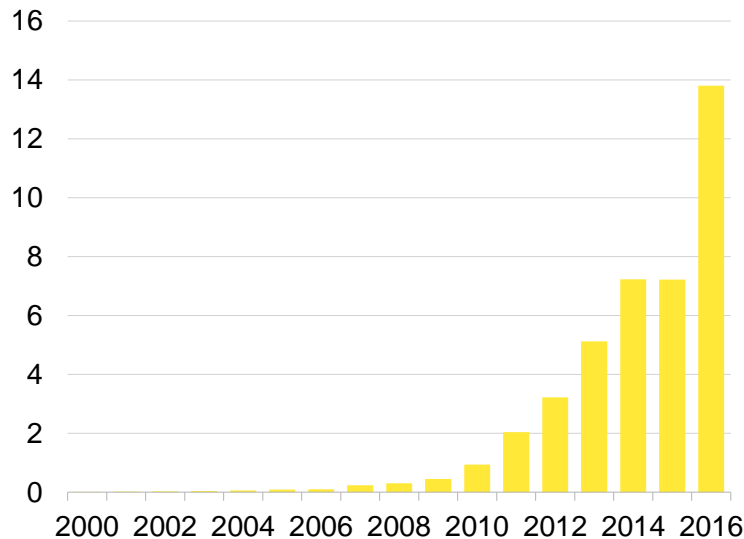
**2008-16
Up 262%**

Note: Cumulative over 2000–16 Source: Bloomberg New Energy Finance

US solar installations

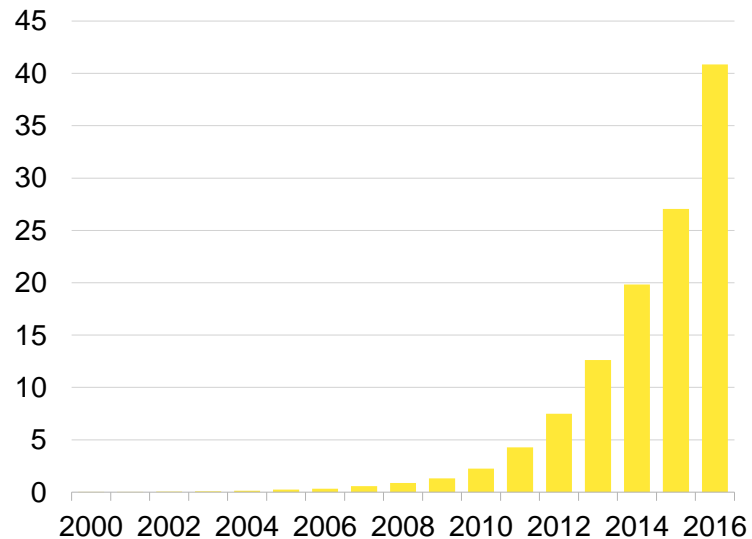
Annual

GW



Cumulative

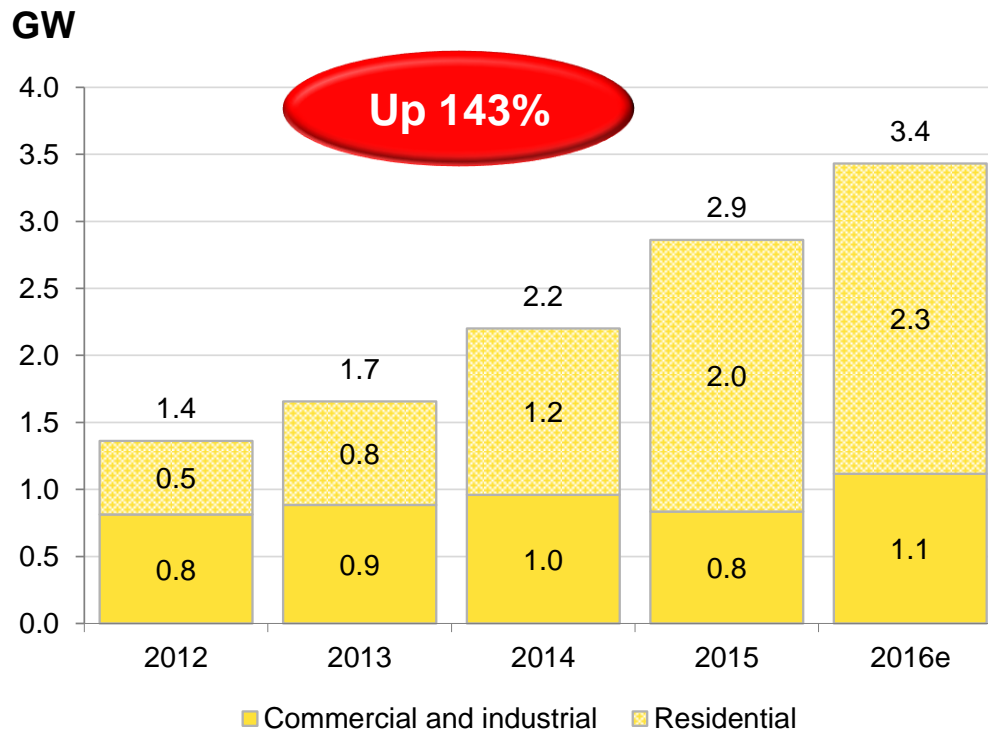
GW



2008-16
Up 4,645%

Note: Cumulative over 2000–16 Source: Bloomberg New Energy Finance

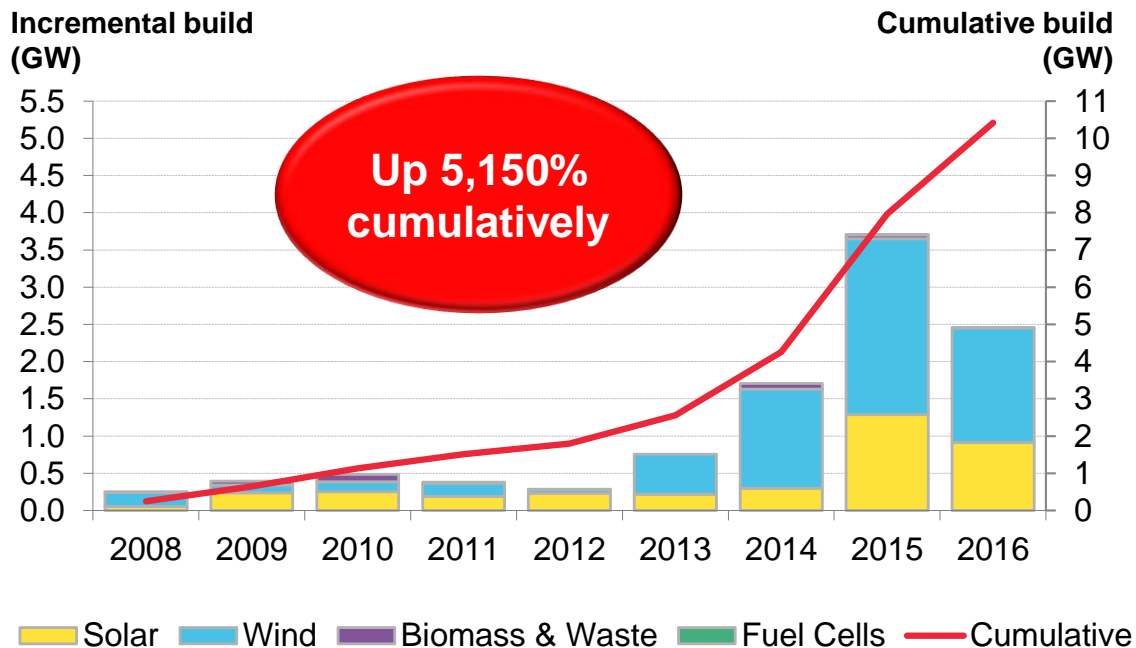
US small-scale solar build by type



Note: 2016 US residential and C&I PV build figures are estimated

Source: Bloomberg New Energy Finance

US corporate procurement of clean energy

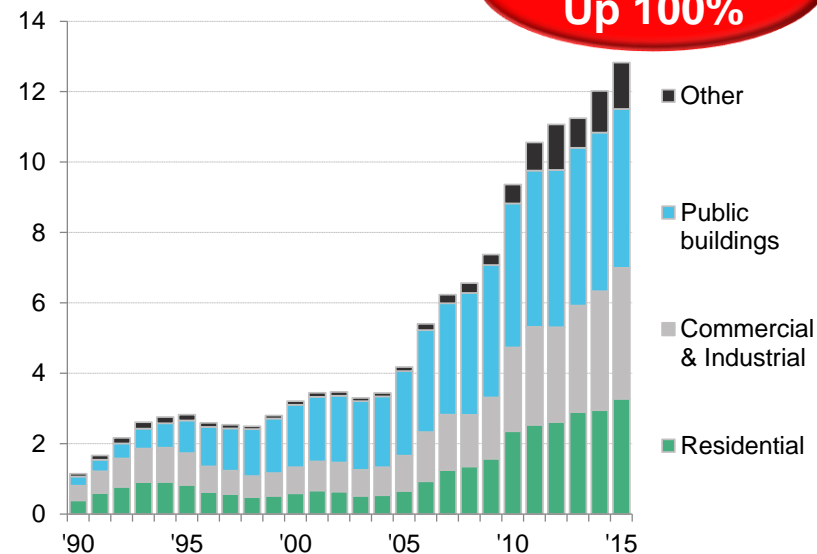


Note: Incremental build left axis, columns; cumulative build right axis, red line
Source: Bloomberg New Energy Finance

US energy efficiency investment

US estimated investment in energy efficiency

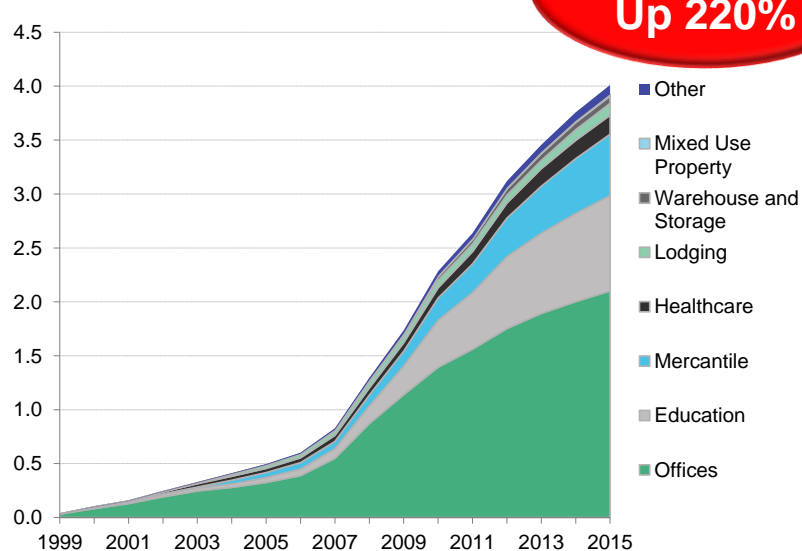
\$ billion (nominal)



Source: ACEEE, NAESCO, LBNL, CEE, IAEE, Bloomberg New Energy Finance

Energy Star-certified floor space in US non-residential buildings

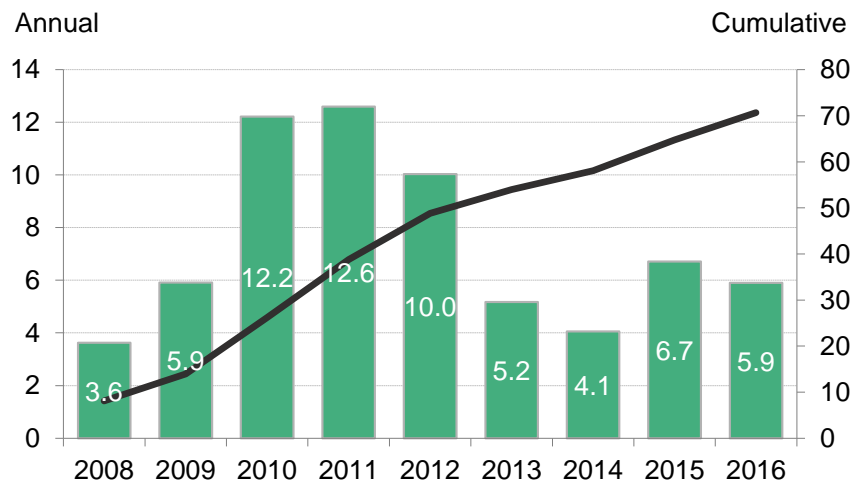
Billions of square feet



Source: EPA, Bloomberg New Energy Finance

US electric smart meter deployment

US smart meter deployments (million units)



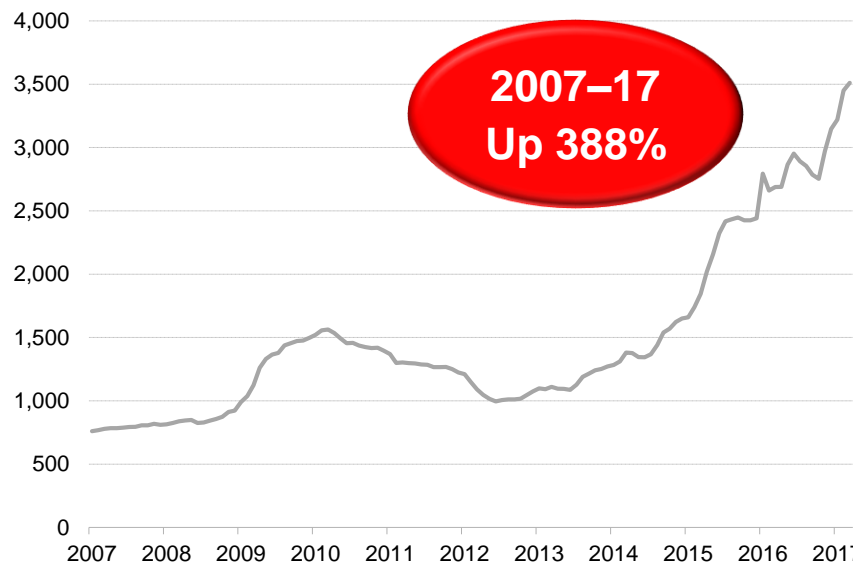
Up 4,300%
cumulative

Notes: Includes data for smart electricity meters, excludes automated meters. Smart meters are defined as those capable of two-way communication over a fixed network.

