Renewable energy economics and trends in renewable energy commercialization & investment

TAIEX Regional Workshop on Renewable Energy Sources

organised in co-operation with Ministry of Civil Affairs of Bosnia and Herzegovina

Bihać, Bosnia and Herzegovina, 15 – 16 November 2018

Author: prof. **Željko TOMŠIĆ**, Ph.D.

University of Zagreb
Faculty of Electrical Engineering and Computing
Department of Power and Energy Systems

November 2018

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INTRODUCTION

- In the last decade, there has been a major uptake in various forms of renewable energy, beyond the proof of concept stage, to mainstream use as a **commercial alternative to fossil-fuel based energy generation**.

RENEWABLE ENERGY SOURCES

- Costs of RES are divided into three groups, according to:
  - **Direct costs,**
  - **System costs,**
  - **Macroeconomic impact.**
- **Direct costs** represent the levelized cost of electricity (LCOE), i.e. they consist of the costs of construction and financing costs, fixed operating and maintenance costs (FO&M), variable operating and maintenance costs (VO&M) and fuel costs. LCOE allocates the costs of and energy plant across its useful life, to give an effective price per each unit of energy (kWh).
- **System costs** represent additional costs incurred by connecting the production unit to the network and consist of balancing costs (balancing energy), network costs (upgrading/construction of the grid, transmission losses, congestions etc.), and integration costs (needed reserve).
- The **macroeconomic impact** is related to the effects of the GDP and social welfare, the unemployment rate and the distribution of damage or benefits within individual sectors.

RENEWABLE ENERGY SOURCES

- **Costs of RES integration**
  - Large use of RES (wind and Sun) results in unique problems that lead to a higher cost of their integration in the power system:
    - **Variability of energy resources**, i.e. the output power of solar and wind power plants depends on the weather conditions and cannot be controlled in the same way conventional power plants can.
    - **Production is unpredictable**, meaning that every deviation between the actual production and the planned production has to be balanced in the short term, which creates the need to maintain reserves in the power system.

EU 2020 Energy Strategy

- By 2020, the EU aims to reduce its **greenhouse gas emissions by at least 20 %**, increase the share of **renewable energy to at least 20 %** of consumption, and achieve **energy savings of 20 %** or more.
- All EU countries must also achieve a 10% share of renewable energy in their transport sector.
- Through the attainment of these targets, the EU can help **combat climate change and air pollution**, decrease its **dependence on foreign fossil fuels**, and keep energy affordable for consumers and businesses.
- **The package sets three key targets:**
  - **20 % cut in greenhouse gas emissions (from 1990 levels)**
  - **20 % of EU energy from renewables**
  - **20 % improvement in energy efficiency**

EU 2020 Energy Strategy: Meeting the targets

- In order to meet the targets, the 2020 Energy Strategy sets out five priorities:
  - **Making Europe more energy efficient** by accelerating investment into efficient buildings, products, and transport.
  - **Building a pan-European energy ma**rket by constructing the necessary transmission lines, pipelines, LNG terminals, and other infrastructure.
  - **Protecting consumer rights** and achieving high safety standards in the energy sector. This includes allowing consumers to easily switch energy suppliers, monitor energy usage, and speedily resolve complaints
  - **Implementing the Strategic Energy Technology Plan** – the EU's strategy to accelerate the development and deployment of low carbon technologies such as solar power, smart grids, and carbon capture and storage
  - **Pursuing good relations with the EU's external suppliers of energy and energy transit countries. Through the Energy Community, the EU also works to integrate neighbouring countries into its internal energy market.**

EU 2030 Energy Strategy

- In October 2014 The European Council agreed on a **new 2030 Framework for climate and energy**, including EU-wide targets and policy objectives for the period between 2020 and 2030.
- These targets aim to help the EU achieve a **more competitive, secure and sustainable energy system** and to meet its long-term 2050 greenhouse gas reductions target.

EU Targets for 2030

- a **40 % cut in greenhouse gas** emissions compared to 1990 levels
- **at least a 27 % share of renewable energy consumption**
- indicative target for an improvement in **energy efficiency at EU level of at least 27 %** (compared to projections), to be reviewed by 2020 (with an EU level of 30% in mind)
- support the **completion of the internal energy market** by achieving the existing electricity interconnection target of 10% by 2020, with a view to reaching 15% by 2030

EU Policies for 2030-new target of 32% from renewables by 2030

- New EU ambitious targets for renewables, including self-consumption and biofuels, were agreed by Parliament and Council negotiators.

- **Parliament and Council provisionally agreed on a share of energy from renewables of at least 32%** of the Union's gross final consumption in 2030, with an upwards revision clause by 2023.

EU 2050 Energy Strategy

- The EU has set itself a long-term goal of reducing greenhouse gas emissions by 80-95%, when compared to 1990 levels, by 2050.
- The Energy Roadmap 2050 explores the transition of the energy system in ways that would be compatible with this greenhouse gas reductions target while also increasing competitiveness and security of supply.
- To achieve these goals, **significant investments** need to be made in new **low-carbon technologies**, **renewable energy**, **energy efficiency, and grid infrastructure**.

Renewable Energy Directive (RED)*

- Therefore, the **adoption of the Renewable Energy Directive in December 2008 represents an historical moment for the further development of wind power in Europe**.
- The Directive is a breakthrough piece of legislation that enabled wind power and other renewables to push past barriers and confirms Europe as the leader of the energy revolution the world needs.
- Under the terms of the directive, for the first time each Member State has a **legally binding renewable target** for 2020 and by June 2010 each Member State will have drawn up a National Action Plan (NAP) detailing plans to meet their 2020 targets.

* *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources.*

Renewable Energy Directive

Key aspects of the Directive are:

1. **Legally binding national targets** and indicative trajectory.
2. **National Action Plans** (NAPs): the directive legally obliges each EU Member State to ensure that its 2020 target is met and to outline the 'appropriate measures' it will take do so, by drafting a National Renewable Energy Action Plan (NAP) to be submitted by 30 June 2010 to the European Commission.
3. **Priority Access to the electricity grid**: The Directive requires that EU countries take "the appropriate steps to develop transmission and distribution grid infrastructure, intelligent networks, storage facilities and the electricity system ...

Update of the Renewable Energy Directive for the period 2021 – 2030 (RED II)

- As part of its '**Clean Energy for all Europeans**' package, the European Commission in 2016 proposed an **update of the Renewable Energy Directive** for the period 2021 – 2030 (**RED II**).
- A final compromise document was agreed among EU Institutions on June 14, 2018
- The RED II compromise raises the overall EU target for Renewable Energy Sources (RES) consumption by 2030 **to 32%.**

Update of the Renewable Energy Directive for the period 2021 – 2030 (RED II)

- The **recast RES directive** provides **guiding principles on future financial support schemes for RES**, renewable energy self-consumption, renewable energy communities, and district heating and cooling systems.

- The recast directive **enhances mechanisms for cross-border cooperation**, simplifies administrative processes and outlines measures to mainstream the use of RES in the transport and heating and cooling sector.

- The recast directive strengthens the sustainability and greenhouse gas emissions savings criteria for biofuels.

EU'S RENEWABLE ENERGY HISTORY

2001

Renewable Electricity Directive

Indicative 22.1% share of renewable **power** in 2010

National **indicative** targets for renewable **electricity**

2009

Renewable Energy Directive - 1

EU-binding target of 20% share of renewable **energy** in 2020

National **binding** targets for renewable **energy** by 2020

2018

Renewable Energy Directive - 2

EU- binding target of 32% share of renewable **energy** in 2030

National energy and climate plans with **contribution** in **renewable energy share** to achieve EU- wide target

Indicative formula to assess national contributions

Investment risk in RES

- Investments in renewable energies are characterised by **high upfront costs and low operational costs**.
- Once an investment decision has been taken, investors have little room for adapting it to changing regulatory and market conditions.
- **Political or regulatory uncertainty increases the risk for investors**, and consequently **raises the cost of capital**, making the overall investment more costly.

Investment risk in RES

- Support for RES also affects investments in conventional power plants.
  - As Member States give electricity from renewable sources **priority access to the power grid**, some conventional plants are needed only in periods of peak demand or low RES production.
  - As a result, **investments in conventional plants become less attractive**.
  - Some Member States have therefore introduced or consider introducing **payments for reserve generation capacity**, in order to ensure that enough power plants are available to handle demand peaks.

Support schemes for renewables

- Public interventions such as support schemes remain necessary to make certain renewable energy technologies competitive.
- To avoid **distorting energy prices** and the **market** however, these schemes should be **time-limited and carefully designed**.
- The EU has issued guidance on support schemes to help governments when they design or revise support schemes.
- Energy markets alone cannot deliver the desired level of renewables in the EU, meaning that **national support schemes may be needed** to overcome this market failure and spur increased investment in renewable energy.
- If these public interventions are not **carefully de**signed however, they **can distort the functioning of the energy market** and lead to higher costs for European households and businesses.

Renewable energy support schemes nationally

- **Overview of policy instruments implemented**
  - To reach its individual RES target, a mix of different policy instruments to support the development and deployment of RES is implemented by each MS.
  - The majority of policy instruments implemented focus thereby **on the power sector**, although also targets for specific RES shares in heating and cooling as well as for the transport sector have been introduced.
  - Types of policy instruments implemented include **regulatory policies, fiscal incentives as well as public financing.**

Renewable energy support schemes nationally

- **Key mechanisms** in national renewable energy support policies include:
  - **Feed-in tariffs (FIT)**
  - **Feed-in premiums (FIP)**
  - **Quota obligations with tradable green certificates**
  - **Loan guarantees**
  - **Soft loans**
  - **Investment grants**
  - **Tax incentives**
  - **Tendering schemes**
- Key mechanisms that have been introduced by various EU MS to increase RES within the power sector are **feed-in tariffs (FIT)** and **feed-in premiums (FIPs)**.

Renewable energy support schemes - FIT

- **Feed-in tariffs** are policy mechanisms designed to increase investment in renewable energy technologies by guaranteeing continuous retail prices for renewable energy plant operators for a given period.

- **FIT guarantee continuous retail prices for RES plant operators for a given period**.
  - The **cost for FIT can be funded through tax revenues** (i.e. the public budget), or be **placed on market participants** such as electricity suppliers or network operators, who then socialise these costs among electricity consumers.
  - **FIT provide predictability and stability**, both for the overall renewable energy landscape from a policy perspective and for the individual producers and investors with regard to their revenue.

Renewable energy support schemes - FIP

- **Feed-in premium** is a policy mechanism designed to increase investment in renewable energy technologies by providing an additional payment on top of the electricity market price – either as fixed payment or adapted to changing market prices – on which renewable energy plant operators sell their generated electricity on the market.
- In an **Feed-in premiums** (FIP) - limit both the price risks for plant operators and the risks of providing windfall profits at the same time.
- The **revenue risk is increased** in a FIP compared to a FIT.

Renewable energy support schemes – FIT & FIP

- Furthermore, FIT as well as FIP are price instruments that do not by themselves restrict quantity.
- The **government fixes the amount of funding available**; quantity is determined by the ratio of particular technology costs and amount of feed-in tariff granted for a particular technology.

Renewable energy support schemes

- With **quota obligations**, the government requires electricity distributors to obtain a fixed proportion of their electricity from renewable sources.
- If they do not produce enough renewable electricity themselves, they must obtain tradable certificates from RES producers.
- The **government sets the quantity, and the market determines the price**.

Renewable energy support schemes

- Another option for RES support are to use **tender or auction schemes** to allocate financial support to different renewables technologies and to **determine the support level** of other types of support schemes, such as feed-in systems, in a **competitive bidding procedure**.
- There are **different ways to design an auction**, but the **static sealed-bid and the dynamic descending clock auction** or a combination of the two have been used the most to support new renewable energy plants.
- Different **mitigation measures** exist to ensure that winning **bidders effectively implement** their project.
  - Tendering is used e.g. in Denmark, the Netherlands and France.

Renewable energy support schemes - Fiscal incentives

- **Fiscal incentives** such as **grants and investment subsidies** are the most popular policy mechanisms implemented to promote renewable heating and cooling.

Renewable energy support schemes

- Incentivising the deployment of **RES in a cost-effective manner remains a challenge** in an environment where the costs of technologies are changing rapidly.
- The recent trend moves away from schemes where **the government sets the level of support towards auctions in which market participants make competitive bids**.

