Bloomberg New Energy Finance Summit

New York

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25 April 2017
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
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

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Source: Bloomberg New Energy Finance; Images Siemens; Wikimedia Commons
Unsubsidised clean energy world records since April 2016

<table>
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<th>Country</th>
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<th>Construction</th>
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<td>United Arab Emirates</td>
<td>May 2016</td>
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<td>US$ 2.99 c/kWh</td>
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Unsubsidised clean energy world records since April 2016

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

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

**Offshore wind**
- Country: Chile
- Bidder: Solarpack Corporation
- Signed: August 2016
- Construction: 2019
- Price: US$ 2.91 c/kWh

Source: Bloomberg New Energy Finance; Images Siemens; 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; Images: Siemens; Wikimedia Commons*
# Unsubsidised clean energy world records since April 2016

## Solar PV
- **Country:** Morocco
- **Bidder:** Enel Green Power
- **Signed:** January 2016
- **Construction:** 2018
- **Price:** US$ 3.0 c/kWh

## Onshore wind
- **Country:** Mexico
- **Bidder:** FRV
- **Signed:** September 2016
- **Construction:** 2019
- **Price:** US$ 2.69 c/kWh

## Offshore wind
- **Country:** Denmark
- **Bidder:** Vattenfall
- **Signed:** Dec 2015
- **Construction:** 2019
- **Price:** US$ 5.3 c/kWh

*Source: Bloomberg New Energy Finance; Images: Siemens; Wikimedia Commons*
# Unsubsidised clean energy world records since April 2016

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- **Country:** Mexico
- **Bidder:** FRV
- **Signed:** September 2016
- **Construction:** 2019
- **Price:** US$ 2.69 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; Images Siemens; 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

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
India snapshot

Annual capacity additions vs Modi plan

Rate needed to achieve Modi plan

Annual capacity additions

India clean energy investment

$bn

Source: Bloomberg New Energy Finance

Note: Modi plan annual additions rate assumes linear trajectory to 175GW 2022 target. Figures exclude large hydro
Europe new investment in clean energy

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

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

2008-16 Up 262%
US solar installations

Annual

Cumulative

GW

GW

0
10
20
30
40
50

16
14
12
10
8
6
4
2
0


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

2008-16 Up 4,645%
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

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

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

Source: EPA, Bloomberg New Energy Finance

2008-15 Up 100%

2008-15 Up 220%
US electric smart meter deployment

US smart meter deployments (million units)

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 (bcf)

2007–17
Up 388%

2007–17
Up 35%

Source: EIA
US oil production and rig efficiency

New-well production per rig (bbl/day)

2007–17
Up 1,300%

US monthly oil production (mbbl)

2007–17
Up 83%

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

![Graph showing 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.

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

US energy productivity

![Graph showing US energy productivity]

**2008-16 Up 13%**

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

- 2008-16 Down 20%

Gasoline

- 2008-16 Down 43%

Source: US Bureau of Economic Analysis, Bloomberg New Energy Finance
US power sector fuel mix

**Generation by source**

- **Coal**
- **Natural gas**
- **Nuclear**
- **Renewables**
- **Oil**

**Change in generation 2007-16**

- **Coal**: -776 TWh/yr
- **Power demand**: -78 TWh/yr
- **Gas**: +483 TWh/yr
- **Renewables**: +256 TWh/yr

Source: EIA
US coal jobs and productivity

Jobs

Productivity

Source: Bloomberg New Energy Finance, US Department of Labour
New generation of mining trucks
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
Making America Great Again?
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)_

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

_Scott Pruitt
EPA Director_

“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)_

“[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.)
Climate-related flood risk
Mar a Lago Club, Miami, Florida

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
Keeping America Great!
BNEF global EV sales forecast by region

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

Vehicle choices

- Audi A7 Q
  - Price (without tax): $44,392
  - Price (with tax): $82,363

- Tesla S 60D
  - Price: $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

Source: Bloomberg New Energy Finance
Lithium-ion battery pack prices will drop another 75% by 2030

Lithium-ion battery price forecast

Source: Bloomberg New Energy Finance
BEV model availability, 2008-2020

SUVs/Trucks
- Land Rover Defender
- Toyota RAV4
- Trumpchi GS4
- M-B B-Class
- BYD e6
- Mitsubishi eX
- Tesla Model Y
- NIO ES8
- LG G4
- NIO EP9
- VW I.D.*
- BMW i5
- M-B EQ
- Audi E-tron Quattro