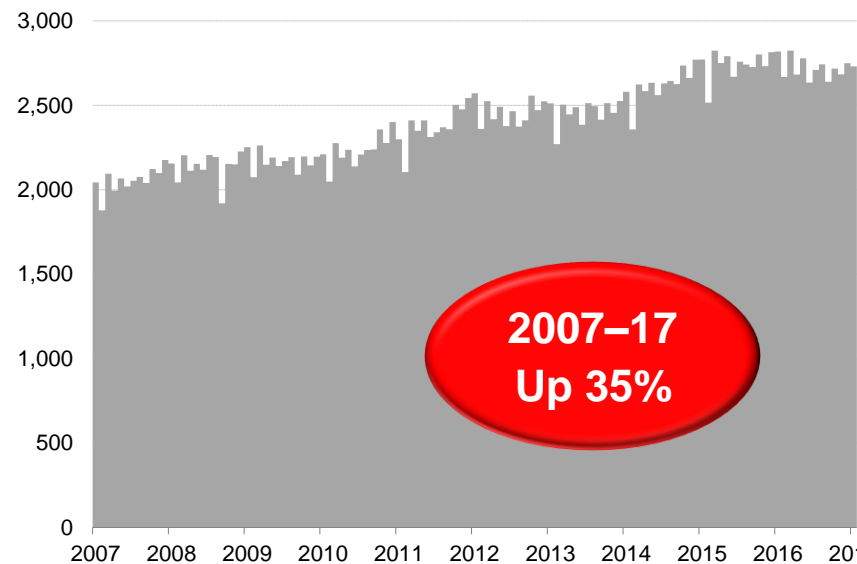
Source: Bloomberg New Energy Finance, EIA

US gas production and rig efficiency

New-well production per rig ('000 cf/day)



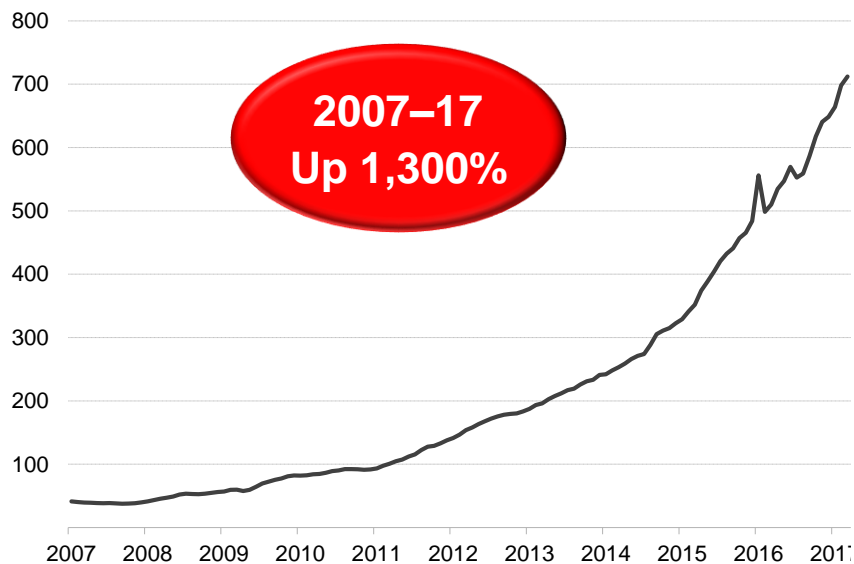
US monthly natural gas production (mcf)



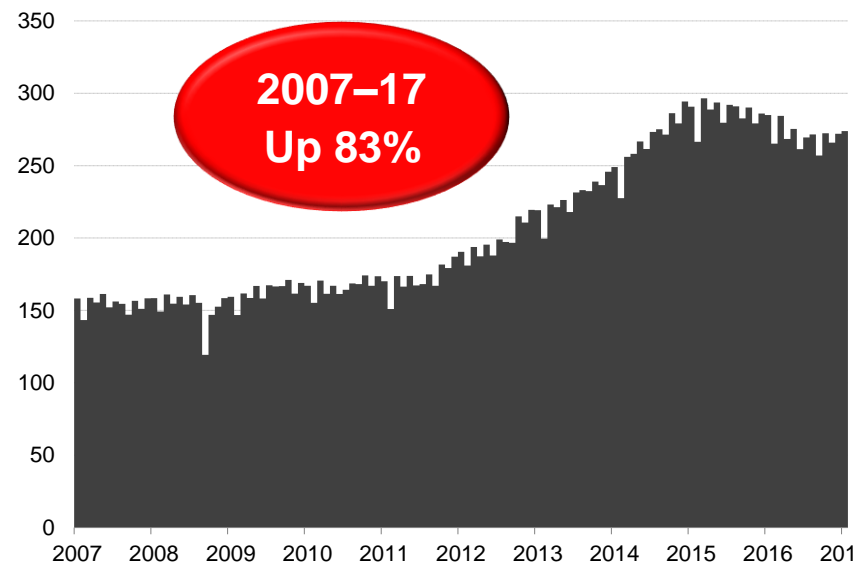
Source: EIA

US oil production and rig efficiency

New-well production per rig (bbl/day)

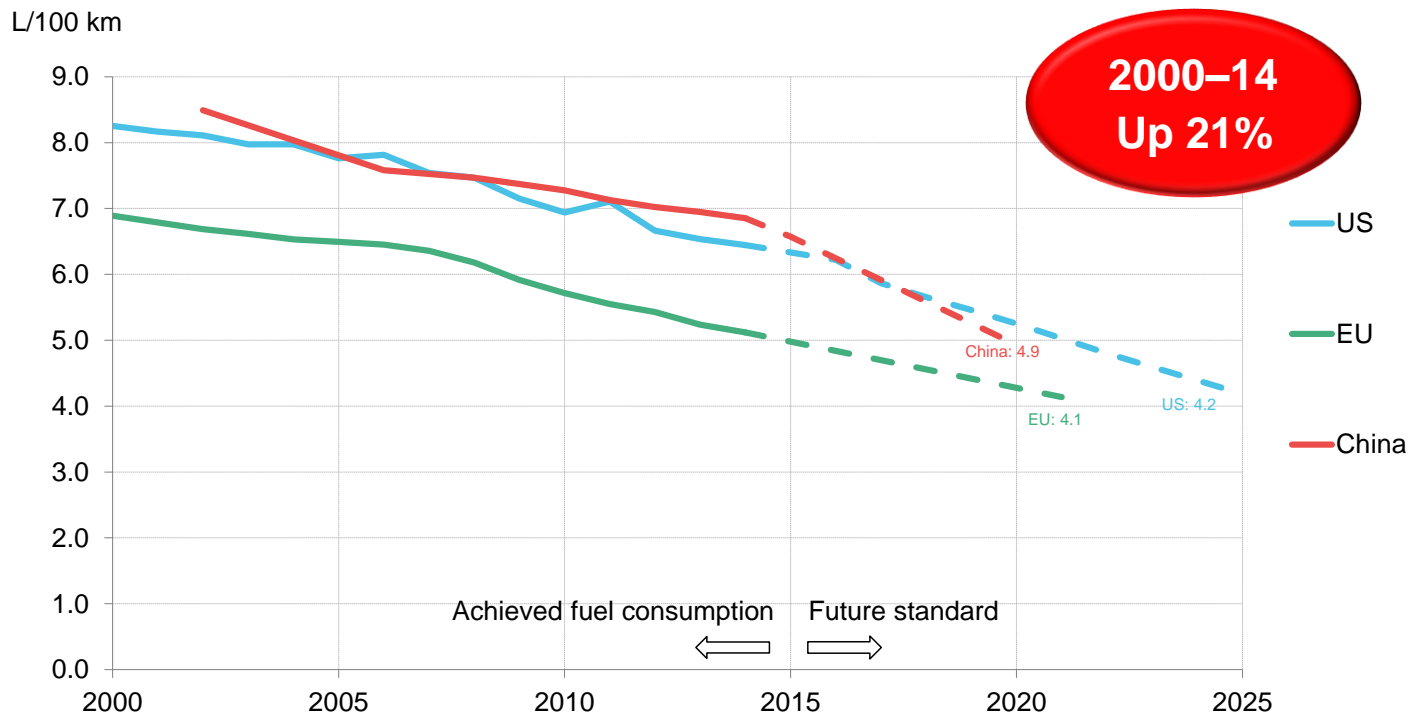


US monthly oil production ('000 bbl/month)



Source: EIA

Fuel economy regulations for China, US and Europe, 2000-25 (litres/100km)

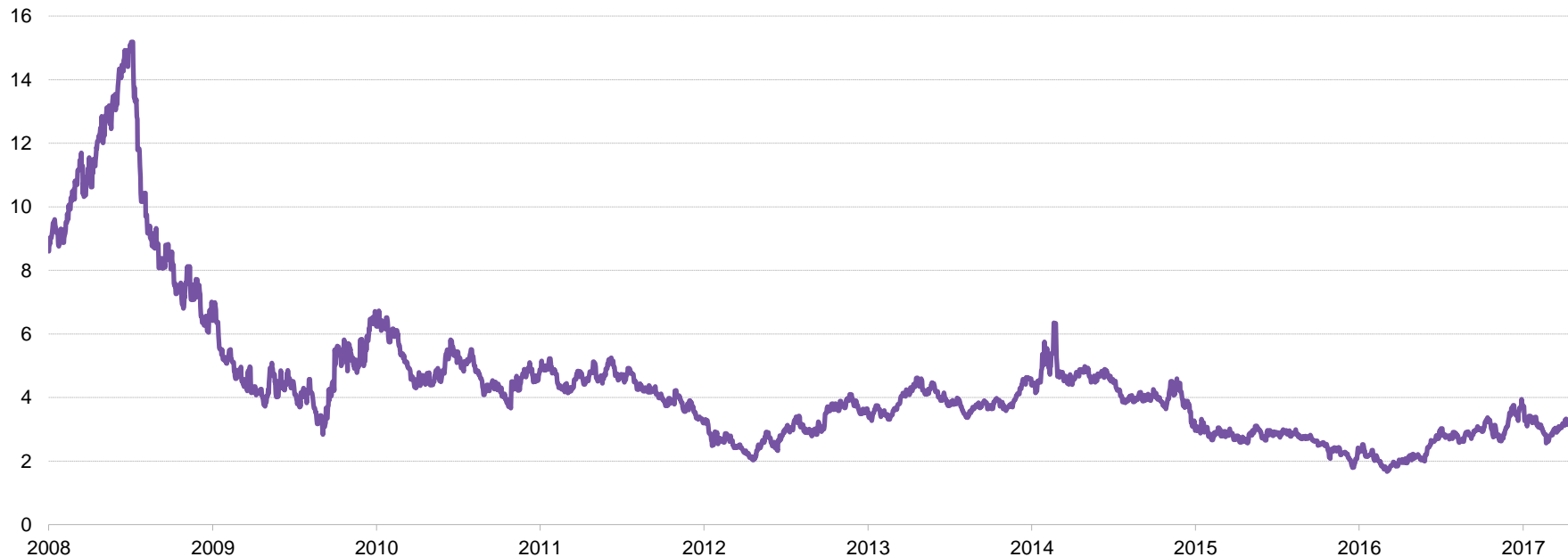


Note: The fuel economy targets have been normalised to the CAFE testing procedure. US targets are for passenger cars only.