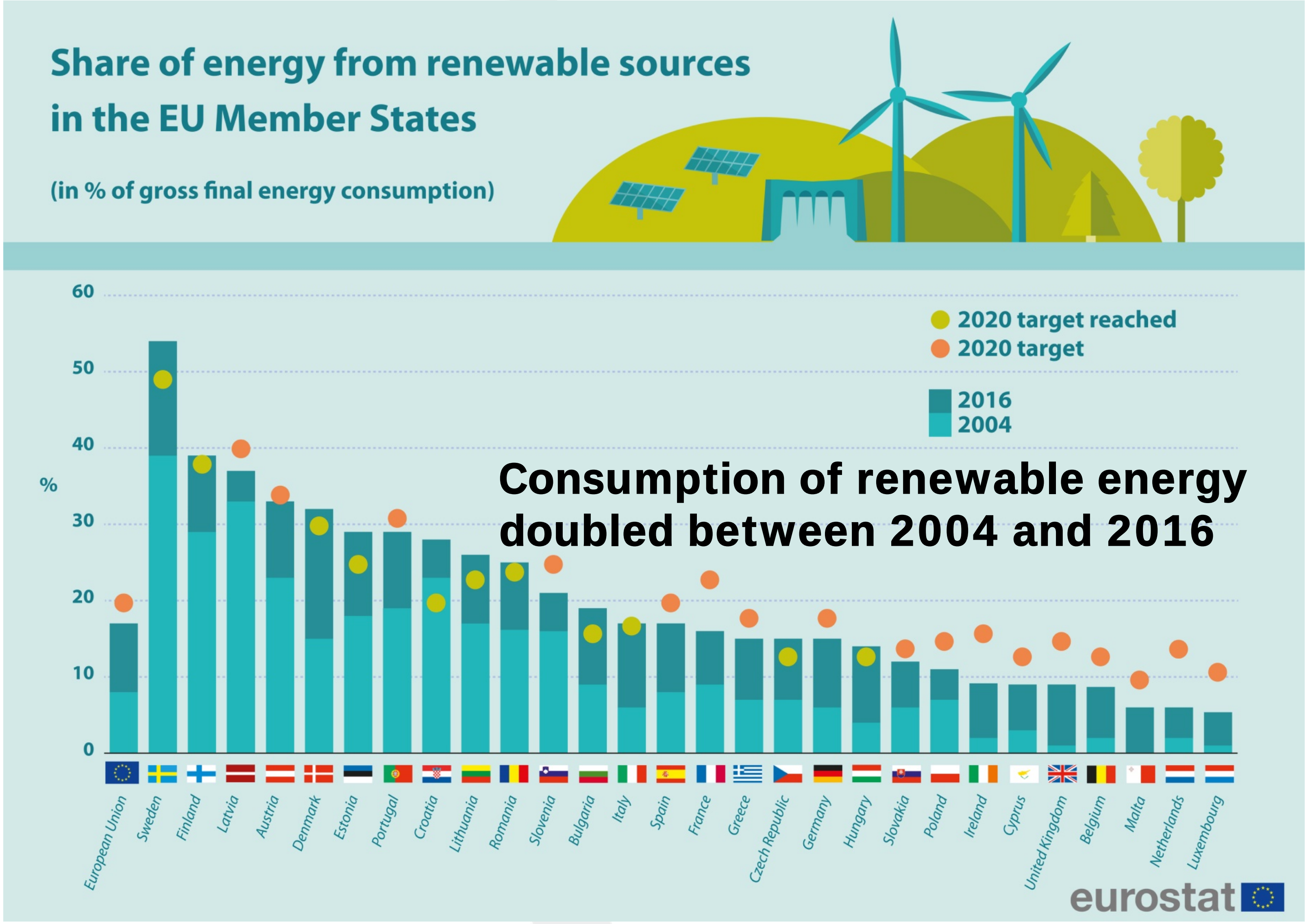
New state aid rules 2014 and implications for RES support schemes

- The European Commission has decided on **comprehensive rules for the assessment of state aid in the energy sector**.
- The text adopted on 9 April 2014 creates the framework for the ability of MS to grant state aid in this sector until 2020.
- These guidelines were published in the context of an intense debate on energy prices and the cost of support to RES.
- The new state aid rules foresee the gradual **introduction of competitive bidding processes** for allocating public support, while offering MS flexibility to take account of national circumstances.
- The guidelines also foresee the gradual replacement of FITs by FIPs, which expose RES to market signals.
- **Small installations** benefit from a special regime and can still be supported with FITs or equivalent forms of support.
- Furthermore, the rules **do not affect schemes already in place** that were approved under the existing rules.

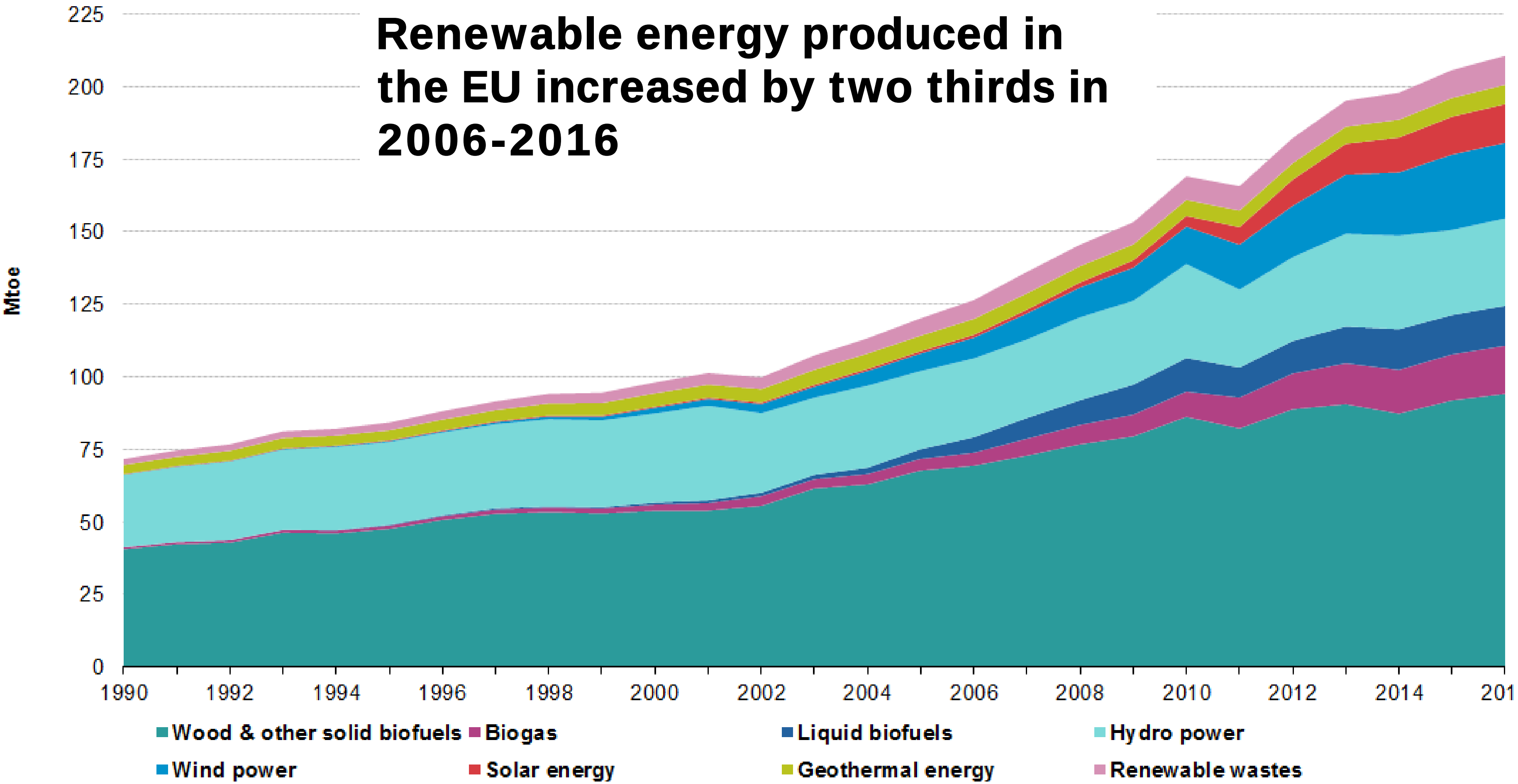
Guidance for renewables support schemes

- **The EU adopted guidance for EU countries** when designing and reforming **renewable energy support schemes**.
- This guidance (https://ec.europa.eu/energy/sites/ener/files/com_2013_public_intervention_swd04_en.pdf) suggests that :
  - **financial support for renewables should be limited** to what is necessary and should aim to make renewables competitive in the market
  - **support schemes should be flexible** and **respond to falling production costs**. As technologies mature, schemes should be gradually removed. For instance, **feed in tariffs should be replaced by feed in premiums and other support instruments** that incentivize producers to respond to market developments
  - unannounced or **retroactive changes to support schemes should be avoided** as they undermine investor confidence and prevent future investment
  - EU countries should take advantage of the renewable energy potential in other countries via **cooperation mechanisms**. This would keep costs low for consumers and boost investor confidence.

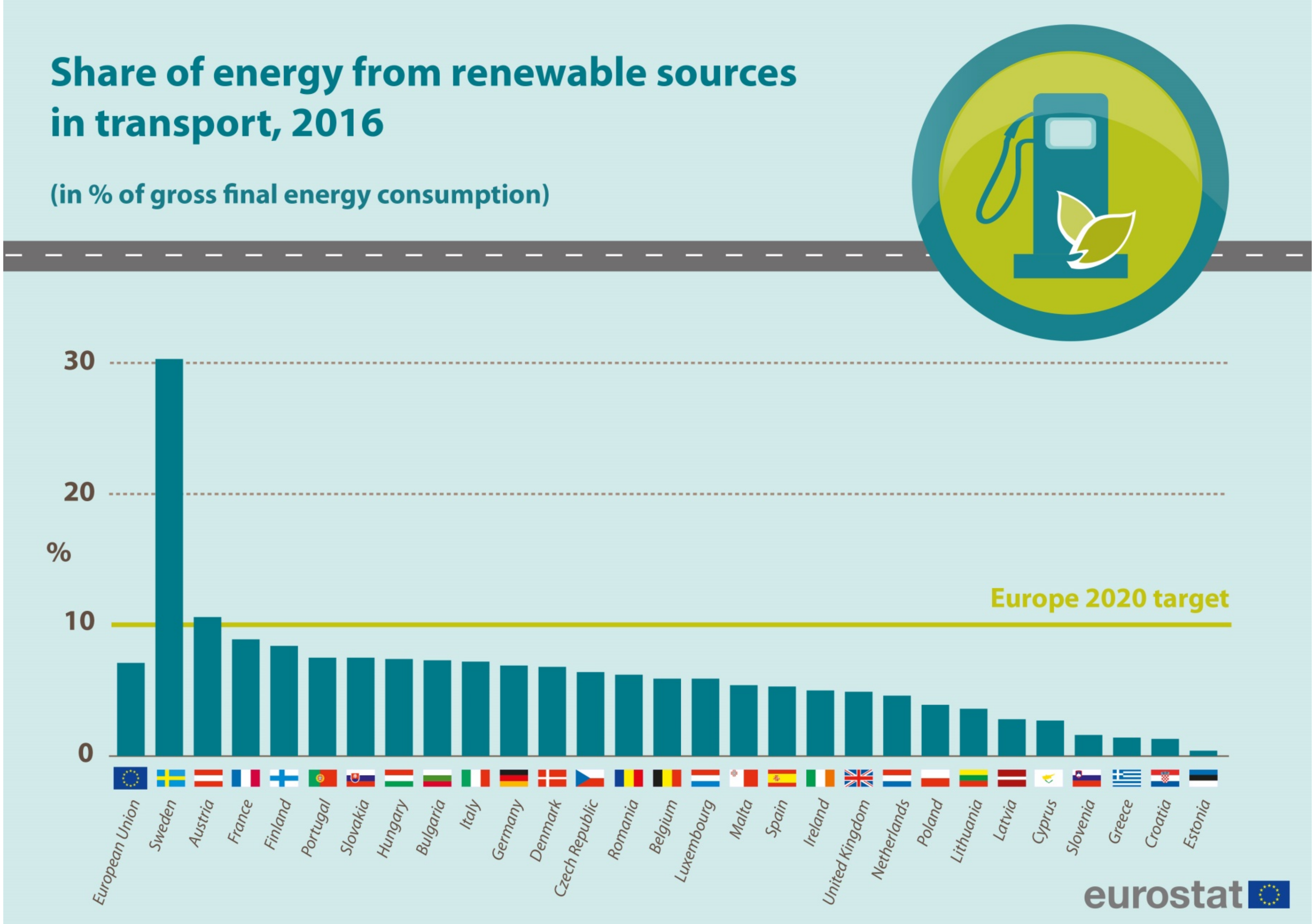
Share of energy from renewable sources 2004-2016



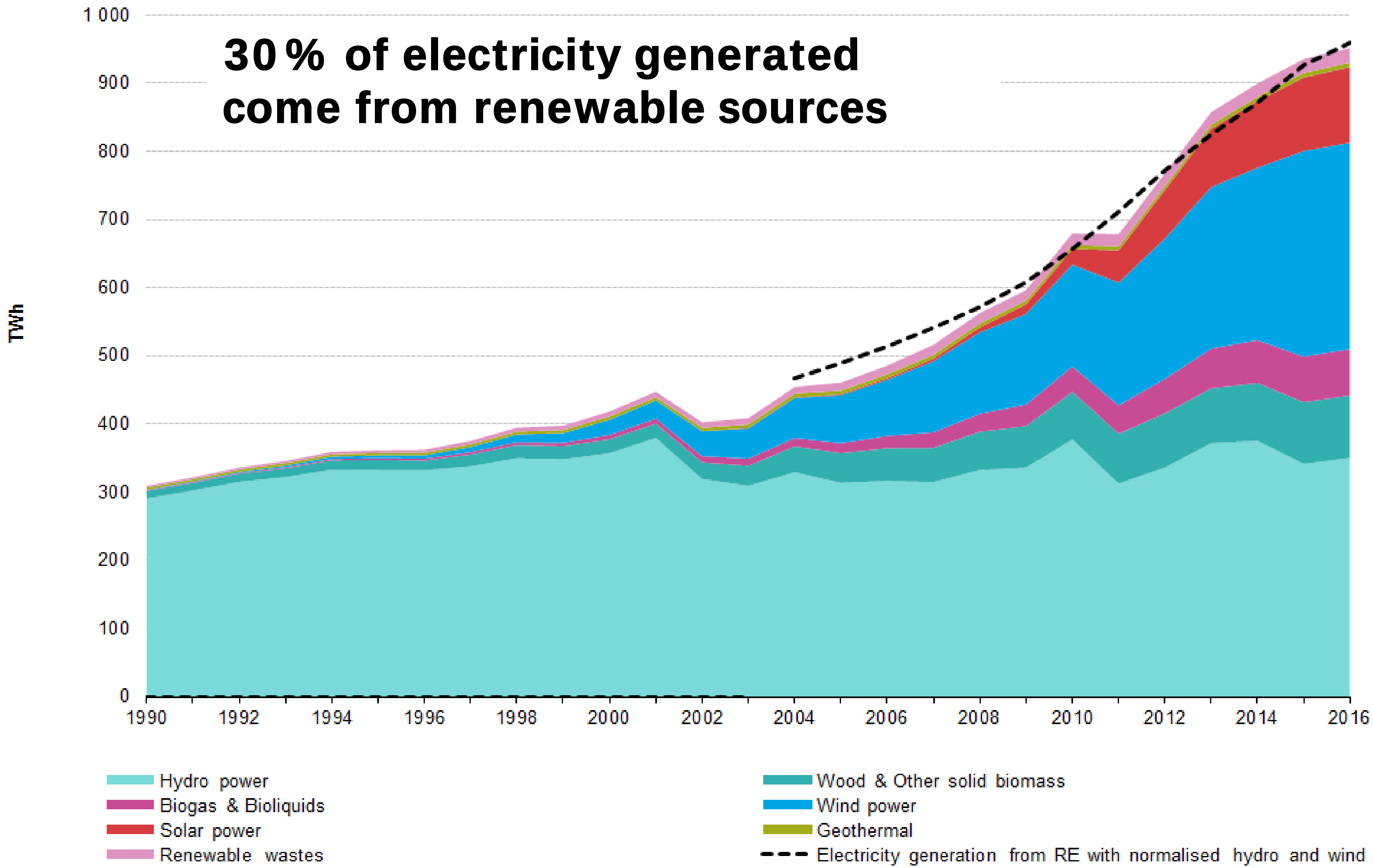
Primary production of energy from renewable sources, EU-28, 1990-2016



Share of renewable energy sources in transport, 2016 (in % of gross final energy consumption)



Gross electricity generation from renewable sources, EU-28, 1990-2016



Global Trends in Renewable Energy Investment 2017

- The renewable energy market continues to make remarkable progress.
- Last year was the eighth in a row that global investment in renewables exceeded US$200 billion.
- Much of this can be attributed to **falling costs for solar electricity**, and to **some extent wind power**, which continues to drive deployment.
- More electricity generated by renewable sources in 2017 signals **strong commitment to addressing climate change** and reducing carbon emissions.
- The world installed a record number of new solar power projects in 2017, more than net additions of coal, gas and nuclear plants put together.

