

Towards 100 % Sustainable Energy

Tomas Kåberger

Executive Board Chair of Renewable Energy Institute, Tokyo

Affiliate professor Chalmers University of Technology

Industrial Growth Executive InnoEnergy

Member of the Swedish Royal Academy of Engineering Sciences

2016:

Free Energy, \$10 A Barrel Oil By 2025 Says French Utility Company

December 28th, 2016 by Steve Hanley

"The promise of quasi-infinite and free energy is here," says Thierry Lepercq, head of research, technology and innovation for Engie SA. He thinks the cost of solar power will drop below \$10 a megawatt-hour (\$0.01 per kWh) before 2025 in the world's sunniest places. Engie recently conducted "very deep modeling" of the Provence-Alpes-Cote d'Azur region of France, which has about 5 million inhabitants. The study showed those regions could run entirely on renewable energy for about 20% less than the price of electricity today.



Portug record

According to €0.0112/kWh and China's last month

AUGUST 24

HIGHLIGHTS

Saudi Arabia's second PV tender draws world record low bid of \$.0104/kW

The record low price was offered for the 600 MW Al-Faisaliah PV IP project, which competed in the second round of the country's procurement scheme for renewable energies.

APRIL 8, 2021 **EMILIANO BELLINI**

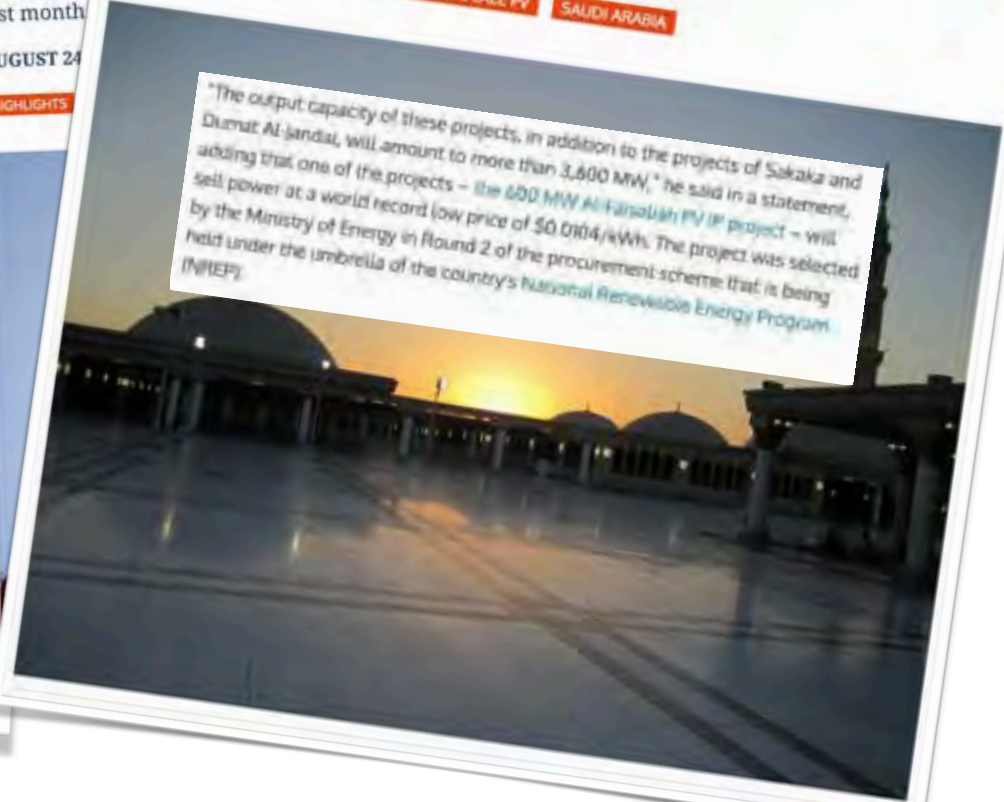
MARKETS

MARKETS & POLICY

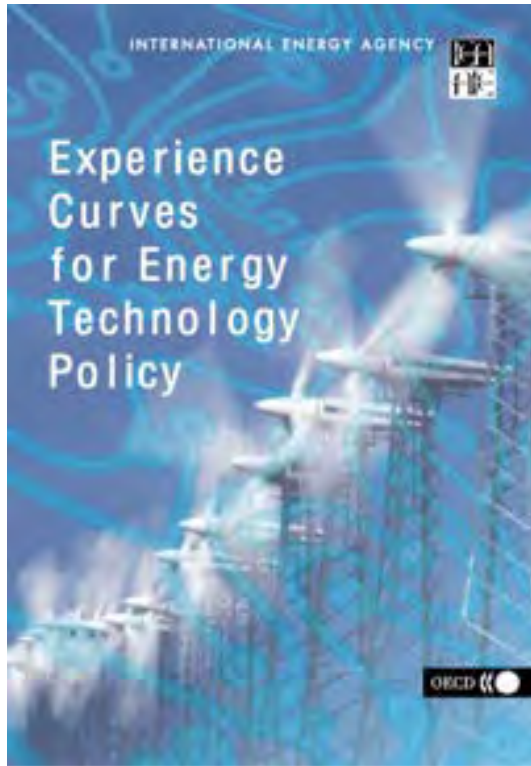
UTILITY SCALE PV

SAUDI ARABIA

"The output capacity of these projects, in addition to the projects of Sakaka and Dumat Al-Jandal, will amount to more than 3,600 MW," he said in a statement, adding that one of the projects – the 600 MW Al-Faisaliah PV IP project – will sell power at a world record low price of \$0.0104/kWh. The project was selected by the Ministry of Energy in Round 2 of the procurement scheme that is being held under the umbrella of the country's National Renewable Energy Program (NREP).