Source: EPA, NHTSA, EU, ICCT

Henry Hub gas prices

\$/MMBTU



Note: Real 2017 \$US

Source: Bloomberg

US coal prices

\$/short ton



Note: Central Appalachian benchmark price, real 2017 \$US

Source: Bloomberg

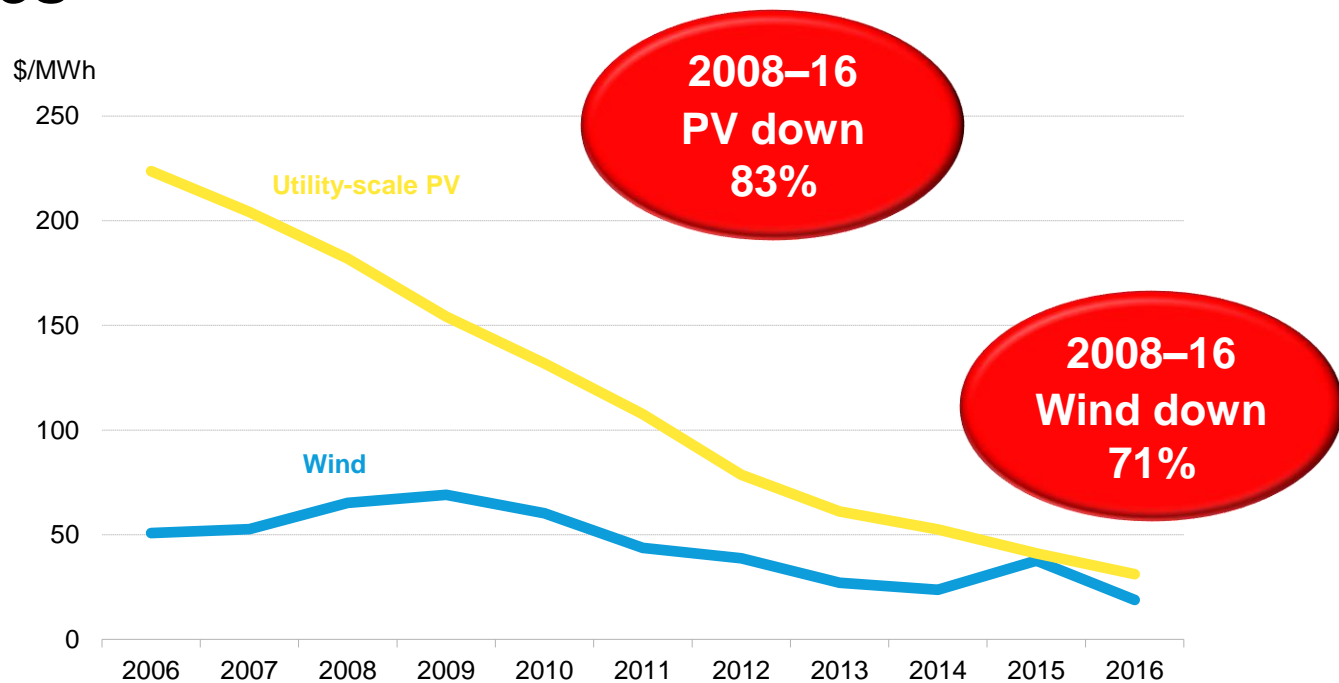
Oil prices



Note: Front-month Brent crude contract, real 2017 \$US

Source: Bloomberg

Average US renewable energy PPA prices

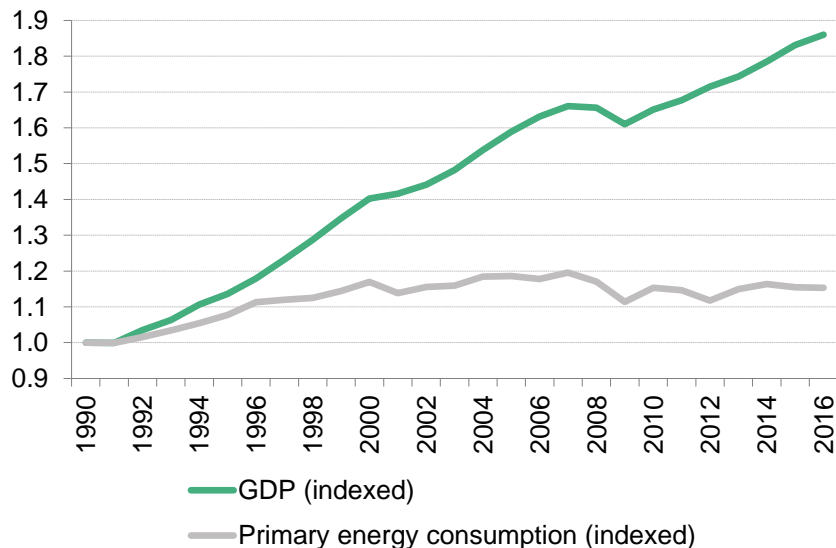


Note: Levelized, time-of-day adjusted contract price shown in real 2015 USD. 2016 PV PPA price based on preliminary data and subject to review.

Source: U.S. Department of Energy (LBNL), Bloomberg New Energy Finance

US energy productivity

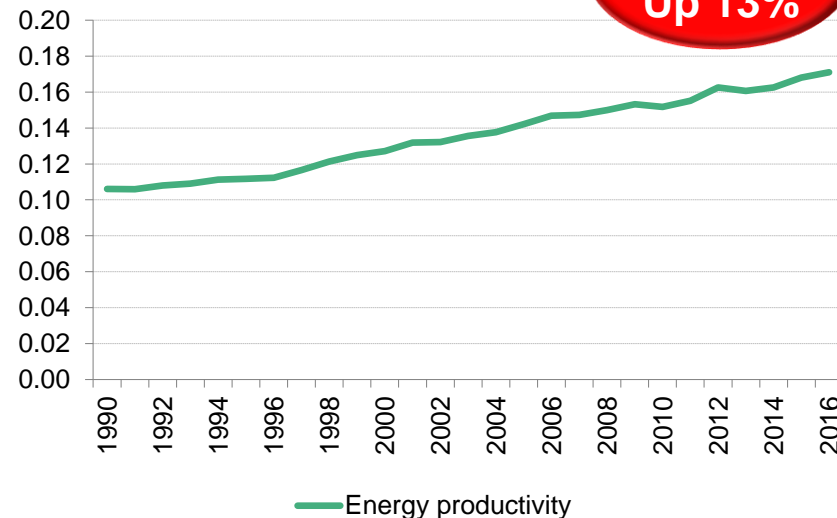
US GDP and primary energy consumption



Note: Indexed to 1990 levels. Values for 2016 energy consumption are projected, accounting for seasonality, based on latest monthly values from EIA (data available through October 2016). GDP is real and chained (2009 dollars); annual growth rate for GDP for 2016 is based on consensus of economic forecasts gathered on the Bloomberg Terminal as of January 2017.

US energy productivity

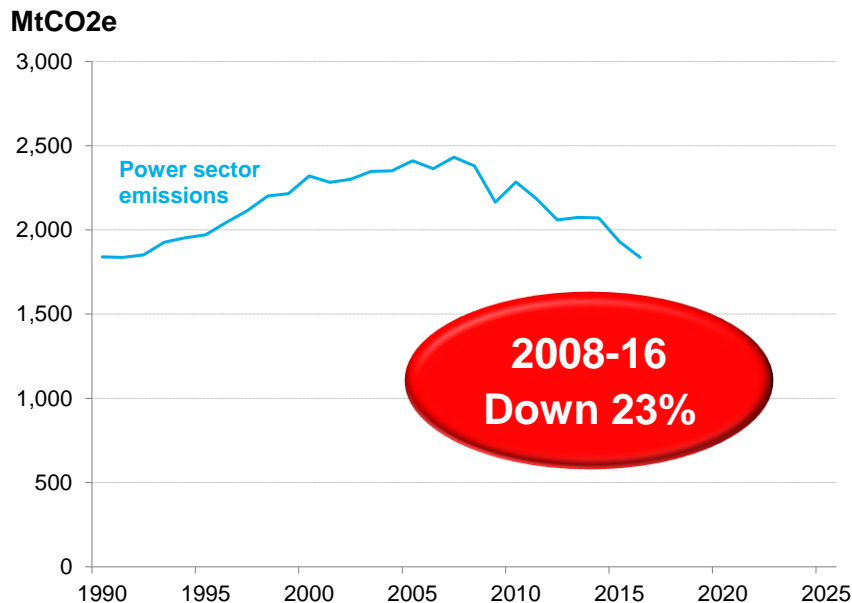
\$ trillion of GDP/quadrillion BTU



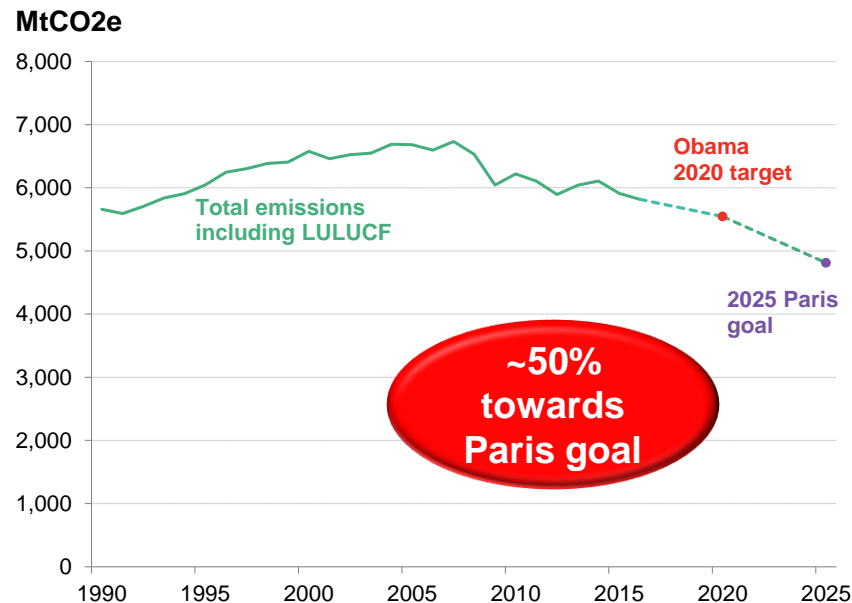
Source: US Energy Information Administration (EIA), Bureau of Economic Analysis, Bloomberg Terminal

Greenhouse gas emissions and progress towards targets

US power sector emissions



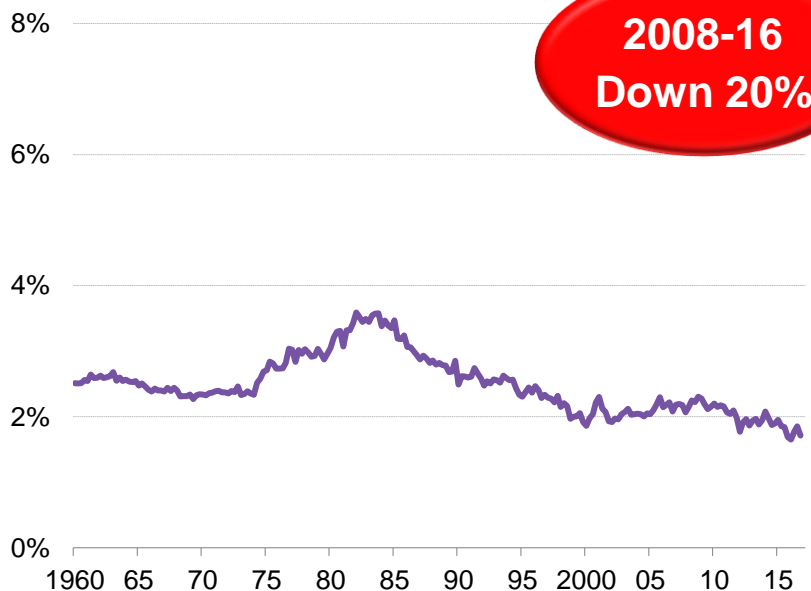
US total emissions



Source: Bloomberg New Energy Finance, EIA, EPA

Share of US personal expenditure on energy

Electricity & gas



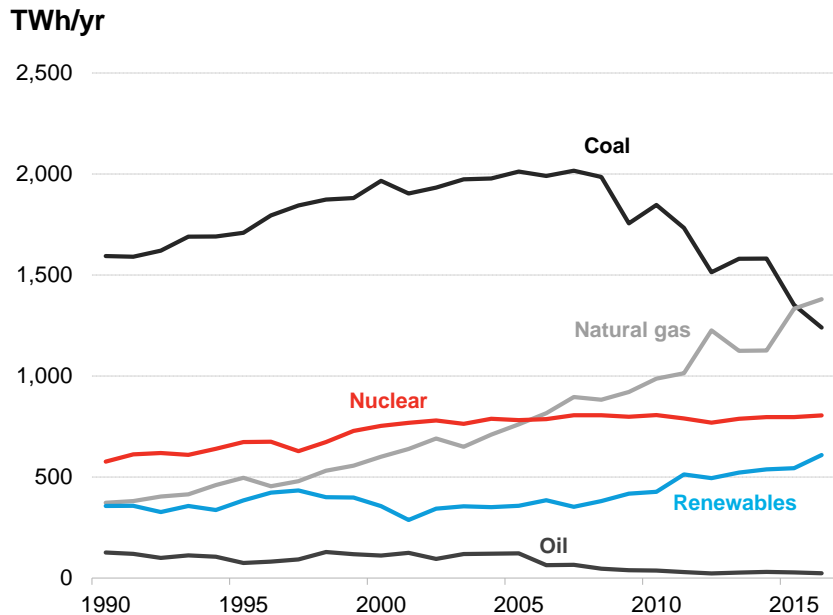
Gasoline



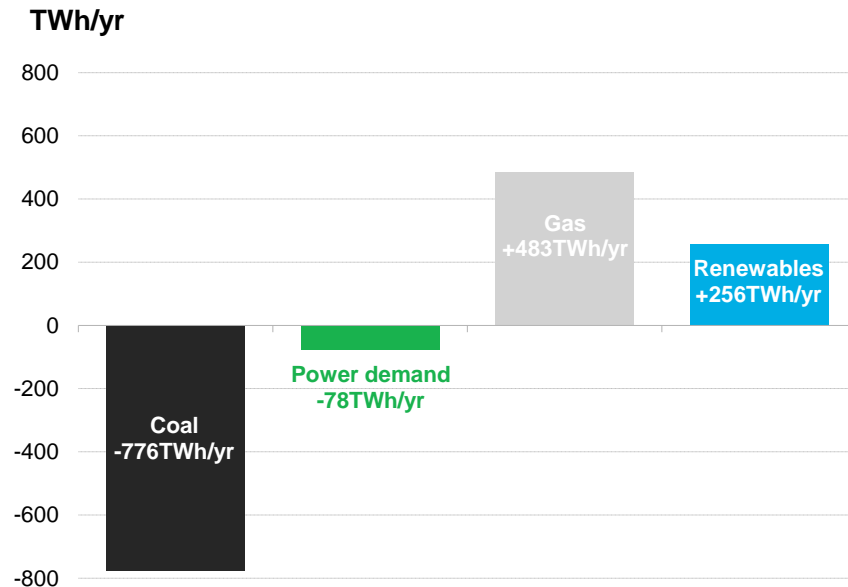
Source: US Bureau of Economic Analysis, Bloomberg New Energy Finance

US power sector fuel mix

Generation by source



Change in generation 2007-16

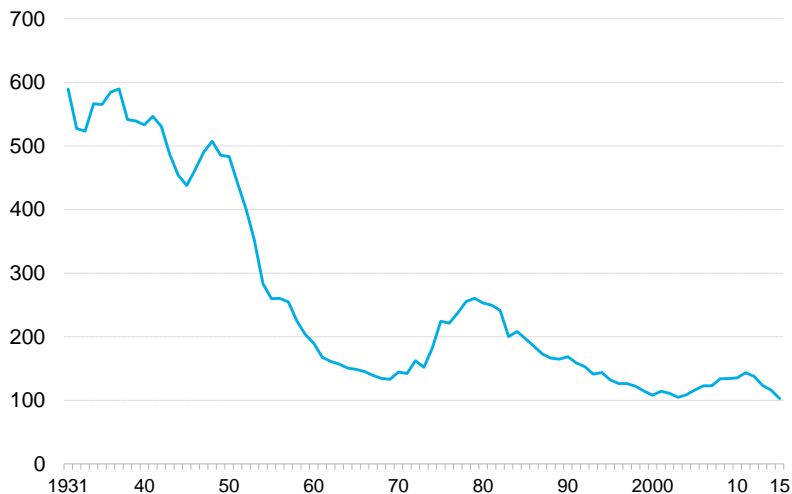


Source: EIA

US coal jobs and productivity

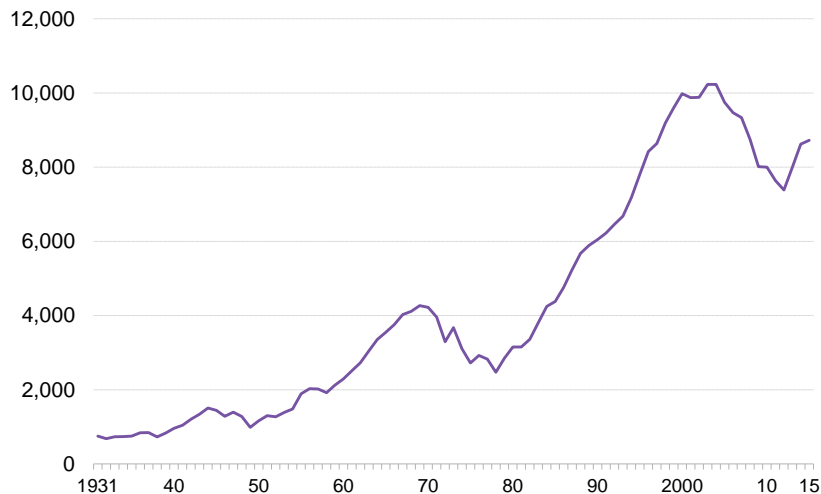
Jobs

Thousand jobs



Productivity

Tonnes per employee per year



Source: Bloomberg New Energy Finance, US Department of Labour

New generation of mining trucks



Image: Komatsu

Adani Mining Carmichael coal mine Queensland Australia

“

When we ramp up the [Carmichael] mine, everything will be autonomous from mine to port. In our eyes, this is the mine of the future.”