Sports cars
- Venturi Fetish
- Tesla Roadster
- Tesla Model S
- Porsche E-sport
- Tesla Roadster*
- Audi R8 E-tron

Sedans
- Mitsubishi i-MiEV
- CODA EV
- Honda Clarity
- BAIC EU260
- BYD e5
- Tesla Model 3
- Audi E-tron Sportback
- LeEco LeSEE
- NIO EVE
- Lucid Air
- Faraday FF91

Hatchbacks
- Kia Ray
- Hyundai Ioniq
- M-B E-Cell
- BMW i3
- M-B E-Golf
- BMW mini e
- Seat Mii*
- Mahindra e2o
- Bolloré Bluesummer
- NIO EVE
- Tesla Model X
- VW Budd-e

Runabouts
- BMW i
- VW e-Up
- Smart ForTwo
- Seat Mii*
- Mahindra e2o
- Bolloré Bluesummer

Small vans
- Ford Transit
- Nissan NV200
- Peugeot Partner
- Tata IRIS
- M-B Vito
- ChangAn EM80
- Renault Kangoo

0 50 100 150 200 250 300 350+ miles range per charge

2020

Source: Bloomberg New Energy Finance, Images various.

Notes: Not exhaustive.
(*) Range is estimate
Tesla’s gamble

Model S and Model X
production reached 76,230 in 2016

Model 3
alone must top
350,000 cars in 2018
to hit Musk’s goals

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

- **2013:** Mercedes’s Level 2 ‘Dystonic Plus’

- **2015:** Tesla’s Level 2 ‘Autopilot’

- **2016:** Intel + Delphi + Mobileye Level 4

- **2017:** Audi’s Level 2 ‘Traffic Jam Assist’

- **2018:** Audi’s Level 3 ‘Traffic Jam Pilot’ on A8

- **2020:** Audi’s Level 3+ ‘Drive Wise’

- **2021:** BMW’s Level 4 in ‘iNext’

- **2020+:** VW’s Level 4 ‘ID Pilot’

- **2021:** Ford’s Level 4

- **2022:** Lyft Level 4 ride hailing cars

- **2025:** VW’s Level 4 ‘ID Pilot’

- **2030:** Kia’s Level 4 ‘Urban Autonomous Driving’

- **2040:** Honda’s Level 4 by 2040 in all models

Legend

- **Level 2**
- **Level 3**
- **Level 4/5**
5000 x improvement in safety performance required

AVs: distance between human interventions (miles)
Humans: distance between crashes (miles)
Distance between fatalities (million miles)

Google Waymo | 5,128
BMW | 638
Ford | 197
Nissan | 146
Uber (2017) | 105
VW (2015) | 57
GM Cruise | 54
Delphi | 17
Tesla | 3
Mercedes | 2
Bosch | 1

US Average | 525,000

Commercial aviation | 15,342
Buses | 9,178
Mainline trains | 6,667
Cars & light trucks | 137
Motorcycles | 4.7

* 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
When 20,789 people all want to get to Madison Square Gardens at the same time
Algorithms which are individually smart and collectively dumb
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
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

Key: RE penetration
- 0%
- 20%
- 50%+

Source: Bloomberg New Energy Finance, EIA
Variable renewables high penetration

- **13 February 2017**
  - SPP
  - 52% wind

- **25 December 2016**
  - Scotland
  - 153% wind

- **9 July 2015**
  - Denmark
  - 140% wind

- **23 March 2017**
  - CAISO
  - 46% wind & solar

- **9 April 2017**
  - UK 56%
  - wind & solar

- **May 2016**
  - Germany
  - 67% wind & solar

- **26 December 2014**
  - South Australia
  - 61% wind & solar

- **November 2017**
  - ERCOT
  - 45% wind

- **November 2015**
  - Spain
  - 70% wind

Source: Bloomberg New Energy Finance, various
US thermal capacity factors

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:

- United Kingdom
- France
- Italy
- Germany
- Mexico
- California Republic
- Alberta

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

Past – winter

Current – winter

Future – winter

Past – summer

Current – summer

Future – summer

Source: Bloomberg New Energy Finance

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

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

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

Source: Bloomberg New Energy Finance
Evolving structure of power supply

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

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
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