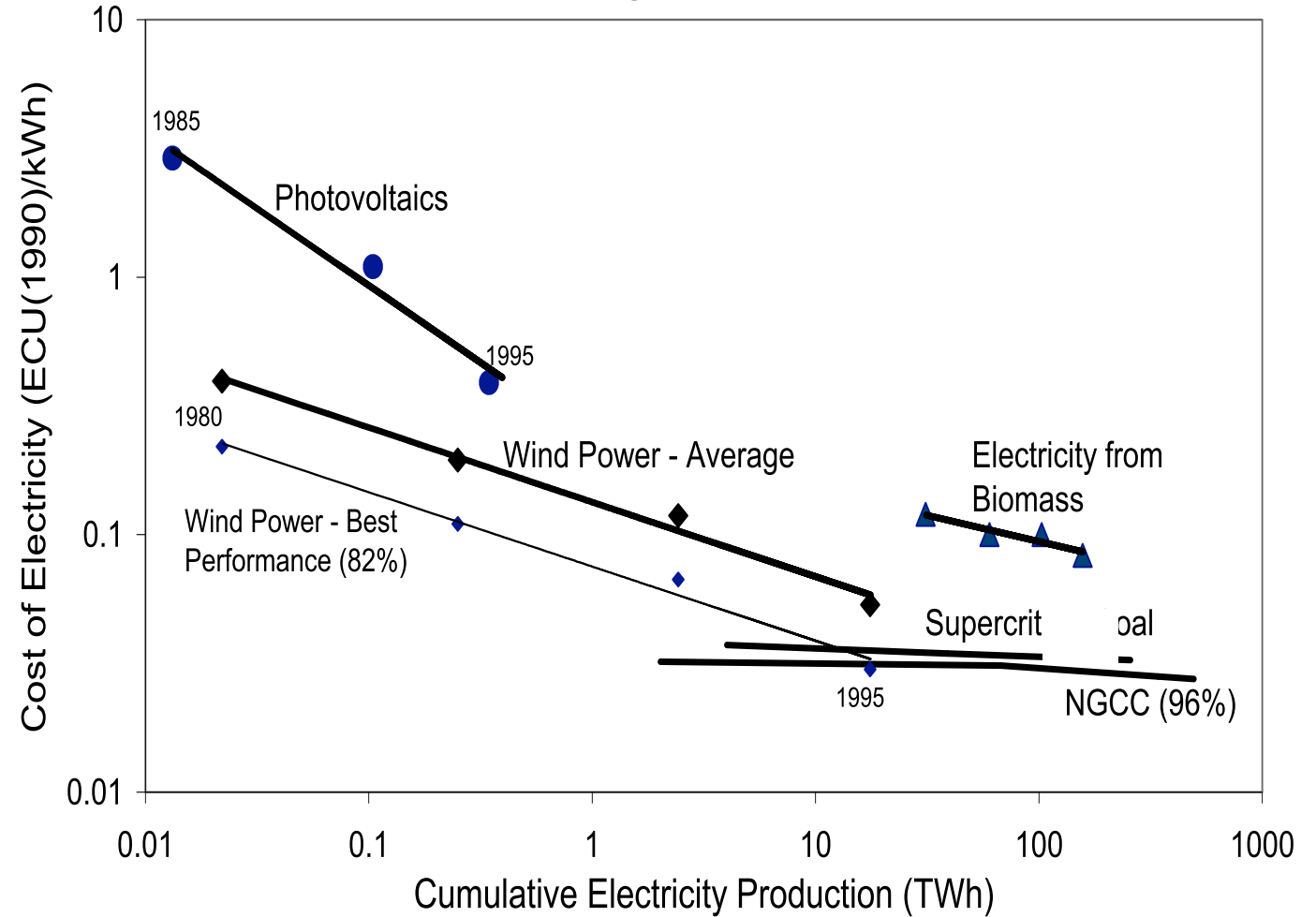


Industrial learning by experience



Prof. Clas-Otto Wene, Chalmers Univ. of Technology, 2000

Electric Technologies in EU 1980-1995



Global Wind power capacity 1980-2020

GW

700

600

500

400

300

200

100

0

1980

1985

1990

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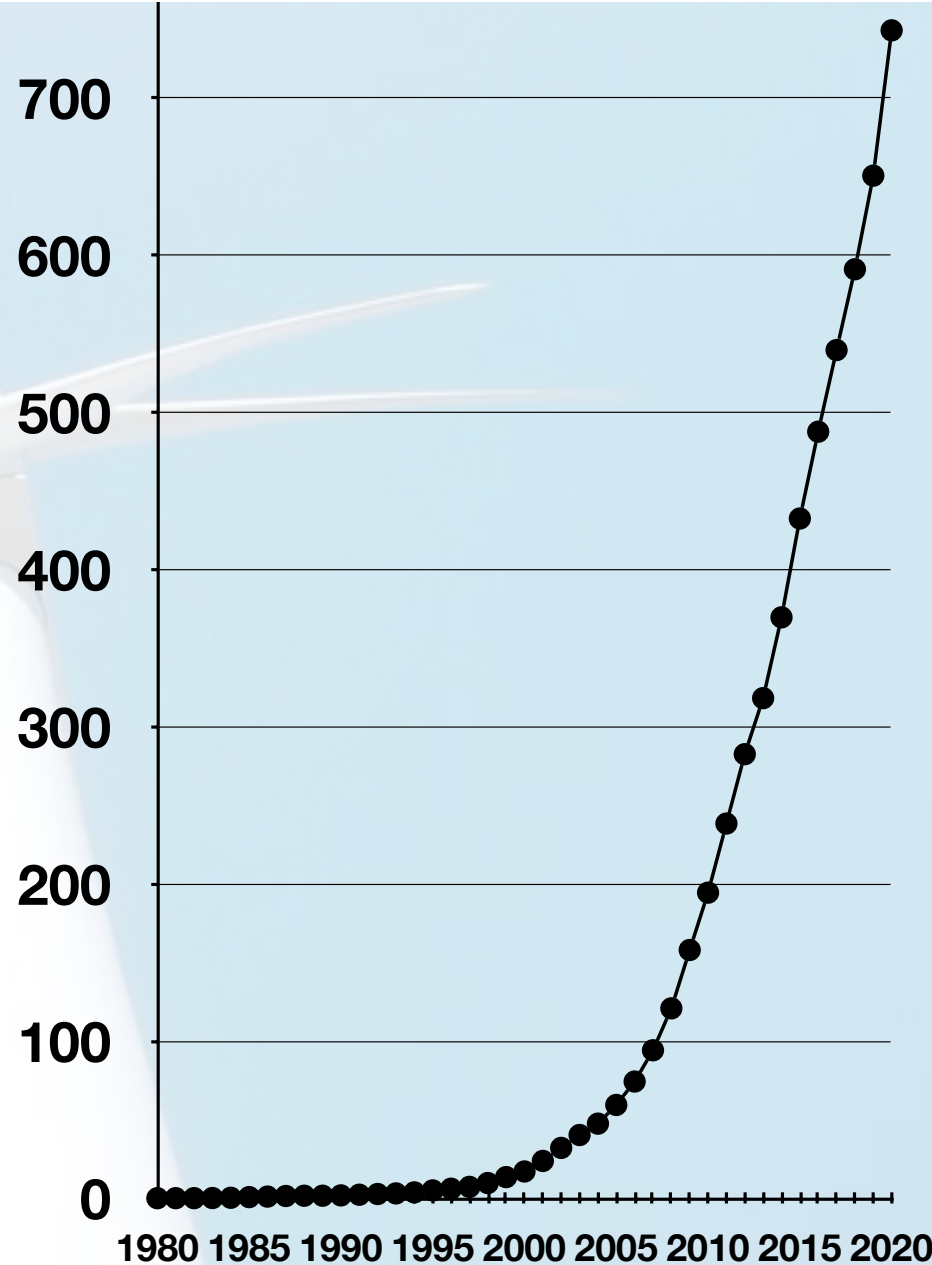
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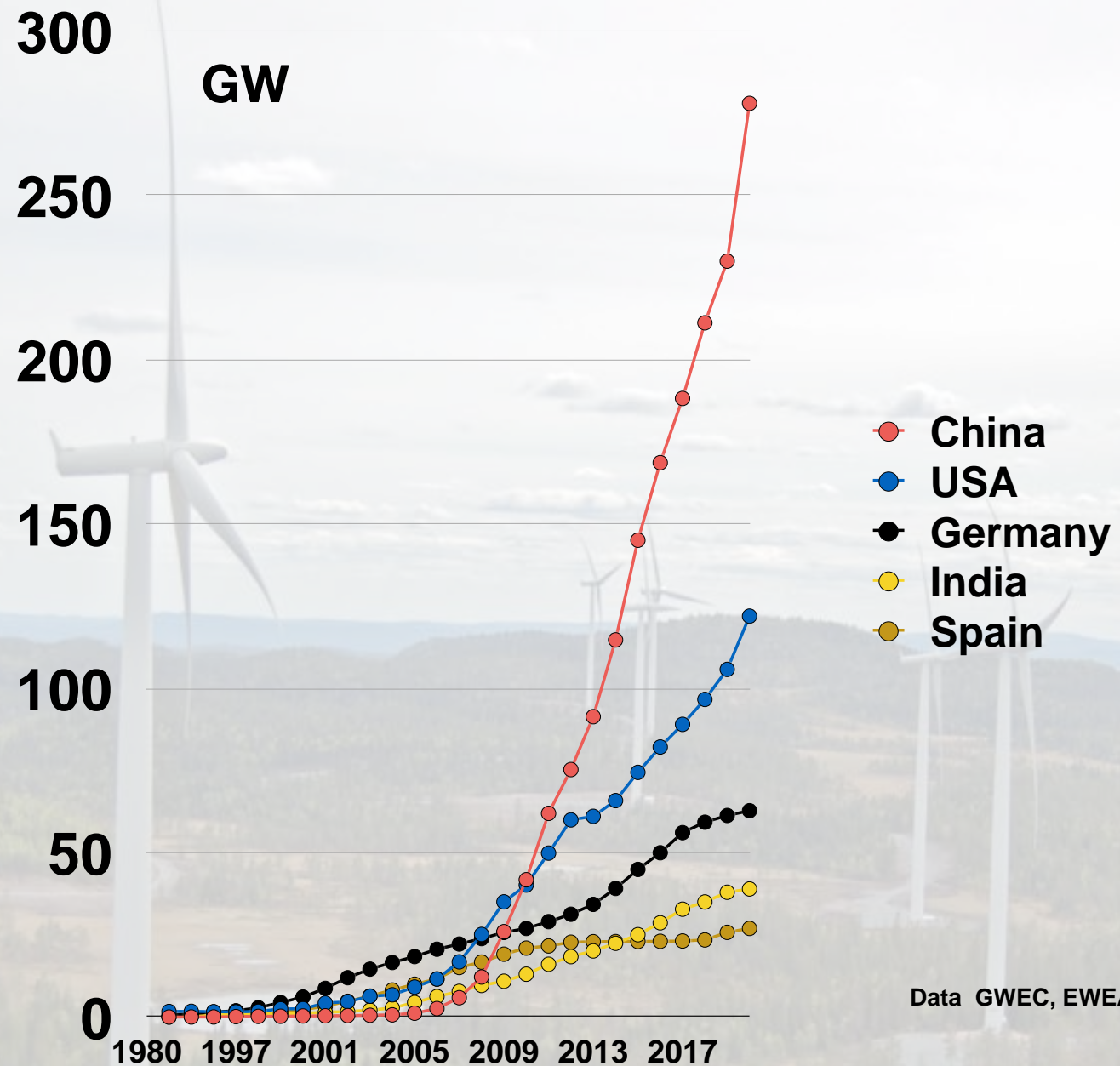
2015

2020

Data: GWEC, 2021



Wind power capacity leading countries 1980-2020



Data GWEC, EWEA, 2021

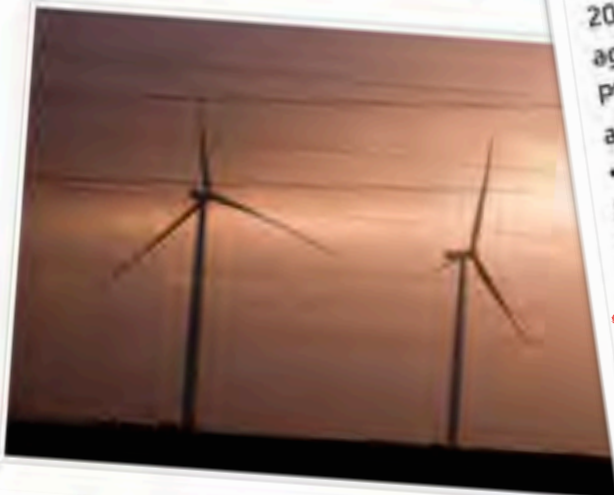
New low for wind energy costs: Morocco tender averages \$US30/MWh

By Giles Parkinson on 17 January 2016

The north African country of Morocco has achieved a new low for wind energy costs, securing average bids of just \$US30/MWh from its first large-scale wind energy projects, with the lowest at \$US25/MWh.

The pricing – revealed by its energy ministry at the Energy summit in Abu Dhabi on Saturday – sets a new benchmark for wind energy resource prices, boosted by the remarkable wind energy resource and concessional finance.

Abderrahim El Hafidi, vice minister of energy and electricity, said the new pricing is "amazing" and said it pointed to a "real revolution" in the industry. He said the US have been in and around \$US25/MWh, although that includes a production tax credit.



Enel sets a new world wind record in Mexico, below \$18/MWh

November 29, 2017 Paul Dvorak : 0 Comments

This Flash Note from Make Consulting examines the results of Mexico's third long-term power auction held in November 2017. The note evaluates the event and its bidding within the context of previous auction rounds in Mexico as well as within the Latin American region. It analyses the dynamics that contributed to Enel's record low bidding and posits dynamics that favor low bidding in the Mexican market.

Key points:

- Mexico hosted a long-term power auction in November 2017 which awarded offtake agreements to wind power and PV projects totaling 5.5 TWh of annual production
- Enel submitted four successful bids for wind power sites with the lowest reaching \$17.70/MWh
- In total, the auction awarded PPAs to 2 GW of new project sites, including 689 MW of new wind power sites which are due online in 2020



Offshore wind record low

1k Shares



Published on 06/07/2016, 10:57am

Two 350MW arrays in the power at €87/MWh, beat by miles

By Megan Darby

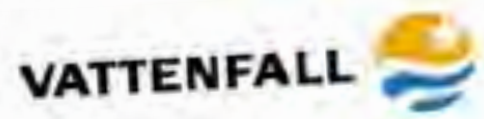
Dong Energy has set a wind power in a winning bid on the coast of the Netherlands.

The Danish company offered €72.70/MWh (US\$80.40/MWh) for the power. The winning bid is the lowest ever for offshore wind power. The cables will be laid in the next few weeks.