”

*Jeyakumar “JJ” Janakaraju
Adani Mining CEO*



Image: Adani Mining

Making America Great Again?

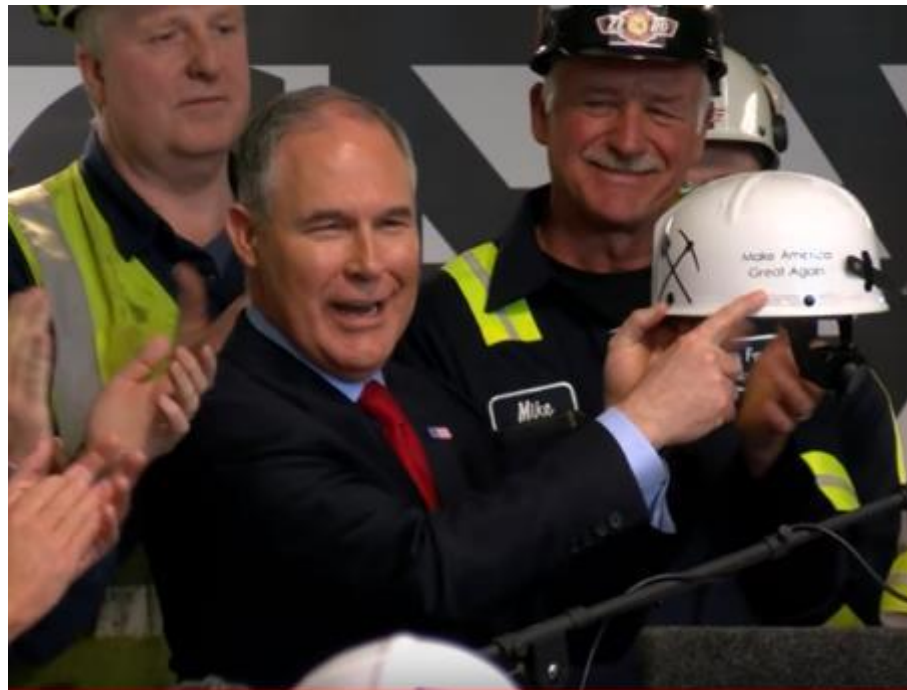


Image: White House; EPA



2015 BNEF SUMMIT KEYNOTE

AN AGE OF PLENTY...

... ON STEROIDS

US administration views on climate change

“The concept of global warming was created by and for the Chinese in order to make US manufacturing non-competitive”

*Donald Trump, US Presidential Candidate 2016
(now President)*

“Climate change could be happening and it could be a part of human action, but its costs in the near term certainly are not great”

*Jeff Sessions, 2015
(now US Attorney General)*

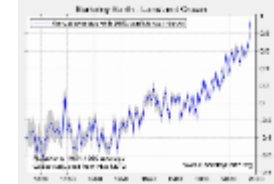
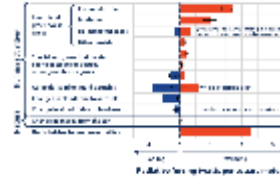
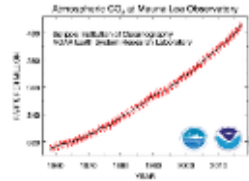
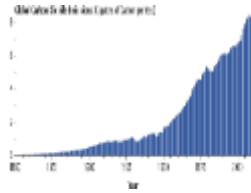
“I would not agree that [human activity] is a primary contributor to the global warming that we see”

*Scott Pruitt
EPA Director*

“[Climate change] is all one contrived phony mess that is falling apart under its own weight. Al Gore is a false prophet of a secular carbon cult”

*Rick Perry, US Presidential Candidate 2012
(now Secretary of Energy)*

I'm not a climate scientist but...



Investing in fossil-fuel energy and transport assets...

means we emit more greenhouse gases...
(NASA et al.)

which accumulate in the atmosphere...
(NOAA et al.)

driving human climate forcing...
(EPA et al.)

thereby pushing up temperatures...
(Berkeley et al.)

and causing climate impacts
(IPCC et al.)

Source: Various; BNEF

Climate-related flood risk Mar a Lago Club, Miami, Florida



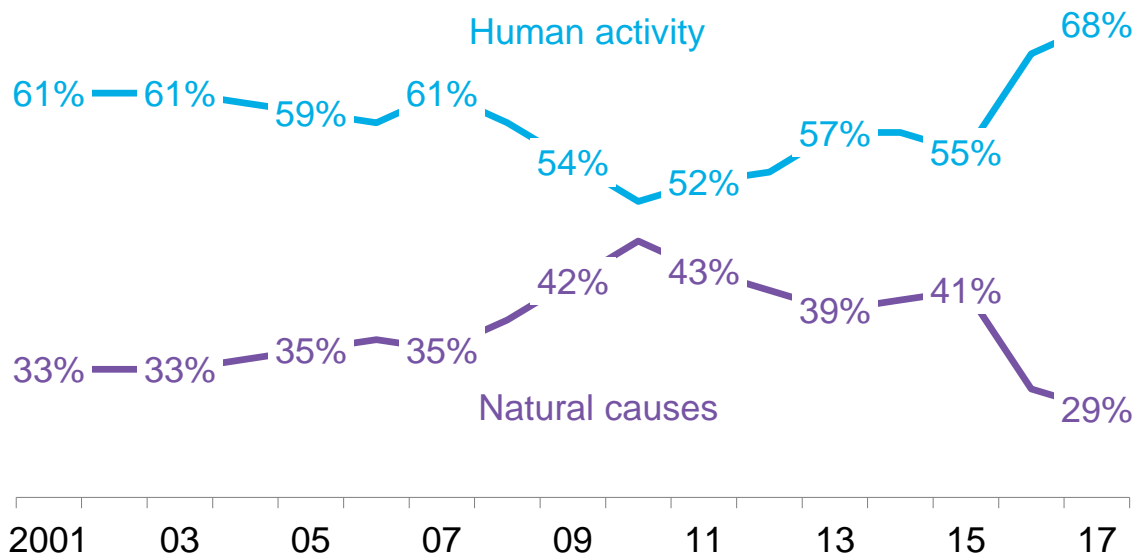
2045

Note: Blue areas indicate risk of flooding.

Source: Coastal Risk Consulting © Mapbox, © OpenStreetMap Graphic: Jan Diehm/The Guardian

US public view of climate change

Do you believe increases in the Earth's temperature are due more to the effects of pollution from human activities or natural changes in the environment that are not due to human activities?



Source: Gallup

Kentucky Coal Museum's solar roof Harlan County



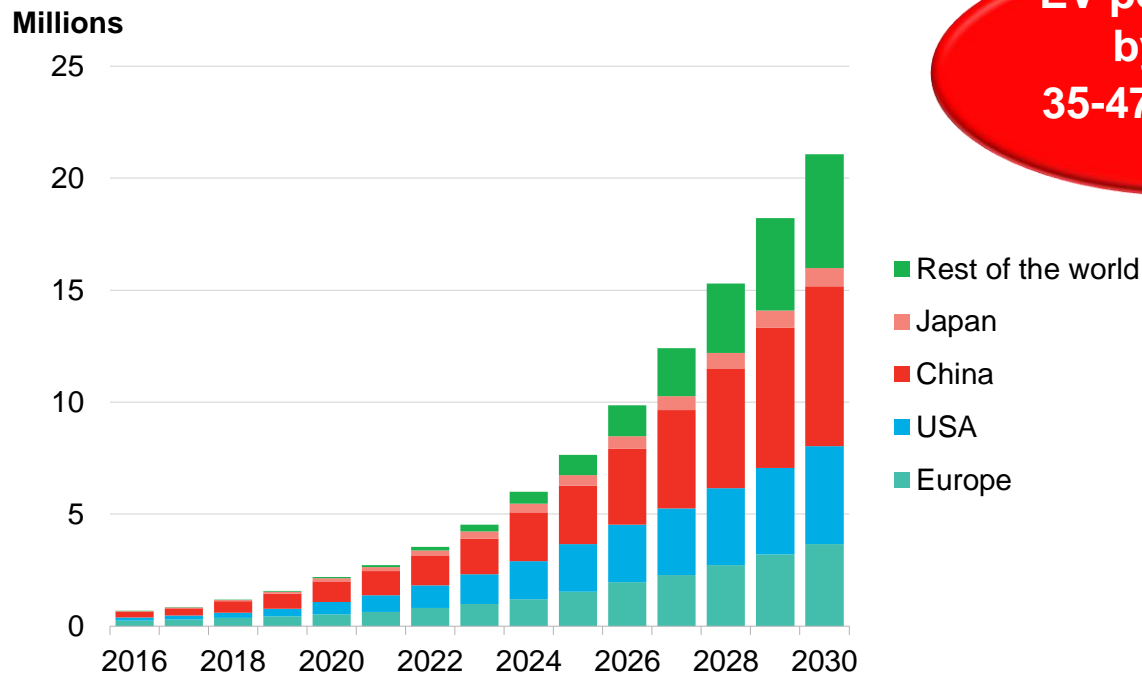
Image: EKB TV

Keeping America Great!



Images: various companies

BNEF global EV sales forecast by region

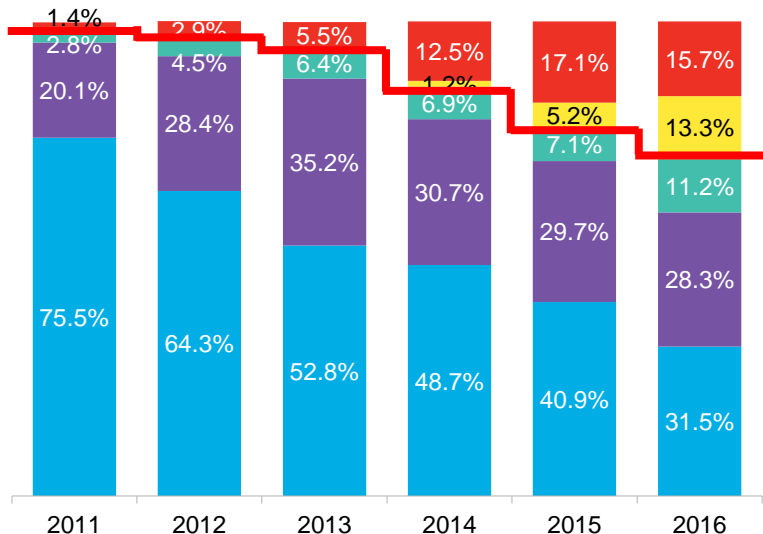


**EV penetration
by 2040
35-47% of new
cars**

*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.*

The Norwegian experience

Split of annual car sales by type



29% of new cars in Norway have plugs

- Battery
- Plug-in hybrid
- Hybrid
- Gasoline
- Diesel

Vehicle choices



Audi A7 Q

Tesla S 60D

Price
(without tax):

\$44,392

\$75,117

Price
(with tax):

