Renewable technologies: a quiet revolution

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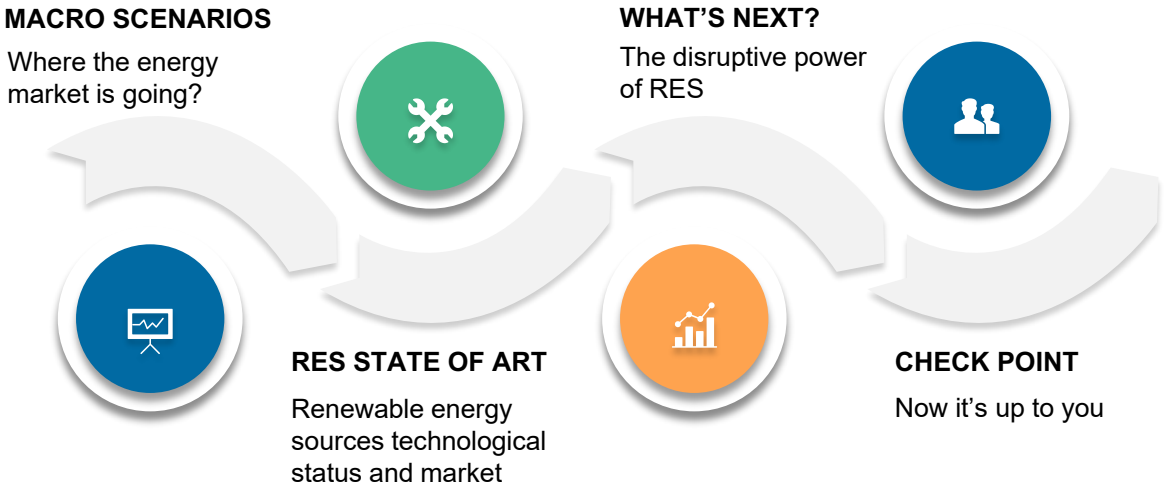
AGENDA


MACRO SCENARIOS
Where the energy market is going?
RES STATE OF ART
Renewable energy sources technological status and market
WHAT'S NEXT?
The disruptive power of RES
CHECK POINT
Now it's up to you

Renewable technologies: a quiet revolution

MACRO SCENARIOS

The evolution of the energy sector

Urbanization

By 2050,
6.3 billion people
will live in cities

Digitalization

Global Internet Traffic entered in the **ZB era**

Electrification

Electric passengers vehicle
sales reached 2.1 million in 2019

Energy Storage

The cost of Lithium-ion batteries will fall ***below 100 $/kWh in 3 years***

Climate Change

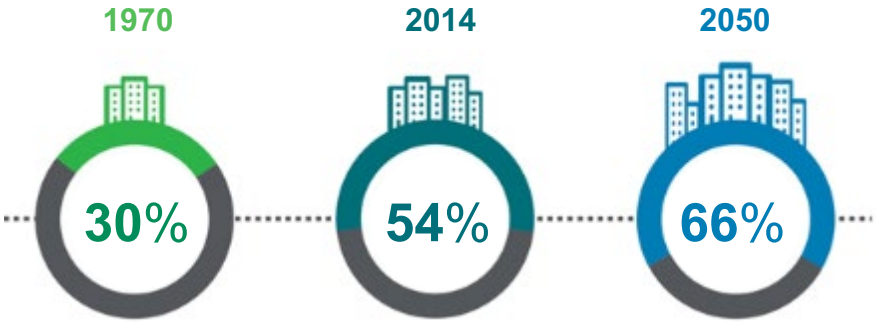
2 degree scenario requires **additional $5.3 trillion investments**

The energy sector is experimenting a deep transformation.

Source: United Nations 2014; BNEF EVO 2020 and WEO 2017

Urbanization

Global urbanization trends:
Percentage of population living in urban areas



Shanghai population: 24.1 mln (2014)

A new city the size of Shanghai
every four months

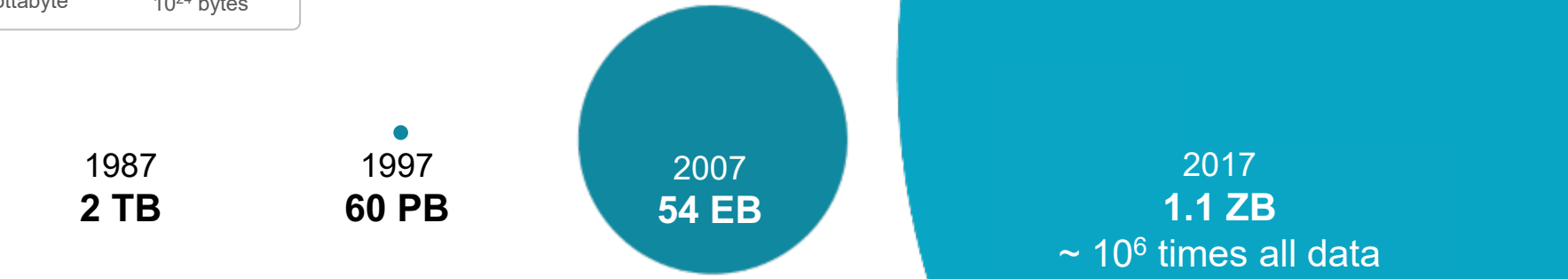
An extra 2.5 billion people added to the urban population by 2050.
Two thirds of clients will need smart and resilient power.

Source: United Nations 2014

Digitalization

Global Internet Traffic entered in the ZB era

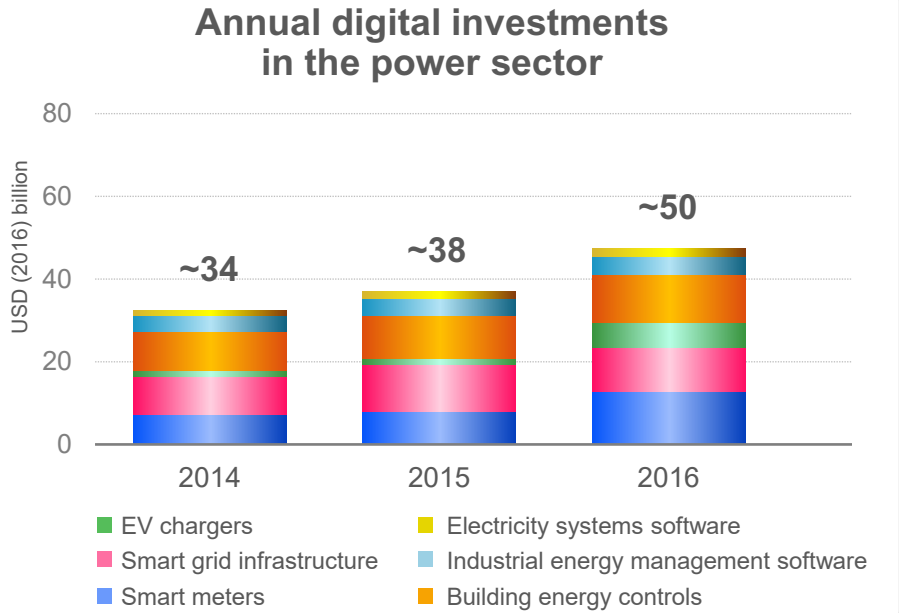
KB kilobyte	10^3 bytes
MB megabyte	10^6 bytes
GB gigabyte	10^9 bytes
TB terabyte	10^{12} bytes
PB petabyte	10^{15} bytes
EB exabyte	10^{18} bytes
ZB zettabyte	10^{21} bytes
YB yottabyte	10^{24} bytes

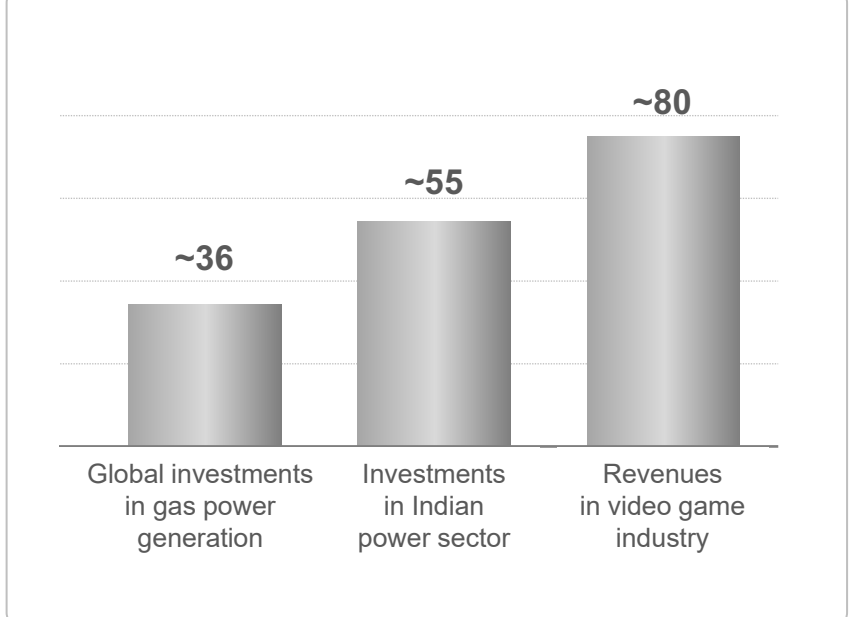


Around 90% of the data in the world today was created over the past two years

Source: IEA 2017

Investments in digital technologies





Investments in digital electricity infrastructure and software grew over 20% annually between 2014 and 2016, overtaking global investments in gas-fired power generation

Source: IEA
Note: Global gas power generation and India power sector refer to 2016 data; EV: Electric Vehicles.

Digitalization for Renewables

BiG Data & A.I.

BIG Data infrastructure to valorize data, in order to improve plant maintenance efficiency:

- ✓ Cost optimization
- ✓ Reduction of maintenance stop
- ✓ Higher revenues

Internet of Things

Fleet Retrofitting with sensors
Wearable devices for maintenance of plants

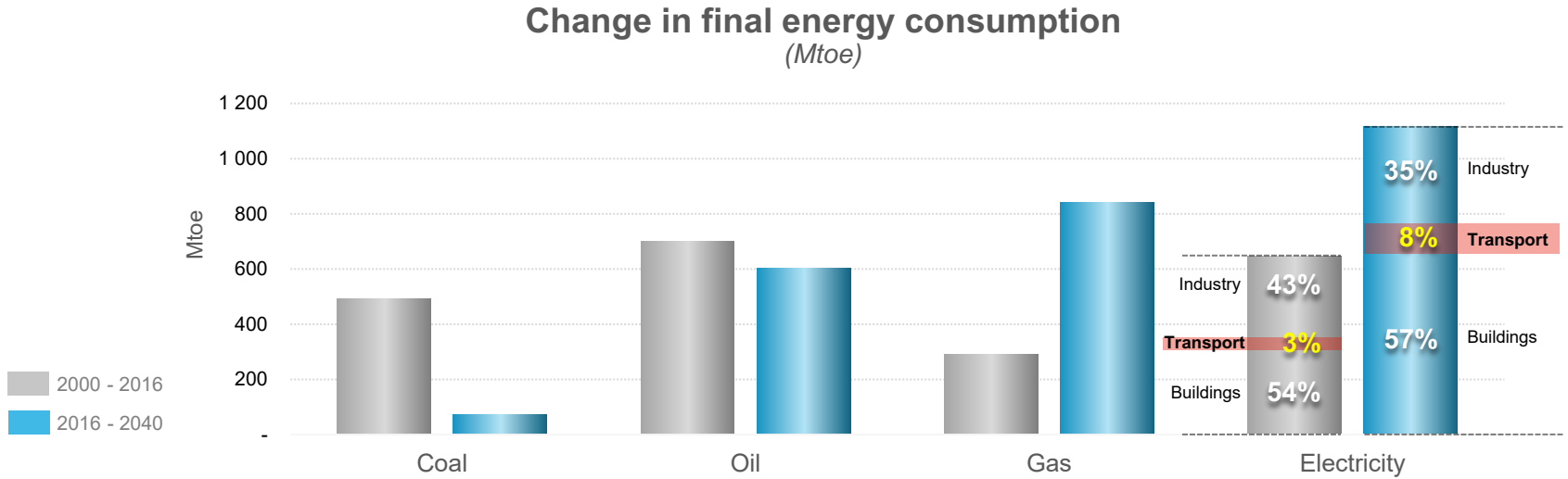
Augmented Reality

Enhanced reality tools to increase plant operation efficiency and safety on worksites

Forecasting - Nowcasting

Use of Weather forecasting for energy yield

Electrification

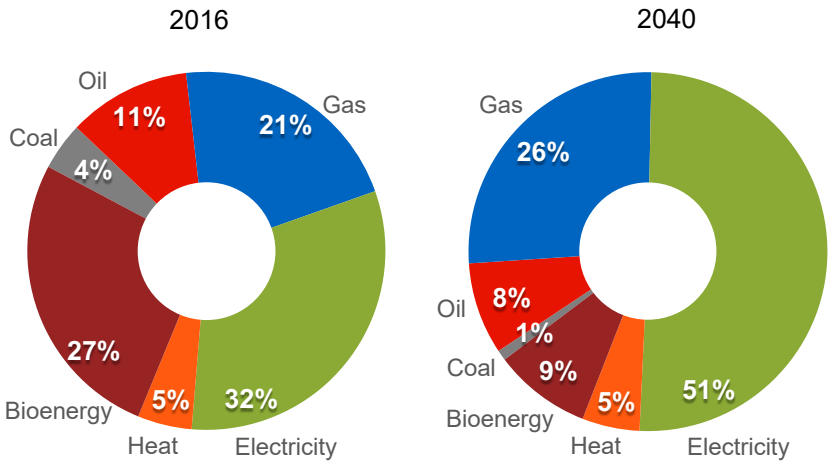


Final energy consumptions increase globally,
with electricity expected to be the first source of growth

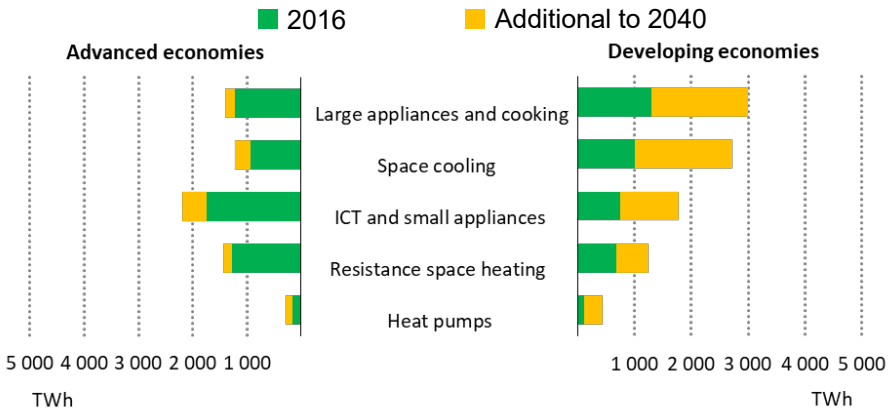
Source: IEA – World Energy Outlook 2017
Note: do not include the new final energy consumption from heat, bioenergy and other Renewables (9% in 2000-2016; 11% in 2016-2040)