That beats an industry target of €100/MWh by 2020. The current average cost was €103/MWh last year.

"It was a result that exceeded expectations," said a spokesman for European Wind Energy Association.

New record for cheapest offshore wind farm



7.33 AM CET / 9-Nov-2016 / Vattenfall (STO:ONOT)

Vattenfall wins tender to build the largest wind farm in the Nordics



The costs of offshore wind power have fallen to a new low, according to a report by Credit Suisse.

By Emily Gosden
14 SEPTEMBER 2016

The cost of building a new low, with contracts to build over €60 (£51) per MWh.

Today, Vattenfall has won the tender to build Danish Kriegers Flak, a 600 MW offshore wind farm in the Baltic Sea. The winning bid was EUR 49.9 per MWh, which is among the lowest costs in the world for offshore wind power.

"The announcement is an essential milestone for our ambition to increase our production of renewable power. We are already the second largest offshore player globally. The winning bid of EUR 49.9 per MWh proves that Vattenfall is highly competitive and brings down the costs for renewable energy", says Magnus Hall, CEO Vattenfall.

Kriegers Flak will be Denmark's largest offshore wind farm and can supply 600,000 Danish households with renewable energy – corresponding to 23 percent of all households in Denmark. Vattenfall's investment in Kriegers Flak will be EUR 1.1 – 1.3 billion, pending a final investment decision.

"This is exciting news. I'm very proud of our people in the Wind organisation who once again delivered a winning bid. Vattenfall has won the three latest offshore wind tenders in Denmark; Horns Rev 3, Danish Near Shore and Kriegers Flak, equivalent to the energy consumption of 55 percent of the Danish households", says Gunnar Groebler, Head of Vattenfall Wind.

Clean
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About Electric

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April 14th, 2017 by

Germany's first
average bid pri
also included v

VATTENFALL

NEWS • WIND • 5 JULY 2021 • 2 MIN

Vattenfall starts construction of offshore wind farm Hollandse Kust Zuid



The construction of the 1.5GW Hollandse Kust Zuid offshore wind farm has started. The first vessel transporting foundations to the construction site departed today. Over the next two years, the world's first subsidy-free offshore wind farm will be built off the Dutch coast. The fossil-free energy generated by the wind farm will benefit both households, businesses and industrial partners.

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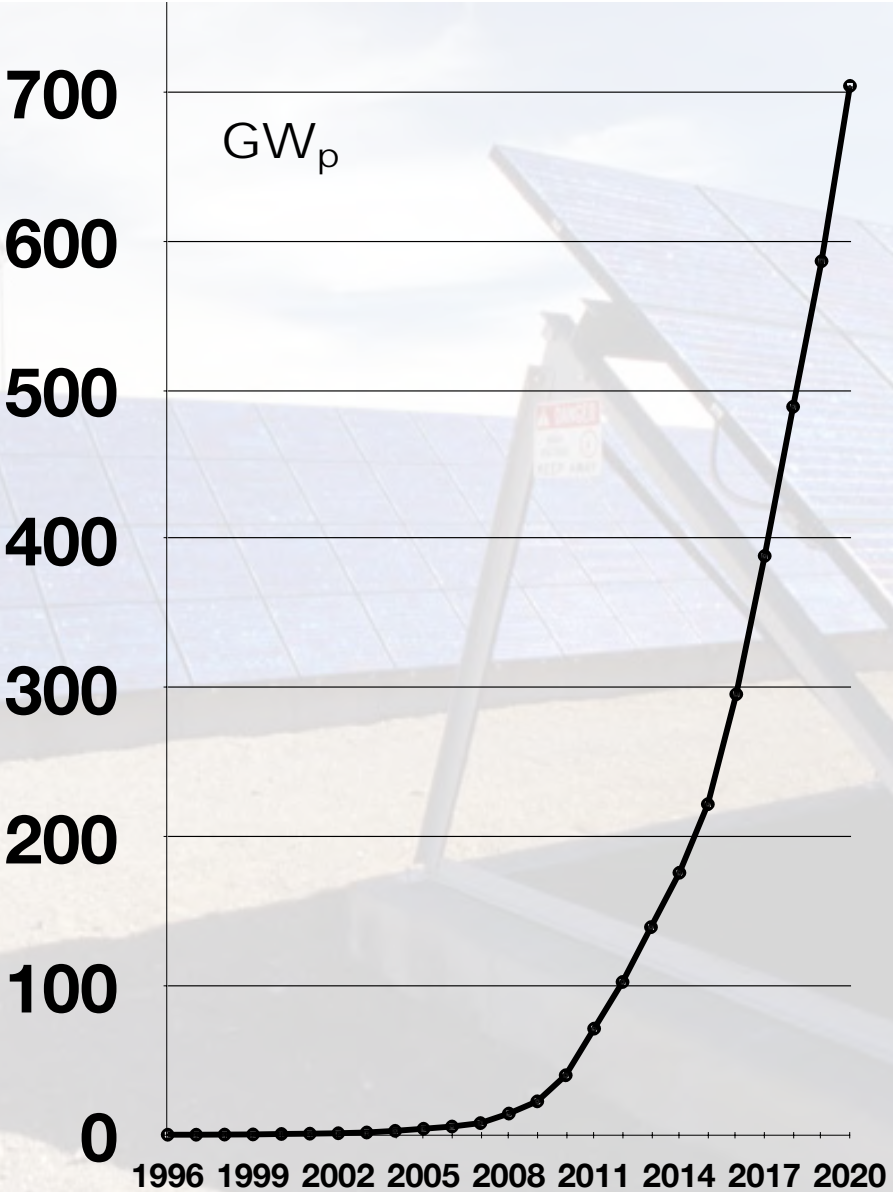
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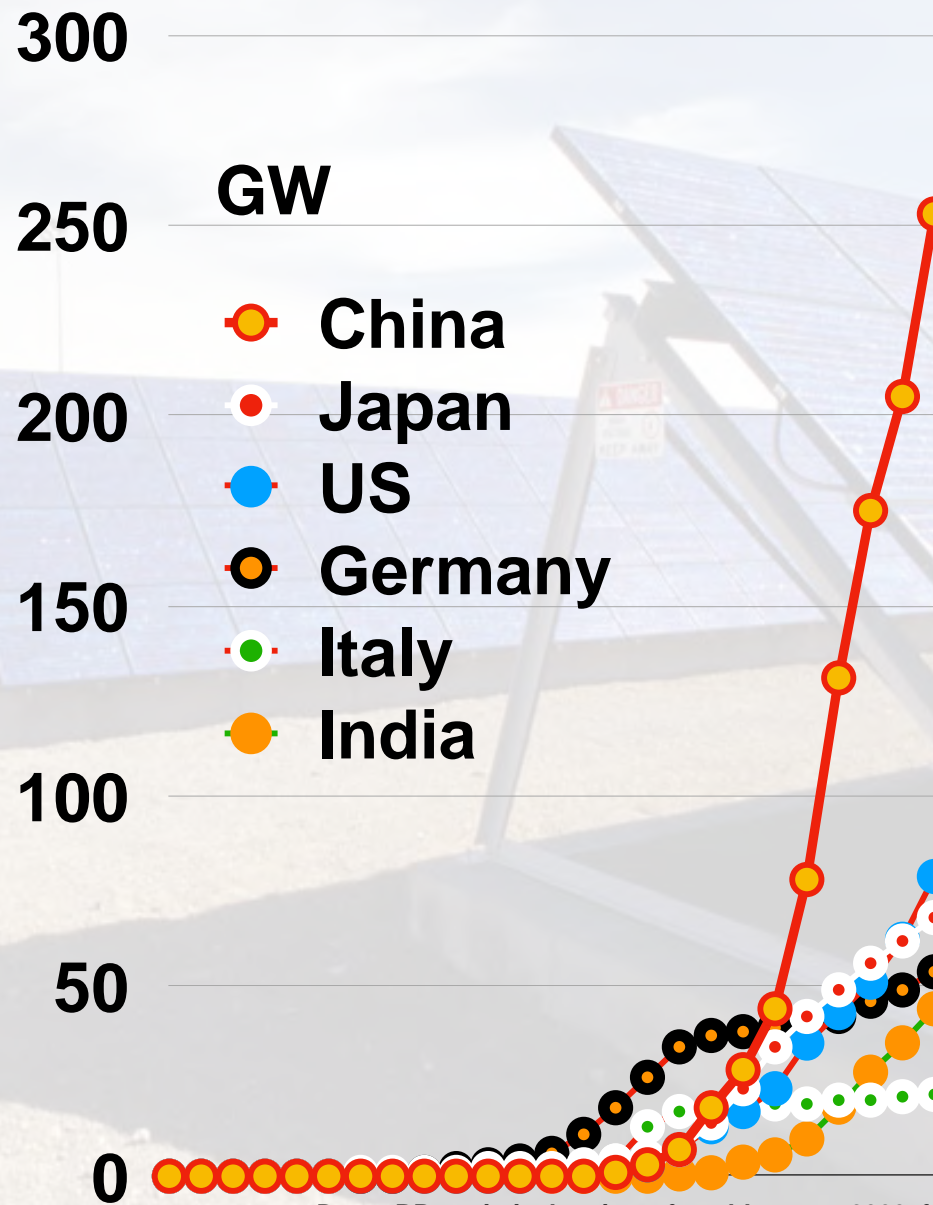
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Global solar PV capacity 1996-2020



Data: BP statistical review 2020, Bloomberg for 2020

Solar PV- capacity leading countries. 1996-2020



Data: BP statistical review of world energy 2020, for 2020 own collection from various sources

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PVTech:
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JANUARY 23, 20

FINANCE HIGHLI

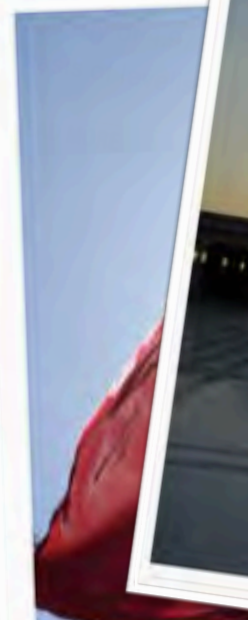


Portugal's record low

According to financ
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AUGUST 24, 2020