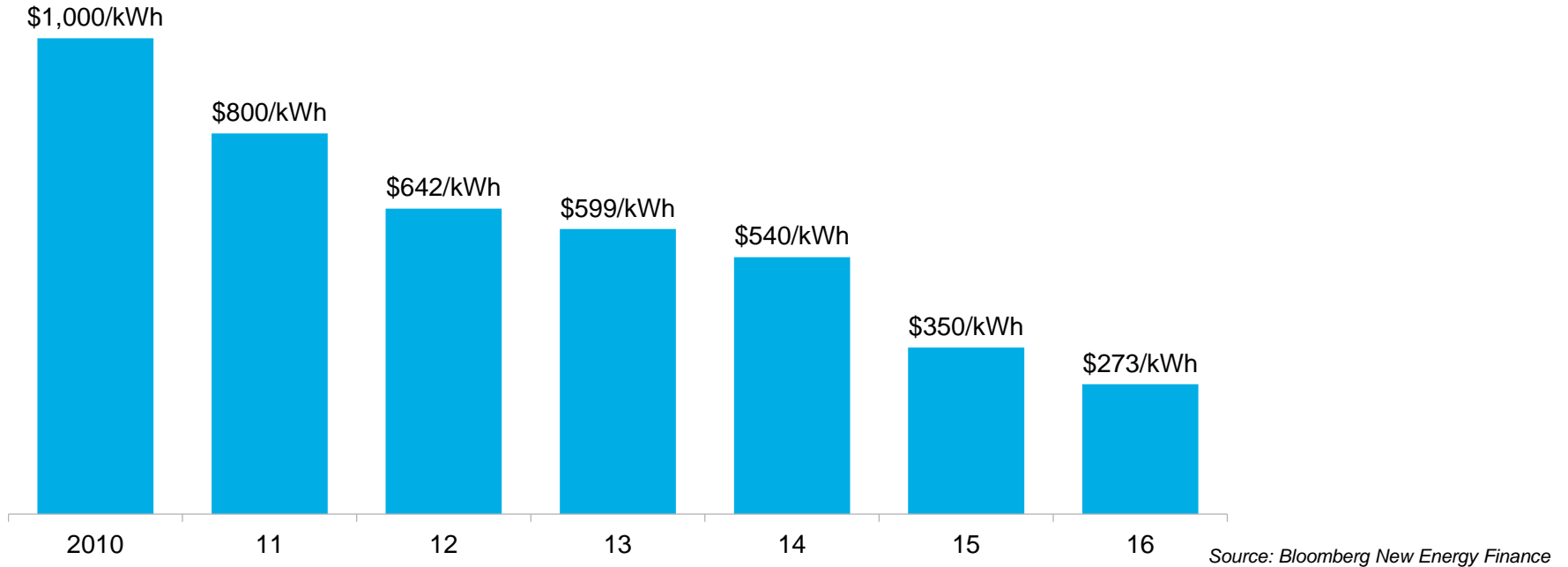
\$82,363

\$75,117

Source: Bloomberg New Energy Finance, Ofv.no

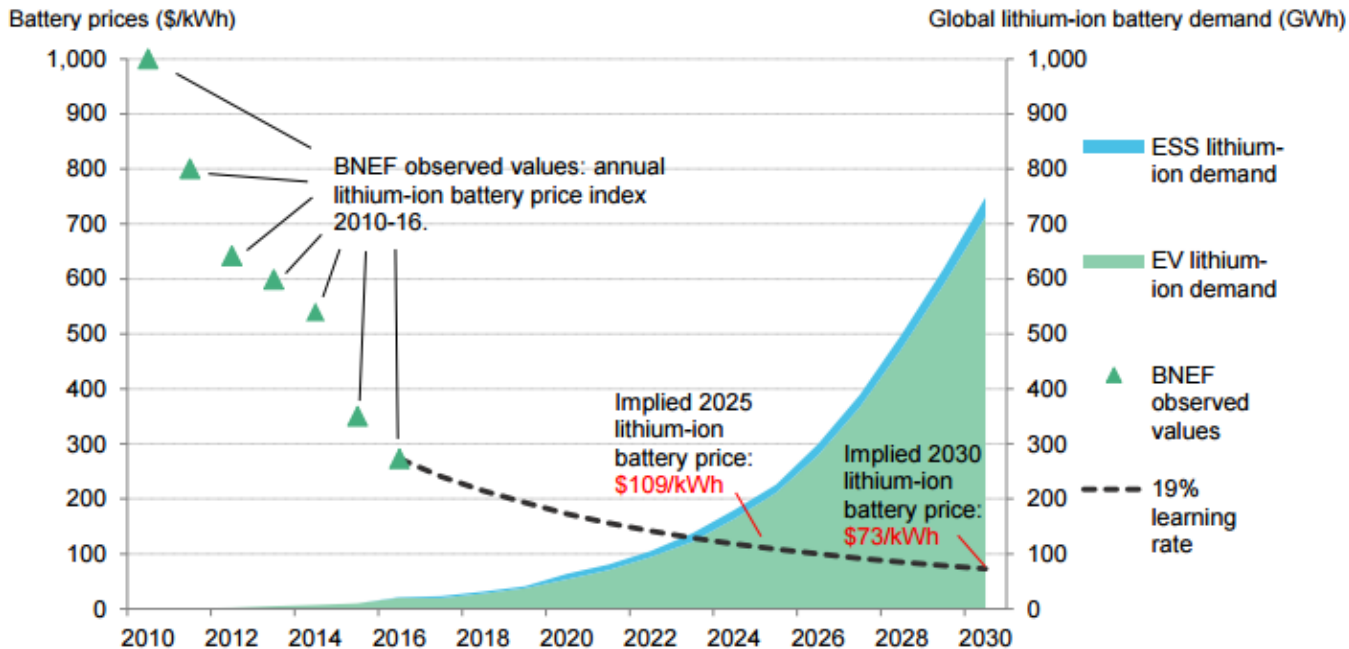
Lithium-ion battery pack prices are down 73% since 2010

BNEF 2016 battery pack price survey results



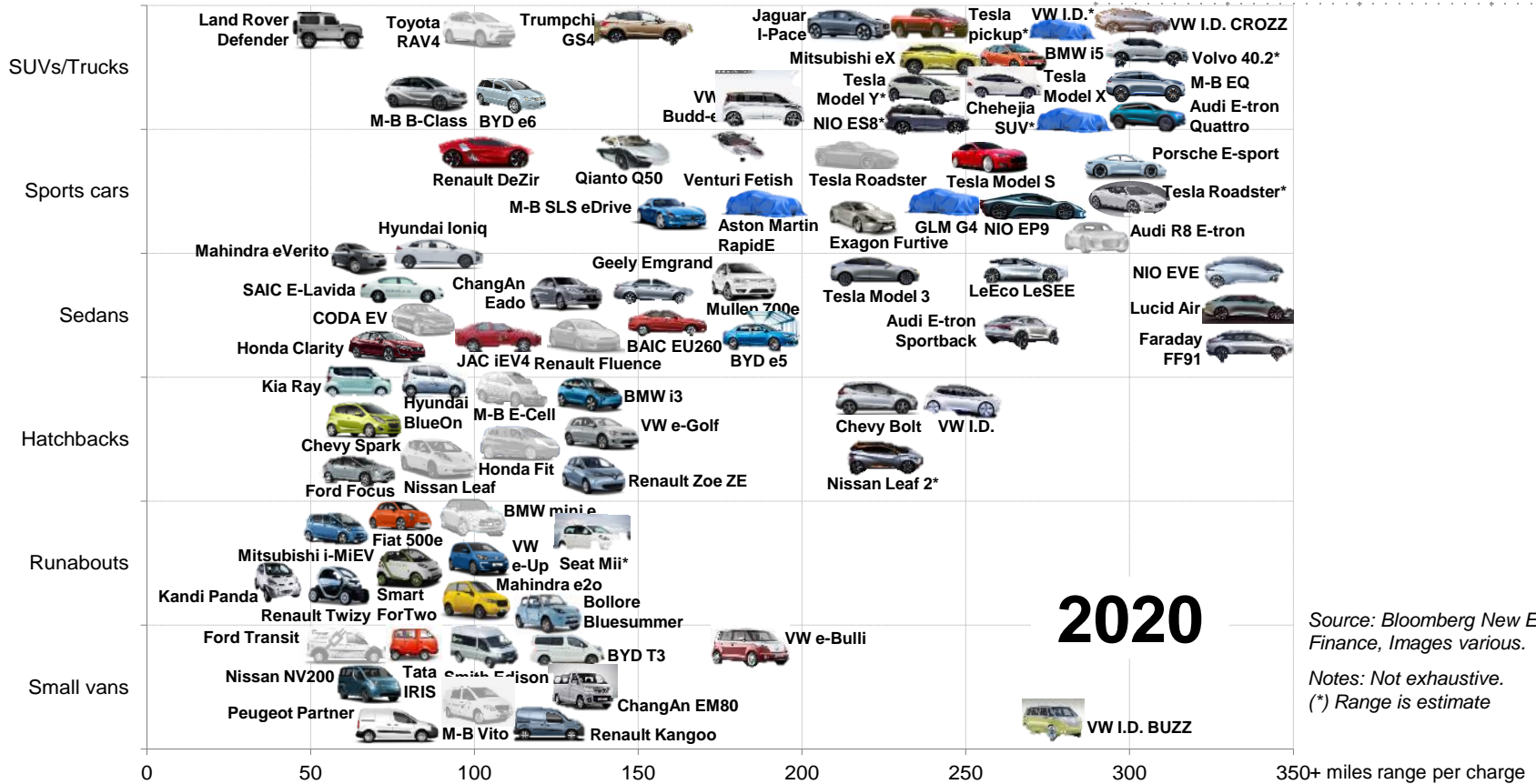
Lithium-ion battery pack prices will drop another 75% by 2030

Lithium-ion battery price forecast



Source: Bloomberg New Energy Finance

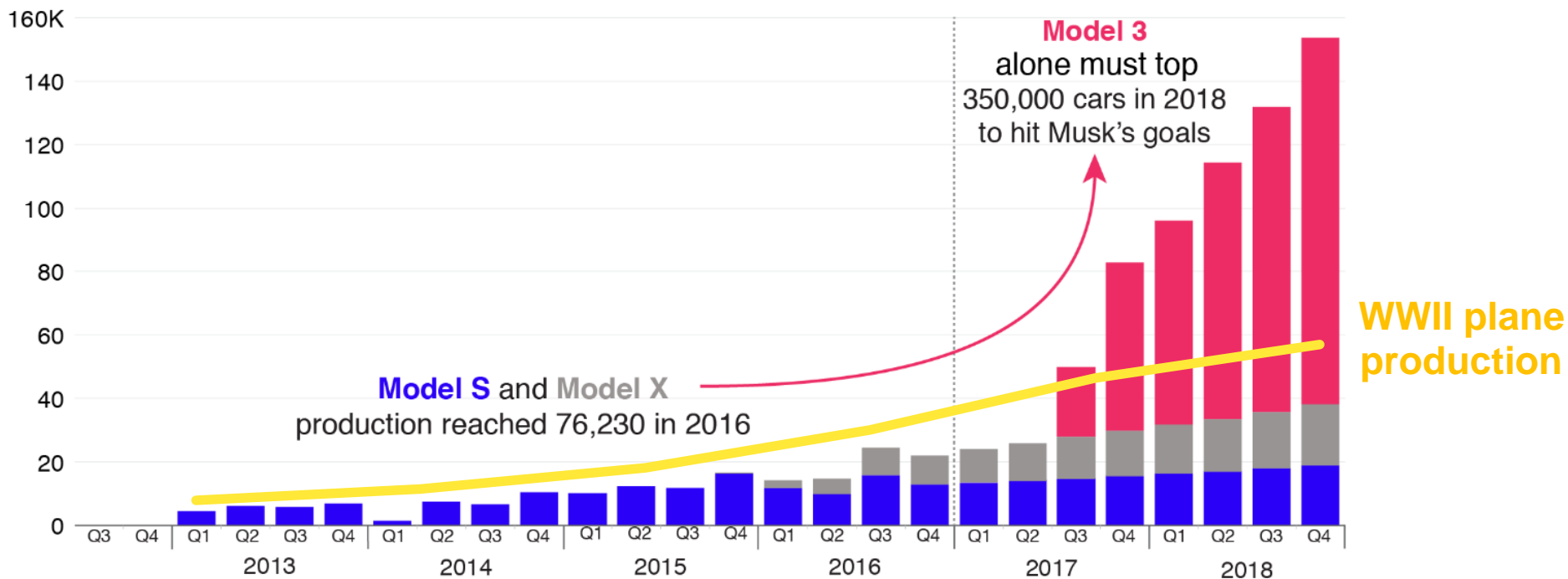
BEV model availability, 2008-20



Source: Bloomberg New Energy Finance, Images various.

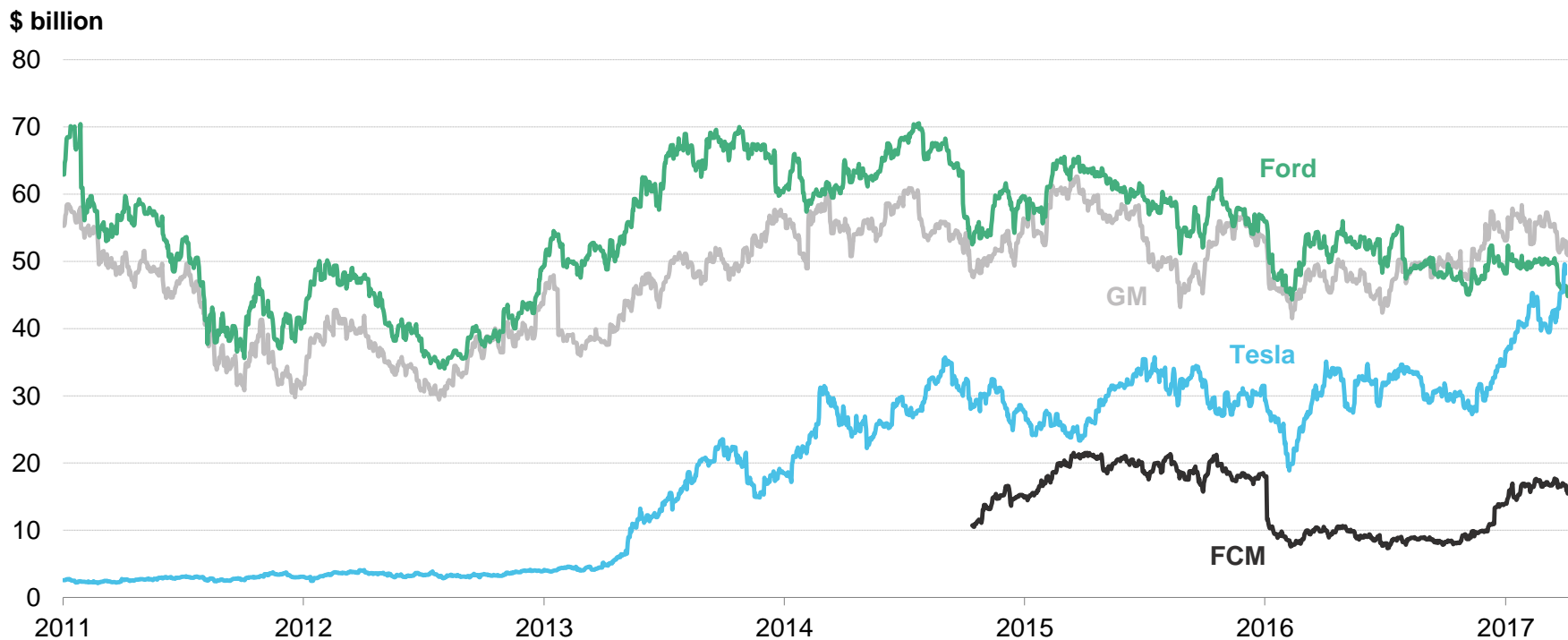
Notes: Not exhaustive.
(*) Range is estimate