Global Trends in Renewable Energy Investment 2017

- A **record** 157 gigawatts of **renewable power were commissioned** in 2017, up from 143GW in 2016 and far out-stripping the **70 GW of net fossil fuel** generating capacity added last year.
- **Solar** alone accounted for **98GW**, or **38%** of the net new power capacity coming on stream during 2017.
- The proportion of world electricity generated by wind, solar, biomass and waste-to-energy, geothermal, marine and small hydro **rose from 11% in 2016 to 12.1% in 2017.**
- This corresponds to approximately **1.8 gigatonnes of carbon dioxide emissions avoided.**

Global Trends in Renewable Energy Investment 2017

- **Global investm**ent in renewable energy edged up 2% in 2017 to **$279.8 billion**, taking cumulative investment since 2010 to $2.2 trillion, and since 2004 to $2.9 trillion.
- The latest rise in capital outlays took place in a **context of further falls in the costs of wind and solar** that made it possible to buy megawatts of equipment more cheaply than ever before.
- **The leading location** by far for renewable energy investment in 2017 **was China**, which accounted for $126.6 billion, its highest figure ever and no less than 45% of the global total.
- There was an **extraordinary solar boom** in that country in 2017, with some 53GW installed (more than the whole world market as recently as 2014), and solar investment of $86.5 billion, up 58%.

Global Trends in Renewable Energy Investment 2017

- **Europe suffered a bigger decline, of 36 %** to $40.9 billion.
- The biggest reason was a **fall of 65 % in U**.K.
- **Investment to $7.6 billion, reflecting an end to subsidies for onshore wind and utility-scale solar**, and a big gap between auctions for offshore wind projects.
- **Germany also saw a drop in investment**, of 35% to $10.4 billion, on lower costs per MW for offshore wind, and uncertainty over a shift to auctions for onshore wind.
- The latter change was also one reason, along with grid connection issues, for a fall in Japanese outlays of 28% to $13.4 billion.

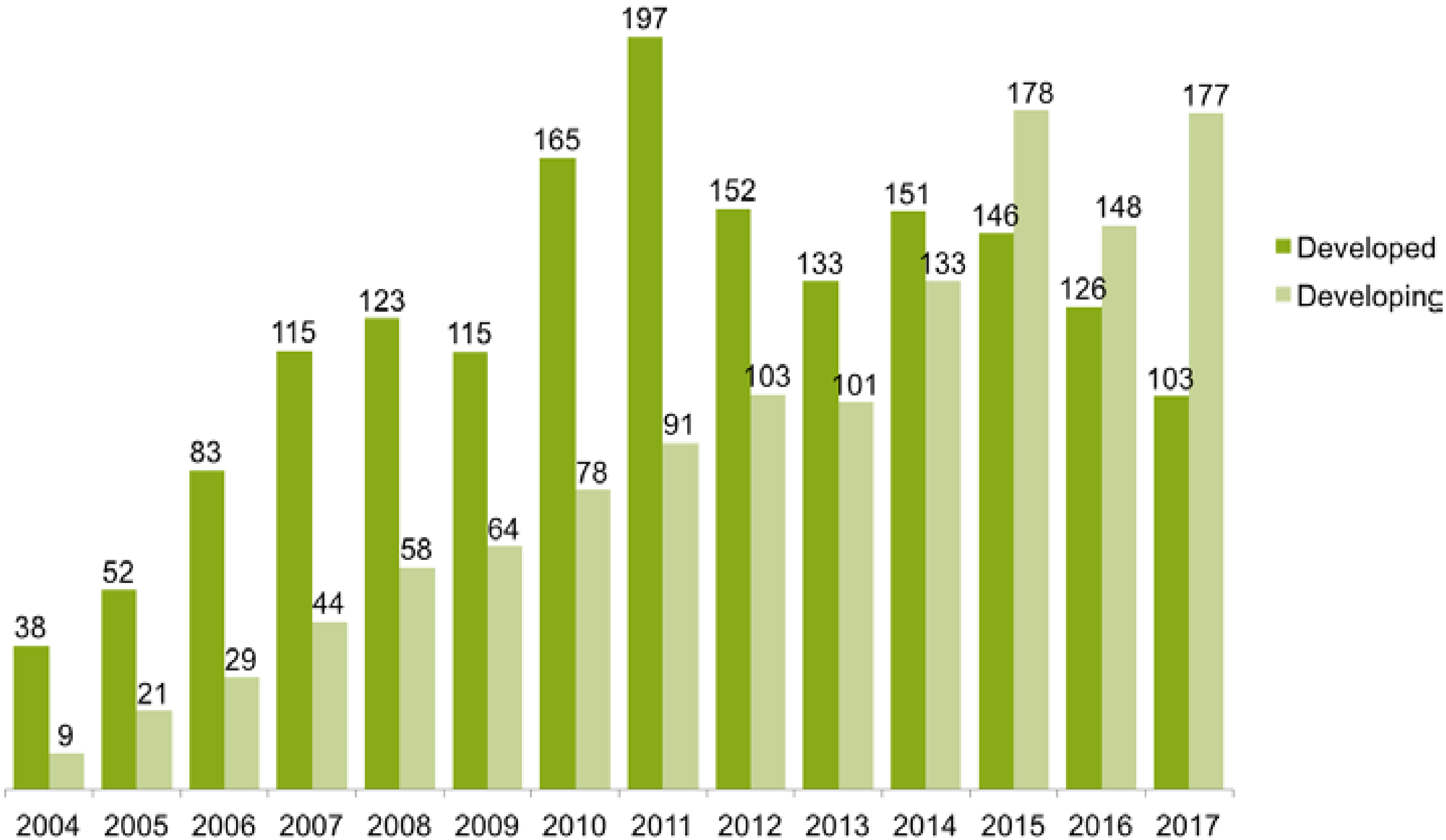
Global Trends in Renewable Energy Investment 2017

- In 2017, **costs continued to fall for solar, in particular**.
- The benchmark levelized cost of electricity for a **utility-scale photovoltaic** project **dropped to $86** per megawatt-hour, **down 15%** on a year earlier and **72% since 2009.**
- Some of this was due to a **fall in capital costs**, some to improvements in efficiency.
- **Renewable energy auctions** around the world once again **produced record-low figures** for the resulting tariffs.
  - In Mexico in November, **solar contracts were agreed at an average of $20.80 per MWh, and onshore wind at an average of $18.60**.
  - A U.K. auction in September saw offshore wind projects for commissioning in 2022-23 win through with bids 50% below the 2015 auction.

Global Trends in Renewable Energy Investment 2017

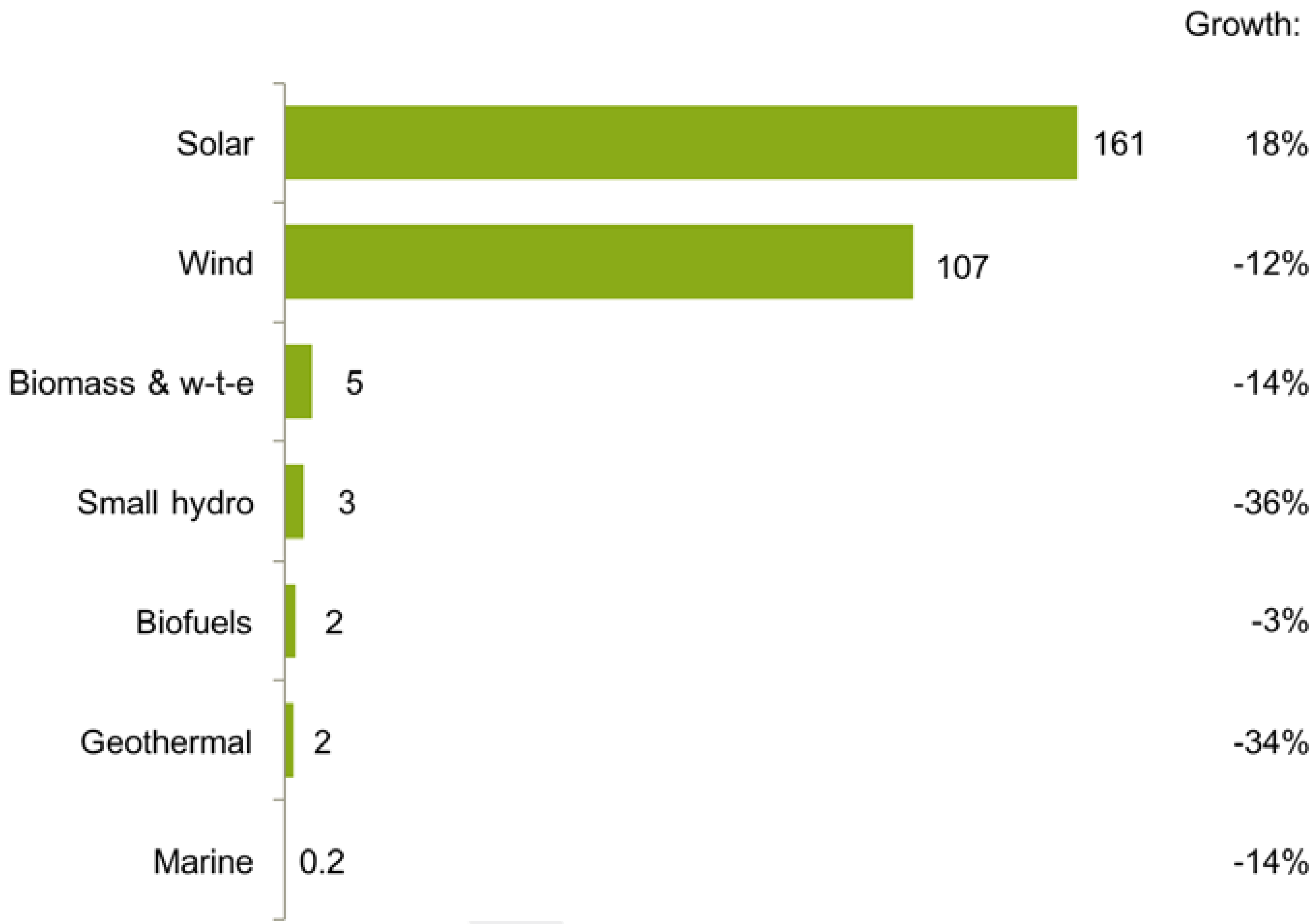
- One **uncertainty ahead** for renewable energy is how investors will take to the coming period in which project revenues **have no government price support**, and instead depend on **private sector power purchase agreements** or even just merchant power prices.
- Another potential issue for the sector in the years ahead could be **rising interest rates**.
- The **record-low rates of recent years** have helped to reduce overall costs per MW, and also attracted new capital from institutional investors into the financing of projects.