HIGHLIGHTS UTILITY S



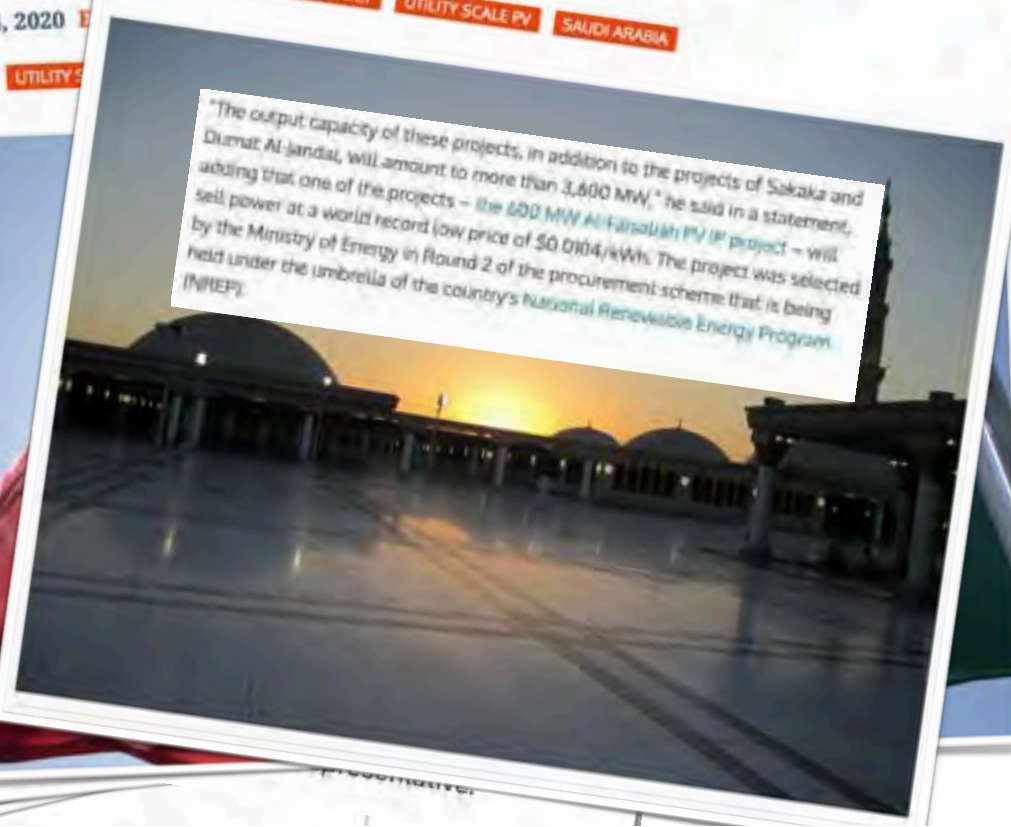
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APRIL 8, 2021 EMILIANO BELLINI

MARKETS MARKETS & POLICY UTILITY SCALE PV SAUDI ARABIA

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Home / Pub
German PV

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18 Oct 2017

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Solar Grid Edge Storage Wind Trending Podcasts Downloads

UK's Largest Solar Project Approved, Will Snub Government Subsidies

A 350-megawatt U.K. solar project won its planning approval in Britain, hinting at a revival of a once-booming market.

JOHN PARNELL | MAY 29, 2020



The 350 MW Clive Mill solar project is located in Kent, south-eastern England.

The latest tender set a new record for
Image: Belectric

Unsubsidized solar is gaining ground in Denmark.
Image: Kirstinsfotos/Pixabay

PHOTOVOLTAICS

Danish bidde

Photovoltaics

30.11.2016

In the first cross-border PV plants in Germany were awarded contracts with a volume of 50 MW. The price is 4.91 cents/kWh.

The German Federal Network Agency announced an auction for PV projects that is almost identical to the one in Denmark. Unlike Germany, Denmark uses a feed-in tariff for PV projects, and not a competitive bidding system. Agricultural areas are used for solar installations that the sun is not used for. Agricultural areas are used for solar installations that the sun is not used for. Agricultural areas are used for solar installations that the sun is not used for.

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Das Gebot

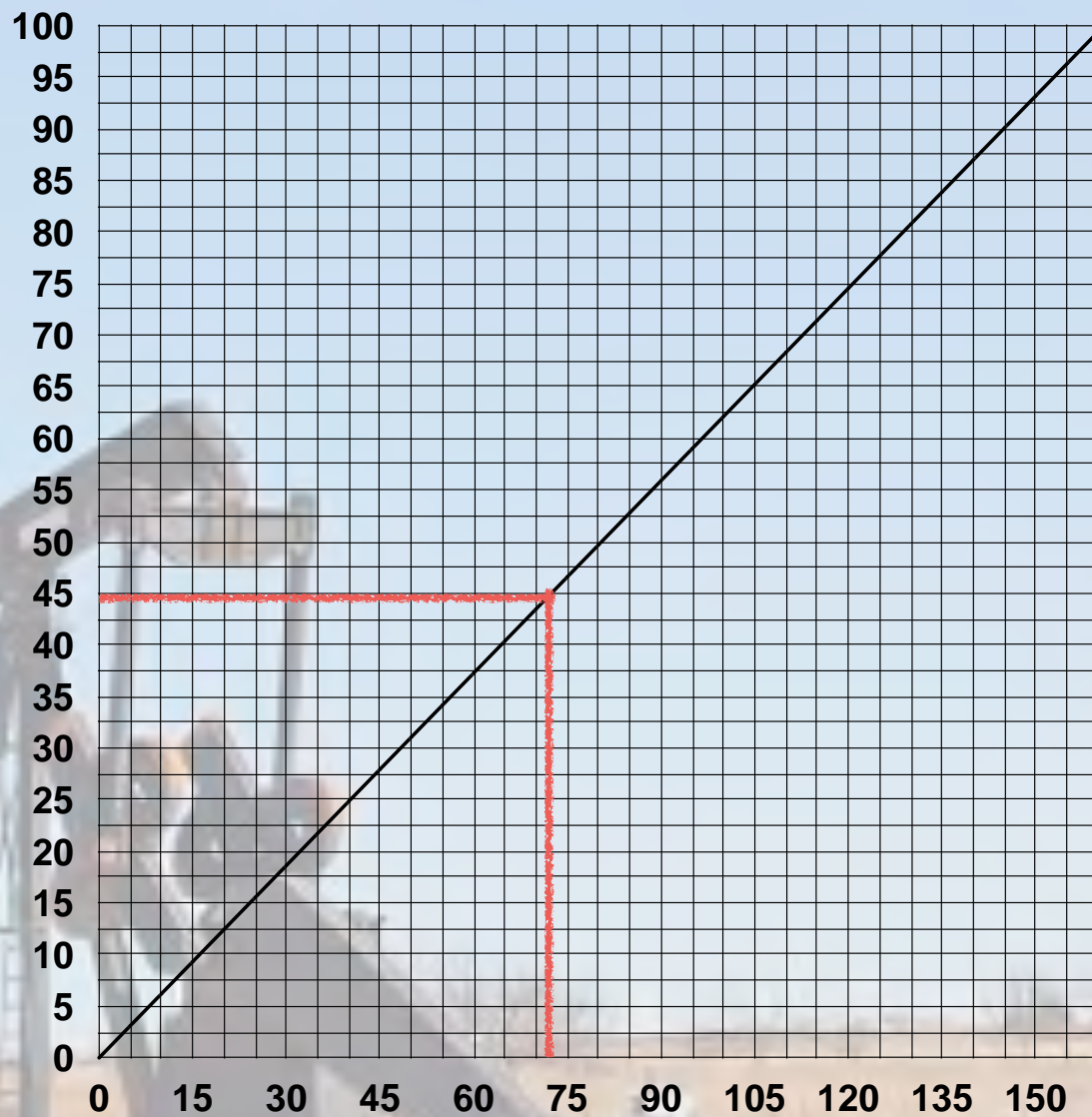
Der durchs

Die Bundesnetzagentur
Gebotstermin 1.

Conclusion no 1

- Renewable electricity provides the lowest cost **electricity**
- Countries efficiently deploying renewable electricity will get the cheapest electricity benefitting industrial competitiveness as well as households