Electrification in Buildings

Total final consumption in Buildings



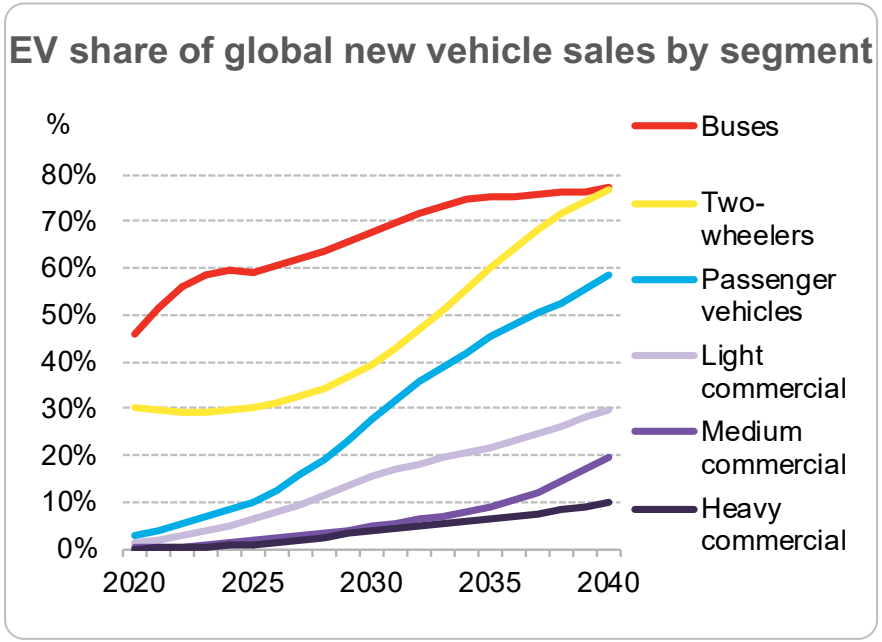
Electricity demand by end use in Buildings

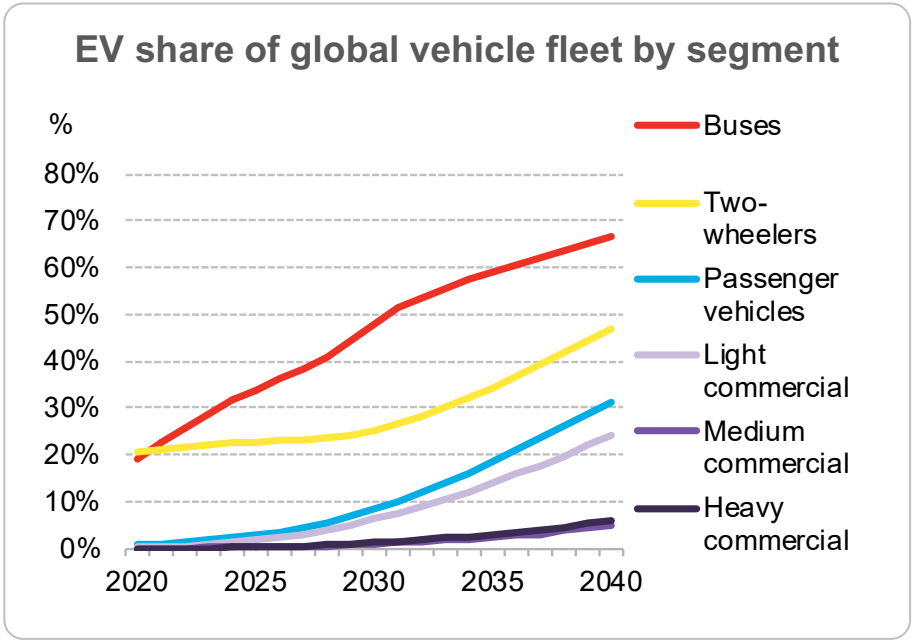


Electricity is expected to be the first source of energy in Buildings by 2040, mainly driven by large appliances, space cooling and plug-in devices

Source: IEA – World Energy Outlook 2017

Electrification of Transport

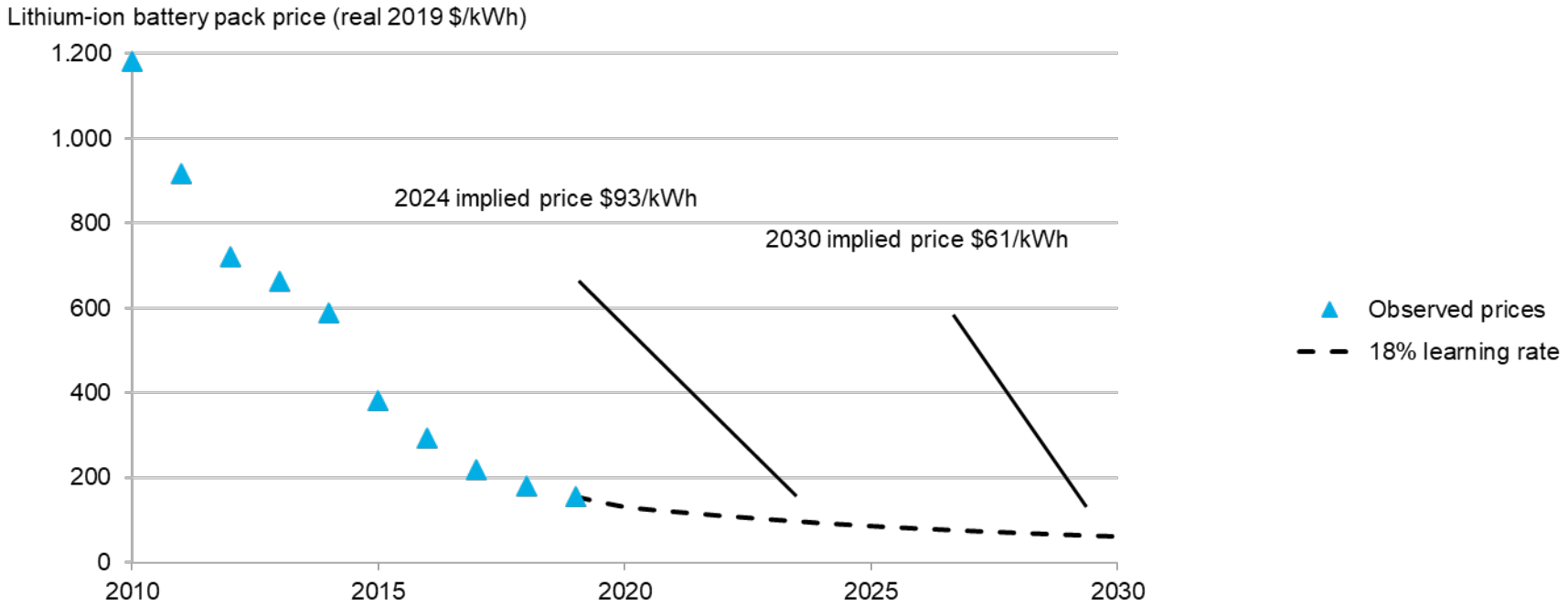




By 2040 1/3 of passenger vehicles will be electrical (EV sales 60%)
E-bus will be dominant in world fleet

Source: BNEF EVO 2020

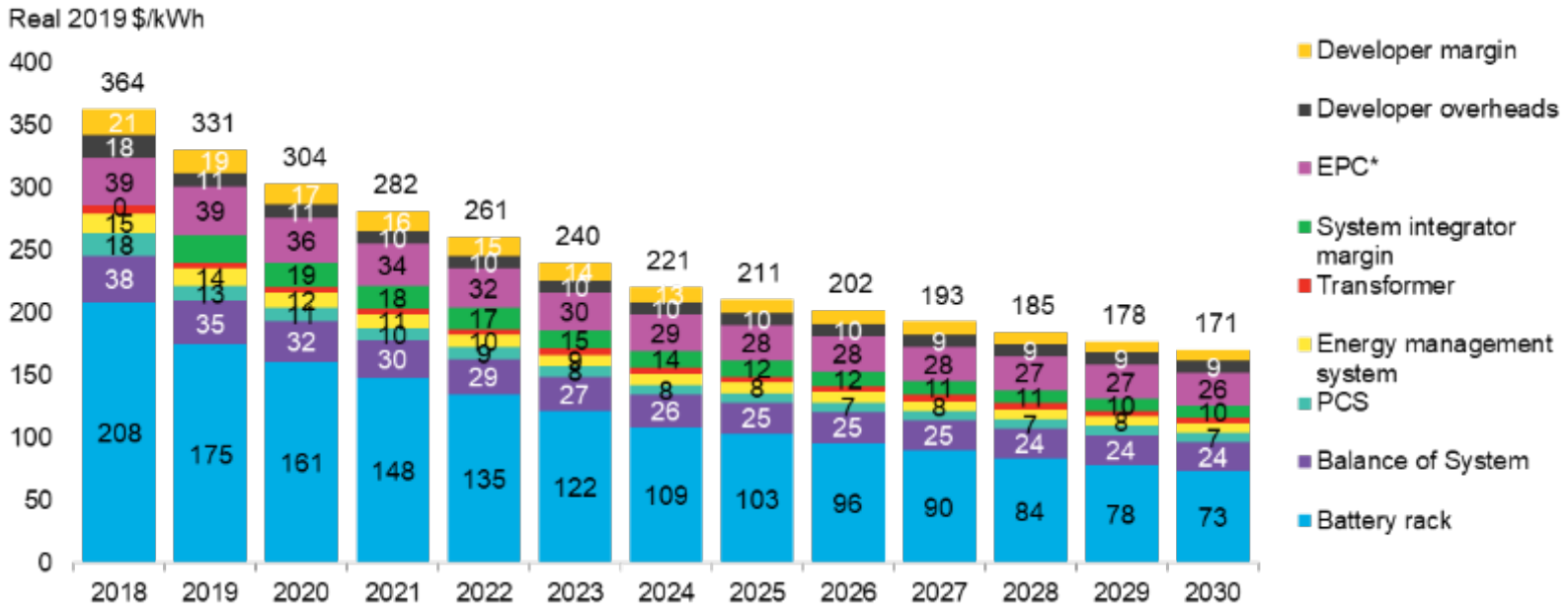
Energy Storage - Lithium-ion battery pack price forecast



A conservative 18% learning rate takes to break the $100/kWh threshold in 3 years.

Source: Bloomberg New Energy Finance NEO 2020.

Energy Storage – Utility scale systems



A typical 20 MW/80 MWh energy storage system can now balance load and generation fluctuations in a competitive way.

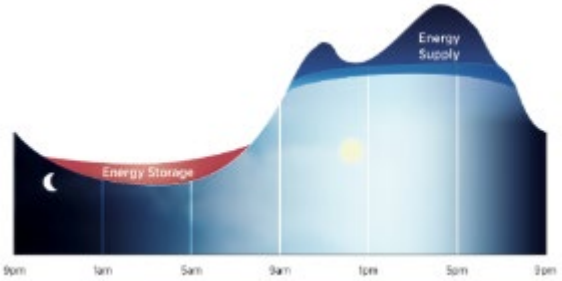
Source: Bloomberg New Energy Finance NEO 2020.

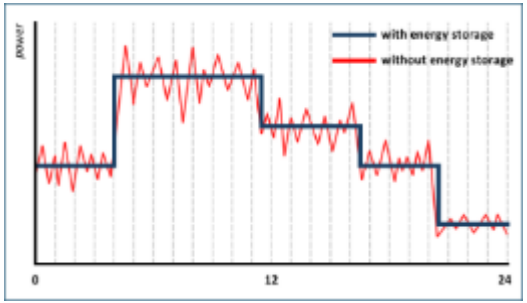
The Enabling Role of Energy Storage

Energy storage systems (**ESS**) can enable **high levels of renewable energy adoption** by complementing the predictably variable and sometimes intermittent nature of solar and wind resources. Two main categories of services can be identified:

- **Energy shifting:** ESS can shift wind or solar renewable power plants production to optimize grid energy flow and to fit the renewable sources with demand, allowing them to participate to the energy market as a conventional "fossil" power plant.

- **Ancillary services:** ESS can provide various "grid-stabilizing services", such as frequency and voltage regulation, quickly injecting/absorbing power to/from the grid. Dedicated markets are growing to compensate for these contributions.





Anything Coal and Gas can do, Renewables and Energy Storage will do cheaper.