Global new investment in renewable energy: developed vs developing countries, 2004-2017, $BN

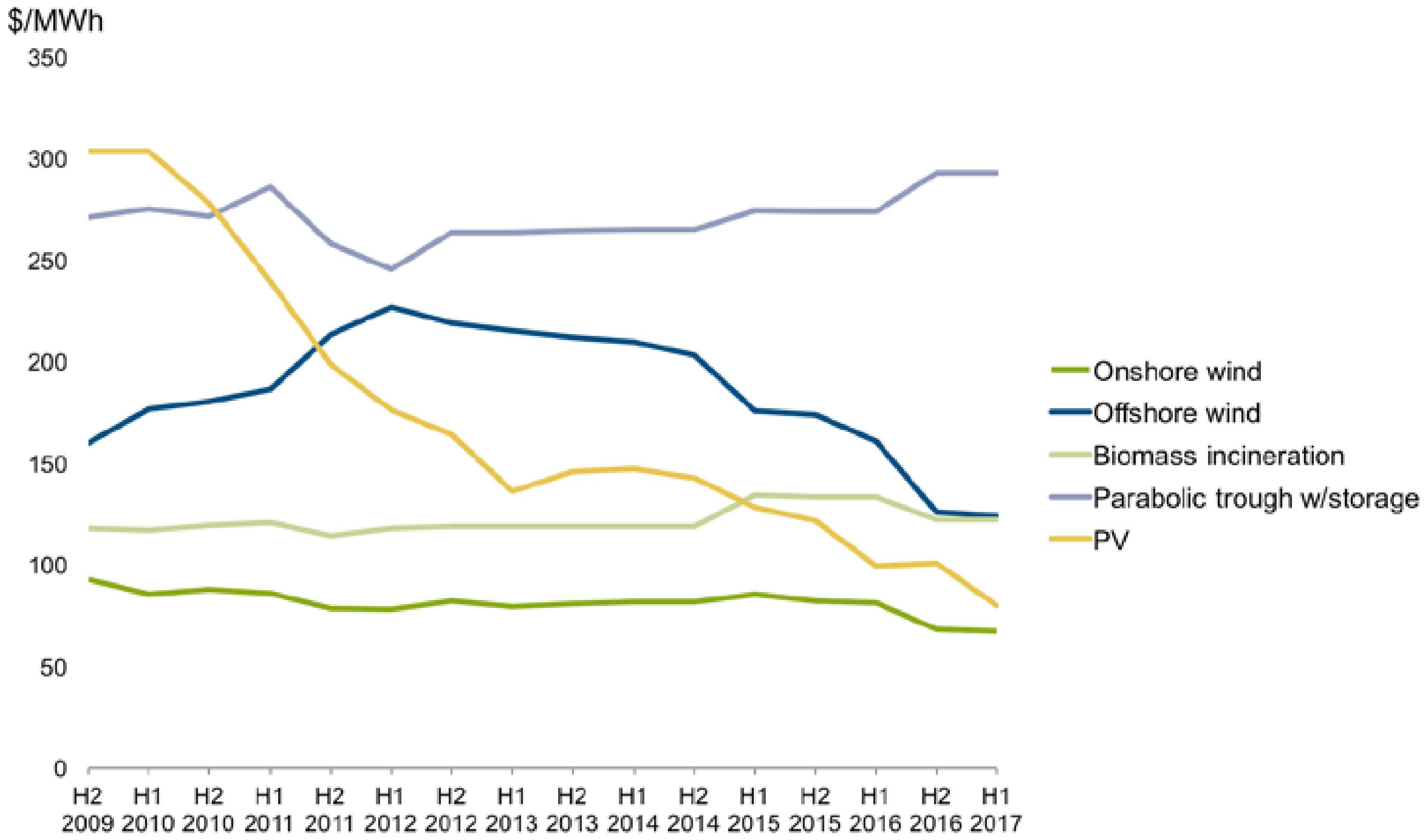


Global new investment in renewable energy by sector, 2017, and growth on 2016, $BN

- Indicates how **solar and wind dwarf the other renewable** energy sectors in terms of overall investment



Levelized cost of electricity, by renewable energy technology, 2009 TO 2017, $ PER MWH

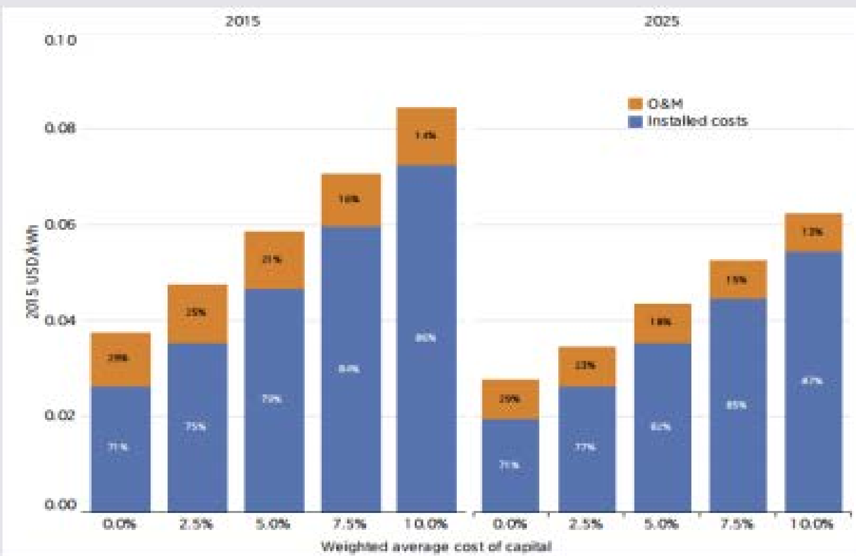


Levelized cost of electricity, by renewable energy technology

- Between 2009 and 2017, the benchmark levelized cost of electricity, or **LCOE, for photovoltaics without tracking systems fell** from $304 per megawatt-hour to just $86, a reduction of 72%.
- **Onshore wind's** LCOE **dropped from $93 to $67** per MWh, a reduction of 27%.
- For **offshore wind**, there was an increasing cost trend for some years as project developers moved into deeper waters, further from shore, but since the peak in 2012, there has been an **LCOE decline of 44% to $124 per MWh**.
- Two other technologies – solar thermal parabolic trough, and biomass incineration - neither has seen a significant change in its LCOE since 2009.
- The LCOE reductions for PV, onshore wind and offshore wind have boosted the competitiveness of these sources against established technologies such as coal and gas.
- **In 2017 the average LCOE without subsidy for PV without tracking was $54 per MWh, with onshore wind at $51 per MWh, versus gas-fired generation at $49 per MWh, coal at $66 and nuclear at $174.5**

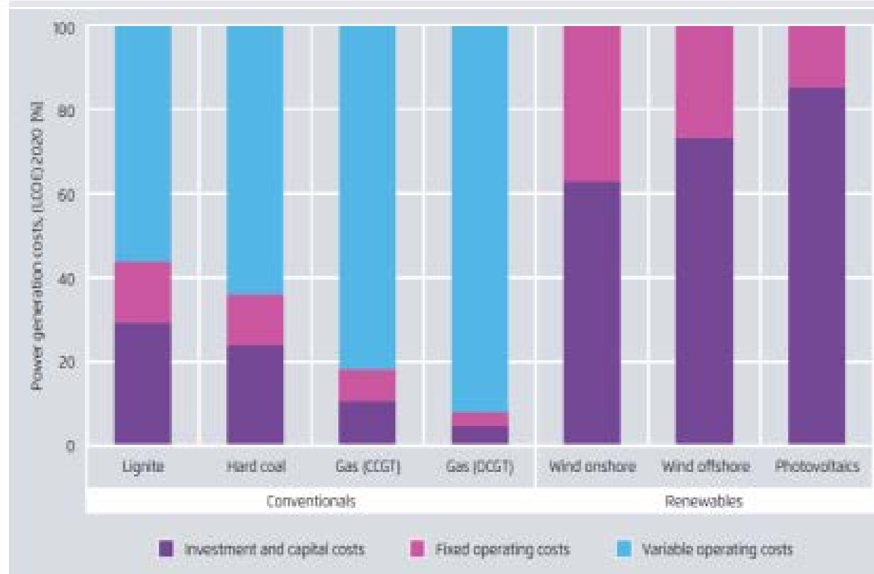
Wind power and solar PV have high upfront investment cost and very low operating cost. Financing conditions for upfront investment are critical for economic viability of RES projects

Sensitivity of LCOE of wind to the cost of capital, 2015 and 2025



Source: *IRENA 2016*

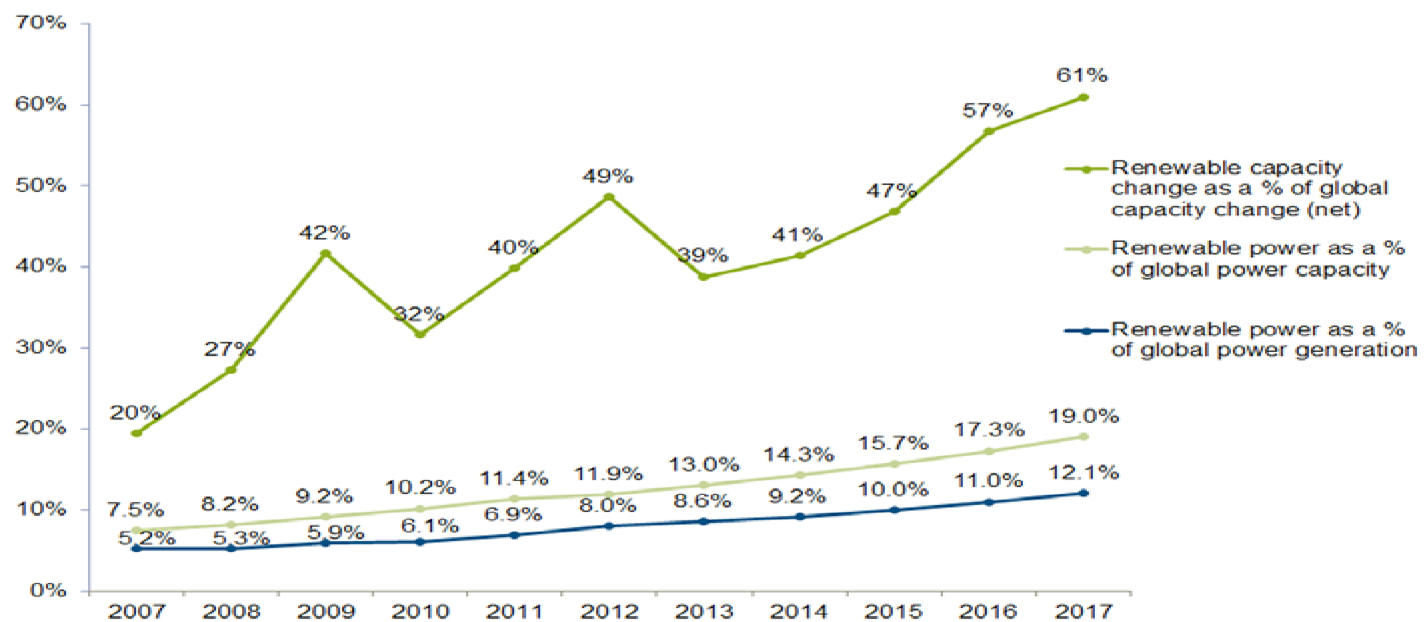
High fixed costs for renewables



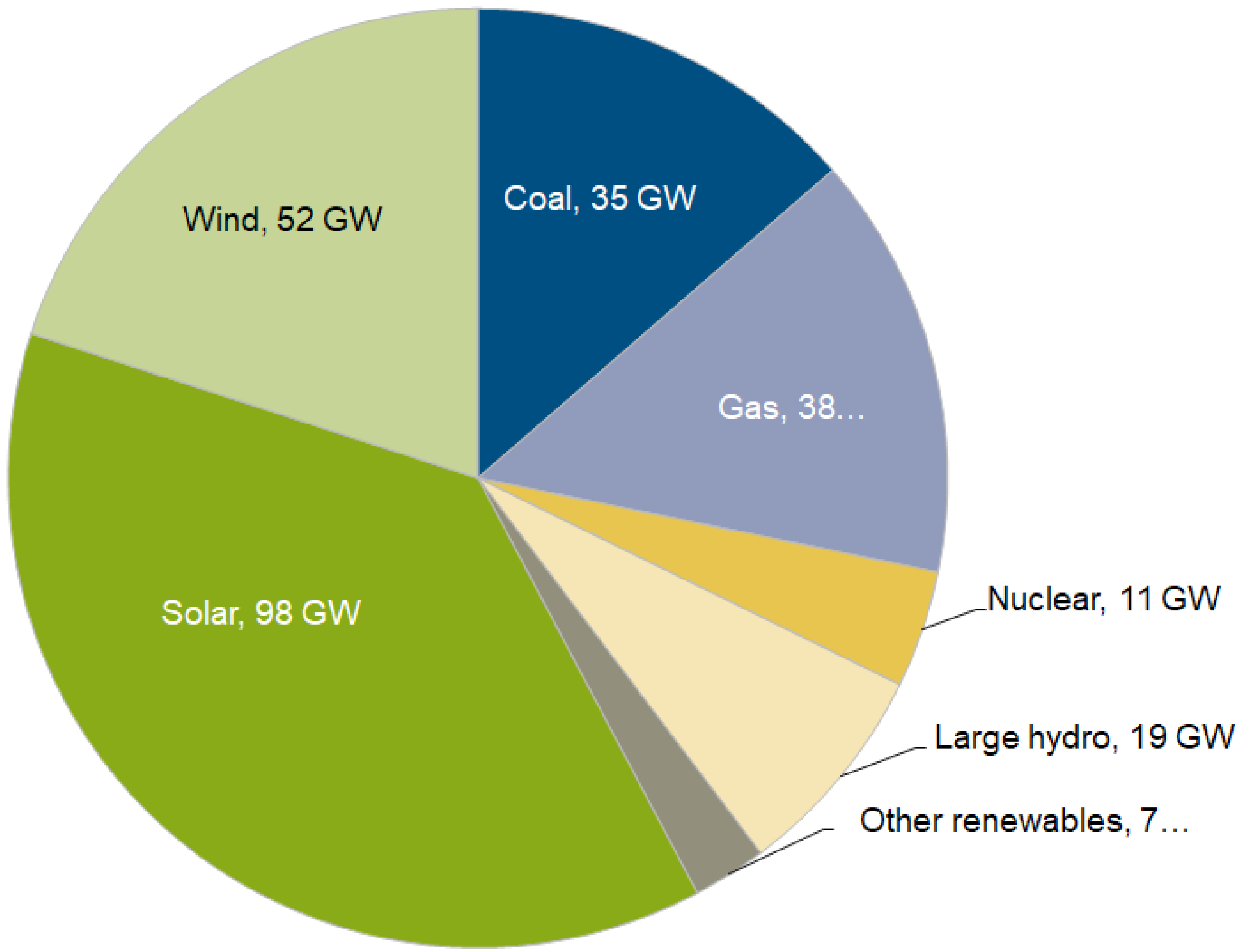
Source: *Agora, based on IEA/NEA (2015)*

Renewable power generation and capacity as a share of global power, 2007-2017, %

- The rising importance of renewable energy in the global electricity generation mix is confirmed in three ways.
- The upper line shows the percentage of net new generating capacity added in each year that is made up of renewable technologies (excluding large hydro).
- **Share of capacity** has increased spectacularly over the years, from just under 20% in 2007, to 39% in 2013, to 57% 2016 and 61% in 2017.