USD/MWh

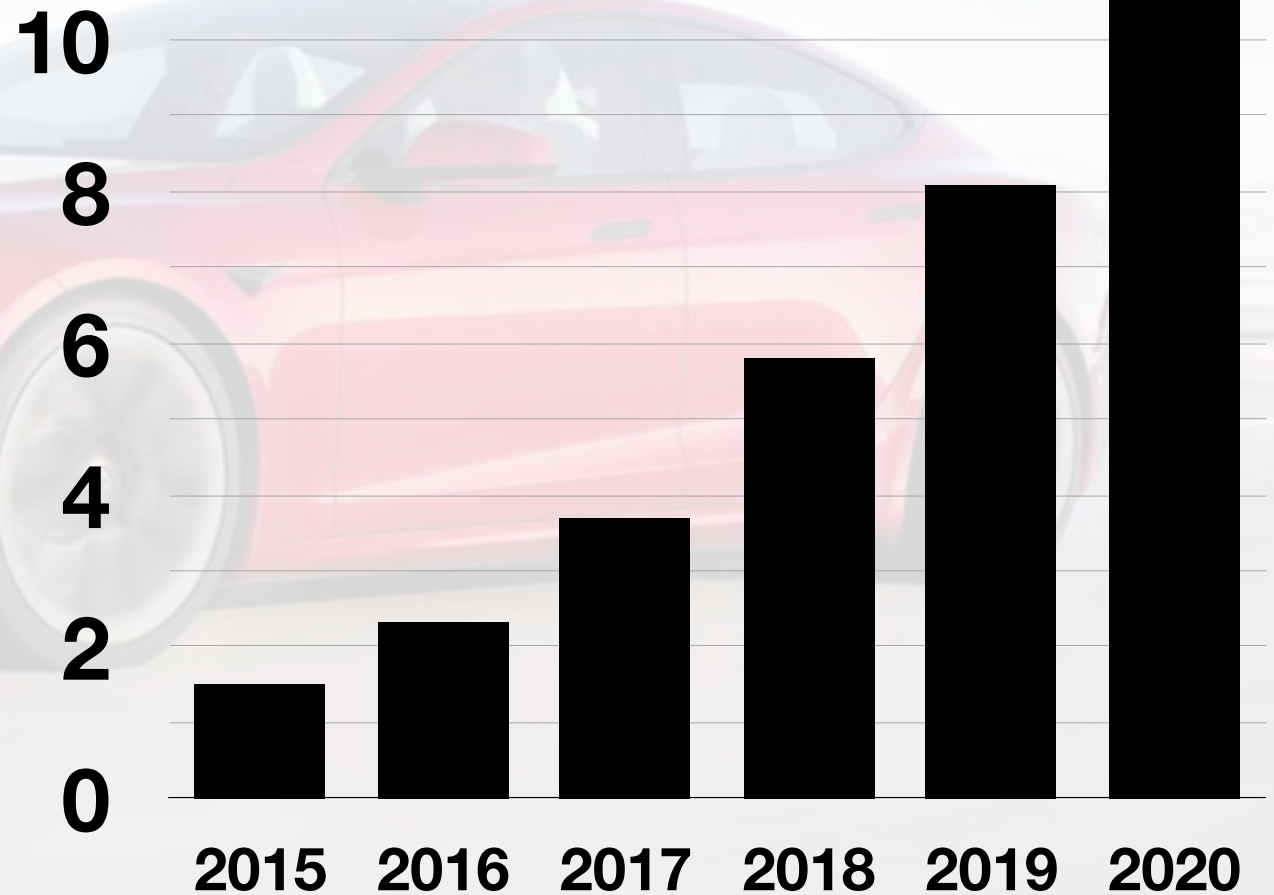


Crude oil price, USD/bbl

**Growing
markets for
electric
vehicles**

Global fleet of electric cars

12 Million




Data from: <https://www.iea.org/data-and-statistics/charts/global-electric-vehicle-stock-by-region-2010-2020>

Norwa

How Did Shanghai Electric Buses

by  **Lu Lu, Lulu**

 Comments

Diesel buses—they spew—are most cities. But China.


The southeast connects Hong China, announced year that all gone electric world's first bus fleet, a New York's Jersey's, Chicago

Jul 05, 202

Electromobility
Setting a Cou

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Tue 21 Jun 20

 Share



In conjunction with Fjellst technology for the world's electric ship, which will enter is in part due to the electric

As silently as a crocodile, the white meters across. Suddenly the silence emerge from the opening. Odd Moe Siemens Norway, smiles. If everything sailing across Norway's fjords will be and producing absolutely no emission