Tesla's gamble



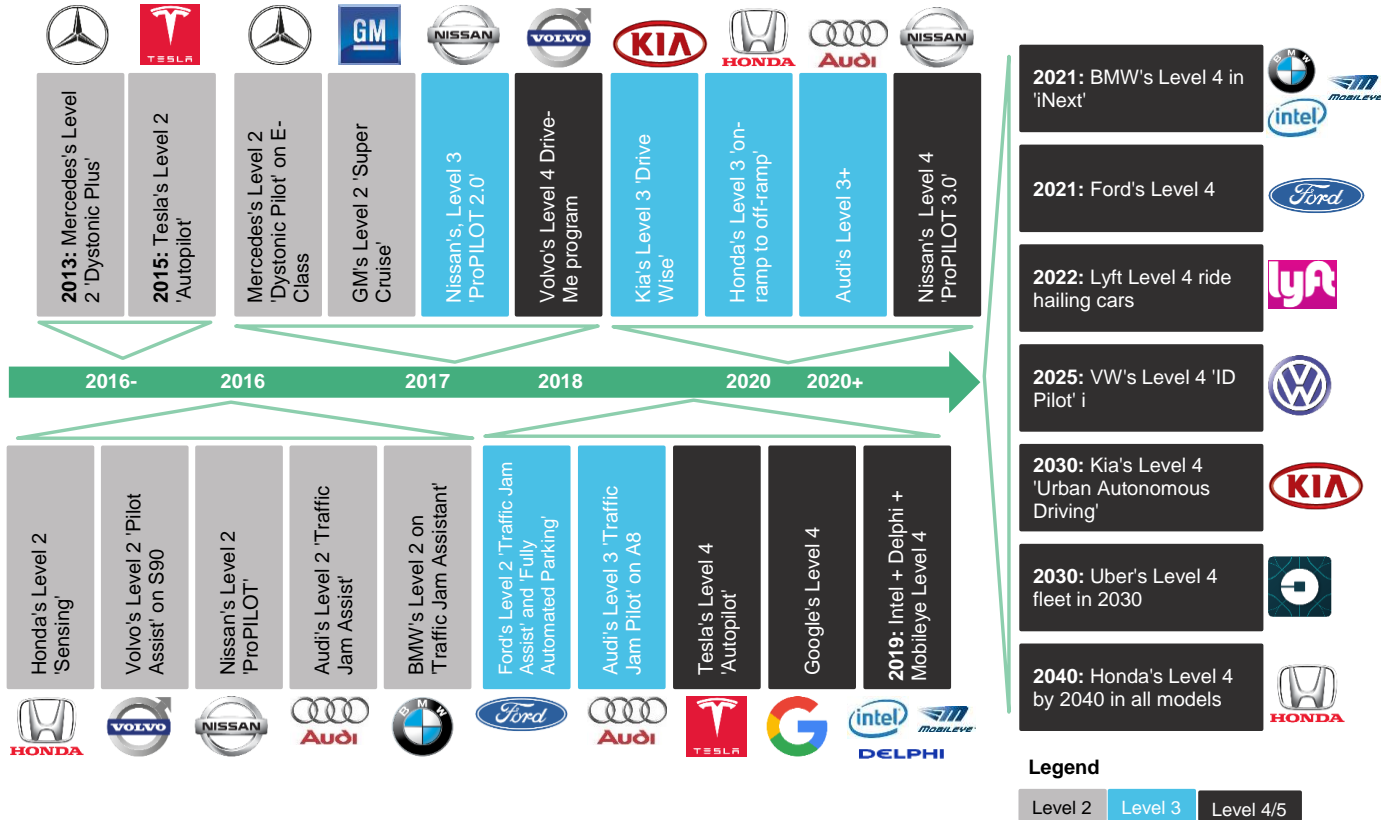
Source: Tesla; Bloomberg <https://www.bloomberg.com/news/articles/2017-03-27/tesla-model-3-ramp-up-aims-to-crush-bmw-and-mercedes>; Bloomberg New Energy Finance, Library of Congress WWII Companion

Car company market capitalisation



Source: Bloomberg, Bloomberg New Energy Finance

Disclosed timelines for autonomous vehicles from select companies, 2016 – 40



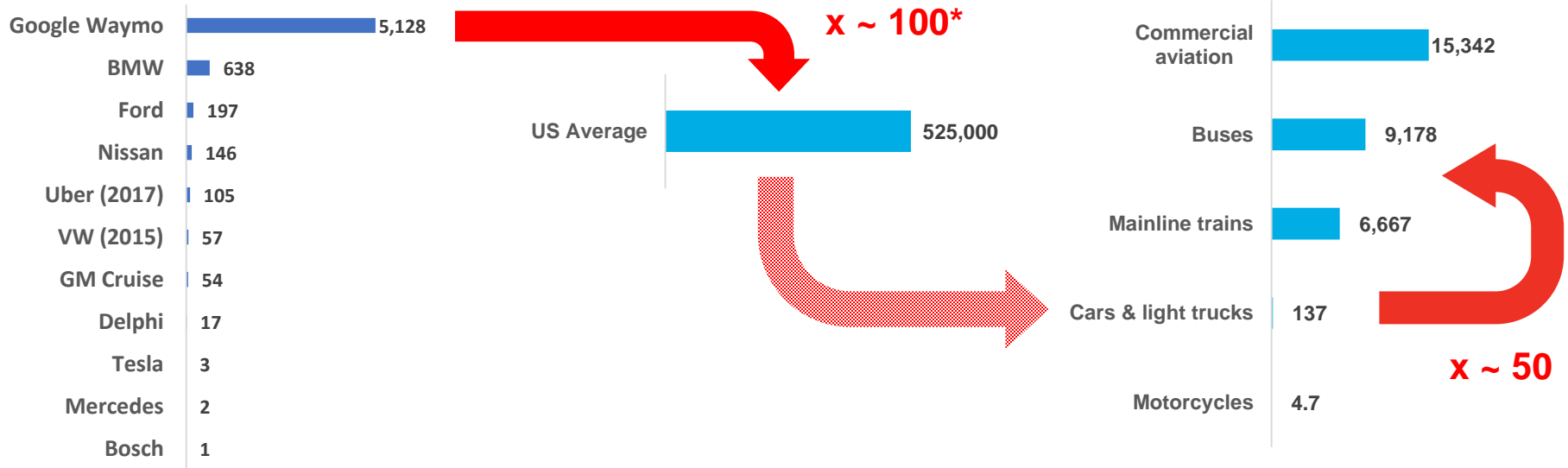
Source: Bloomberg New Energy Finance

5000 x improvement in safety performance required

AVs: distance between human interventions (miles)

Humans: distance between crashes (miles)

Distance between fatalities (million miles)



* Assumes one in 10 human interventions might otherwise have resulted in an accident

Source: California DMV; Recode; NHTSA; FHWA; BNEF

Rich people having empty cars drive round the block instead of parking



Image: Limousine Service Zurich

When 20,789 people all want to get to Madison Square Gardens at the same time

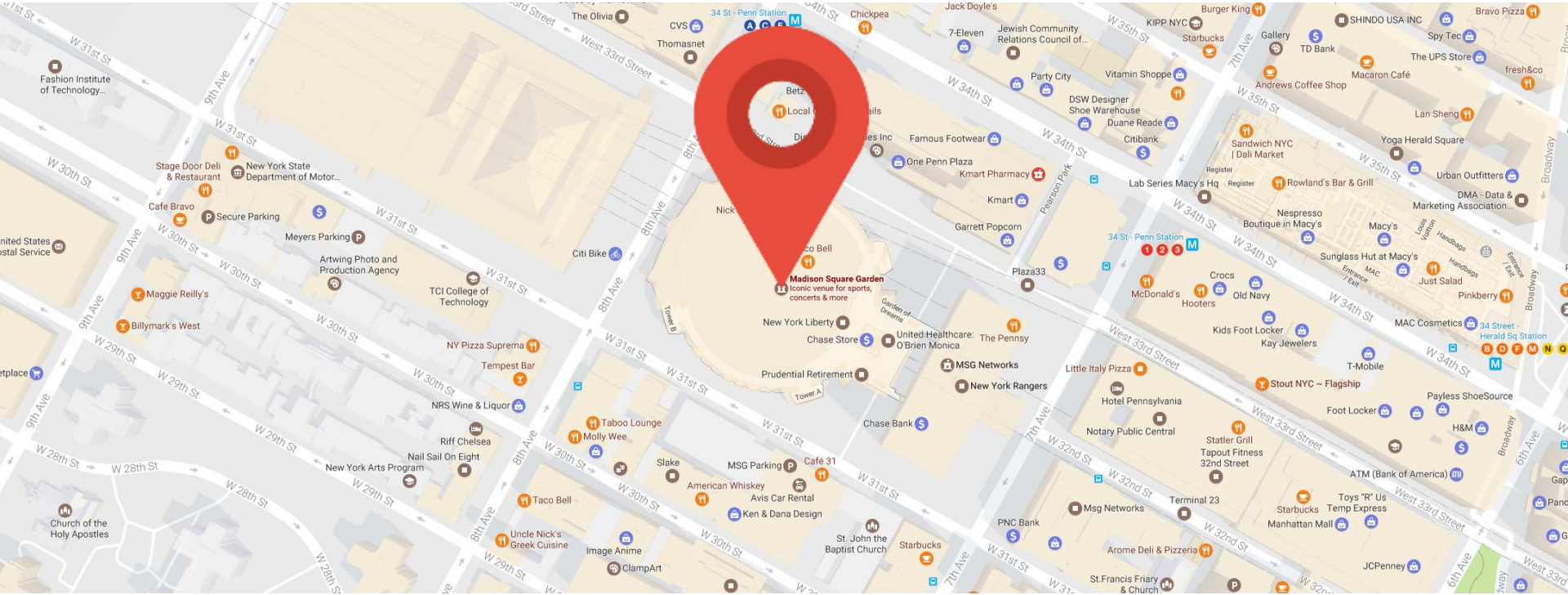


Image: Google Maps

Algorithms which are individually smart and collectively dumb



Image: Obianuju Okafor

Secretary Perry's 60-day review



To what extent are regulatory burdens, subsidies and tax policies responsible for forcing the premature retirement of baseload power plants