Net power generating capacity added in 2017 by main technology, GW



COMPARING INVESTMENT

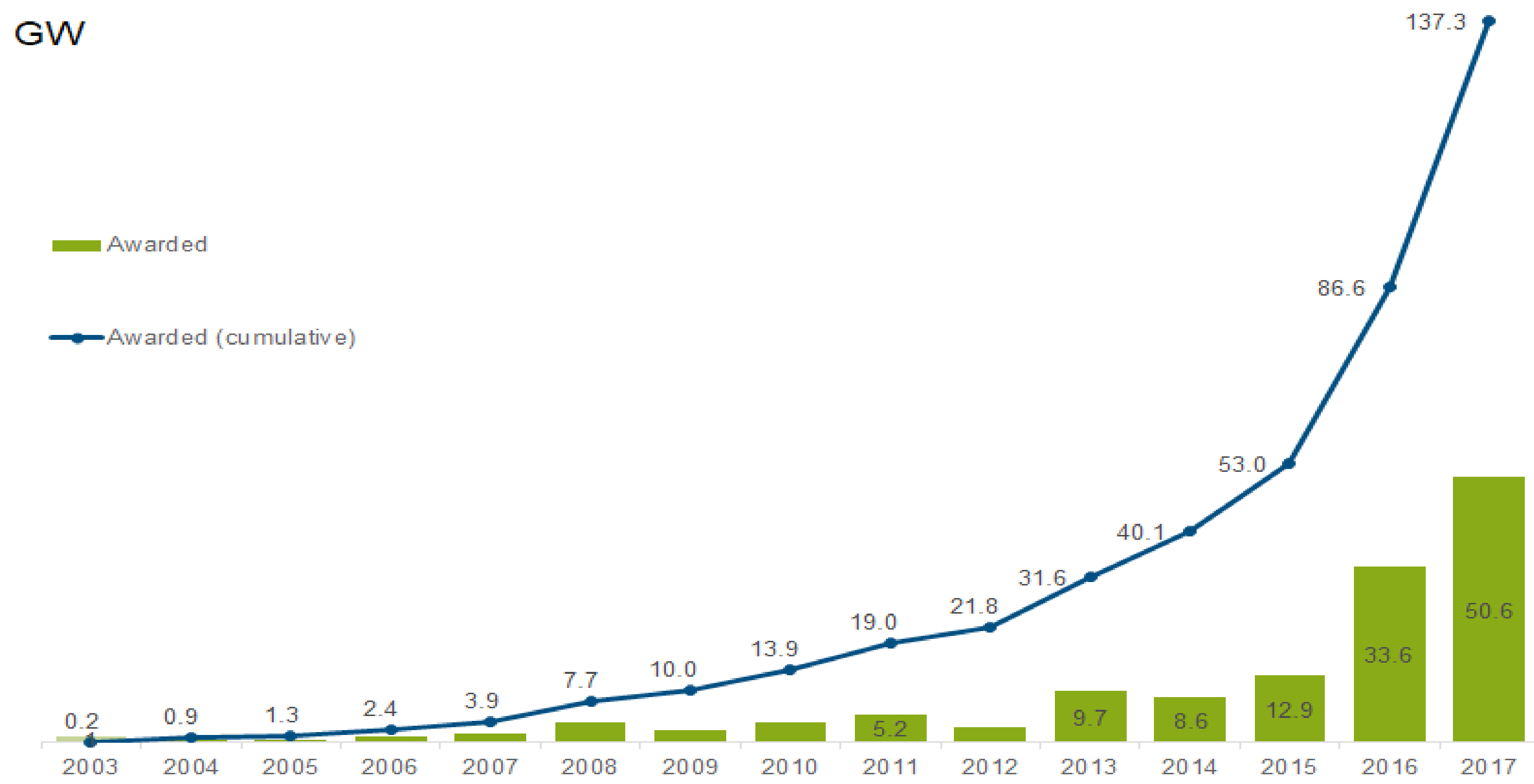
- In 2017, some $265 billion was invested in new capacity of renewables excluding large hydro.
- Bloomberg New Energy Finance estimates that just $103 billion was invested in new fossil fuel power stations around the world last year, consisting of $70 billion spent on new coal-fired power stations, $31 billion on new gas-fired plants and $2 billion on new on-grid oil-fired units.
- Many of the new coal plants were in China and India, many of the new gas turbines were in the U.S. or the Middle East.
- BNEF also estimates that $42 billion was invested in new nuclear reactors and $45 billion in large hydro-electric projects.

DELIVERING INVESTMENT

- Policy and other **support mechanisms** such as power purchase agreements still play an important role in **underpinning returns and limiting risks for project developers**, indirectly bolstering the availability of finance.
- **Low costs of capital** reflected plentiful availability of finance, at least in mature markets.
  - For instance, in Europe, banks provided long-term loans at much lower all-in rates than five years earlier, and institutional investors in 2017 put record amounts into renewable energy projects.

Global auctioned renewables capacity, 2003-2017, GW

- Acceleration in auction activity in 2017 was most pronounced in Europe, where the capacity awarded jumped to 25.2GW, from 5GW the previous year, as countries such as the U.K., Germany and Netherlands put offshore wind through this process, and as Spain held an auction for solar.

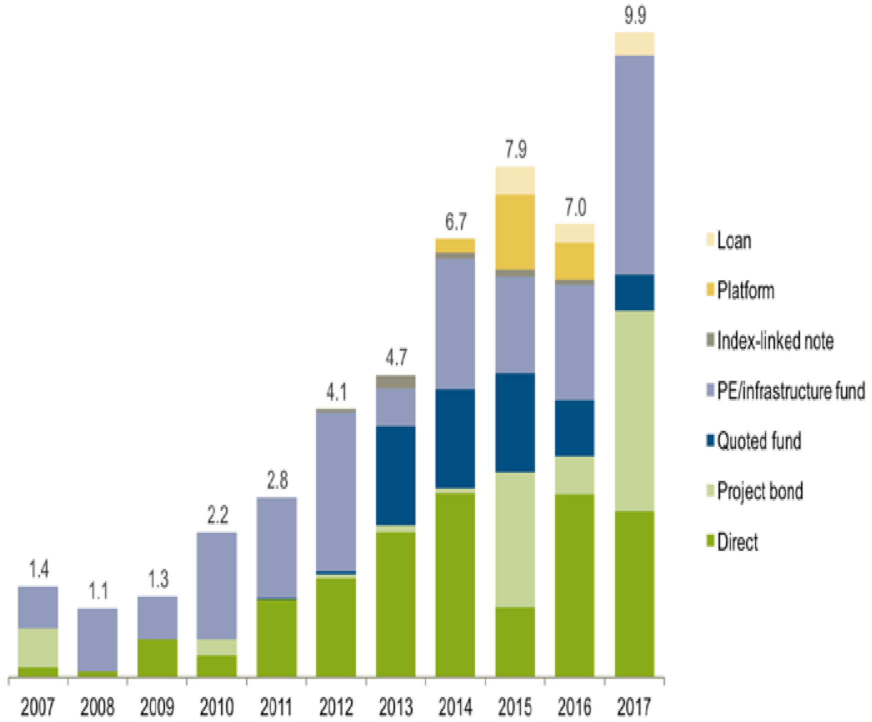


SOURCES OF EQUITY AND DEBT

- Most renewable energy projects are financed in one of two ways – either **on-balance-sheet by a utility**, independent power producer or other investor; or using **non-recourse project finance**, typically made up of a large debt slice from banks, and a smaller equity slice from developers and other investors.
- The **cost of this capital** for renewable energy projects has been **exceptionally low in recent years**.
- Because wind and solar projects incur the dominant part of their lifetime costs upfront, at the construction stage, not during the operating phase, this low cost of capital has helped to push down levelized costs of electricity for these technologies

Institutional investor commitments to European renewable energy projects, $BN

- **Institutional investor** commitments to European renewable energy projects hit a record in 2017, of $9.9 billion, up 42% on 2016.
- This measure covers a number of different ways in which money from **pension funds, insurance companies and other institutions reaches projects**.
- These are direct **investment in project equity;** the purchase of project bonds; investment via quoted project funds or private equity or infrastructure funds devoted to European renewables; the purchase of index-linked notes in projects; investment via platforms set up by specialist investors; and direct provision of loans to projects.

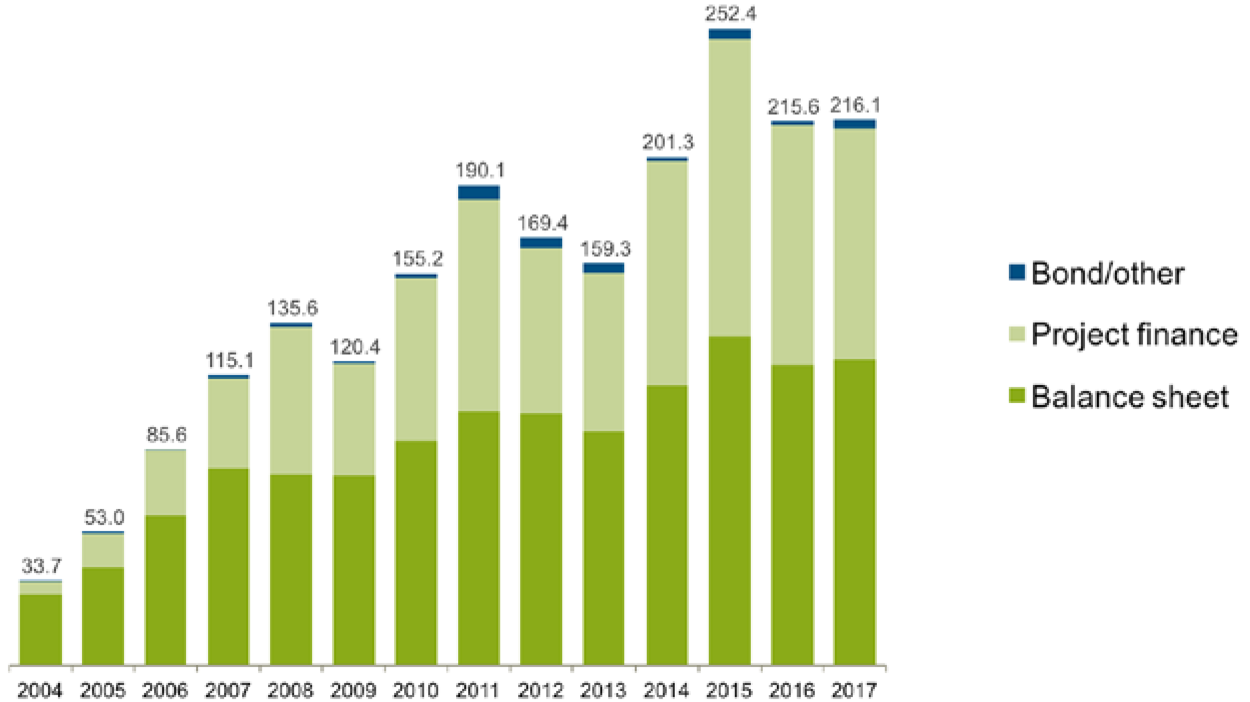


Development Banks and ECAs

- **Multilateral development banks have been important providers of finance** for renewable energy for more than a decade, often backing projects in countries where commercial banks are concerned about risk, or in technologies where commercial banks are only just starting to get comfortable.
- Eight of the largest development banks, led by KfW of Germany, the European Investment Bank and the World Bank Group, lent $55 billion between them to clean power in 2016, a figure comparable to that in other recent yeas.
  - This total includes funding for energy efficiency and transmission, as well as for renewables projects.
  - KfW was by far the largest contributor, with $34.1 billion of commitments, up from $30.7 billion in 2015.1

Asset Finance of Renewable Energy by Type, 2004-2017, $BN

- Asset finance of utility-scale renewable energy projects of more than 1MW totalled $216.1 billion in 2017, up 0.2% on the $215.6 billion reached in 2016.
- These figures exclude hydro-electric projects of more than than 50MW



Priority access and dispatch for renewables?

- Three concepts behind priority access and dispatch
- When considering renewable energy sources and their relation to the access to and operation of the grids, there are three concepts to be distinguished behind the terms “priority access” and “dispatch”:
  - the guaranteed connection of renewable energy generation units to the grid (priority/guaranteed grid access);
  - the obligation for network operators to feed energy produced by renewable generation units into the grid (priority dispatch);
  - the obligation for network operators to reinforce and expand their grids to accommodate increasing shares of renewables (transmission and distribution).

Barriers to Renewable Energy Technologies

- Renewables still face major obstacles.
- Some are inherent with all new technologies; others are the result of a skewed regulatory framework and marketplace
- Barriers to Renewable Energy Technologies
  - **Capital costs**
  - **Siting and transmission**
  - **Market entry**
  - **Unequal playing field**
  - **Reliability misconceptions**

Capital costs

- The most obvious and widely publicized barrier to renewable energy is cost—specifically, **capital costs**, or the upfront expense of building and installing solar and wind farms.
  - Like most renewables, solar and wind are exceedingly cheap to operate - their “fuel” is free, and maintenance is minimal—so the bulk of the expense comes from building the technology.
- The average cost in 2017 to install solar systems ranged from a little over $2,000 per kilowatt for large-scale systems to almost $3,700 for residential systems.
  - A new natural gas plant might have costs around $1,000/kW. Wind comes in around $1,200 to $1,700/kw.

Siting and transmission

- **Siting** is the need to locate things like wind turbines and solar farms on pieces of land.
  - Doing so requires **negotiations, contracts, permits, and community relations**, all of which can increase costs and delay or kill projects.
- **Transmission** refers to the power lines and infrastructure needed to move electricity from where it's generated to where it's consumed.
  - Because wind and solar are relative newcomers, most of what exists today **was built to serve large fossil fuel and nuclear power** plants.

Market entry

- New energy technologies – startups - face even larger barriers.
- They **compete with major market players like** coal and gas, *and* with proven, low-cost solar and wind technologies.
- To prove their worth, they must demonstrate scale: most investors want large quantities of energy, ideally at times when wind and solar aren't available.
- That's difficult to accomplish, and a major reason why new technologies suffer high rates of failure.
- Increased government investment in clean energy - in the form of subsidies, loan assistance, and research and development—would help.

Reliability misconceptions

- Renewable energy opponents love to highlight the **variability of the sun and wind** as a way of bolstering support for coal, gas, and nuclear plants, which can more easily operate on-demand or provide "**baseload**" (continuous) power.
- The argument is used to undermine large investments in renewable energy, presenting a rhetorical barrier to higher rates of wind and solar adoption.
- **Modern grid technologies** like advanced batteries, real-time pricing, and smart appliances can also **help solar and wind** be essential elements of a well-performing grid.