A Century of Battery-Powered Serv

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AIRBUS PUTS EL

 **Dow Chemicals**

Airbus is to put its tw France. Construction into-service for the E-

Sustainable Business

United Airlines to buy 100, 19-seat electric planes from Heart Aerospace

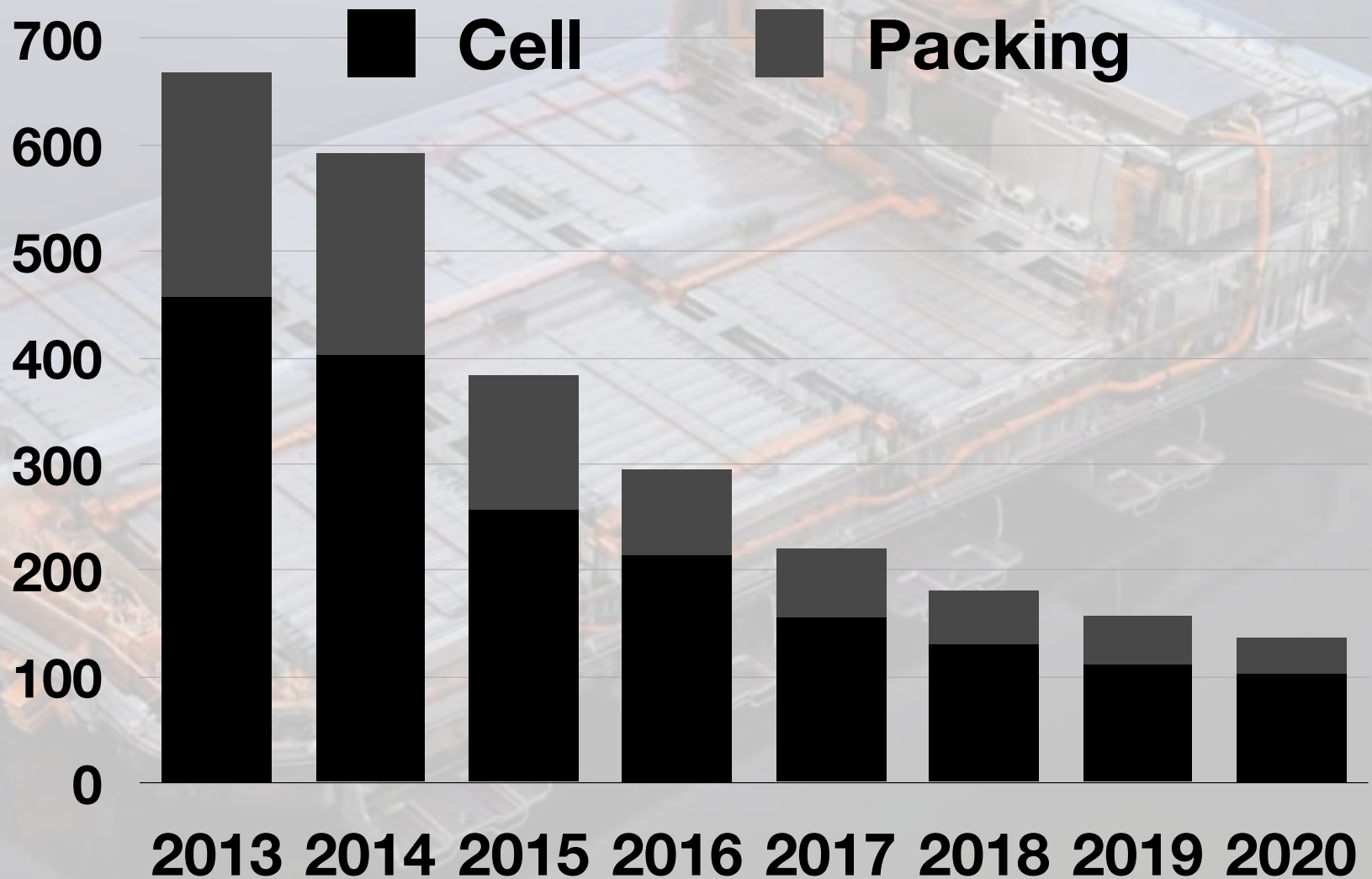
2 minute read

Allison Lampert



BNEF Battery price survey results

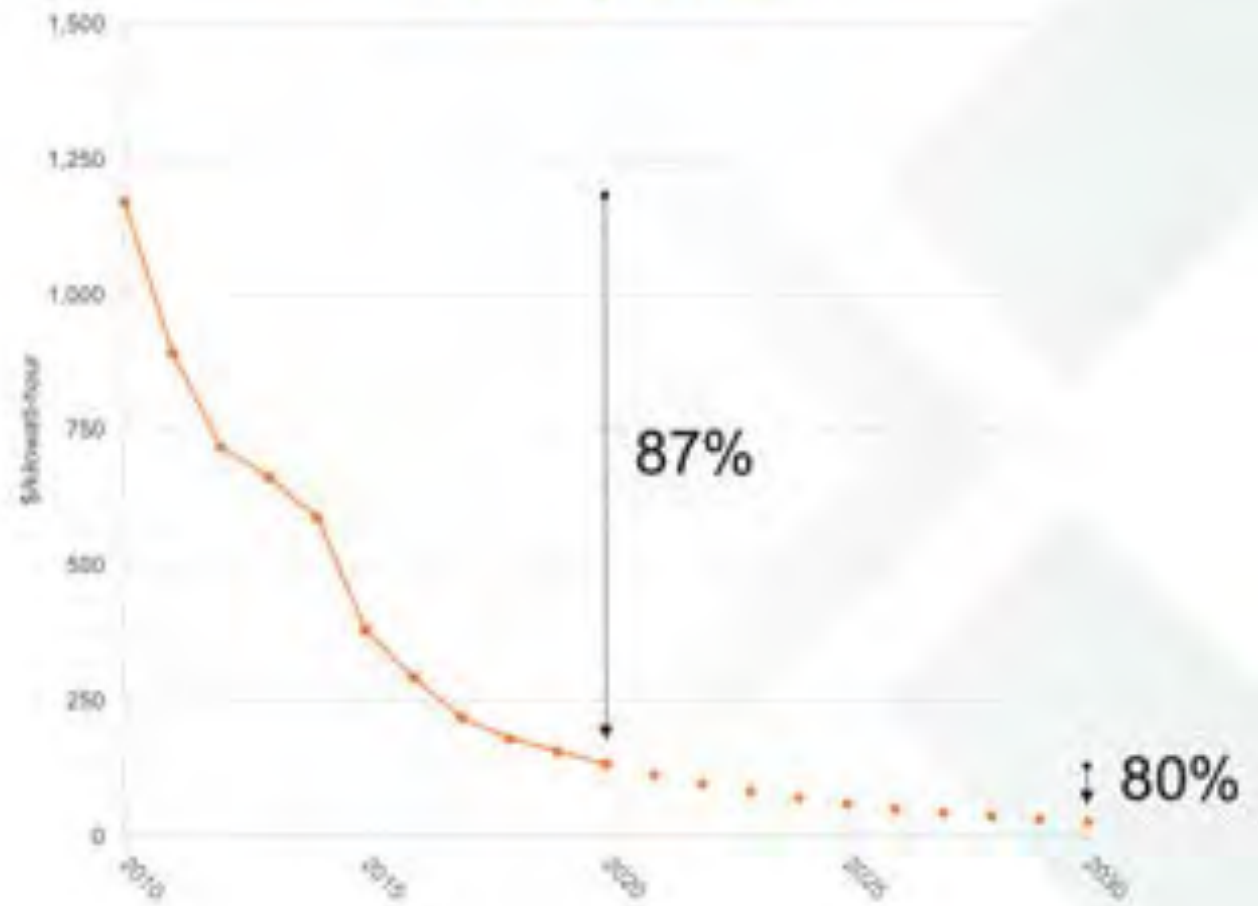
Real 2020
USD/kWh



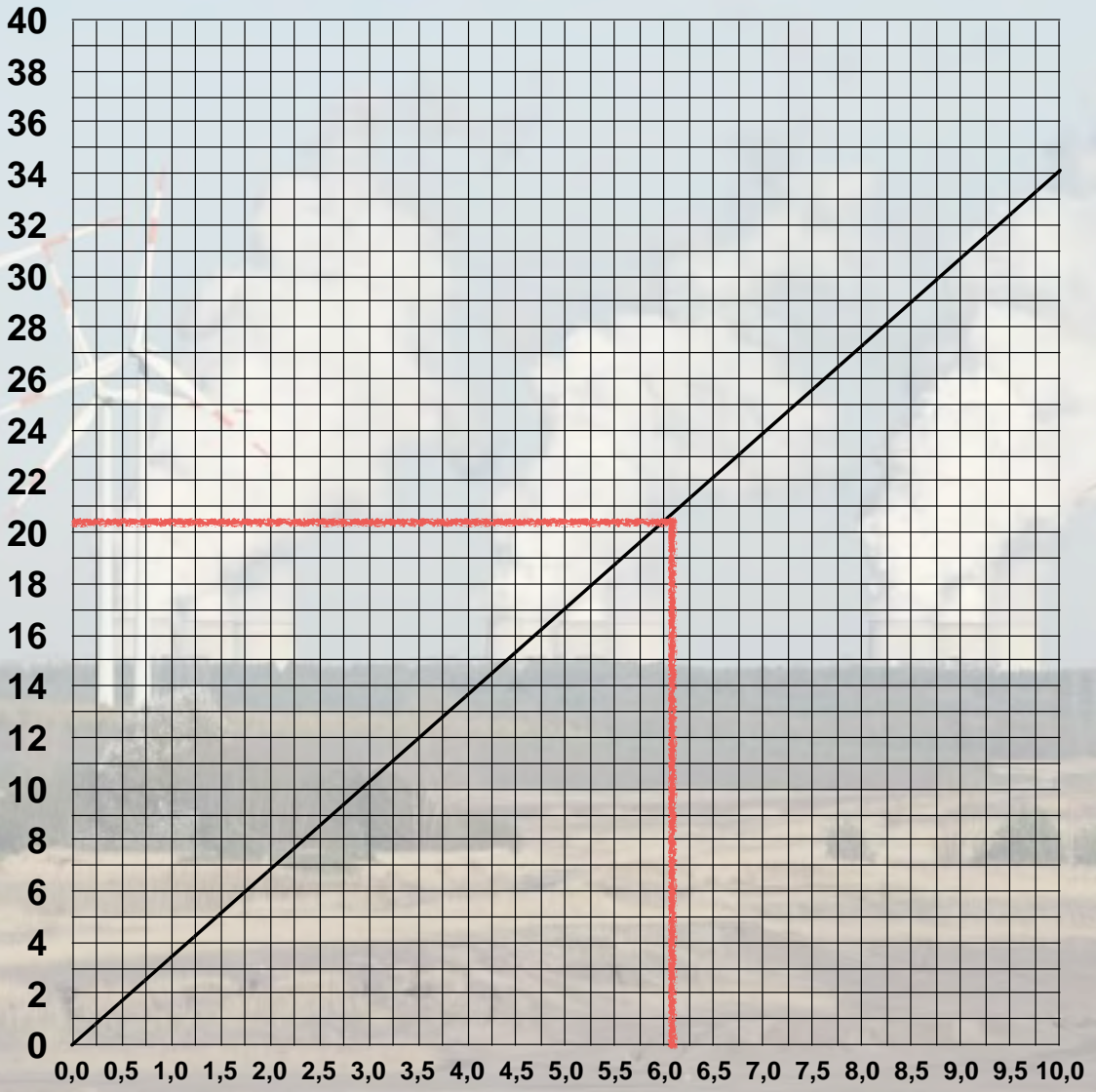
<https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/>



battery costs



USD/MWh



Methane price USD/MMBtu

7 July 2017

Nuon, Statoil and others
forces using hydrogen
CO2-free energy



ISPT has previously been
them being Nuon, together
of electricity in Amman
Norwegian Statoil and
venture that aims to build
power plant in the Emirates
an innovative project
available units fully
This is a very important
energy supply. This
Nuon has been working

Solar-powered hydrogen plant breaks

The production of hydrogen using renewable for power applications in various sectors, will put the ceremony of the region's first solar-powered Green

The solar-driven hydrogen electrolysis facility will be and is the first of its kind in the Middle East and North chairman of the Dubai Supreme Council of Energy and ground for the project on Sunday

The project will be implemented in collaboration with the Dubai Electricity and Water Authority (Dewa), Expo 2020 Dubai and Siemens.

UAE mulls hydrogen as a renewable energy

Rehema Sadayyat /Dubai
Filed on February 3, 2019



AFRICATECH FEBRUARY 3, 2019 8:49 AM 12 DAYS AGO

German energy grids say plan 100MW hydrogen plant

- Amprion, OGE say have completed plans for
- Follows hot on heels of national coal exit
- Could start 2023 to help usher in alternative

FRANKFURT, Feb 11 (Reuters) - German and Open Grid Europe (OGE) said on the country's first large hydrogen plant fuels that are easier to store and transport

The 100 megawatt (MW) power start operations from 2023 at the said in statements presented at a

committee, broke

Dubai and Siemens.

Vattenfall-led consortium plans 50 MW power-to-gas project in Germany

The energy company plans to build the "HySynGas" project in the Brunsbüttel Industrial Park with ARGE Netz and MAN Energy Solutions. The consortium wants to establish a power-to-gas hub for cross-sector decarbonization in northern Germany.

APRIL 4, 2019 SANDRA ENKHARDT
UTILITY SCALE STORAGE GERMANY



Green hydrogen can significantly contribute to the decarbonisation of the transport sector.

UAE mulls hydrogen as a renewable energy source

Rehema Sadayappan / Dubai
Filed on February 3, 2019

AFRICATECH | FEBRUARY 3, 2019 8:49 AM | 2 DAYS AGO

Vattenfall

Contact

7 July 2017

Nuon, Statoil and others
forces

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Hydrogen gas

project in
MAN
power-to-
Germany.



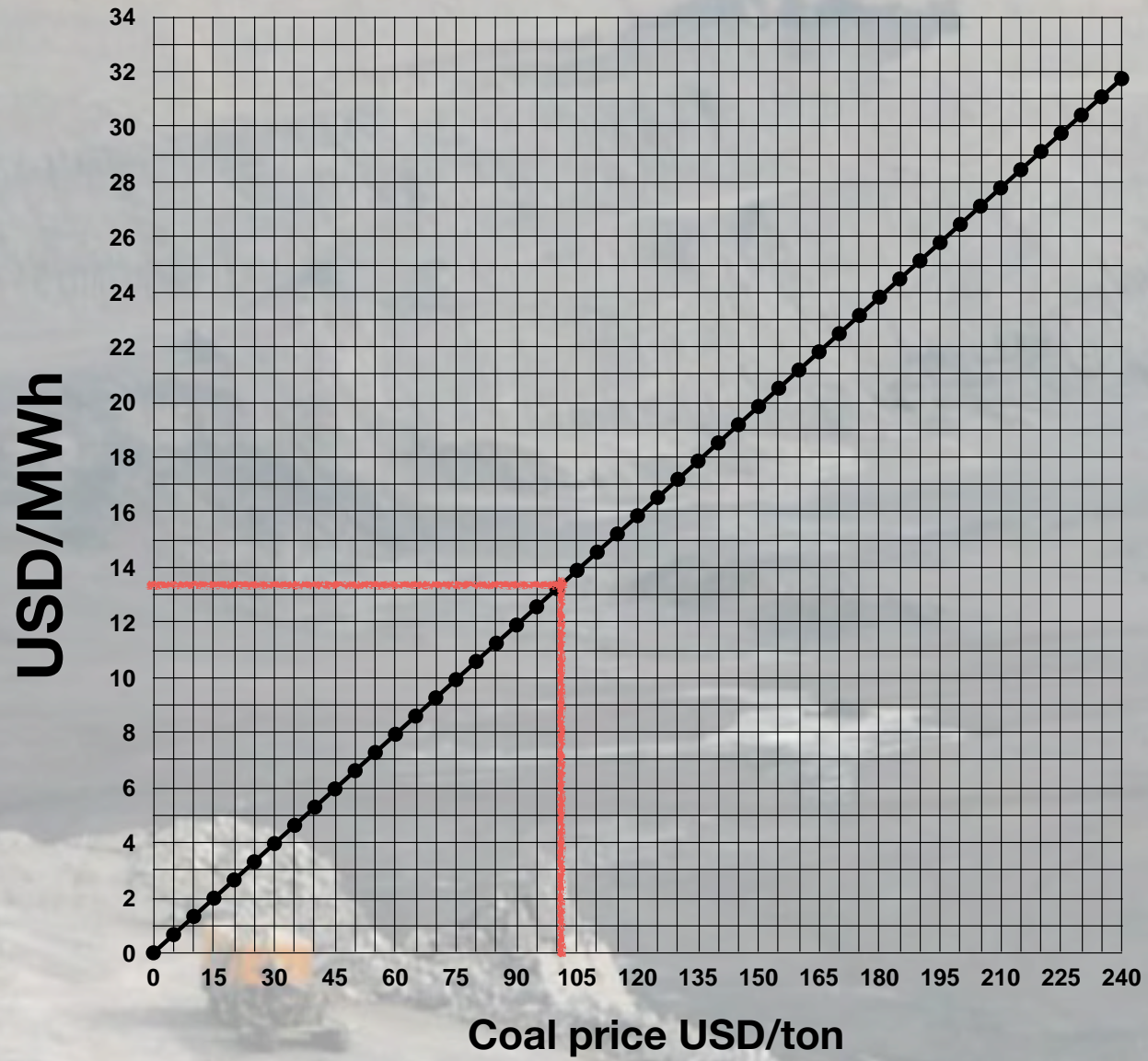
eMPowering our Future.