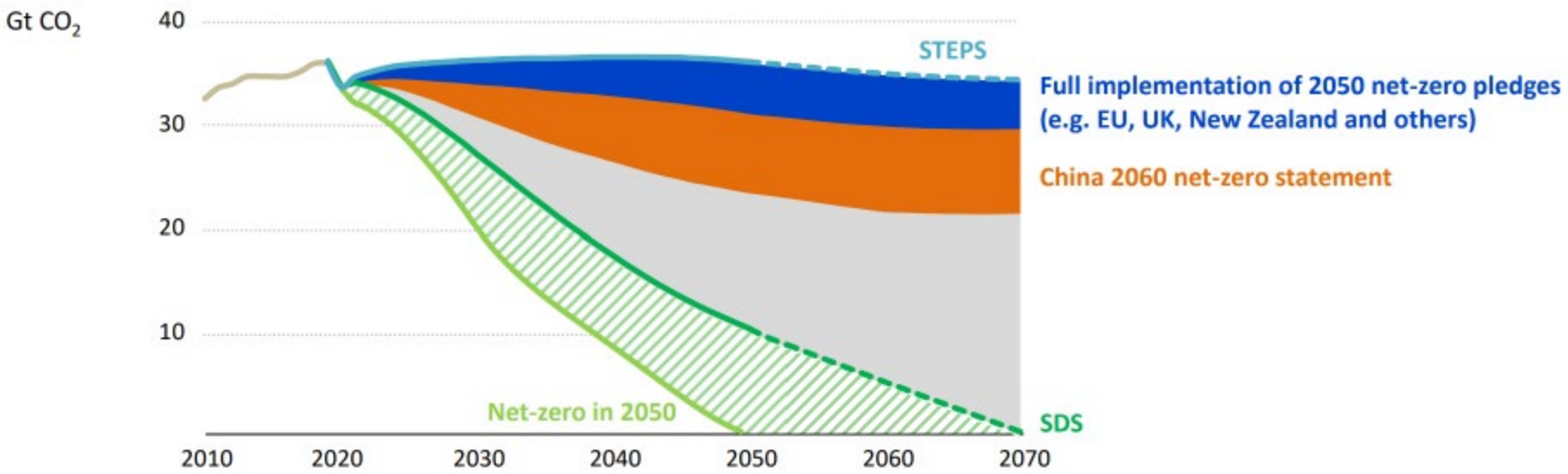
Climate change

1931

2016

Source: Sulle tracce dei ghiacciai, Fabiano Ventura; Upsala Glacier (AR)

Climate Change - CO2 emissions



Gas alone can't get us to 2 degrees – Additional efforts are necessary

Source: IEA WEO 2020

Renewable technologies: a quiet revolution

RES STATE OF ART

LCOE is the main market driver

Main GOAL is to reduce LCOE acting on all possible variables

Life time optimization

Capex reduction based on design optimization and strong negotiation

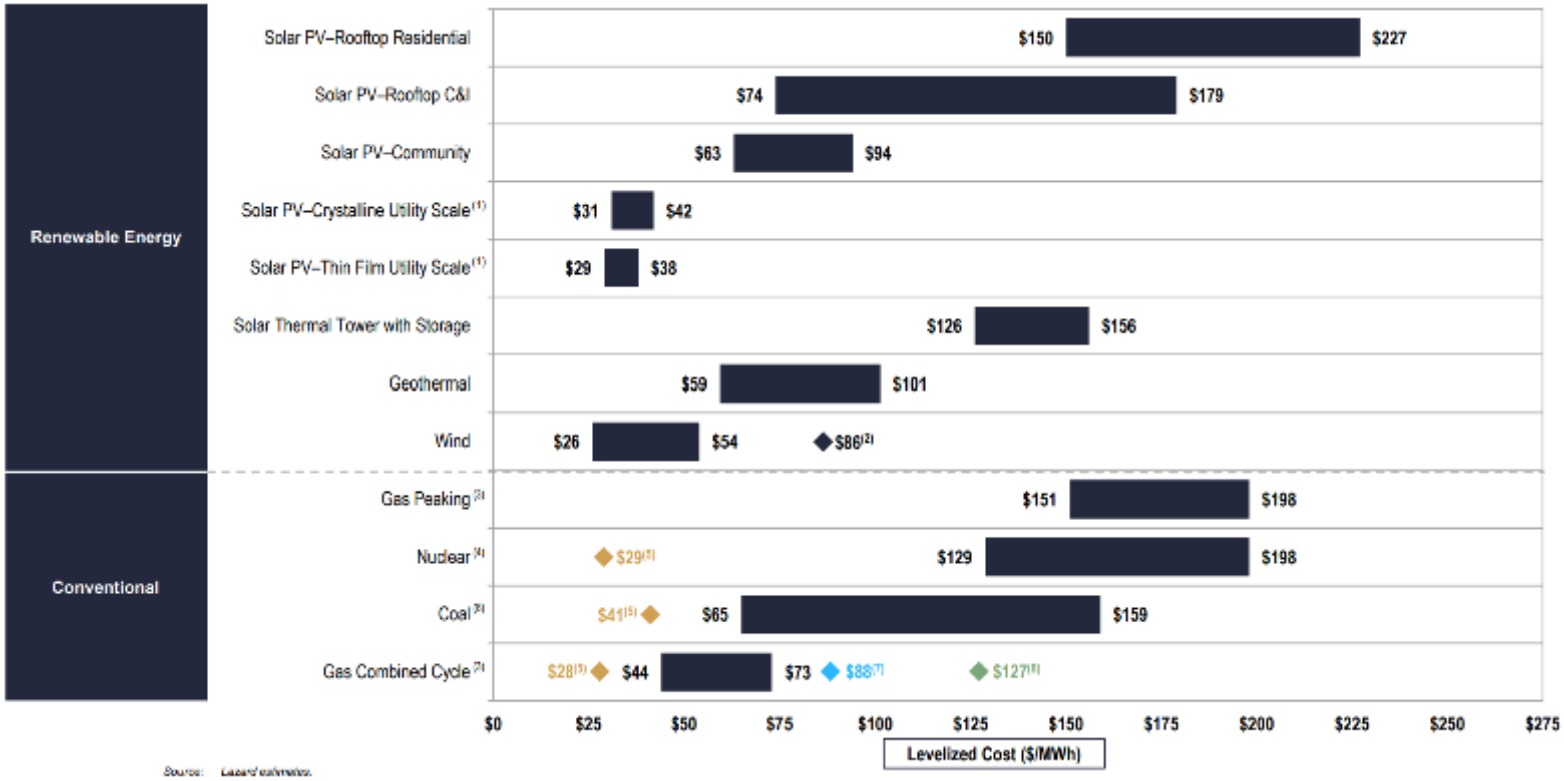
Opex reduction based on predictive maintenance, big data, IoT

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \quad [€/kWh]$$

Resource analysis and data base selection
Energy assessments
Main equipments choice

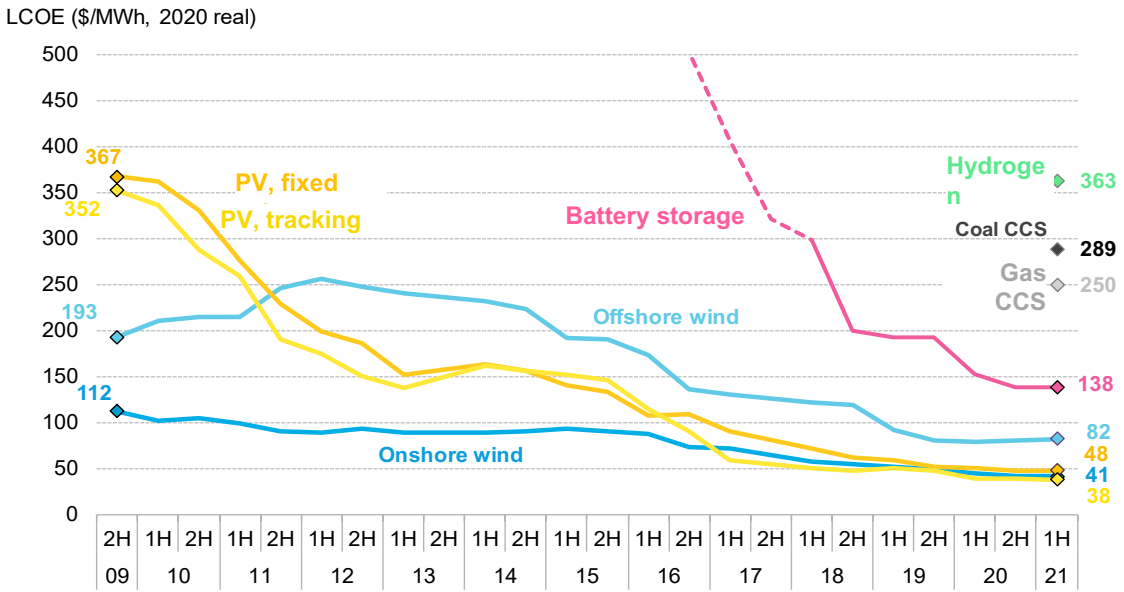
Levelized Cost of Energy (LCOE)
represents one of the utility industry's primary metrics for the cost of electricity produced by a generator.

Renewable vs. Conventional LCOE (2020)



Wind and solar PV utility scale the most competitive power plants that nowadays can be built

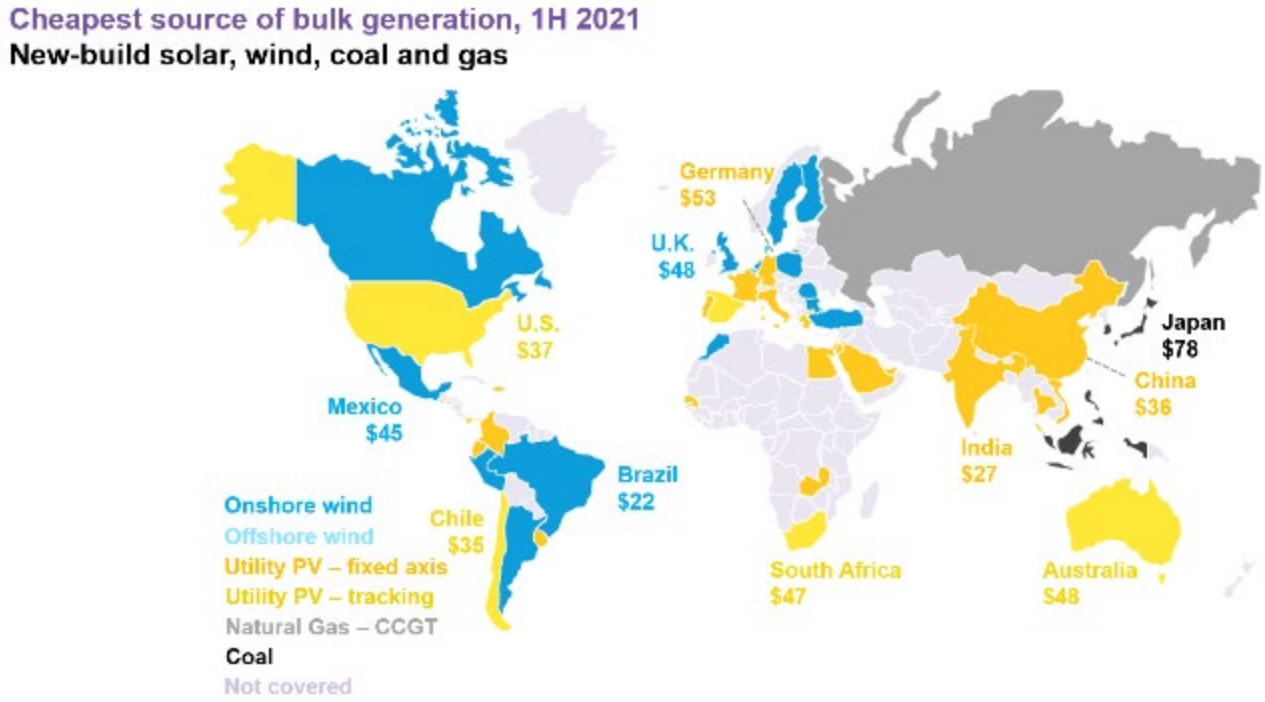
Global benchmarks for selected low-carbon technologies



Best trends for PV and battery storage

Source: BloombergNEF. Note: The global benchmark for PV, wind and storage is a country-weighted average using the latest annual capacity additions. For hydrogen-fired power, coal- and gas-fired power with carbon capture and storage (CCS), it is a simple global average. The storage LCOE is reflective of a utility-scale Li-ion battery storage system with four-hour duration running at a daily cycle and includes charging costs.

The quiet revolution - 1

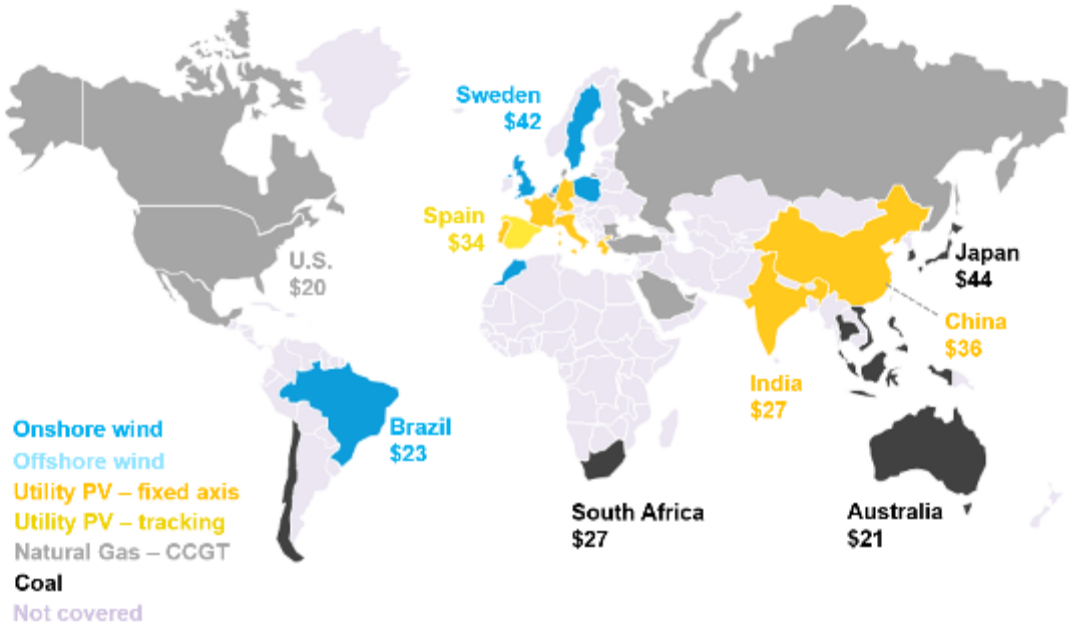


Renewables are the cheapest source of new bulk electricity in countries representing more than two-thirds of the world population and 91% of electricity generation.

Source: BloombergNEF 2021. Note: The map shows the technology with the lowest LCOE for new-build plants in each country where BNEF has data. The dollar numbers denote the per-MWh benchmark levelized cost of the cheapest technology. All LCOEs are in nominal terms. Calculations exclude subsidies, tax-credit or grid connection costs. CCGT is combined-cycle gas turbine.

The quiet revolution - 2

Cheapest source of bulk generation, 1H 2021
New-build solar and wind versus existing coal and gas



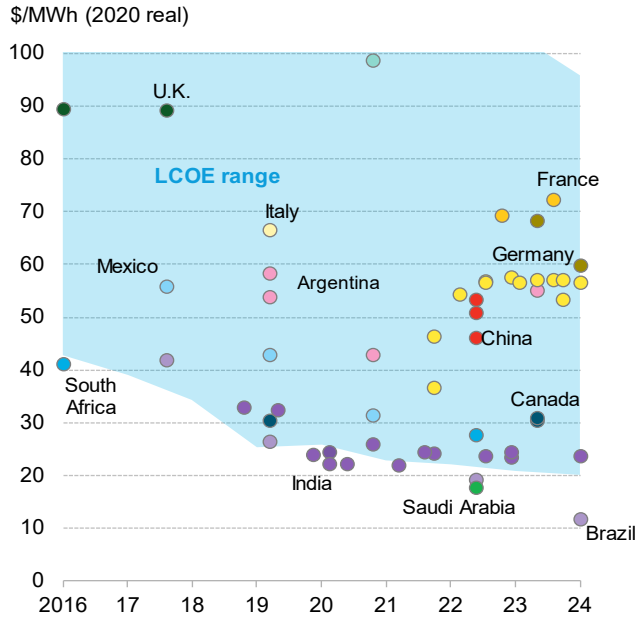
New solar and onshore wind now competes on cost with existing coal and gas power stations in countries representing almost half of the world's population and 48% of electricity generation.