Renewable electricity generation costs in 2017

- **Three key drivers** are increasingly important for reducing the cost of solar and wind power generation.
- These are:
  1. **competitive procurement;**
  2. **a large and growing base of experienced and internationally active project developers; and**
  3. **ongoing technology improvements.**
- Regulatory and institutional frameworks are transitioning to set the stage for competitive procurement of renewable power generation.
- In response, project developers are bringing to the international market their significant experience as well as their increasing access to international capital markets.

Renewable electricity generation costs in 2017

- The average cost of electricity – measured in **unsubsidised levelized cost of electricity (LCOE**) – from renewable power generation technologies either is **already very competitive or is continuing to fall to competitive level**s for new projects commissioned in 2017.
- Costs of the **more mature geothermal, bio-power and hydropower technologies are relatively stable**.
- Most of the **recent reductions in cost** have been associated with **solar PV and wind** power technologies; after years of steady cost declines, **solar and wind power are becoming ever more competitive technologies for meeting new generation needs.**

Renewable electricity generation costs in 2017

- **Onshore wind power has become one of the most competitive sources of new generation**.
- Wind turbine **prices have fallen 37-56 %** since their peaks in 2007-2010, depending on the market.
- In combination with more modest reductions in balance-of-project costs, **total installed costs for onshore wind power fell by a fifth between 2010 and 2017**; at the same time, the **global weighted average capacity factor for new projects increased from 27 % to 30 %.**
- The **LCOE of onshore wind power projects in 2017 fell to as low as USD 30 per MWh, with a global weighted average of USD 60 per MWh**.

Renewable electricity generation costs in 2017

- What has been truly remarkable, however, is the continued cost **declines for solar PV**.
- Driven by an 81% decrease in solar PV module prices since the end of 2009, along with reductions in balance of system costs, the **global weighted average LCOE of utility-scale solar PV fell 73% between 2010 and 2017, to USD 100 per MWh.**
- The **global weighted-average capacity factor** of commissioned utility-scale solar PV **has risen** since 2010, although this increase has been driven **more by a growing share of projects in the sunbelt** than by technology improvements.

Renewable electricity generation costs in 2017

- As a result of all these factors, **solar PV is increasingly competing head-to-head with conventional power sources**, and doing so **without financial support** in a growing **number of locations**.
- **Offshore wind power** and **concentrating solar thermal power (CSP)**, although still at relatively early stages in deployment, both saw their costs fall between 2010 and 2017 to a global weighted average LCOE of USD 140 per MWh and USD 220 per MWh, respectively.
- These values are still relatively high, but the cost reduction potential for these technologies is strong.

Renewable electricity generation costs in 2017

- The lowest auction prices for renewable power reflect a nearly constant set of key competitiveness factors.
- These include:
  - a favourable regulatory and institutional framework;
  - low offtake and country risks;
  - a strong, local civil engineering base;
  - favourable taxation regimes,
  - low project development costs; and
  - excellent renewable energy resources.
- **Based on the auction prices in 2017 and 2018**, the outlook for **solar and wind** electricity prices to **2020** presages the lowest yet seen for these modular technologies, which can be deployed in every country of the world.

Renewable electricity generation costs in 2017

TABLE 3. Status of Renewable Electricity Generating Technologies, Costs and Capacity Factors, 2017 (continued)

CONCENTRATING SOLAR THERMAL POWER (CSP)

Levelised Cost of Energy → USD/kWh

Total Investment Cost → USD/kW	min	max	wa	Capacity Factor → min	max	wa
Africa	6,850	11,300	7,841	0.36	0.53	0.39
Asia	3,053	7,475	4,110	0.21	0.54	0.28
Central America and the Caribbean						
Eurasia						
Europe	5,982	8,970	7,402	0.23	0.41	0.32
Middle East	6,220	6,680	6,373	0.24	0.39	0.29
North America	6,373	7,753	7,002	0.27	0.52	0.35
Oceania	6,672	6,673	6,673	0.11	0.23	0.12
South America						
China	2,550	3,450	3,223	0.28	0.29	0.28
India	3,053	7,475	4,228	0.21	0.54	0.28
United States	6,373	7,753	7,002	0.27	0.52	0.35

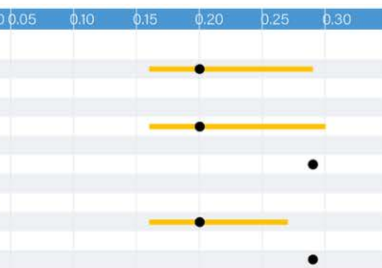
WIND POWER ONSHORE

Levelised Cost of Energy → USD/kWh

Total Investment Cost → USD/kW	min	max	wa	Capacity Factor → min	max	wa
Africa	1,485	2,850	2,040	0.19	0.48	0.37
Asia	1,044	3,882	1,221	0.18	0.46	0.25
Central America and the Caribbean	1,981	3,265	2,184	0.24	0.54	0.33
Eurasia	1,032	2,002	1,605	0.24	0.49	0.37
Europe	1,151	3,702	1,868	0.14	0.51	0.29
Middle East	916	1,857	1,320	0.14	0.29	0.2
North America	1,270	3,001	1,718	0.22	0.51	0.4
Oceania	1,184	3,169	2,124	0.23	0.43	0.33
South America	972	2,909	1,829	0.26	0.55	0.4
China	989	1,414	1,197	0.23	0.29	0.25
India	850	1,282	1,097	0.19	0.33	0.24
United States	1,381	2,534	1,648	0.23	0.44	0.41

WIND POWER OFFSHORE

Levelised Cost of Energy → USD/kWh



Total Investment Cost → USD/kW	min	max	wa	Capacity Factor → min	max	wa
Africa						
Asia	1,890	5,055	3,260	0.23	0.29	0.28
Central America and the Caribbean						
Eurasia						
Europe	2,698	6,480	4,355	0.27	0.55	0.38
Middle East						
North America			9,667			0.48
Oceania						
South America						
China	1,890	4,258	3,249	0.23	0.29	0.28
India						
United States			9,667			0.48

= LCOE range   ● = LCOE weighted average   wa = weighted average

Source: IRENA. See endnote 200 of Wind Power section in this chapter.

Note: All monetary values are expressed in USD2016. LCOE is computed using a weighted average cost of capital of 7.5% for OECD countries and China and 10% for the rest of the world, and excludes subsidies and/or taxes. Where only the weighted average is shown for specific regions/countries and technologies (i.e., without minimum and maximum amounts for LCOE, investment cost or capacity factor), there is only one project in the IRENA Renewable Costing Database. The data methodology and regional groupings are defined in IRENA, *Renewable Power Generation Costs in 2017* (Abu Dhabi: 2018), www.irena.org/costs.

REN21 RENEWABLES 2018 GLOBAL STATUS REPORT

Conclusions

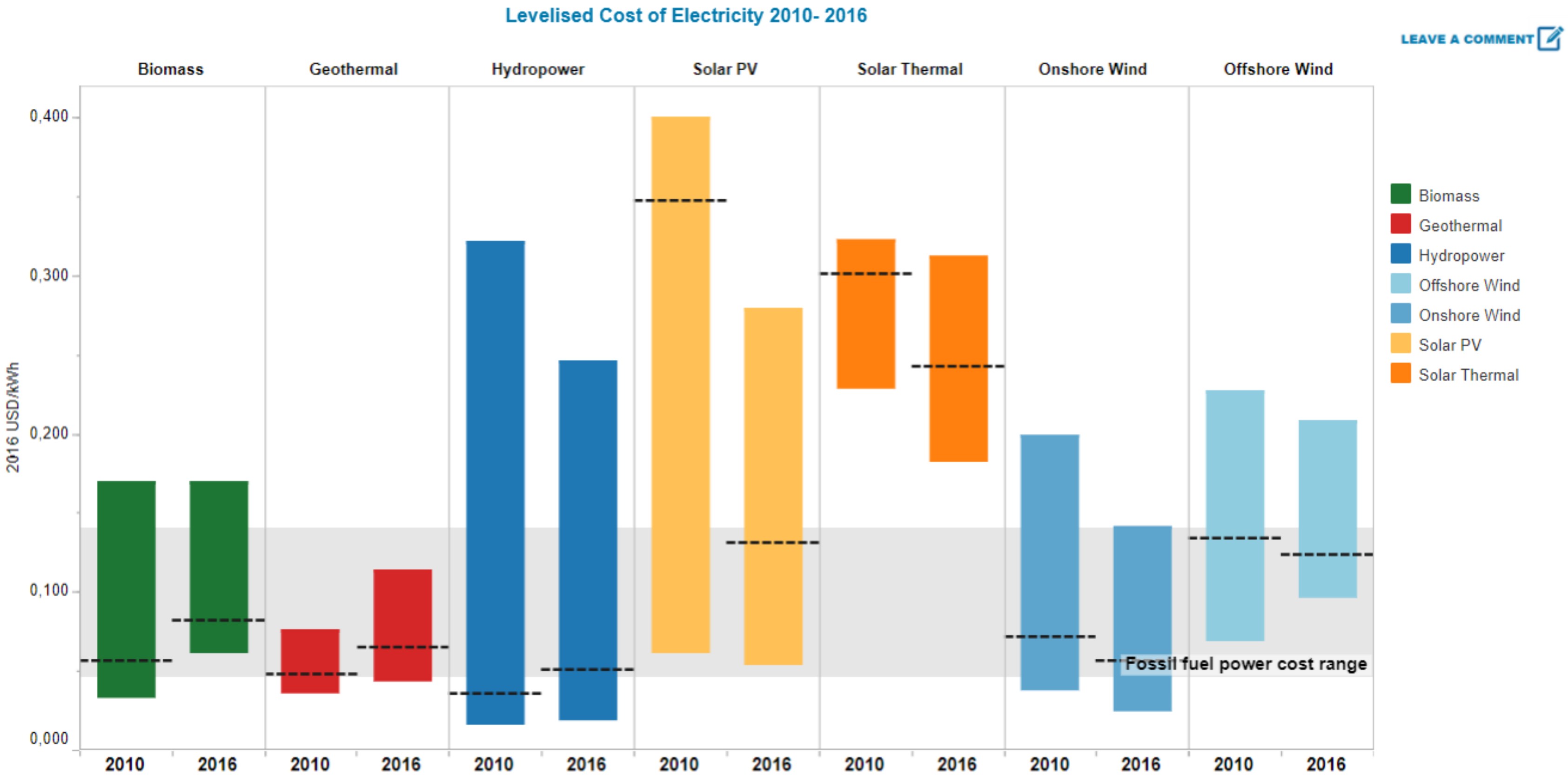
- Solar and wind power recently crossed a new threshold, moving from mainstream to **preferred energy sources across much of the globe**.
- **Wind and solar have reached *grid price parity* and are moving closer to performance parity with conventional sources**.
- In fact, the unsubsidized levelized cost of energy (LCOE) for utility-scale onshore **wind and solar PV** generation has **dropped even with or below most other generation technologies** in much of the world
- Meanwhile, the **demand for renewables is inexorably growing**

Conclusions

- **Utility-scale solar and wind combined with storage are increasingly competitive, providing *grid performance parity* in addition to price parity**.
- With the addition of storage, wind and **solar become more dispatchable**, eroding the long-held advantage of conventional energy sources.
- **Costs are continuing to fall**, and successful integration is proceeding apace, undergirded by new technologies that are bringing even greater efficiencies and capabilities.
- **Solar and wind power now come closest to meeting three energy consumer priorities: reliability, affordability, and environmental responsibility**.

Some additional slides

Electricity generation costs - LCOE 2010-2016



Reference: IRENA

Auctions
Auction design matters

AUCTIONS FOR RENEWABLE ENERGIES

- Competitive determination of support level
- Quantity control through budget limit or auction volume

REQUIRED BY STATEAID GUIDELINES AND RED II

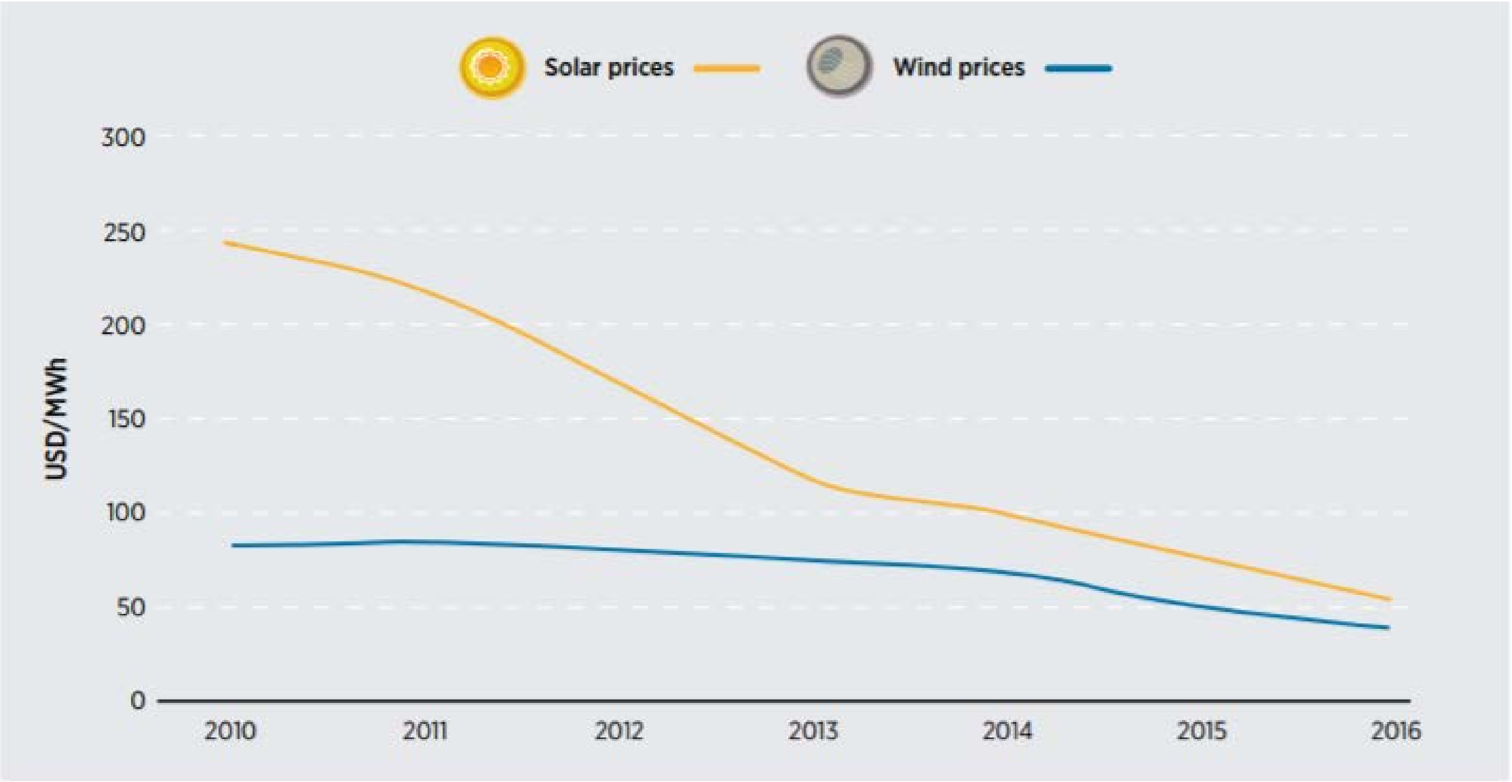
→

BENEFITS OF AUCTIONS

- Cost control/ increased support effiency/lower support levels
- Increased effectiveness of support and more precise control of renewable extension

BUT: AUCTION DESIGN MATTERS!