It's time to electrify fuel and empower our sustainable future.



and Water Authority (Dewa), Expo 2020

may contribute to the decarbonisation of the

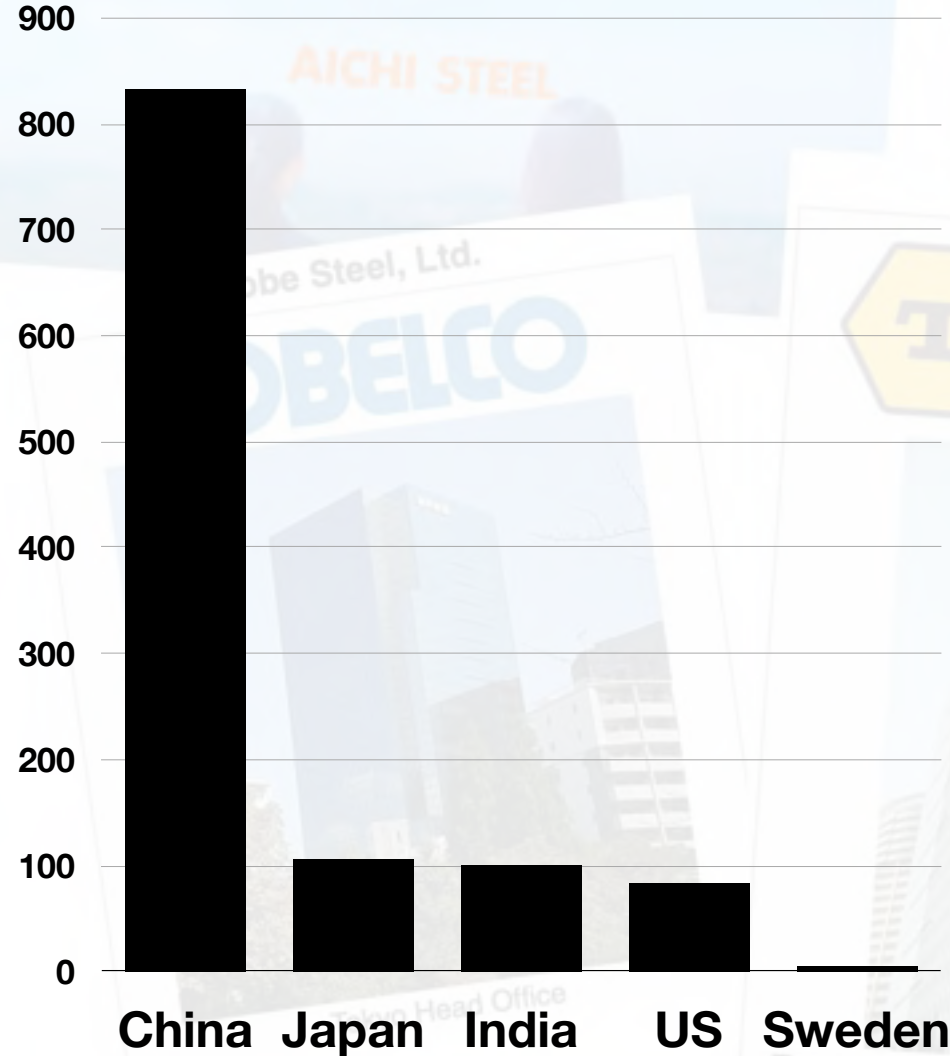


HYBRIT: SSAB, LKAB and Vattenfall first in the world with hydrogen-reduced sponge iron

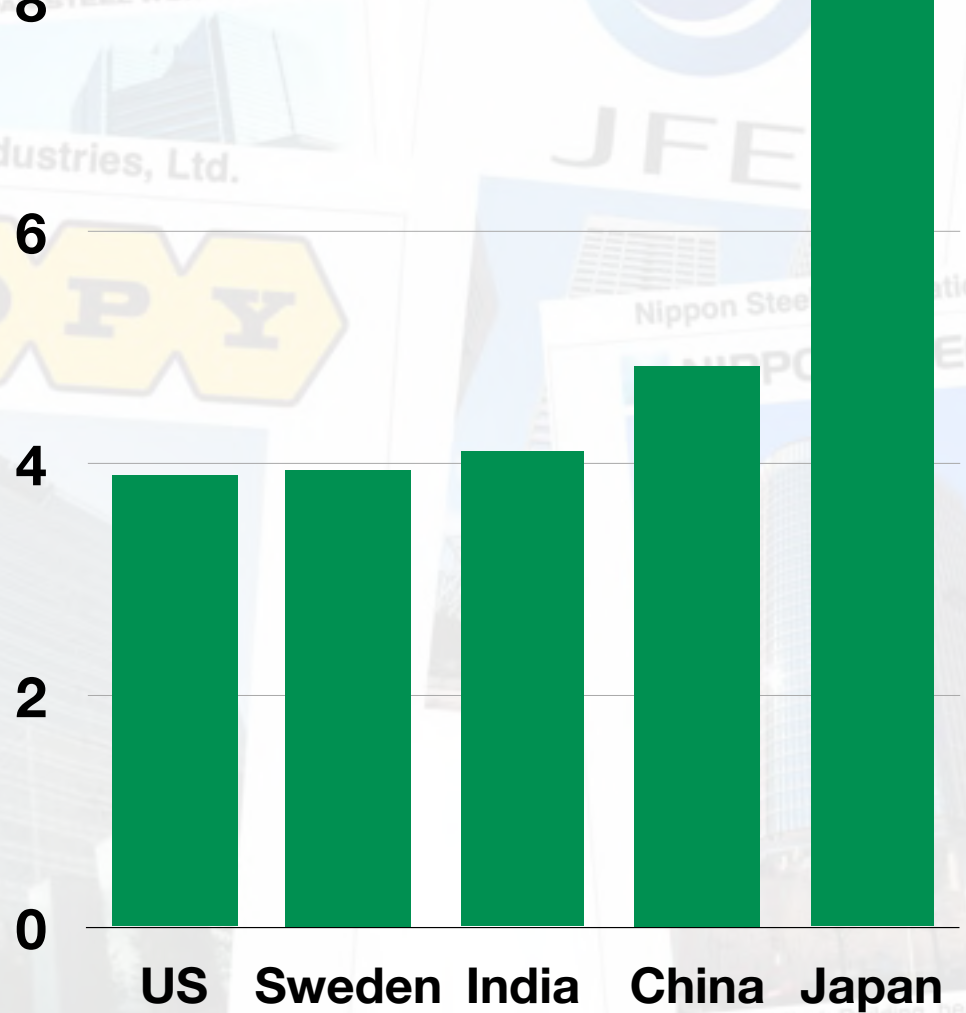
SSAB, LKAB and Vattenfall have now produced the world's first hydrogen-reduced sponge iron at a pilot scale. The technological breakthrough in the HYBRIT initiative eliminates around 90% of emissions in conjunction with steelmaking and is a decisive step on the road to fossil-free steel.

Future competitiveness?

World 4 largest steel producers, & Sweden; Mton steel/a



Cost of renewable H2 in 2021; \$/kg



Conclusion no 2

- Renewable energy will provide the lowest cost Energy

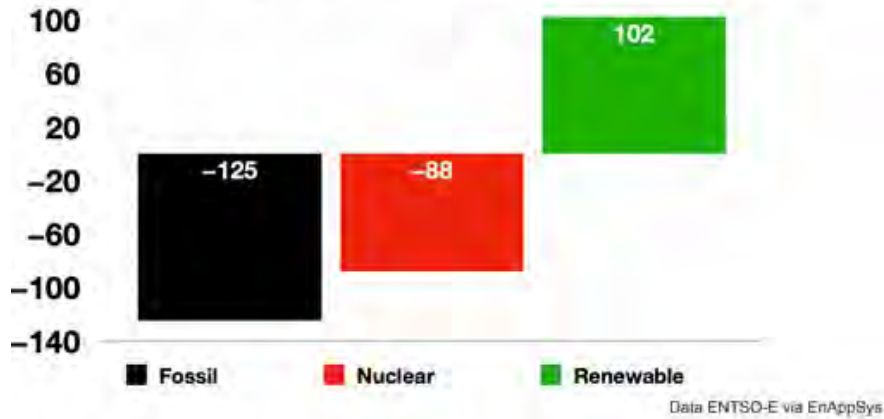
Milestones:

- *Fuel to produce electricity : Electricity price \approx fuel price * 3*
- *Electricity substitutes fuel : Electricity price \approx fuel price*
- *Electricity -> fuel : Electricity price $<$ fuel price*

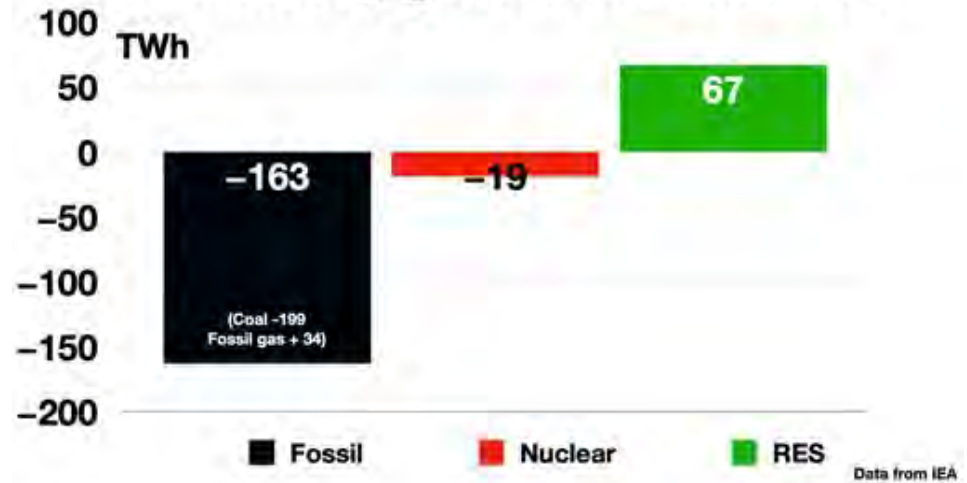
Supporting factors:

- Market growth and learning curves
- Capital cost opportunities
- Power balancing