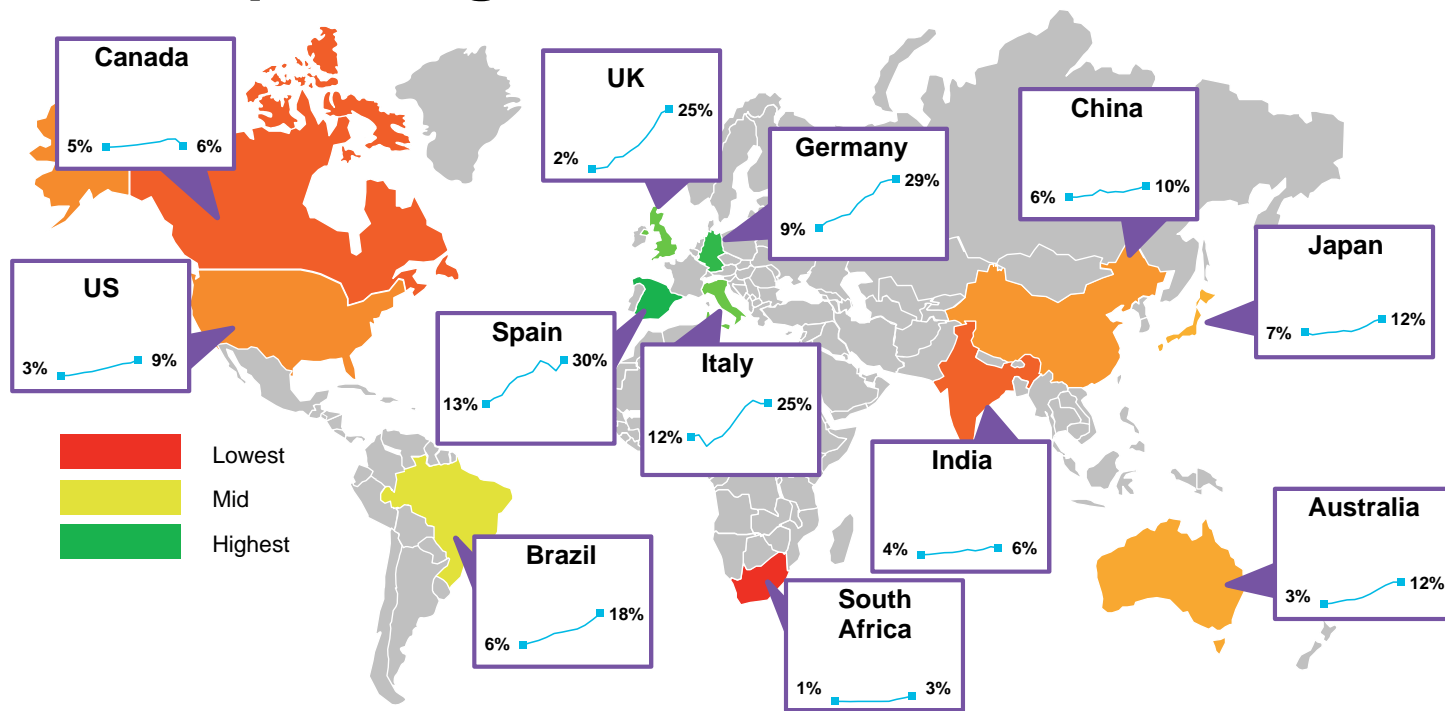


Rick Perry
Secretary of Energy



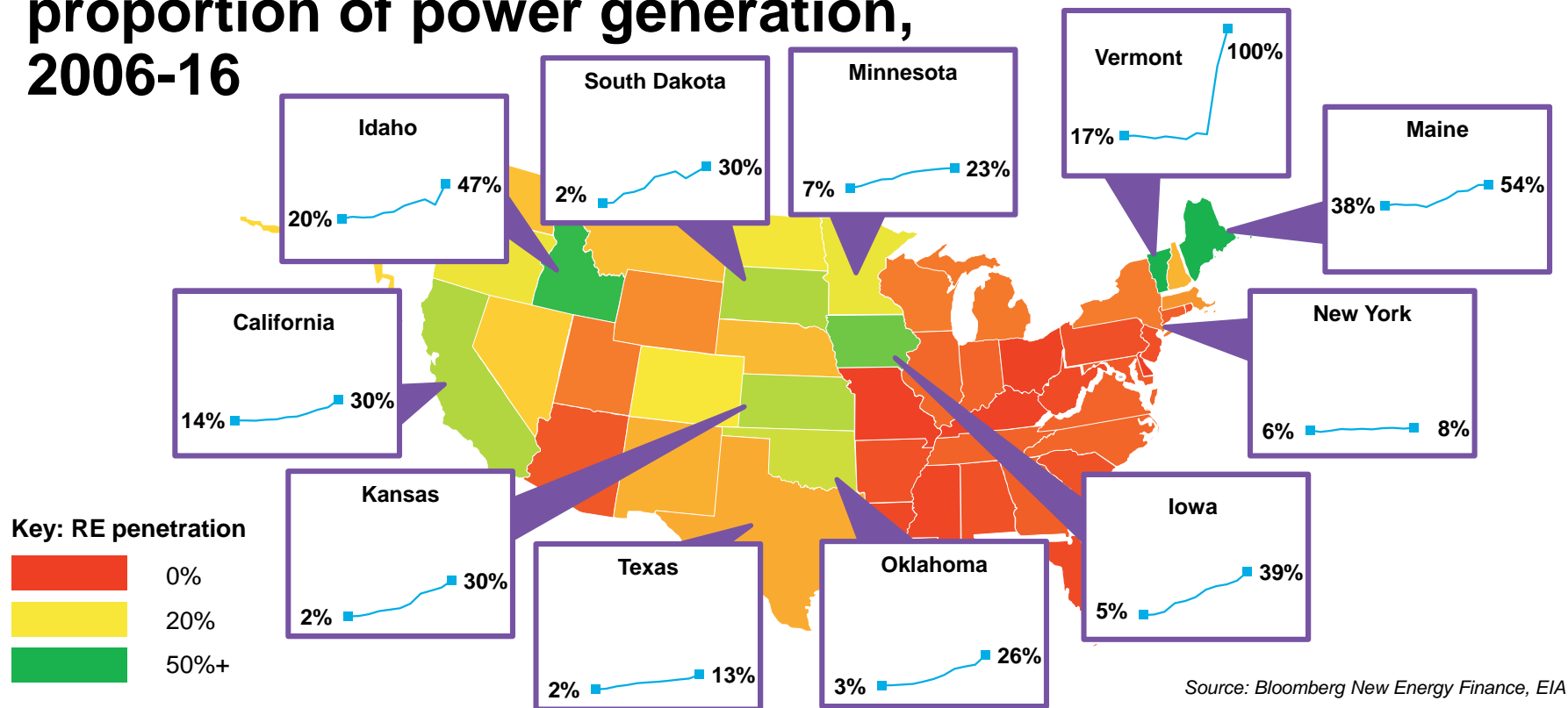
Image: Bloomberg

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



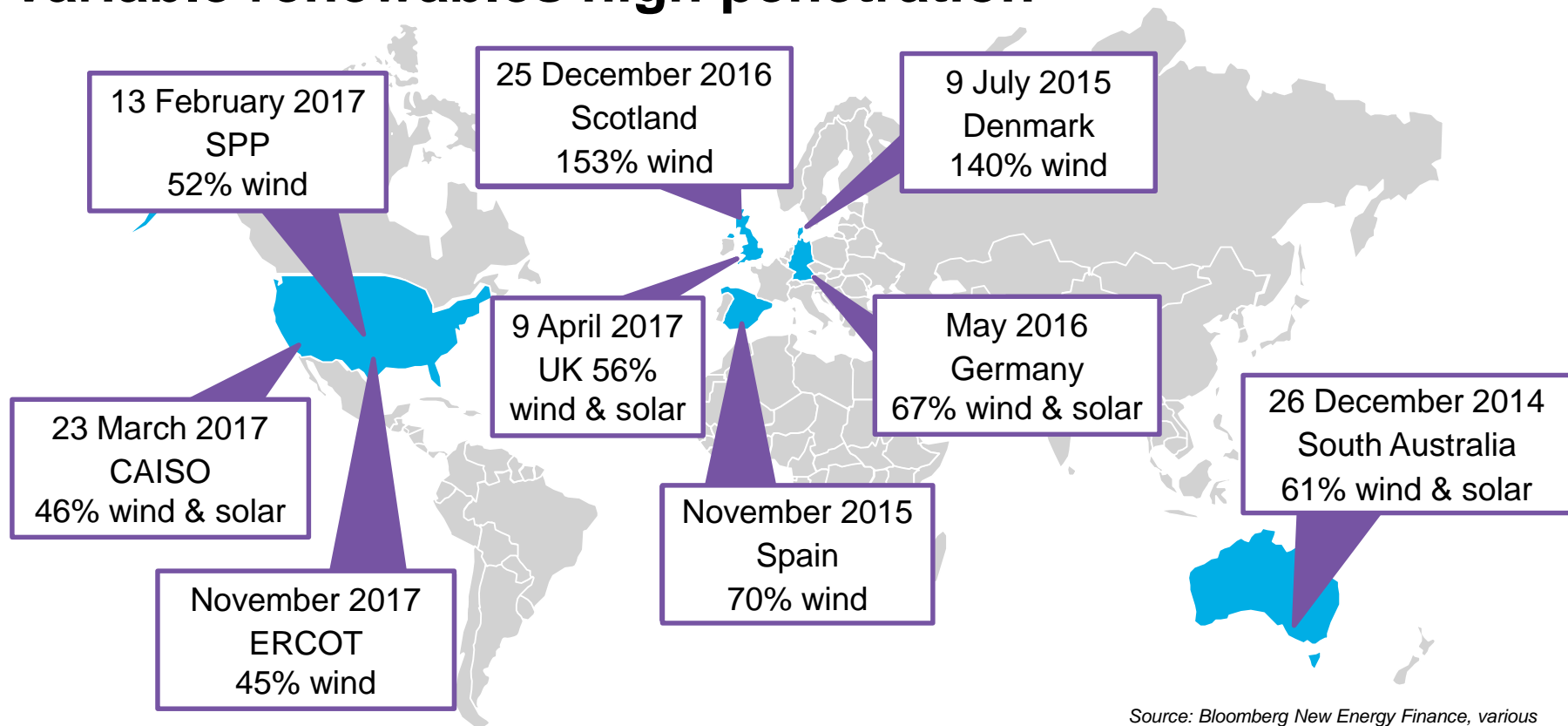
Note: Excludes large hydro Source: Bloomberg New Energy Finance

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



Source: Bloomberg New Energy Finance, EIA

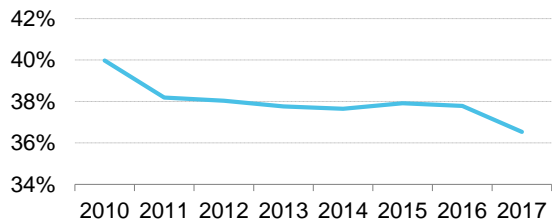
Variable renewables high penetration



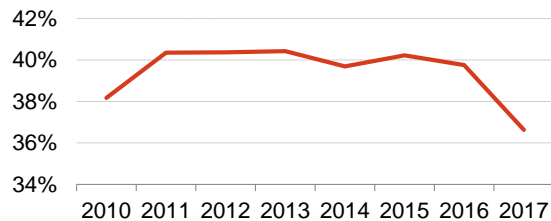
Source: Bloomberg New Energy Finance, various

US thermal capacity factors

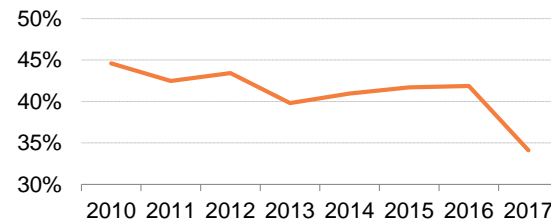
US average



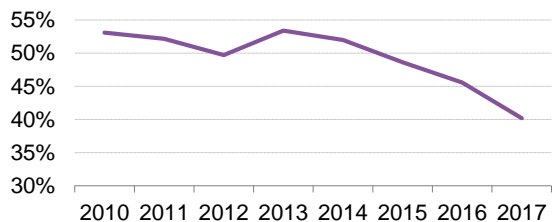
Texas



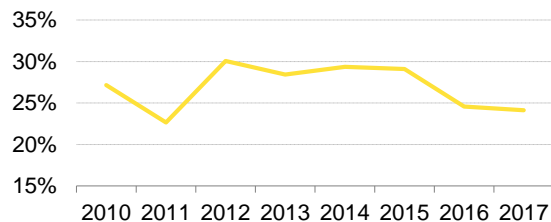
Florida



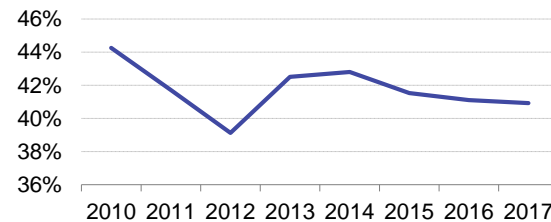
Pennsylvania



California



Ohio



Note: Includes coal and gas capacity. 2017 is based on YTD generation and operational capacities reported in January. Excludes backup capacity.

Source: Bloomberg New Energy Finance, EIA

Capacity markets

March of capacity markets

Regions recently or currently implementing capacity-based mechanisms include:



Weaknesses of capacity markets

Over-procurement

- Inaccurate predictions of supply and demand
- Political risk aversion

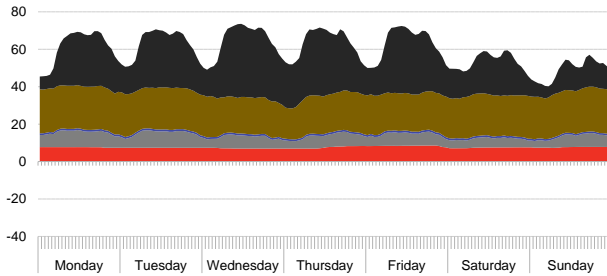
Innovation suppressed by:

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

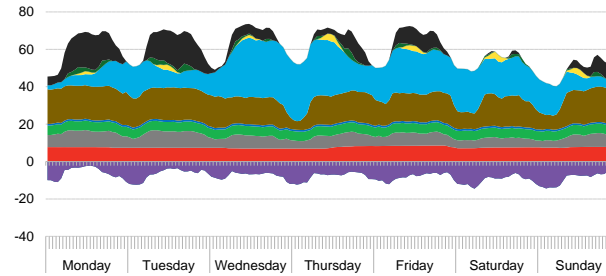
Evolving structure of power supply

- Lots more variable renewables**
- Added storage, interconnections**
- Reduced demand (exc. EVs)**

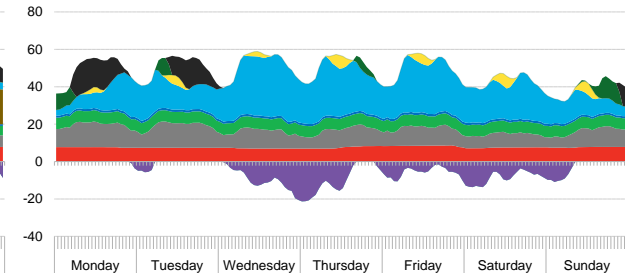
Past – winter



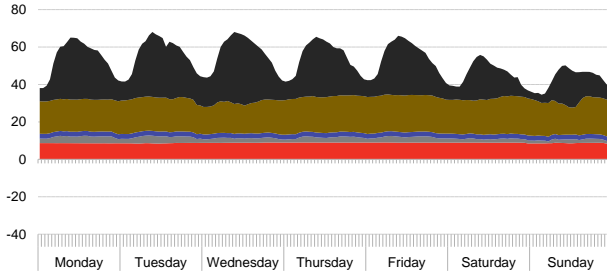
Current – winter



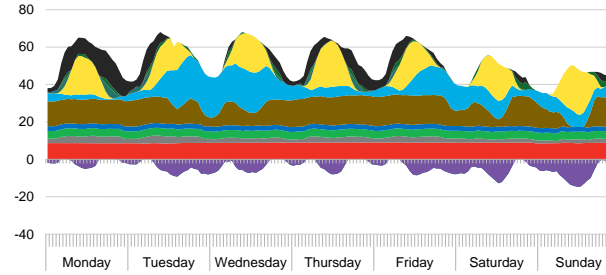
Future – winter



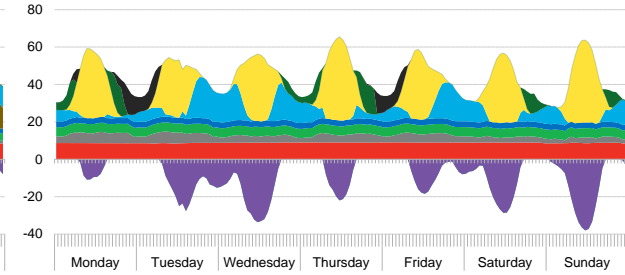
Past – summer



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

Evolving structure of power supply

1. Whatever we come up with must work winter and summer (doh!)

2. Practically impossible to get rid of all fossil fuel use

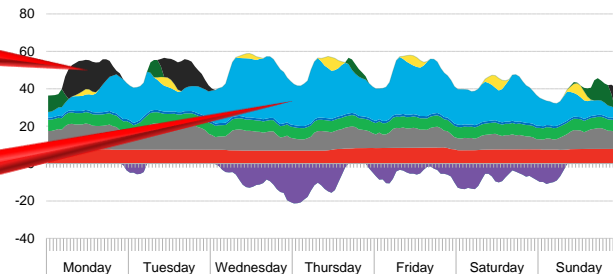
3. Even huge storage gets overwhelmed by wind variability