Source: BloombergNEF 2021. Note: Note: The map indicates for each country the technology with the lowest LCOE for new-build solar and wind plants or short-run marginal costs for coal and gas-fired power plants. Our marginal costs include a carbon price where applicable. The dollar numbers below the country name denote the per-MWh levelized cost of that technology. All LCOEs are in nominal terms. Calculations exclude subsidies, tax-credit or grid connection costs. CCGT is combined-cycle gas turbine.

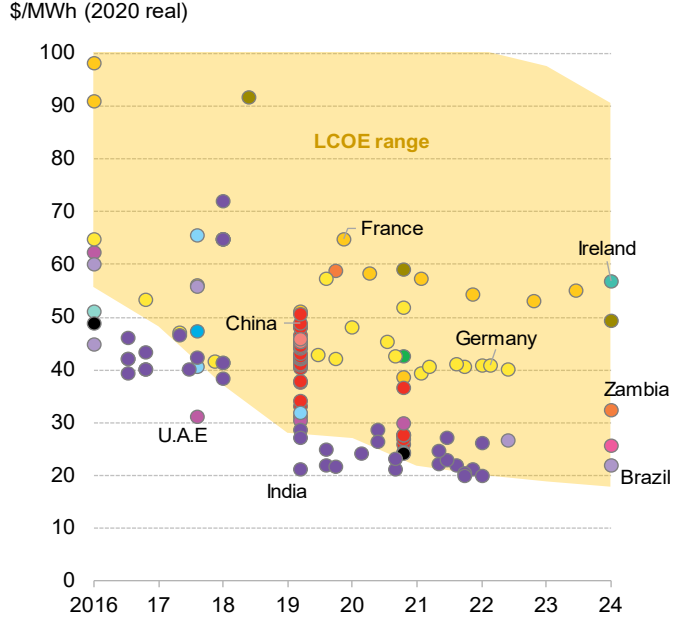
Auctions continue to push down wind and PV prices

Levelized auction bids, global

Onshore wind



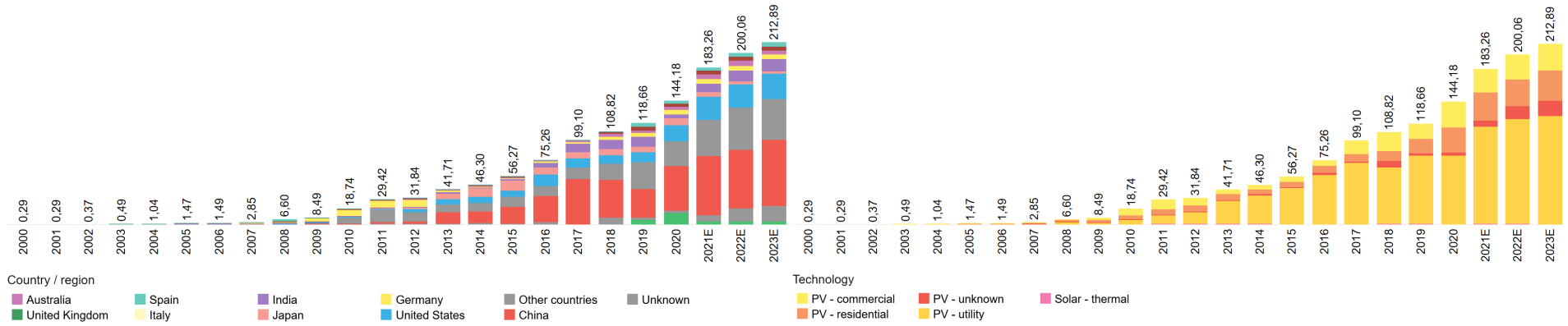
Utility-scale PV



Source: BloombergNEF. Note: Levelized auction bids and LCOEs are shown by commissioning date. For a full list of countries, please consult the Excel document attached on the insight web page.

Remember that the tariffs awarded and the LCOE are not the same thing.

SOLAR annual new additions (GW)

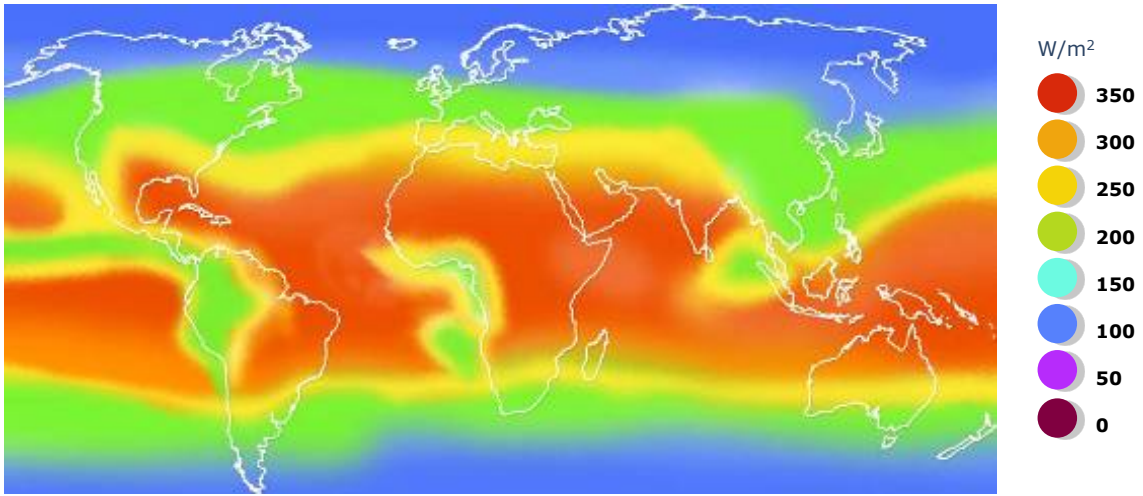


By far the absolute winner. No space for solar thermal in the future.

Source: Bloomberg New Energy Finance, BNEF

SOLAR PV - Uniform distribution

World solar radiation (yearly average)



Good levels in most of the Globe
Stabilizing effect from a macro political point of view
Developing Countries are particularly well irradiated

Source: NASA 2008

SOLAR PV - Modularity, simplicity and flexibility

Stand Alone

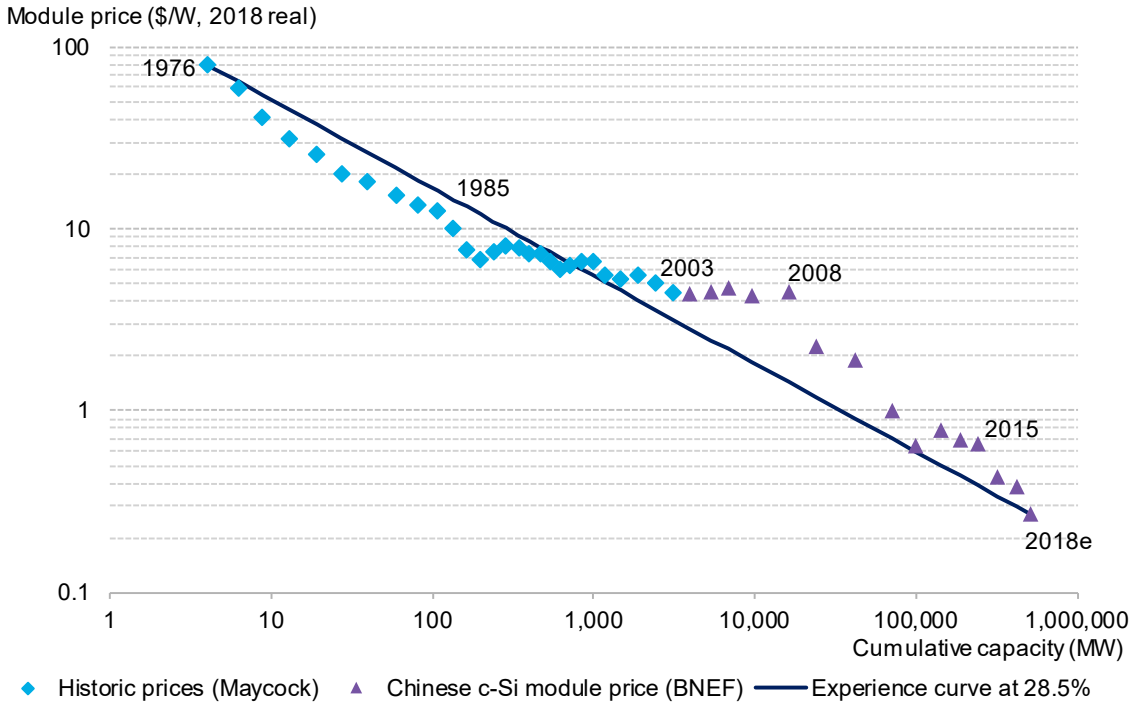
• Electronic devices power supply	1 mW – 10 W
• Micro stand alone systems	10 W – 100 W
• Small home systems	100 W – 1 kW
• Micro grids	10 - 100 kW

Grid Connected

• Residential	1 - 10 kW
• Commercial	10 kW – 1 MW
• Ground mounted, utility scale	1 MW – 1 GW

The same technology base in a wide range and for quite different uses

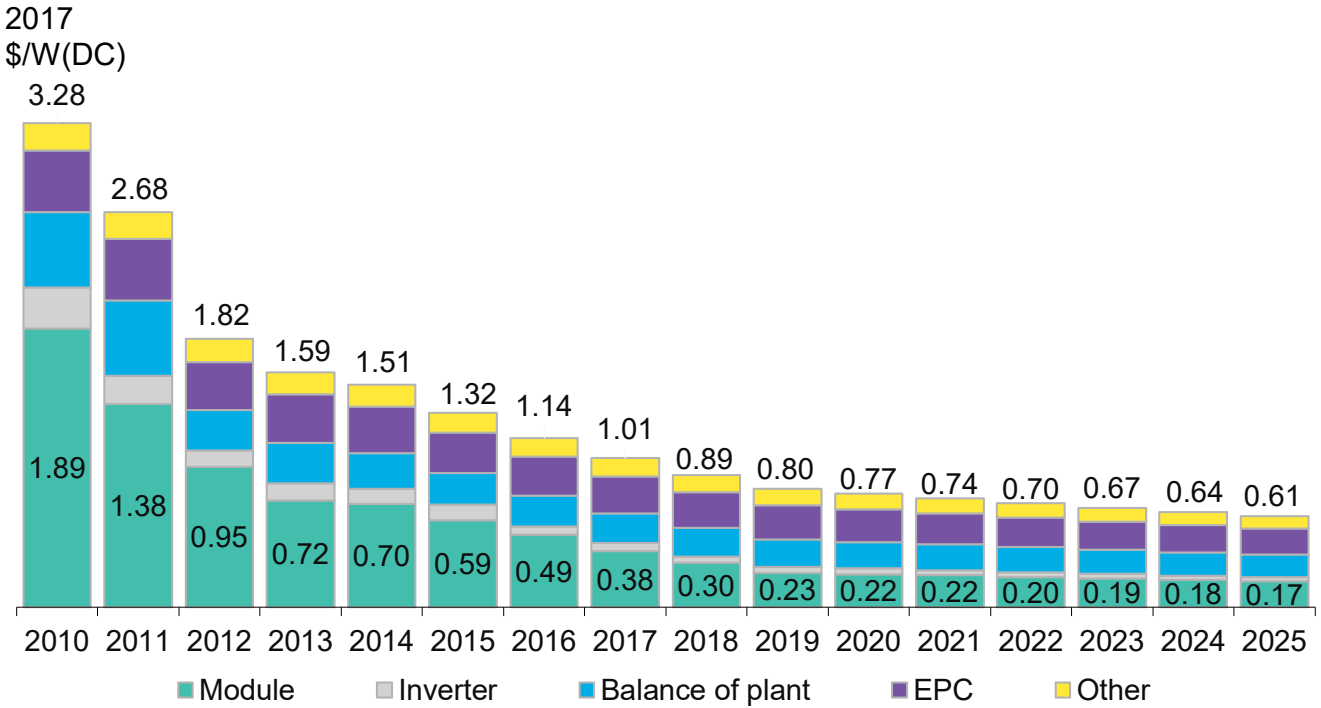
SOLAR PV - The learning curve for c-Si PV modules



Each time that cumulated volumes double price decreases 28%

Source: Bloomberg New Energy Finance, Paul Maycock

SOLAR PV - Benchmark price for utility scale fixed-axis PV system



The PV module doesn't represent the majority of the cost any more

Source: Bloomberg New Energy Finance Note: Inverter loading ratio of 1.2 assumed. Based on disclosed data from medium-capex geographies. Forecast based on experience curve, expectations of module efficiency which has an effect on other costs, process improvements.

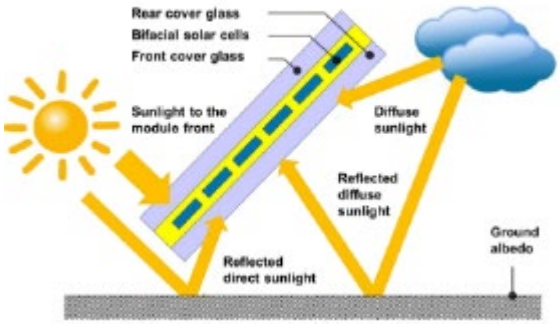
SOLAR PV - Technological reasons to dramatic cost reduction

- Silicon based technology: synergies with electronics both for innovation and industrial scale
- Few mechanical parts, no moving elements
- High purity silicon cheap and cost decreasing due to scaling up of volumes
- Wafering is plenty of new approaches (N type wafers, thickness reduction, epitaxial growth, ...) that allows reducing active material use (<5 g/W, in 2010 more than 10). Waiting for epitaxial deposition.
- Standard crystalline cells are quickly improving in efficiency due to wafer quality and many innovations on the process, up to 22% (16% in 2010)
- High efficiency cells (PERC, HJT, backcontacting, etc.) are decreasing in cost mainly due to scale effect, efficiency up to 24% already commercially available
- New materials (perovskite layers for tandem modules) will give efficiency up to 30%
- Bifacial modules are now a commercial standard
- New BOS choices, especially on conversion units

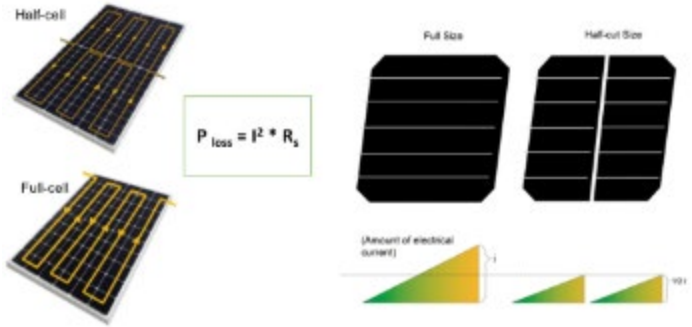
Efficiency improvement is the main driver to PV modules cost reduction

Advanced PV module concepts

Bifacial technology uncovers the rear side of the PV module for sunlight absorption. The gain varies between 5 and 30%, depending on various aspects, such as device design, site albedo, mounting conditions.