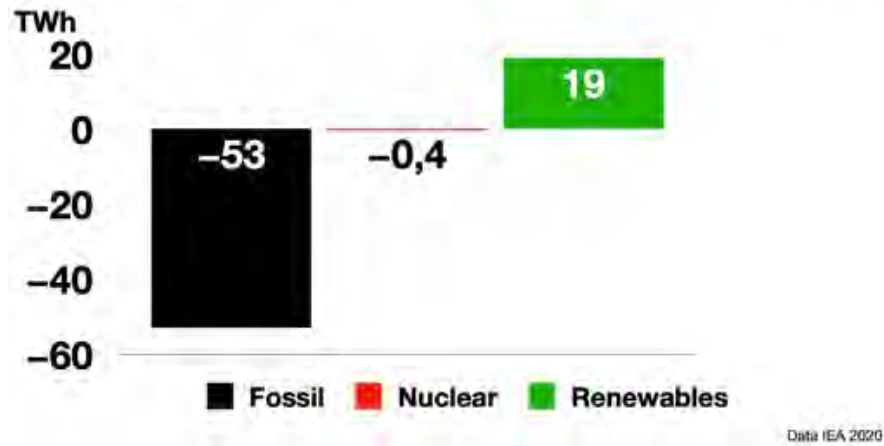
OECD Europe Electricity 2020 - 2019



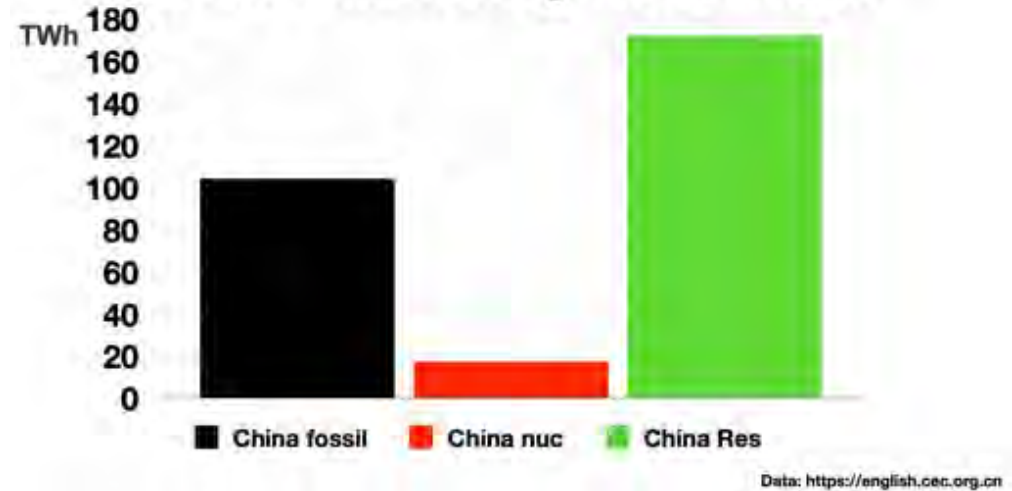
US electricity generation 2020-2019



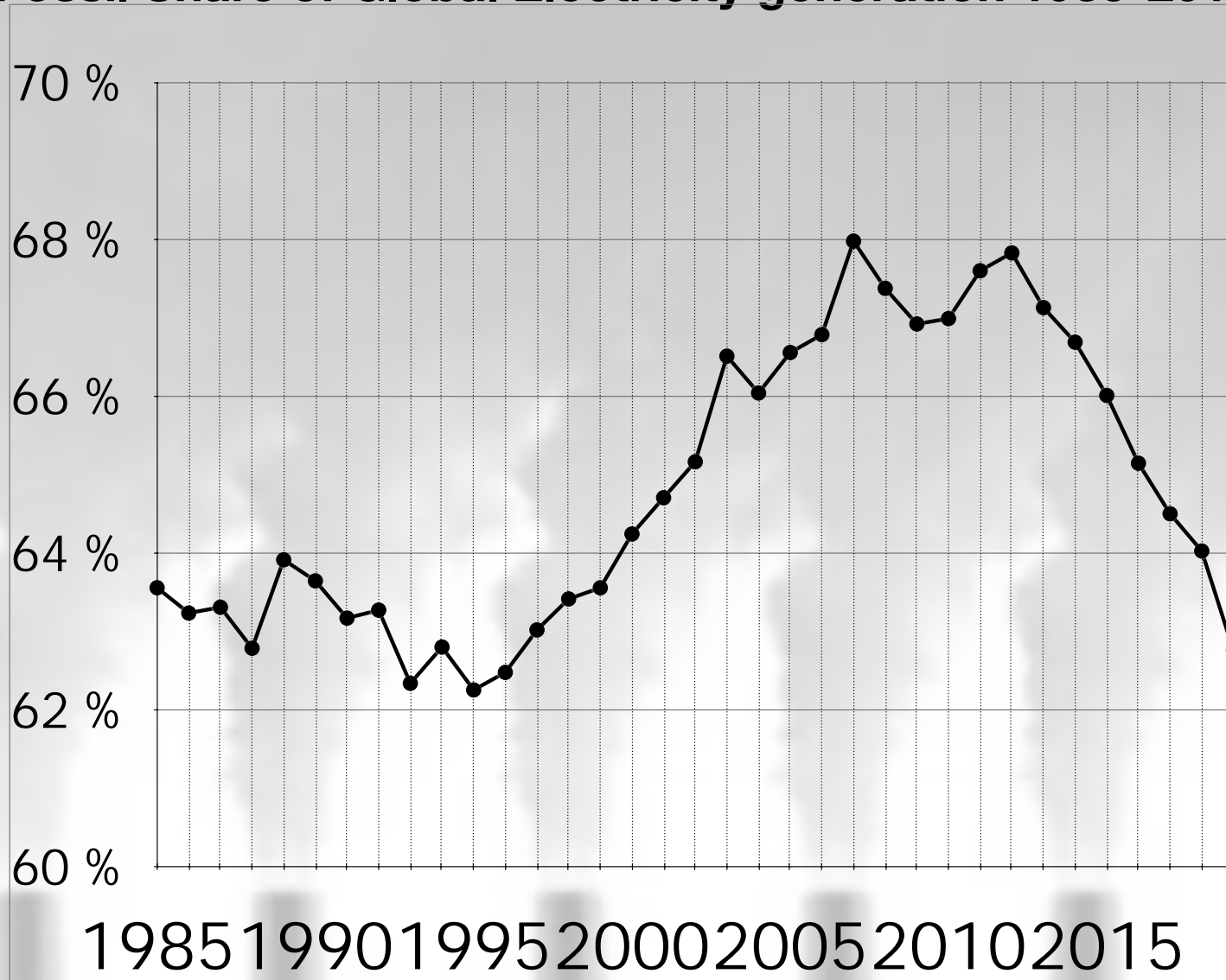
India, electricity generation 2020 - 2019



China Electricity 2020-2019

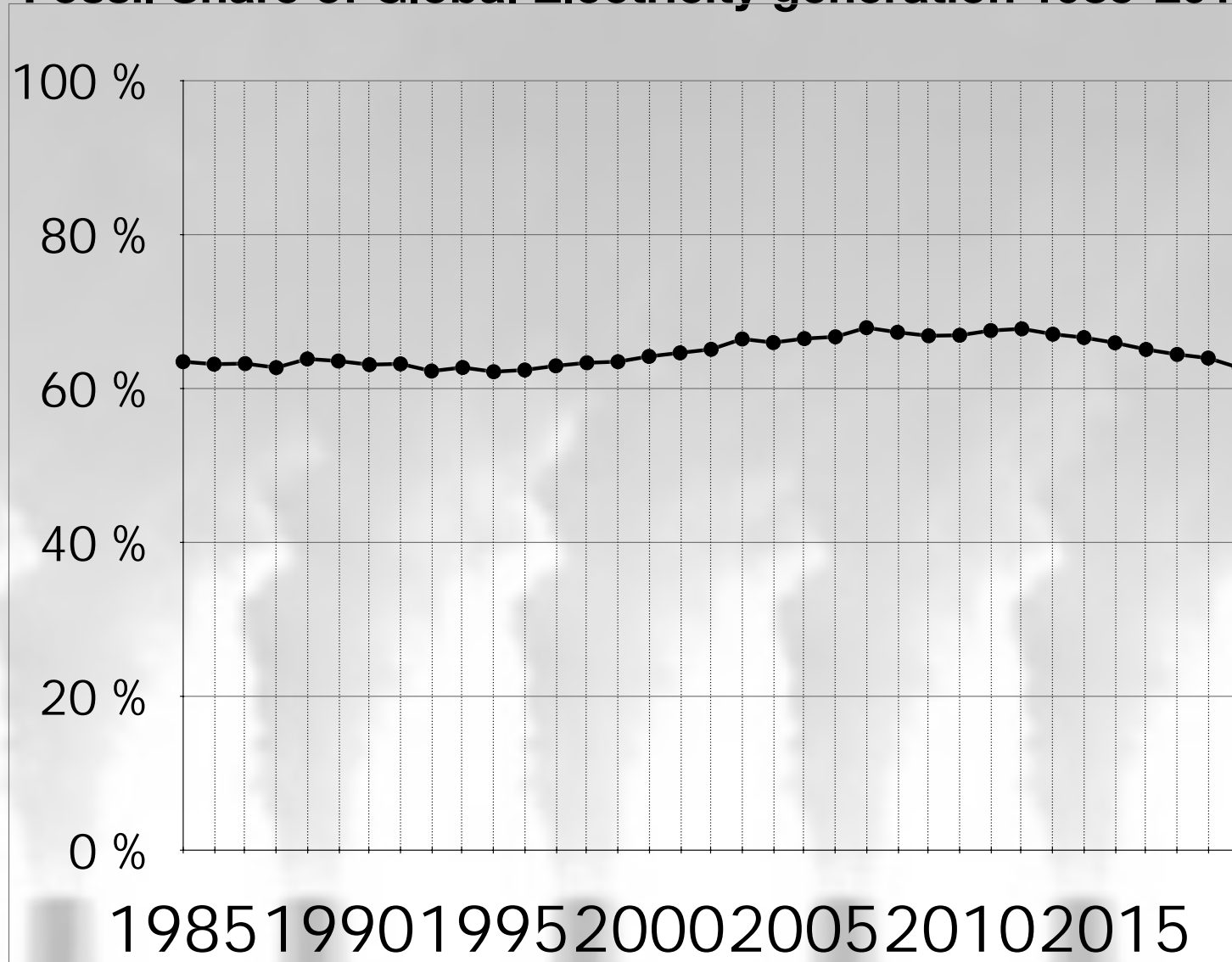


Fossil Share of Global Electricity generation 1985-2019



Data: BP statistical review 2020

Fossil Share of Global Electricity generation 1985-2019



Data: BP statistical review 2019

Towards 100 % Sustainable Energy

Tomas Kåberger

Executive Board Chair of Renewable Energy Institute, Tokyo

Affiliate professor Chalmers University of Technology

Industrial Growth Executive InnoEnergy

Member of the Swedish Royal Academy of Engineering Sciences