PV & Wind Auctions 2010-16



Source: IRENA, 2017.

1. This brief is a summary of Renewable Energy Auctions: Analysing 2016 which can be downloaded from www.irena.org/Publications starting March 2017.

Auctions in some countries: Capacity and price ($/MWh)

In September, China organized its largest solar auction, contracting 1 GW of new capacity with the lowest price at CNY 520/MWh (USD 77.88/MWh) (PV Tech, 2016b).

Winning Auction Bids in 2016		Total Capacity (MW)	Average Price (MWh)
	Solar	1.000,0	77,9

In April, August, and December, Germany continued the auctioning programme initiated in 2015, with the fourth, fifth and sixth solar auction rounds. These auctions represent the country's pilot scheme for replacing solar feed-in tariffs.

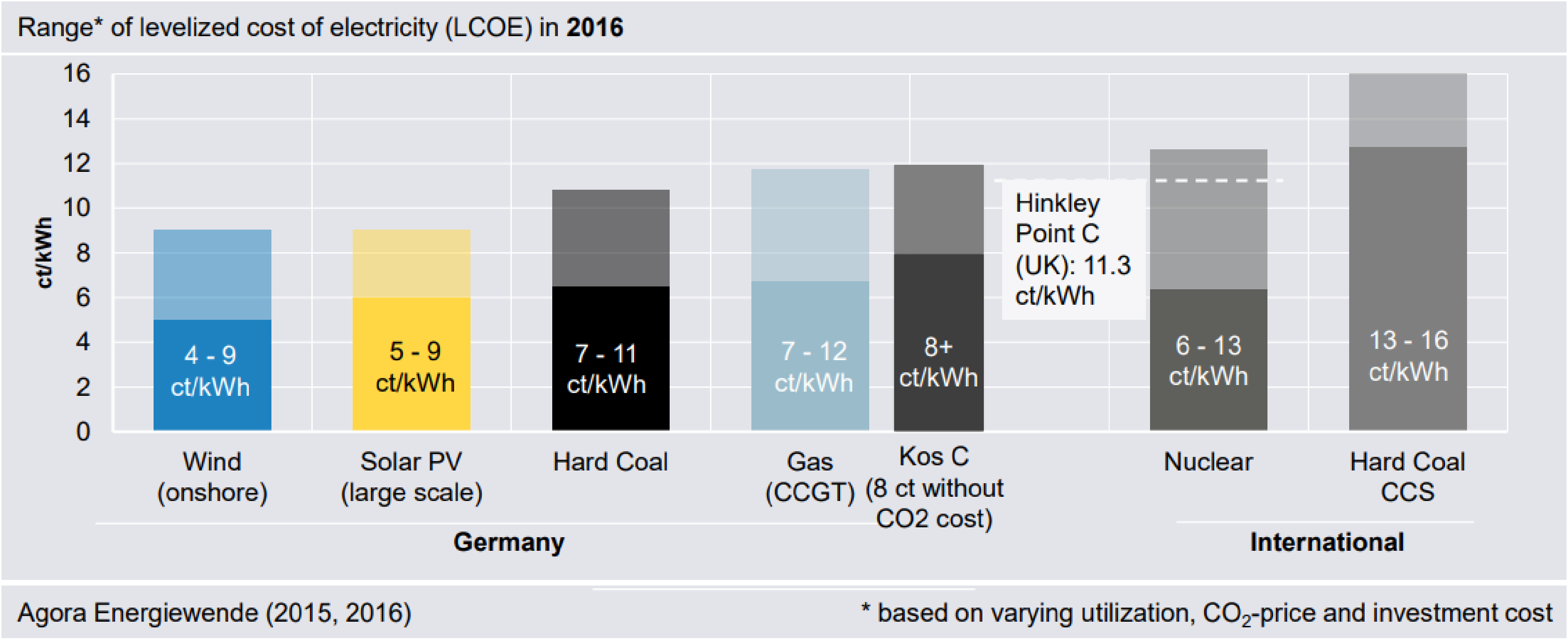
Winning Auction Bids in 2016		Total Capacity (MW)	Average Price (MWh)
4th Tender	Solar	128,0	84,0
5th Tender	Solar	130,0	81,0
6th Tender	Solar	163,0	72,7
7th Tender	Solar	200,0	70,1

In September and November, Denmark carried out two offshore wind auctions as part of a long-running programme in which four largescale projects had already been contracted.

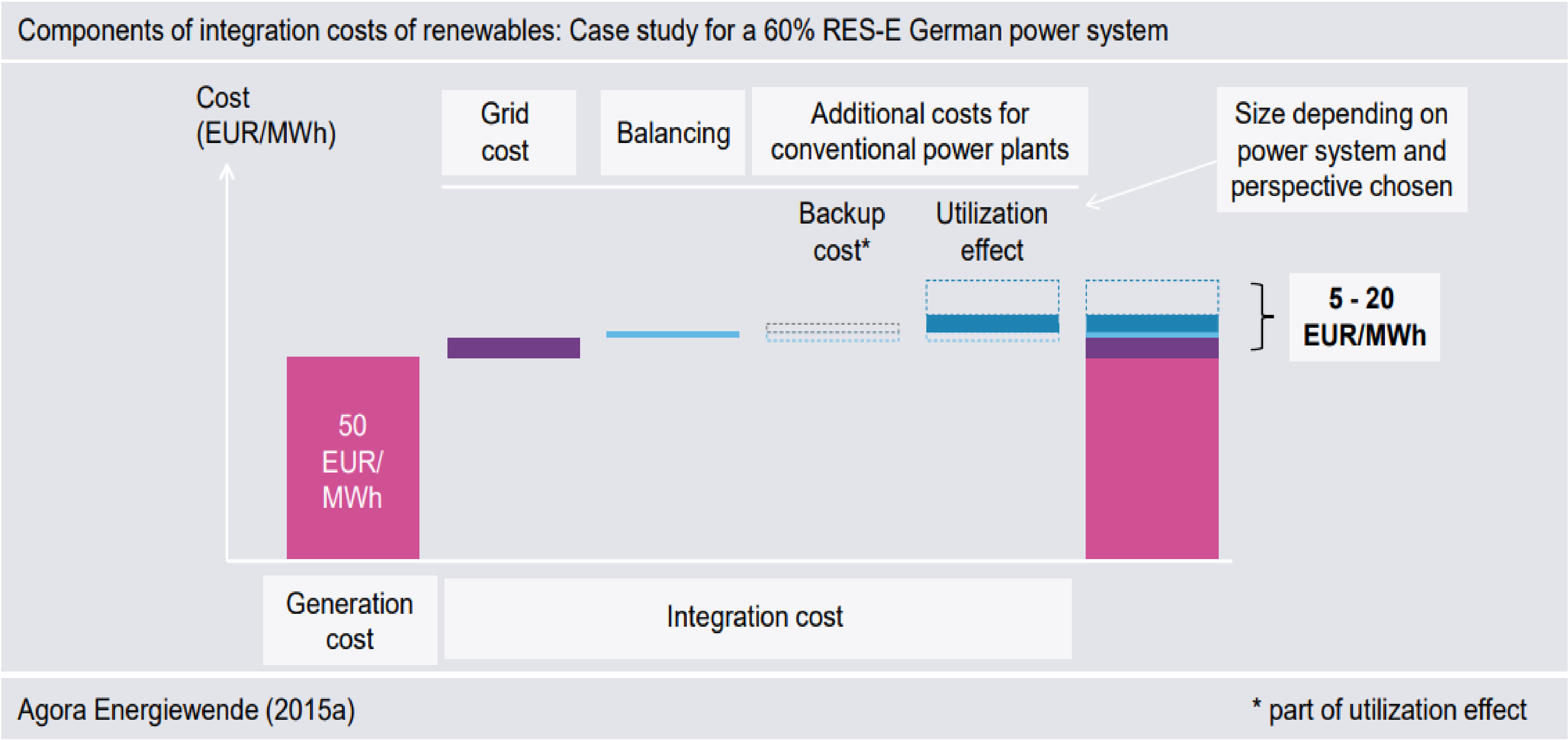
Winning Auction Bids in 2016		Total Capacity (MW)	Average Price (MWh)
	Offshore Wind	950,0	60,4
Premium price over spot price	Solar	21,6	19,9

Reference: IRENA

Wind & PV are in many parts of the world the cheapest low carbon option and cost competitive to new fossil power plants



The integration cost of wind and solar (5 to 20 EUR/MWh) do not change the picture



Wind and solar are now cheap technologies. In many places of the world they are the lowest-cost option for power production

This figure shows the auctions result and power purchase agreements from 2016/2017. See Fortum (2016).
Agora Energiewende

- In places with good wind and or solar conditions, power production costs are now at 2-3 ct/kWh
- Even where there is not much sun (like in Germany or Denmark), new solar is now cheaper than new coal/gas
- **Key requirement**: Low capital costs, as cost structure of wind and solar has low share of operating costs but high share of investment costs
- **Challenge**: Regulations were designed for the old power systems (coal, gas) & are now blocking progress

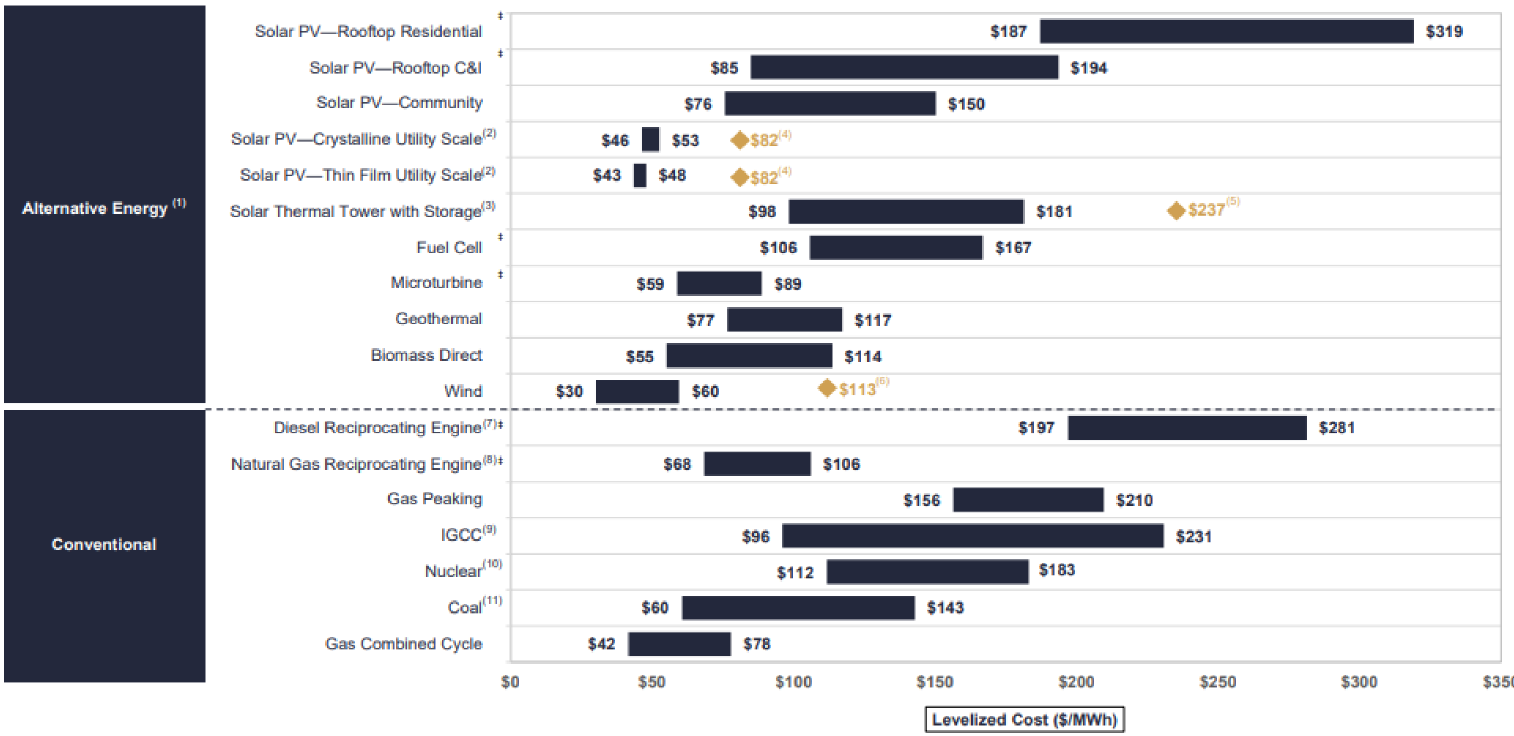
Reaching price and performance parity on and off the grid