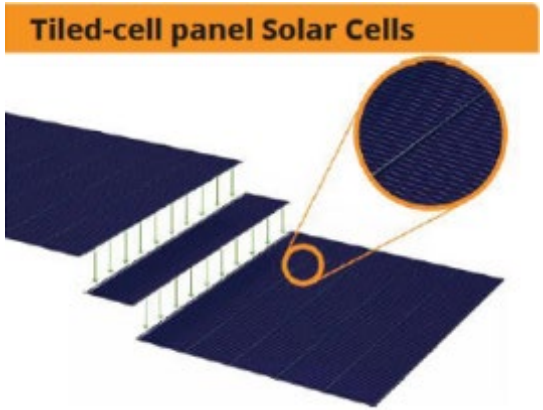
Using **half-cut cells** in a solar module makes a lot of sense. Two half cut pieces have the same voltage as the full cell, but the current – which is a function of the surface area- gets divided accordingly by half. Consequently, the internal electrical losses are reduced to 1/4 for a half cell compared to full square solar cells.



Advanced PV module concepts

Shingles: the beauty of this technology is that it eliminates ribbons completely. That means the cells are interconnected directly by placing them on each other. The shingle interconnection technology following a specific design improves the modules efficiency by 1.86% absolute compared to standard ribbon based interconnection.

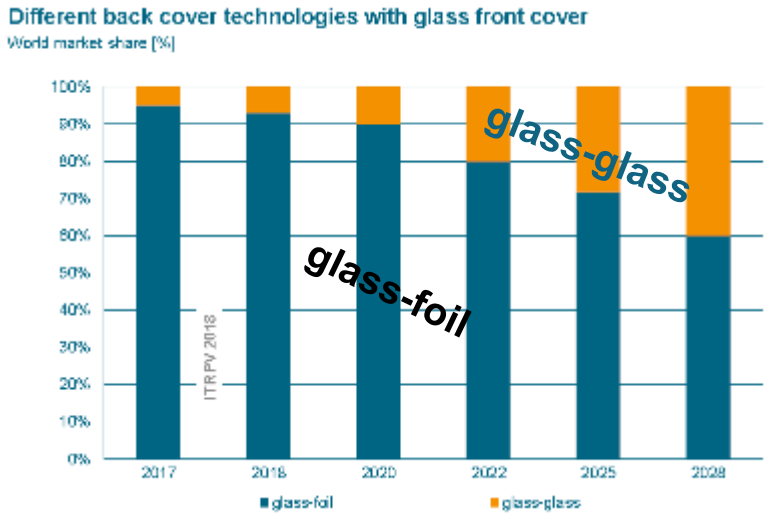
One of the simplest ways to reduce resistance losses is to increase the **number of bus bars.** Same approach aiming at reducing the resistance losses is applied by **multi bus bar**. Instead of employing 4,5 or even 6 ribbons for interconnection between cells, several thin wires are used.

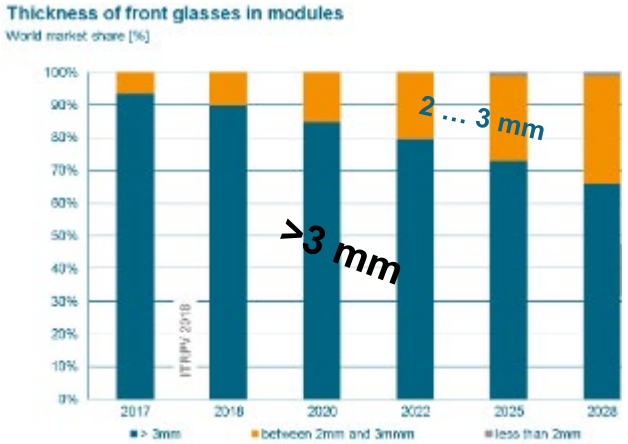


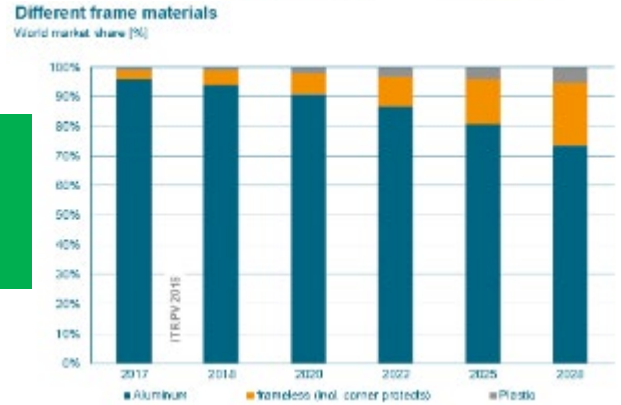
MBB Module

PV market trend

Future Material Trend - let's see until 2028







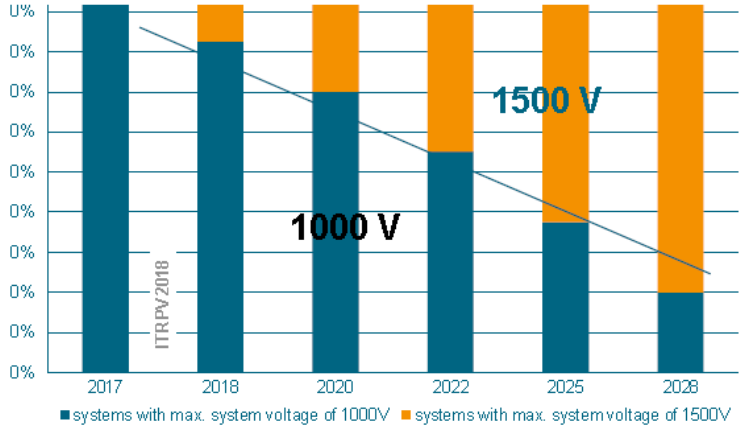
→ glass-glass will gain market share
→ glass – foil will remain mainstream
→ Al frame modules will stay mainstream

Source: ITRPV 2018

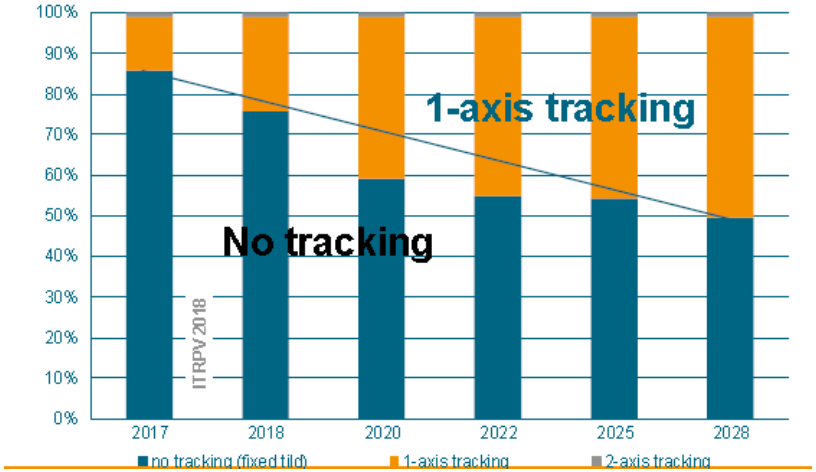
PV market trend and development considerations

Systems – Modules and Mounting

Trend: system voltage in power plants

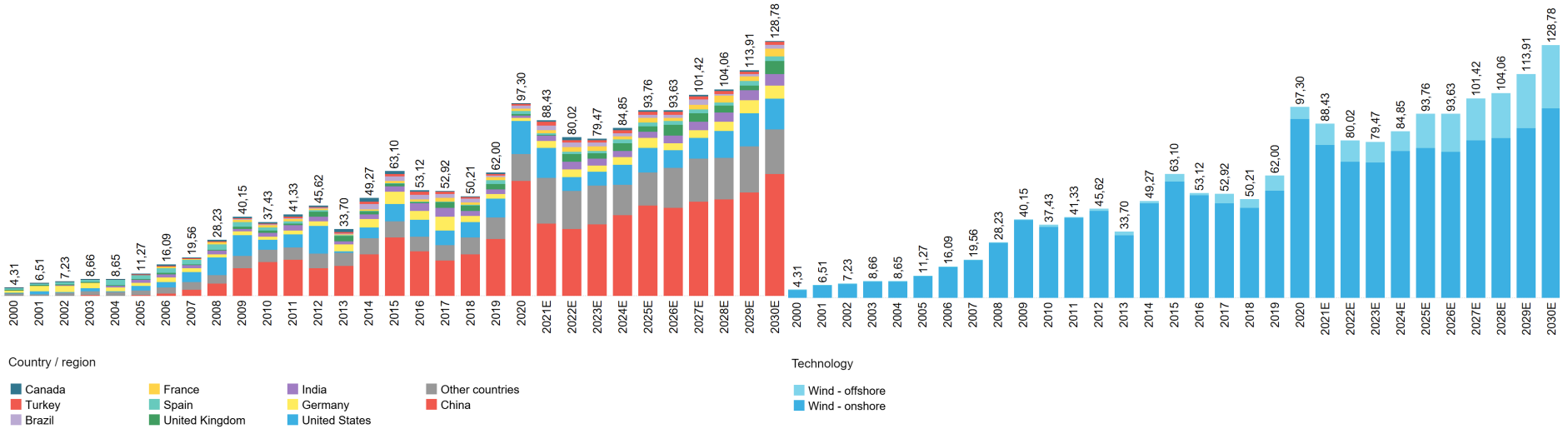


Trend: tracking in PV power plants



Source: ITRPV 2018

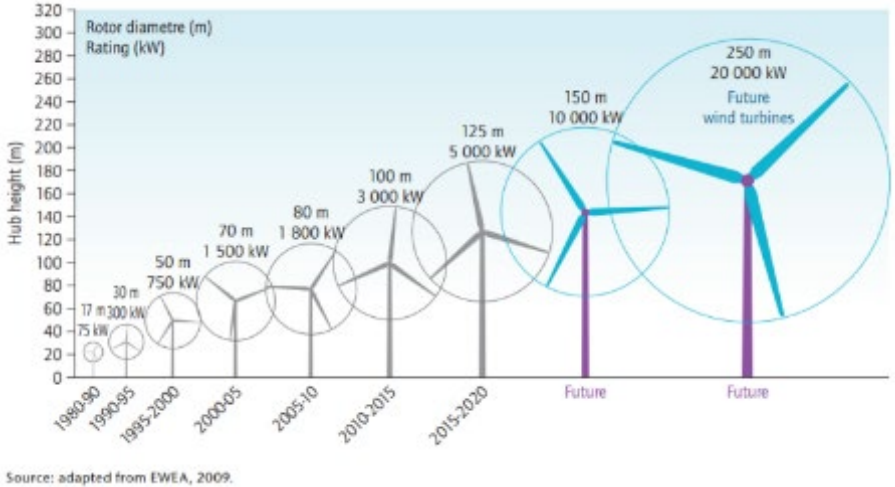
WIND – annual new additions (GW)



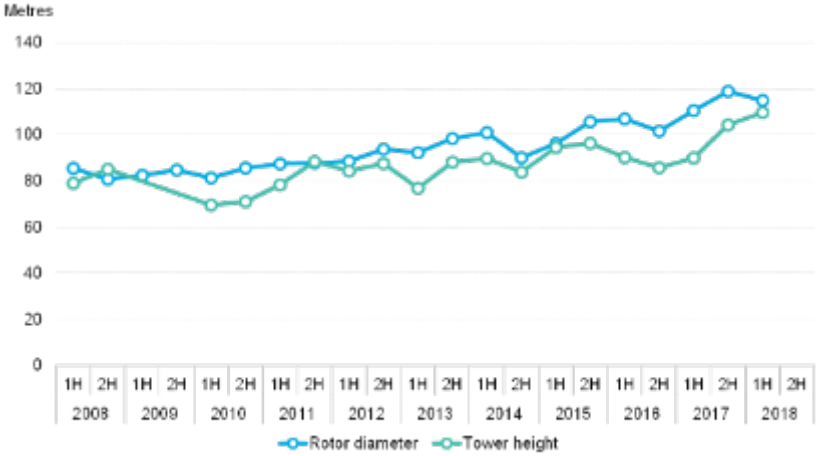
Short - medium term stable growth. Off shore increases.