4. Massive volatility, enormous ramp rates

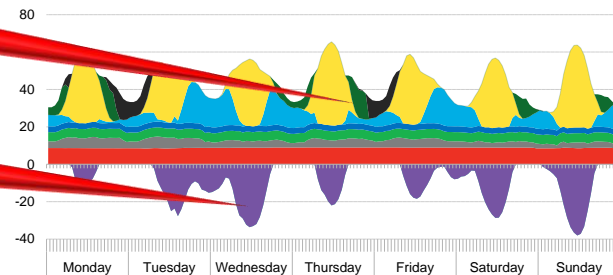
5. Need lots of interconnection capacity (else duck curves, curtailment)

6. And if you think that's complicated, it has to work at every node too!

Future – winter



Future – summer

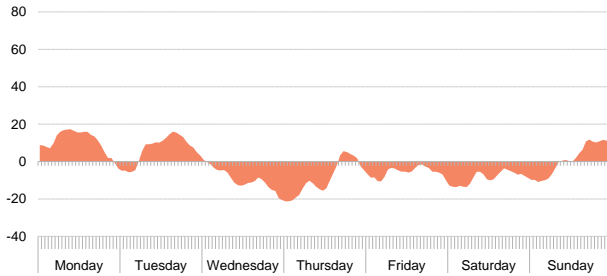


Source: Bloomberg New Energy Finance

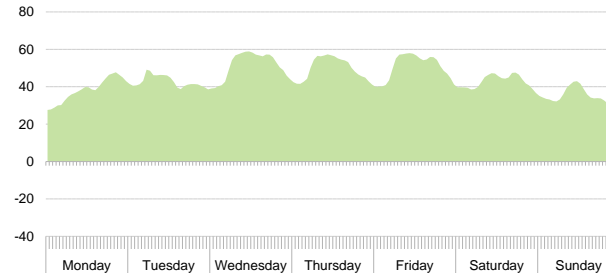
Evolving structure of power supply



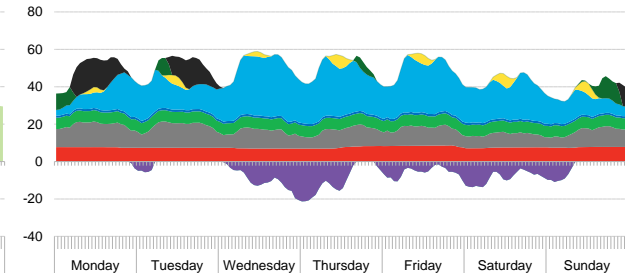
Flexible generation – winter



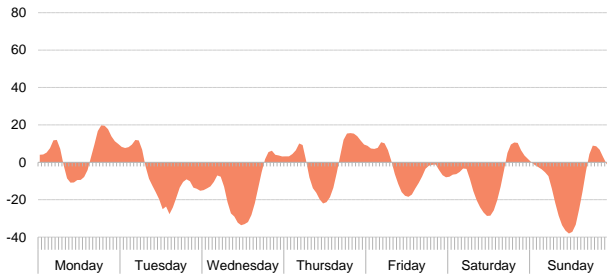
Low carbon generation – winter



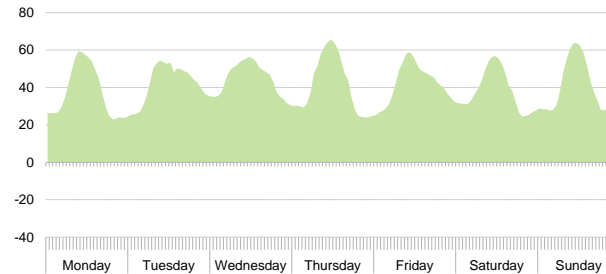
Future – winter



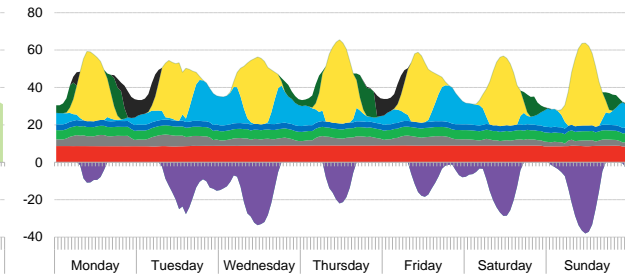
Flexible generation – summer



Low carbon generation – 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

Evolving structure of power supply

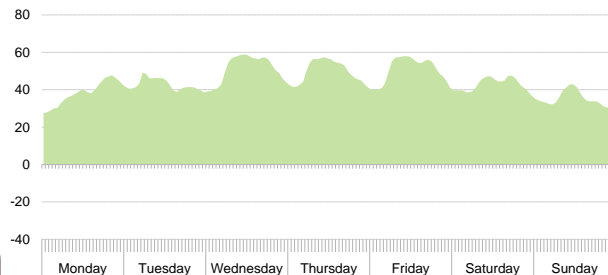
1. Very cheap wind & solar (“base cost renewables”)

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

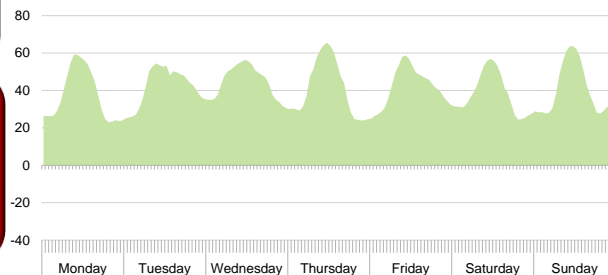
3. Zero mid-day power price every day in sunny countries and windy days

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

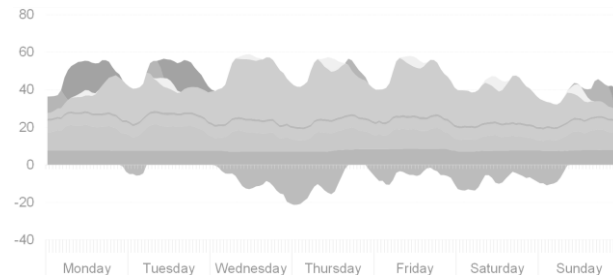
Low carbon generation – winter



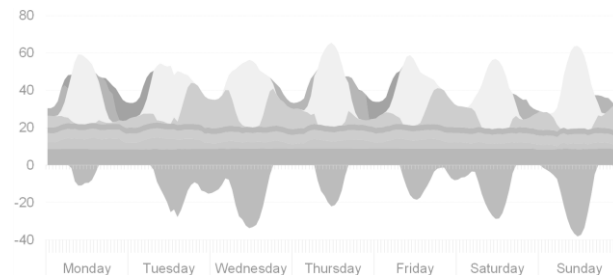
Low carbon generation – summer



Future – winter



Future – summer

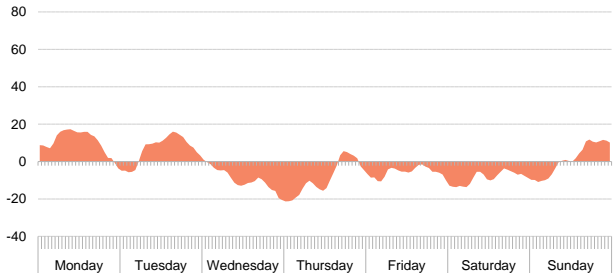


Source: Bloomberg New Energy Finance

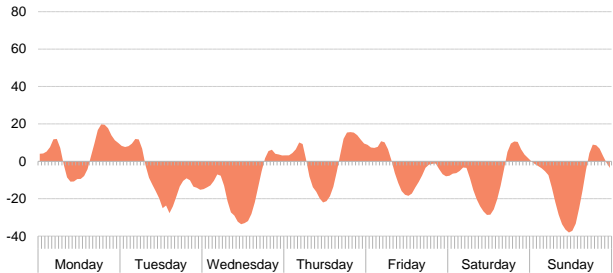
Evolving structure of power supply



Flexible generation – winter



Flexible generation – summer



1. Demand response is likely to be the cheapest

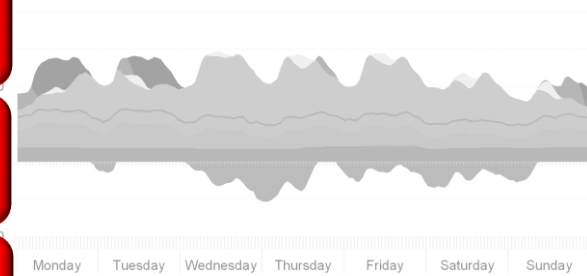
2. Storage

3. Interconnections

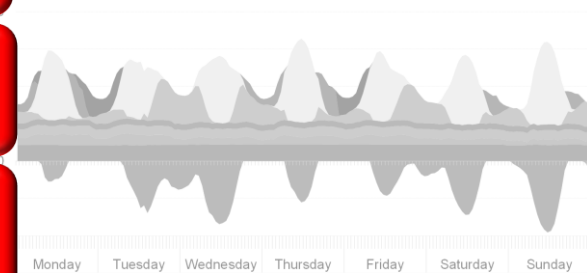
4. Fossil peakers

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

Future – winter



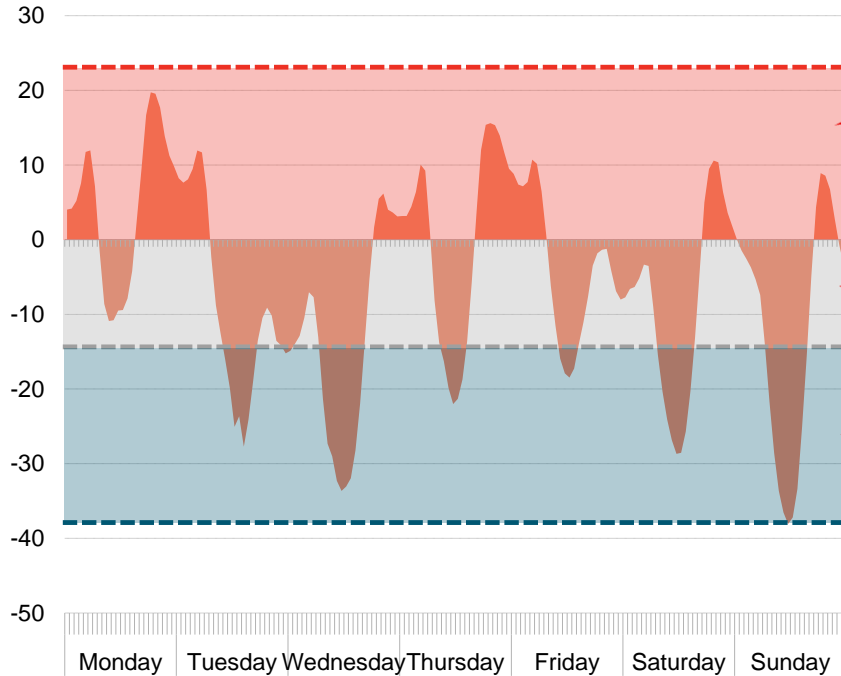
Future – summer



Source: Bloomberg New Energy Finance

Evolving structure of power supply

Option A: “Central Planning”



Centrally designed capacity market, with regulated returns

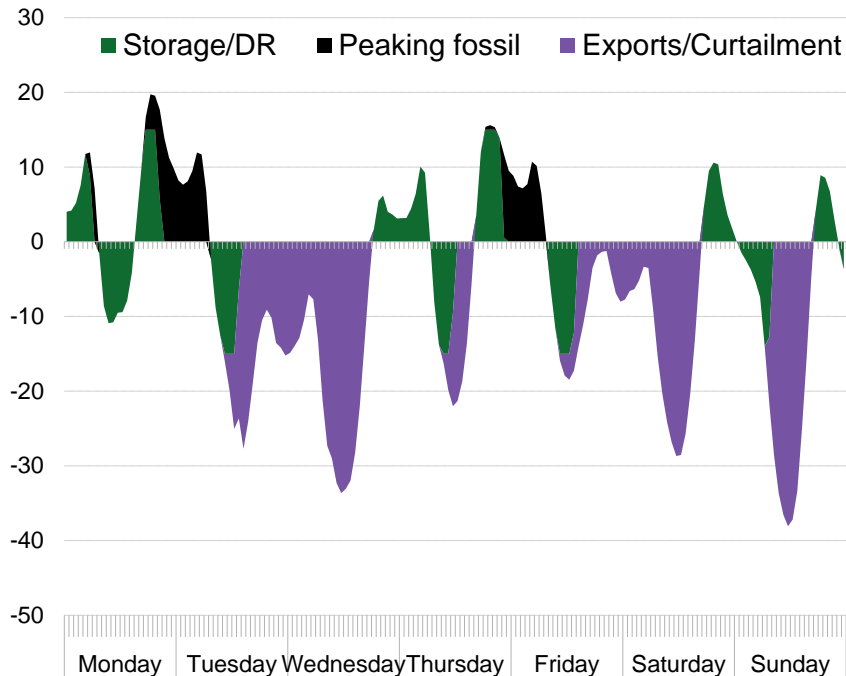
Centrally provisioned interconnections, with regulated returns

Curtailment

Source: Bloomberg New Energy Finance

Evolving structure of power supply

Option B: "Demand-Led"



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

2. Reliability standards at the retail level

3. Carbon regulation via carbon price, carbon intensity or retirement schedule

4. Flexibility costs charged to those who cause them

5. Certificates of origin for imported power

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

Source: Bloomberg New Energy Finance



**TOWARDS
DEMAND-LED
FLEXIBILITY
MARKETS**

Coverage.

Renewable Energy

Power & Utilities

Gas

Carbon Markets & Climate

Negotiations

Energy Smart Technologies

Storage

Electric Vehicles

Mobility and Autonomous Driving

Frontier Power

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