Source: Bloomberg New Energy Finance, BNEF 2021

WIND turbines evolution



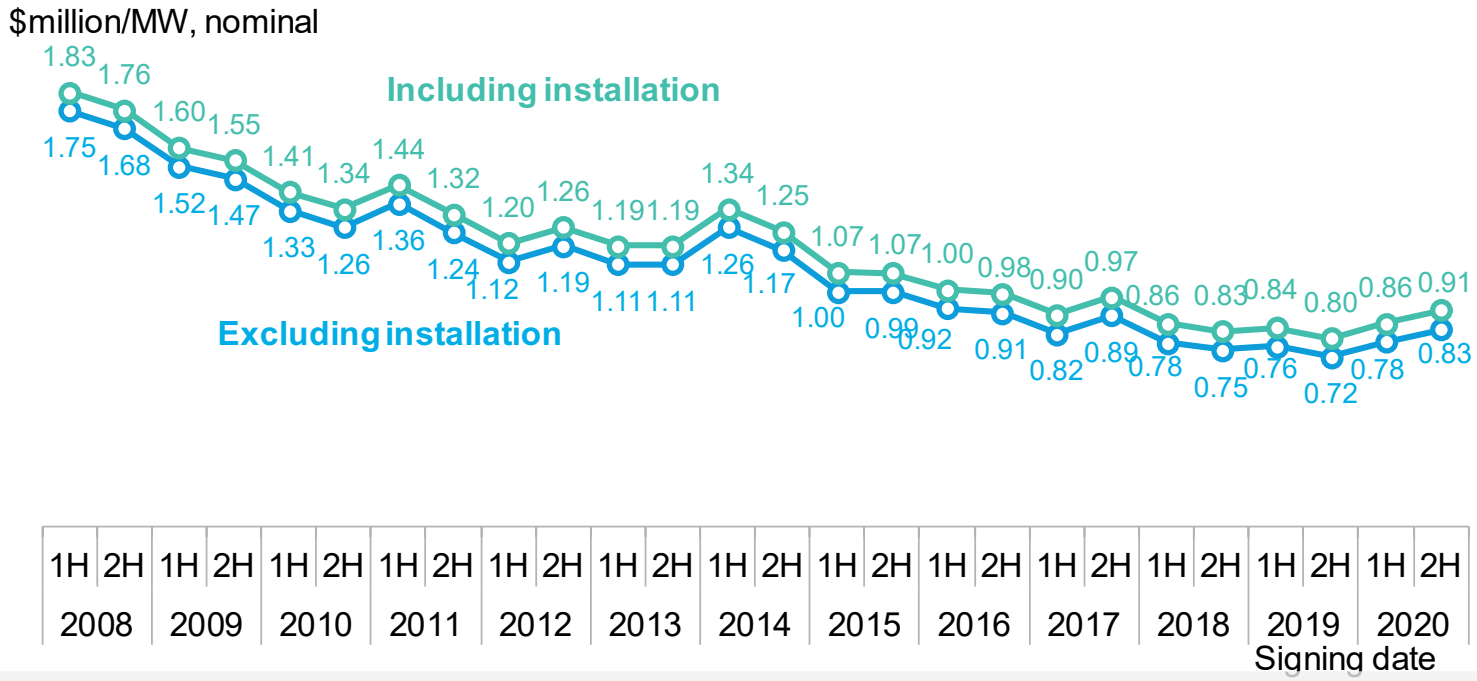
Source: adapted from EWEA, 2009.



Bloomberg New Energy Finance

Wind turbines are reducing LCOE by using bigger rotors, increasing the hub height and improving the design to extract more energy from the same power

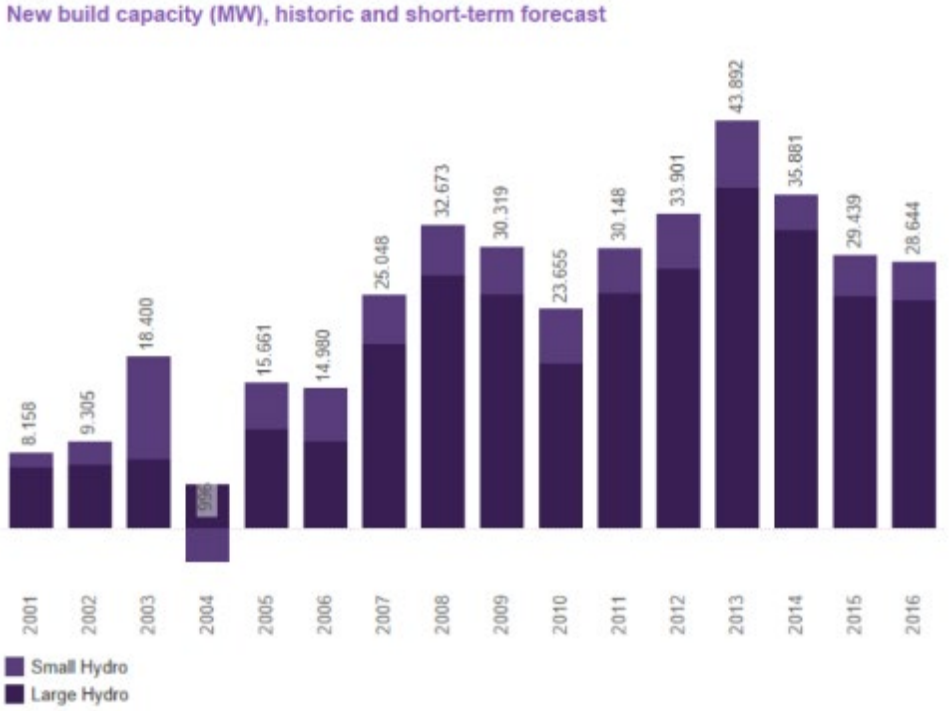
WIND - Turbine price per MW by signing date



Also unitary price decreases steadily but not as fast as solar

Source: BloombergNEF. Note: All index prices are nominal.

HYDRO

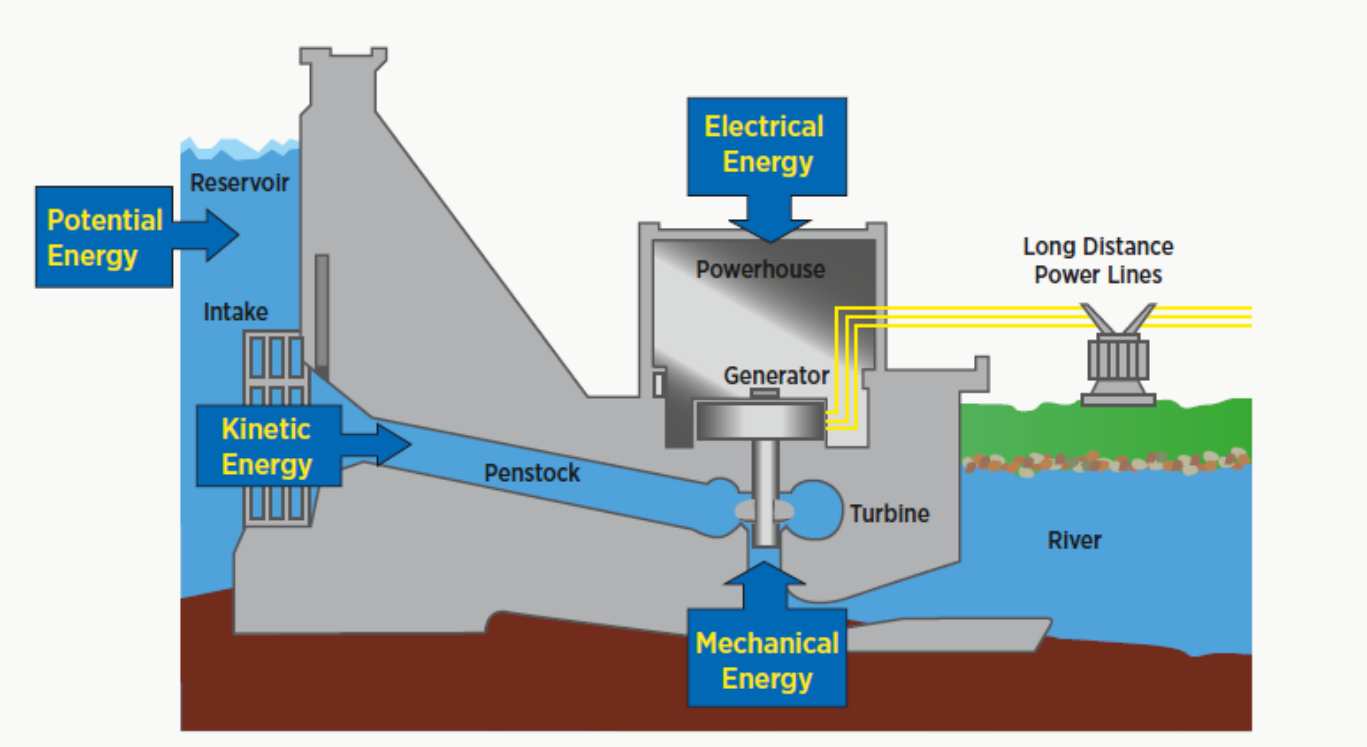


The more mature, still space for moderate development.

Source: Bloomberg New Energy Finance, BNEF

Hydro technology

Basic



Hydropower is:

1. *a renewable*
2. *reduce risks of energy price volatility*
3. *can offer multiple co-benefits*
4. *rapid-response power when intermittent sources (like solar or wind) are off-line*
5. *Possibility to concentrate the production during peak hours*

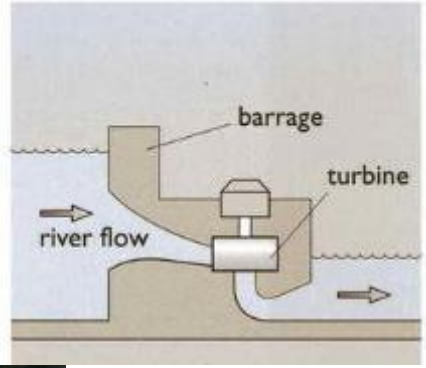
Hydro technology

Type of plants and electromechanical equipments

Run of River HPP

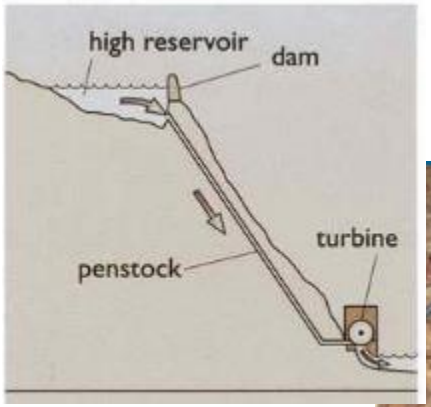
HPPs do not have capacity of regulation.

The instantaneous power depends on the instantaneous water flow.



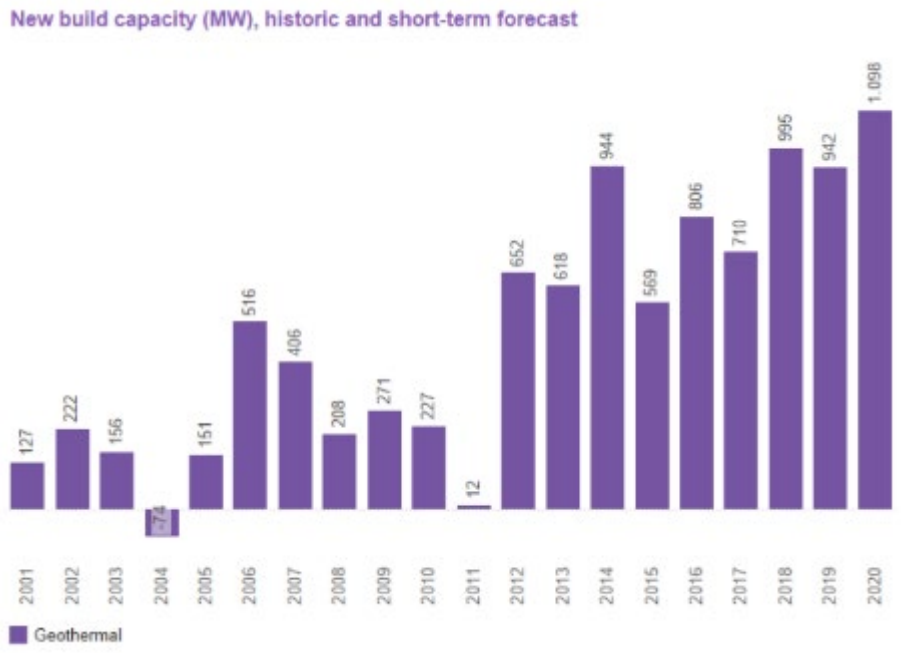
Reservoir HPP

A dam realizes a water ***reservoir***: This makes possible the regulation of the water and of energy produced.



Large plants need time. Environmental impact to be deeply assessed.
The first case of power storage in the electricity history.

GEOTHERMAL

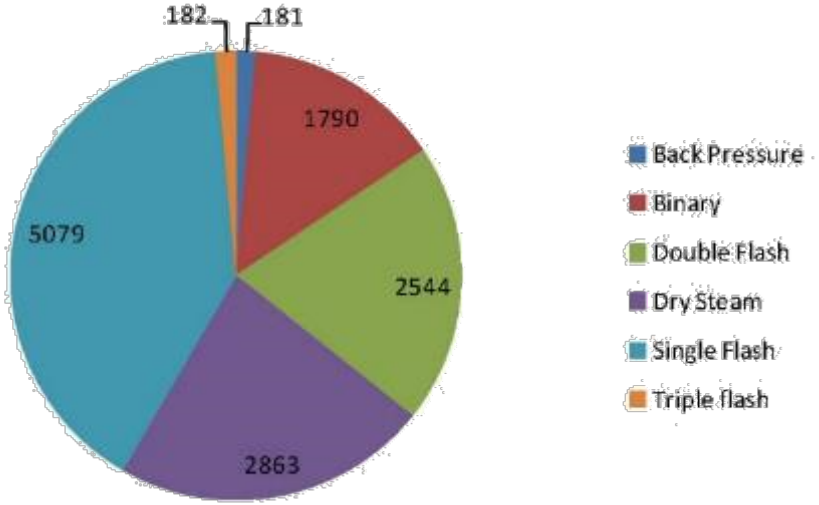


Limited availability of resource, localized. High load factors.

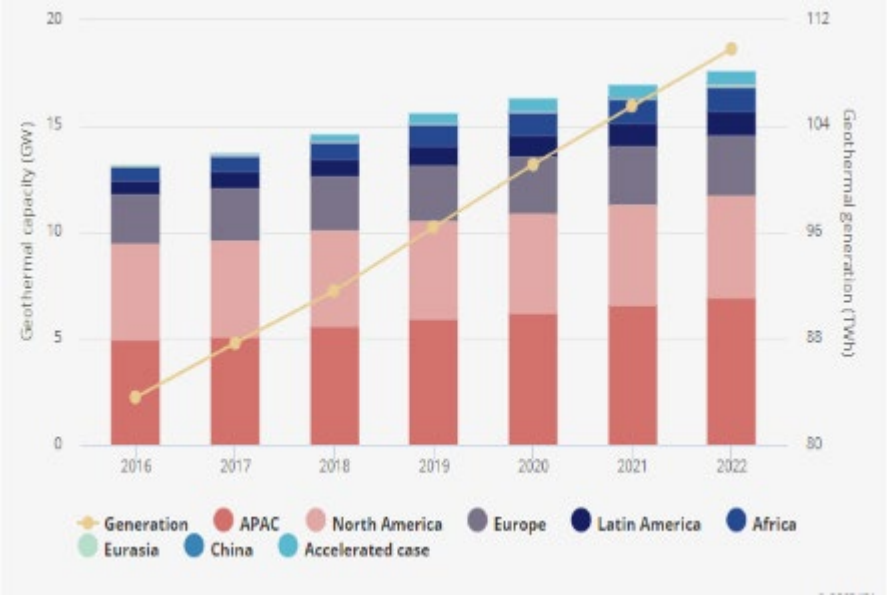
Source: Bloomberg New Energy Finance, BNEF

Geothermal installed capacity by technology

World total amount of geothermal power plant installed capacity up to 2015 was about 12.6 GWe.

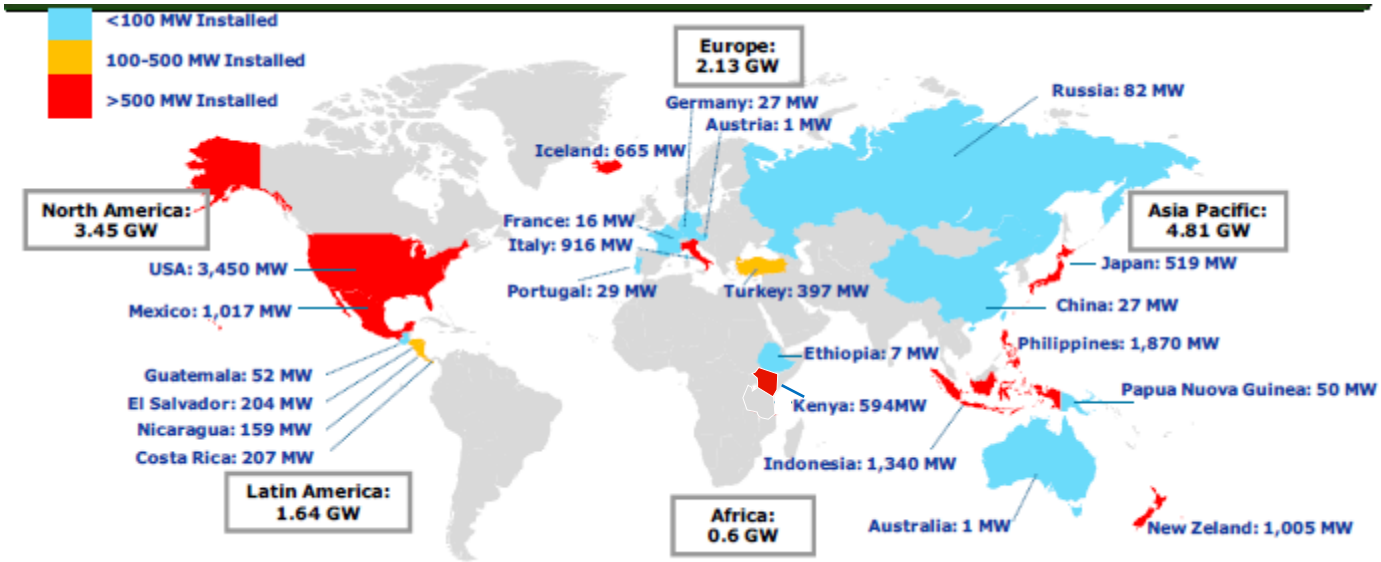


Geothermal power generation and cumulative capacity by region, 2016-2022



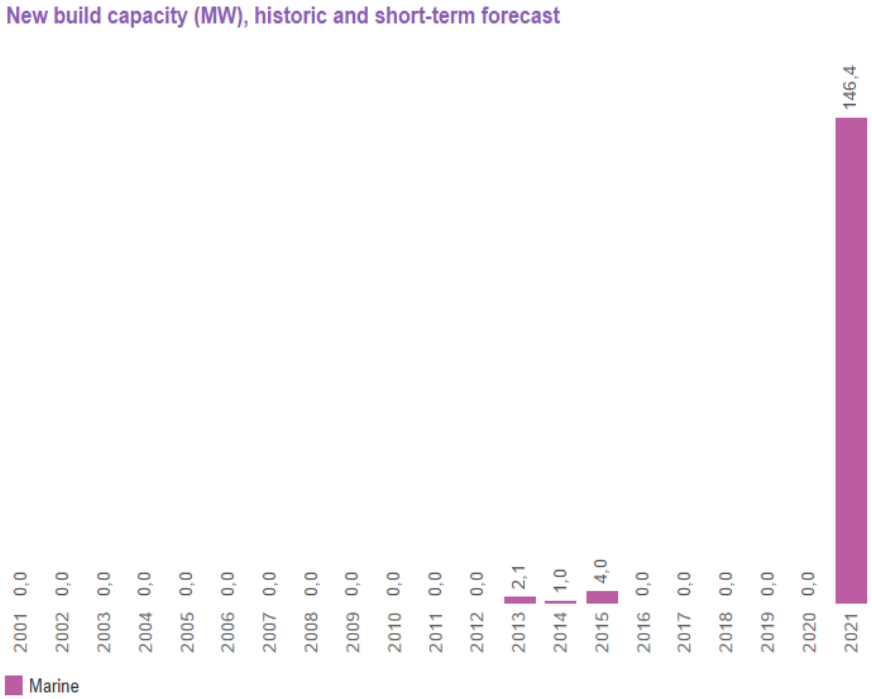
Source: IEA-GIA 2017

Geothermal energy installed capacity worldwide



Installed geothermal capacity worldwide in 2015 (12.6 GWe)

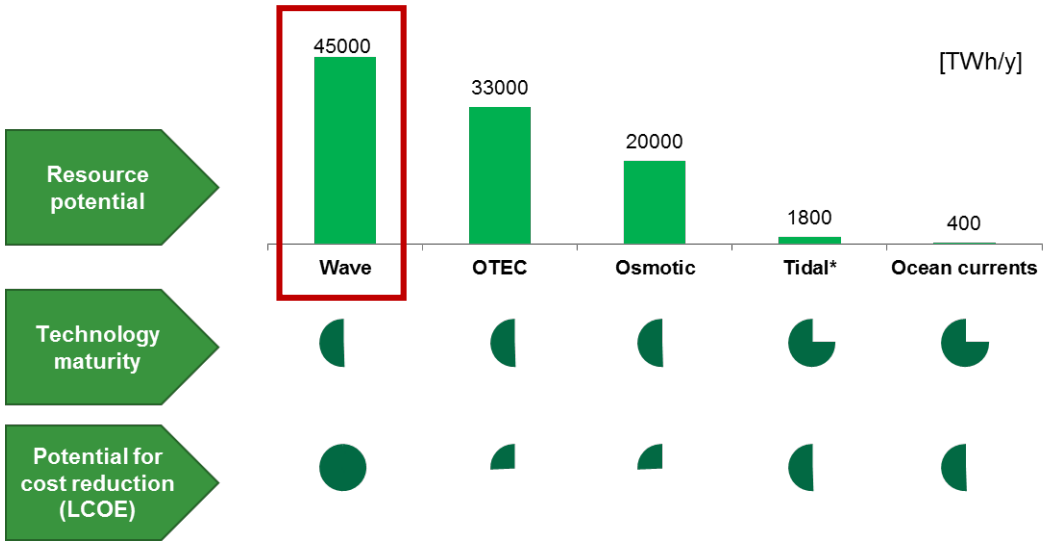
MARINE



Very early stage, only demonstrative projects. High potential.

Source: Bloomberg New Energy Finance, BNEF

Marine Energy

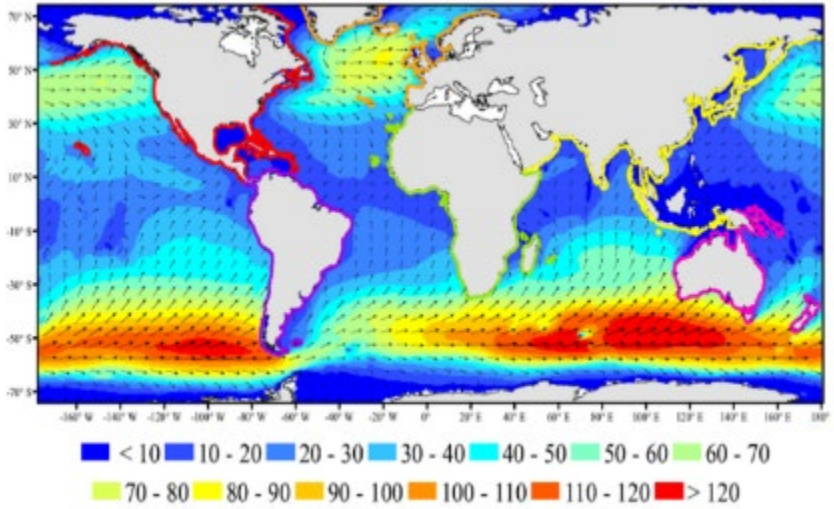


- **Marine** energy looks very attractive in terms of **future development** and **market potentials**
- Nowadays **technologies** are not mature and the **market** has to be built as well as the **supply chain**
- **Environmental impacts** are still a challenge

Source: Ocean Energy: Prospects & Potential, Isaacs & Shmitt with 15% utilization factor & 50% capacity factor

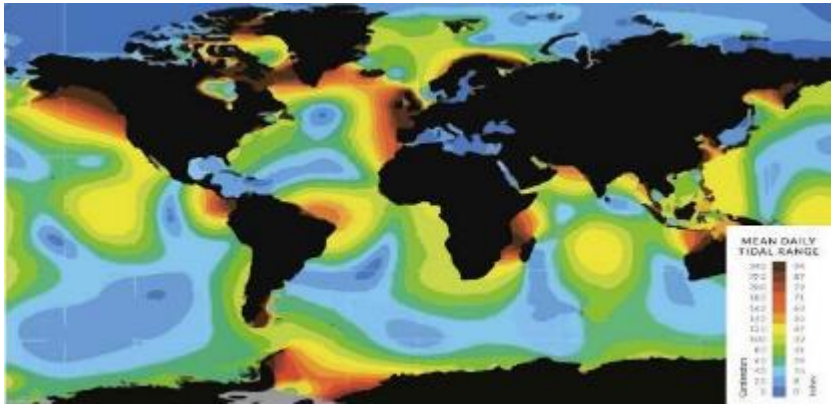
Marine Energy

Huge resource availability and predictability, heterogeneous and geographically distributed, looks very attractive in terms of **future development of the market**



Wave power potential

Annual mean wave-power level (kW/m), from Gunn & Stock-Williams (2012)



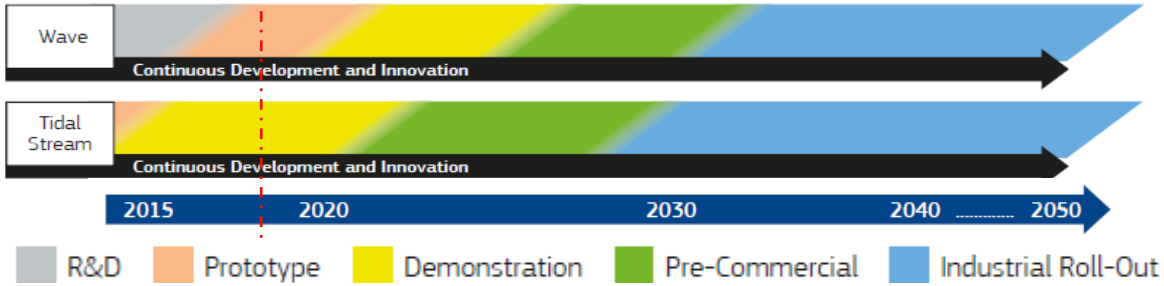
Tidal power potential

provided by *Electric Power Research Institute (EPRI)*

Technologies are not mature and market has to be created as well as the supply chain. Resource quite distributed and complementary with other sources distribution

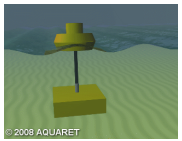
Marine Energy

Timeline for the development phase and main technologies Clusters

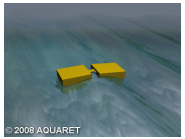


Source: Ocean Energy Europe consultation with Ocean Energy Forum

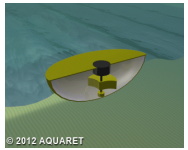
Wave Energy main technologies



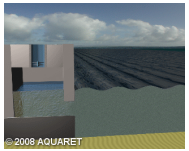
Point Absorber Submerged Pressure differential



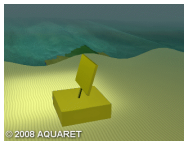
Attenuator



Inertial Rotating Mass

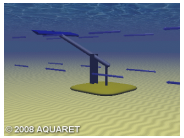


Oscillating water column

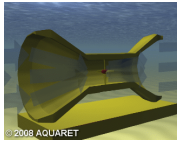


Oscillating wave surge converter

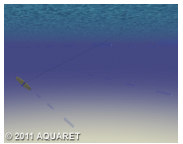
Tidal Stream Energy main technologies



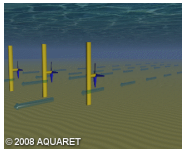
Oscillating Hydrofoil



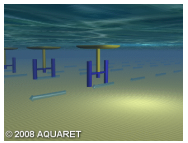
Enclosed tips



Tidal kite



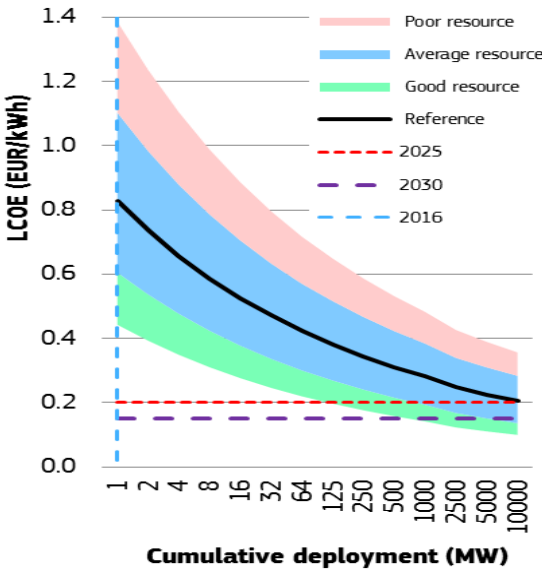
Horizontal Axis turbine



Vertical Axis turbine

Marine Energy

LCOE predictions for wave and tidal arrays



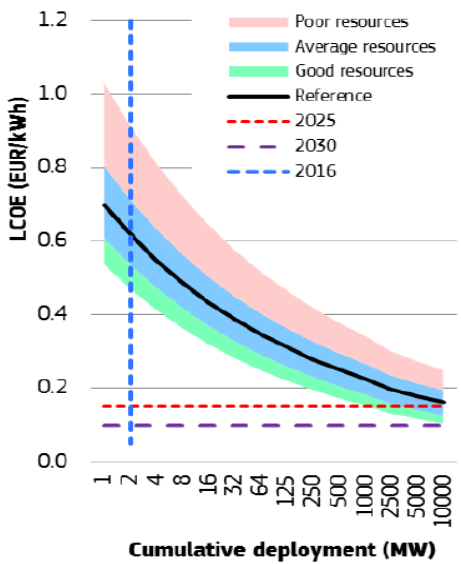
Wave arrays

2017 LCOE range between 60 – 110 c€/kWh

The 2025 targets agreed in the SET-Plan declaration of intent could be reached only after 10 GW of cumulative capacity has been installed and overcome them to reach the 2030 targets*

2025: 20 c€/kWh

2030: 15 c€/kWh



Tidal arrays

2017 LCOE range between 54 – 71 c€/kWh

To meet the 2025 targets agreed in the SET-Plan declaration of intent, the cumulative capacity of tidal energy should reach 1000 MW to 10000 MW and overcome them to reach the 2030 targets*

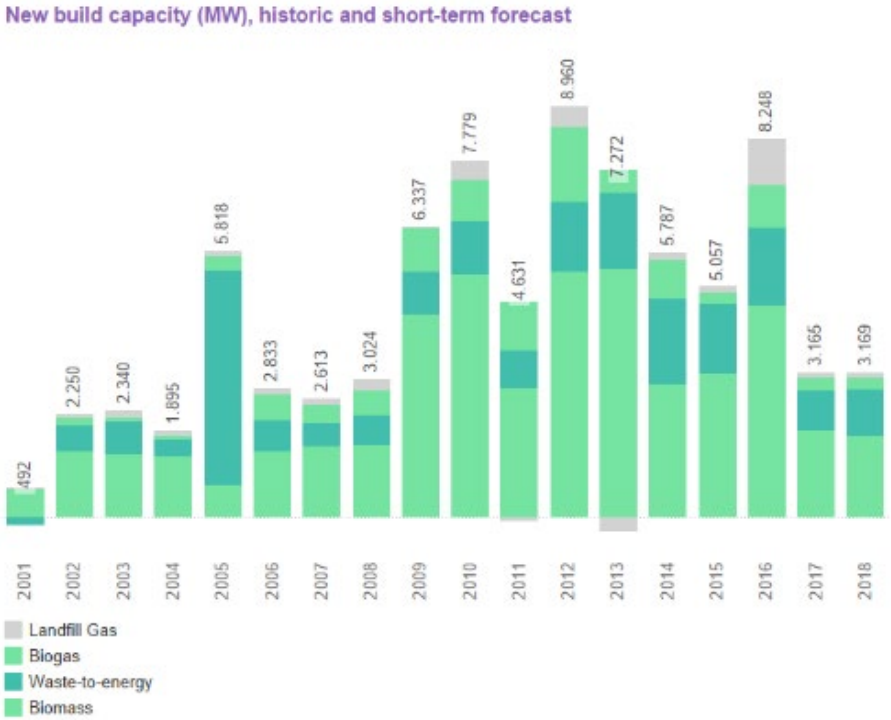
2025: 15 c€/kWh

2030: 10 c€/kWh

* LCOE predictions have been calculated with the learning rates 12% for CapEx and 3% for OpEx. - Low and High resource were represented by using different CFs

Source: JRC Ocean Energy Status Report 2016 closing Report

BIOMASS

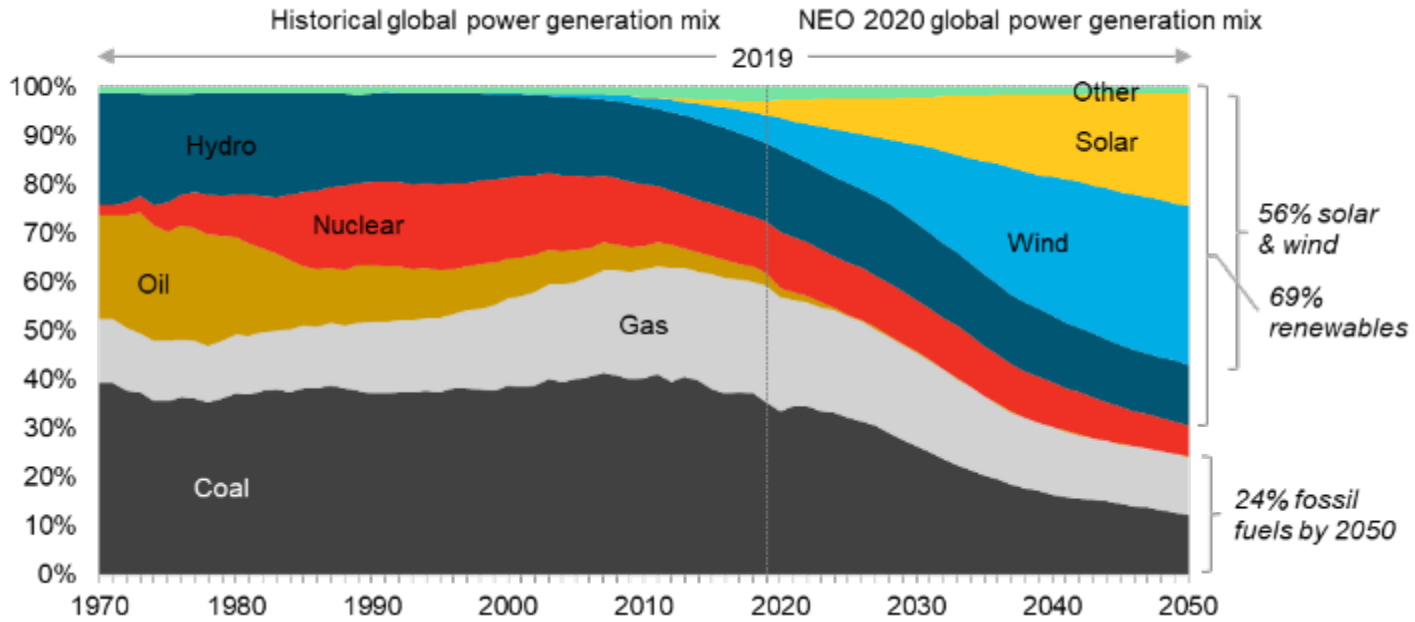


Good solution in case of easy and sustainable resource. Moderate development.

Source: Bloomberg New Energy Finance, BNEF

Renewable technologies: a quiet revolution
WHAT'S NEXT?

Global generation mix

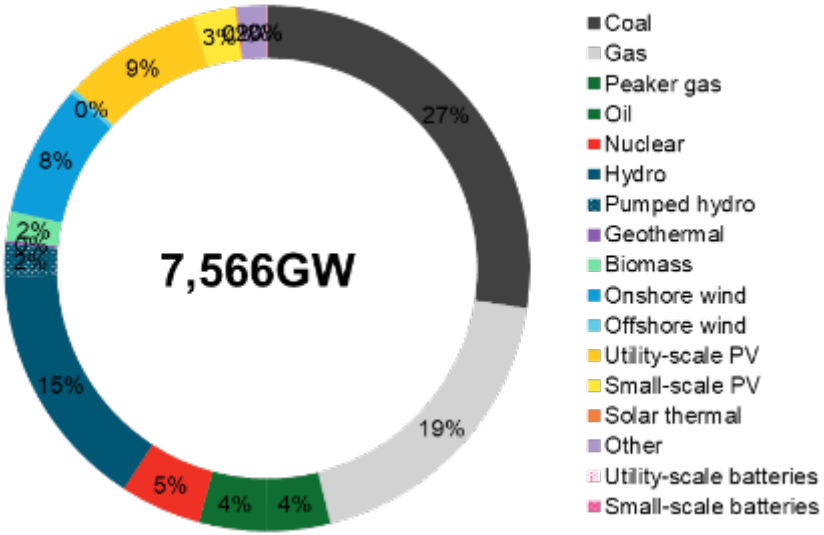


No story in the long run.

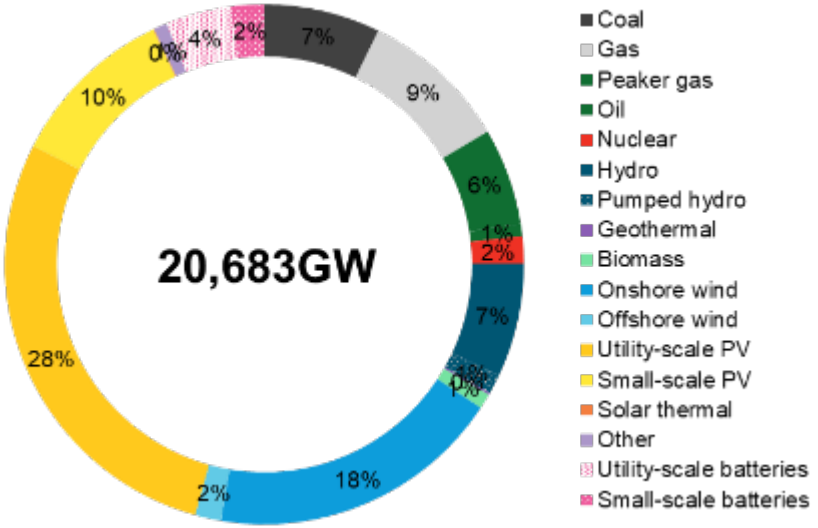
Source: Bloomberg New Energy Finance 2020

The future of electricity: sun, wind and flexible capacity

Global cumulative installed capacity (GW): 2019



Global cumulative installed capacity (GW): 2050

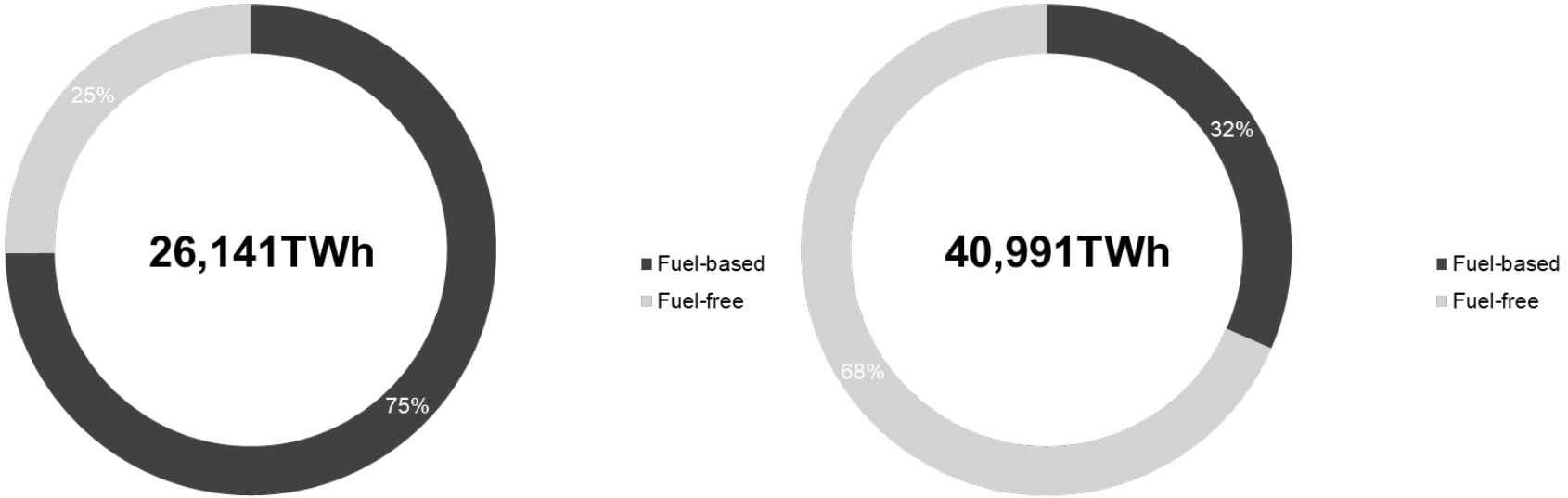


The share of Renewables in power generation almost 70% by 2050.
Increasing need for flexible capacity such as storage and demand response.

Source: Bloomberg New Energy Finance, BNEF New Energy Outlook 2020

RES will dominate also in terms of generation

Global electricity generation mix 2019 - 2050



In terms of energy generation, two thirds will come from Renewables by 2050.

Source: Bloomberg New Energy Finance, BNEF New Energy Outlook 2020

CONCLUSIONS

- Final uses more and more electric thanks to Urbanization, EV, Heat Pumps, …
- Electrification pushing the global electricity demand up
- Global warming urging for clean energy
- Storage and digitalization driving the time decoupling between production and consumption and solving any grid stability issue and RES penetration
- Renewable energy competitive and still with large unexpressed potential of LCOE reduction, mainly for solar PV and wind

THE GOOD NEWS is that renewable energy has demonstrated the ability to solve the complex equation of sustainable and abundant power for all.
Anything Coal and Gas can do, Renewables and Energy Storage can do cheaper.

Renewable technologies: a quiet revolution
CHECK POINT

Check point

Three multiple answer questions

Choose the most appropriate answer, just one is correct!

Question 1

Solar PV is expected to be the cheapest source of power. Why?

1. The fuel costs zero
2. The production comes during the day when the consumption is higher
3. The technology improvement potential is the highest due to intrinsic reasons such as direct conversion, modularity, synergies with electronics, etc.
4. There is no emission (CO_2, pollutants, noise, radiations, etc.) during production
5. The conversion efficiency is very high compared to other sources
6. The capacity factor is very high

Question 2

LCOE allows to compare competitiveness of any power generation systems.

1. YES, because it considers all the elements that contributes to calculate the average cost of the electricity produced all along the useful life of the plant.
2. YES, as for point 1, but only for fossil fuel free sources.
3. NO, it allows to compare only the cost of produced energy without considering operation and maintenance costs that can heavily affect the return of the investment.
4. NO, it allows to have an estimation of final prices of electricity to end users.
5. YES, because by means a complex algorithm it gives the average value of last competitive processes all around the world such as public and private auctions, PPAs, feed in tariff, etc.
6. NO, it is an important KPI to evaluate the efficiency (as the ratio between produced energy and consumed) of a specific technology

Question 3

Batteries (and hydrogen) will play a key role in the development of renewables. Why?

1. The diffusion of many battery equipped devices (including electric vehicles) will increase electricity consumption and it will push renewables growth.
2. The energy produced by emerging renewable technologies (wind and solar) depends on the natural source and cannot be adjusted to match the load. Batteries and hydrogen are entitled to do this.
3. The efficiency of wind and solar plants increases if they are equipped with battery storage.
4. Batteries stabilize the voltage level of the grid and this allows the renewables to produce more and better.
5. The development of the battery technology for electric vehicles is stimulating important innovations in wind and solar technology.
6. Batteries allows to improve the technical parameters of electricity produced by wind and solar plants such us wave form, harmonics, spikes, etc.

CONCLUSIONS

There’s a guy in a forest in the rain and he’s dying of thirst.

He has an axe and he starts cutting down the trees to drink the sap. A mouthful in each tree.

All around him is a wasteland, no wildlife, and he knows that thanks to him the forest is disappearing fast.

So why doesn’t he just open his mouth and drink the rain?

Ian McEwan, Solar