- **Wind and solar have reached *grid price parity* and are moving closer to performance parity with conventional sources**.
- In fact, the unsubsidized levelized cost of energy (LCOE) for utility-scale onshore wind and solar PV generation has dropped even with or below most other generation technologies in much of the world.
- While resources such as combined-cycle gas turbines (CCGT) have more flexibility to follow the load curve, increasingly affordable battery storage and other innovations are helping smooth the effects of wind and solar intermittency, giving them more of the reliability required to compete with conventional sources.
- From a price perspective, onshore wind has become the world's lowest-cost energy source for power generation, with an unsubsidized LCOE range of US$30–60 per megawatt hour (MWh), which falls below the range of the cheapest fossil fuel, natural gas (US$42–78 per MWh)

Reaching price and performance parity on and off the grid

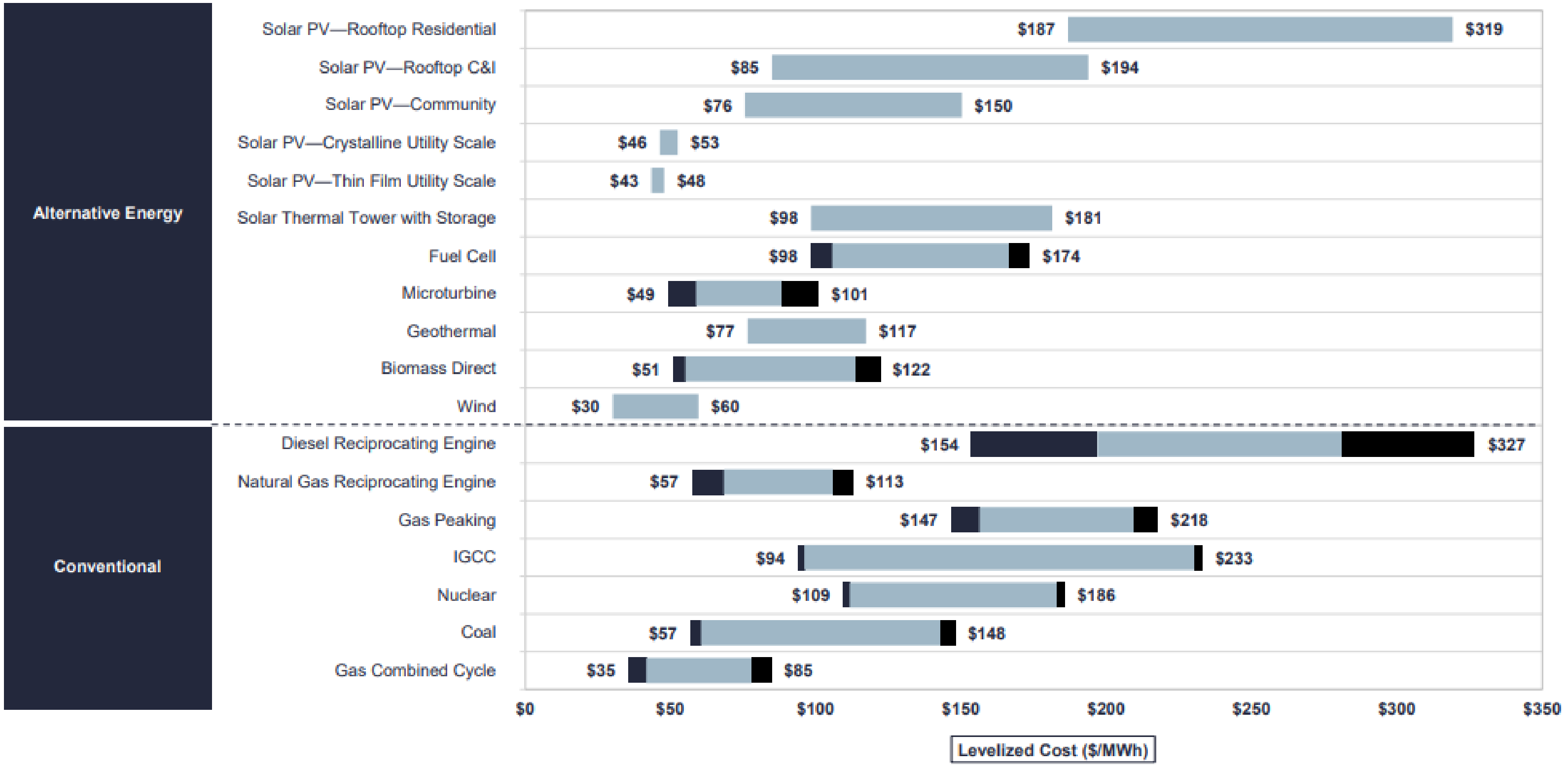
- **Utility-scale solar and wind combined with storage are increasingly competitive, providing *grid performance parity* in addition to price parity**.
- With the addition of storage, wind and solar become more dispatchable, eroding the long-held advantage of conventional energy sources.
- While the cost of renewables plus storage is higher, they can provide capacity and ancillary grid services that make them more valuable.
- Regulatory and market structures determine whether the additional value can be monetized.
- But even if the services cannot be sold, this combination is more valuable because operators can supply more of their own needs and potentially time shift the use of grid-supplied electricity to off-peak, cheaper hours.
- Renewables combined with storage are also reaching price parity as lithium-ion battery costs have fallen nearly 80 percent since 2010 and solar penetration has increased

Unsubsidized Levelized Cost of Energy Comparison



Lazard, *Levelized cost of energy analysis—version 11.0*, November 2017.

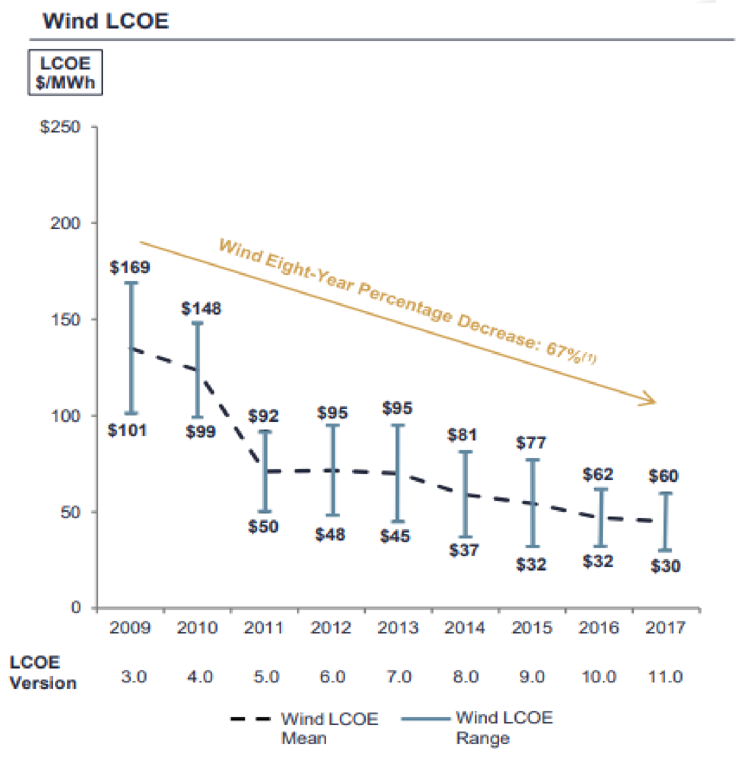
Levelized Cost of Energy Comparison—Sensitivity to Fuel Prices



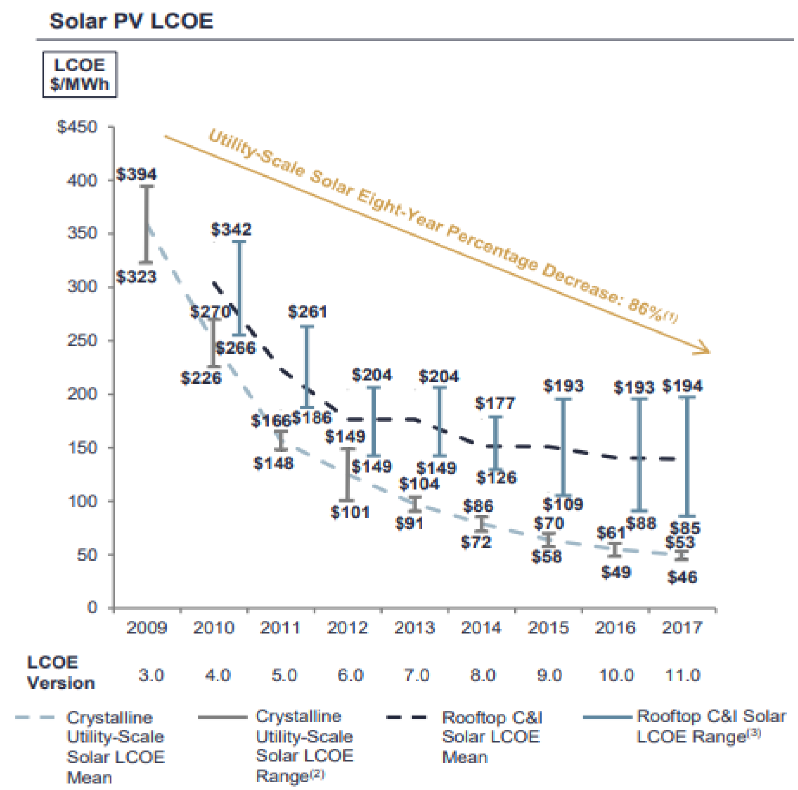
Variations in fuel prices can materially affect the levelized cost of energy for conventional generation technologies, but direct comparisons against "competing" Alternative Energy generation technologies must take into account issues such as dispatch characteristics (e.g., baseload and/or dispatchable intermediate load vs. peaking or intermittent technologies)

Lazard, *Levelized cost of energy analysis—version 11.0*, November 2017.

Unsubsidized Levelized Cost of Energy—Wind & Solar PV (Historical)



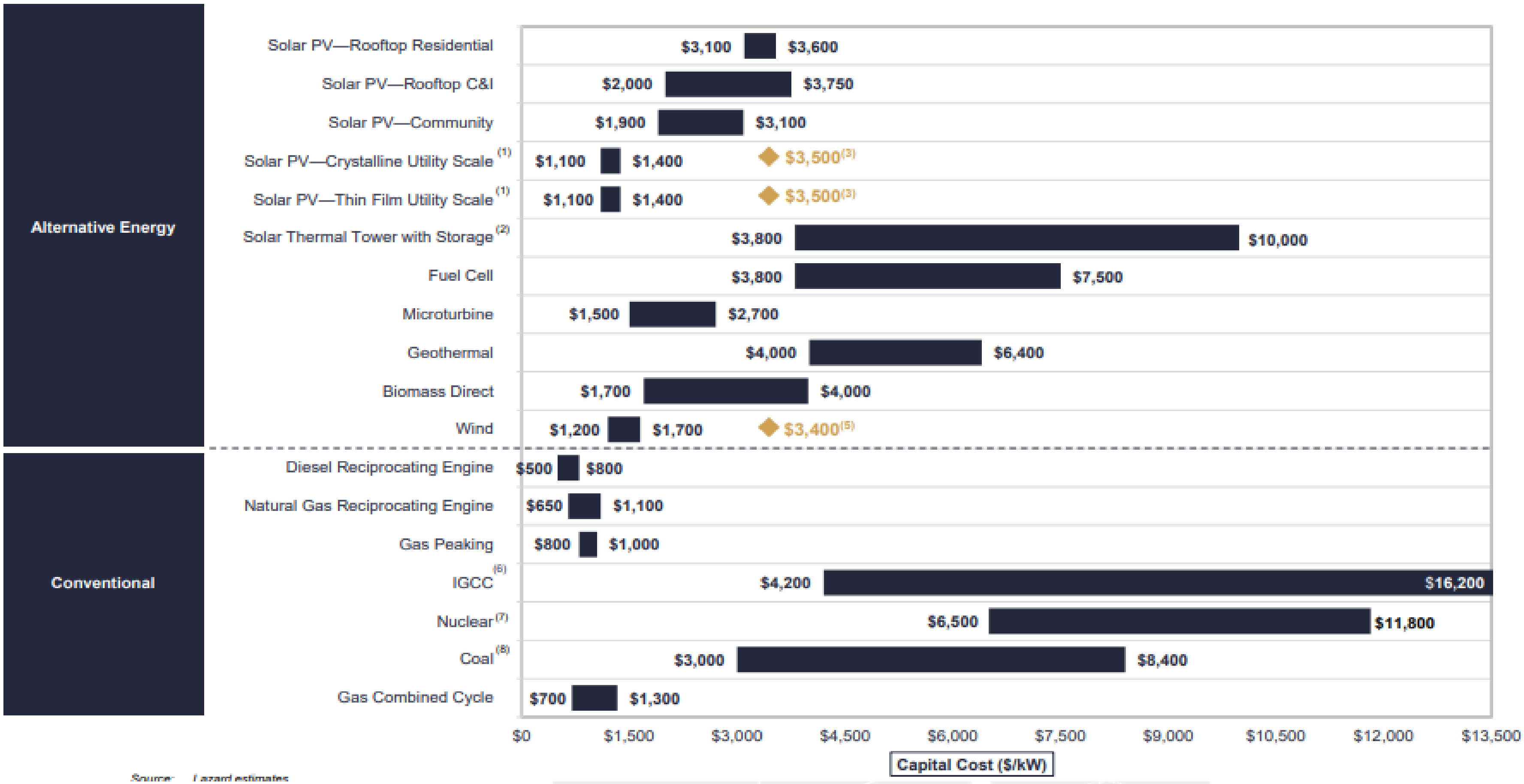
Source: Lazard estimates.



Over the last eight years, wind and solar PV have become increasingly cost-competitive with conventional generation technologies, on an unsubsidized basis, in light of material declines in the pricing of system components (e.g., panels, inverters, racking, turbines, etc.), and dramatic improvements in efficiency, among other factors

Lazard, *Levelized cost of energy analysis—version 11.0*, November 2017.

Capital Cost Comparison

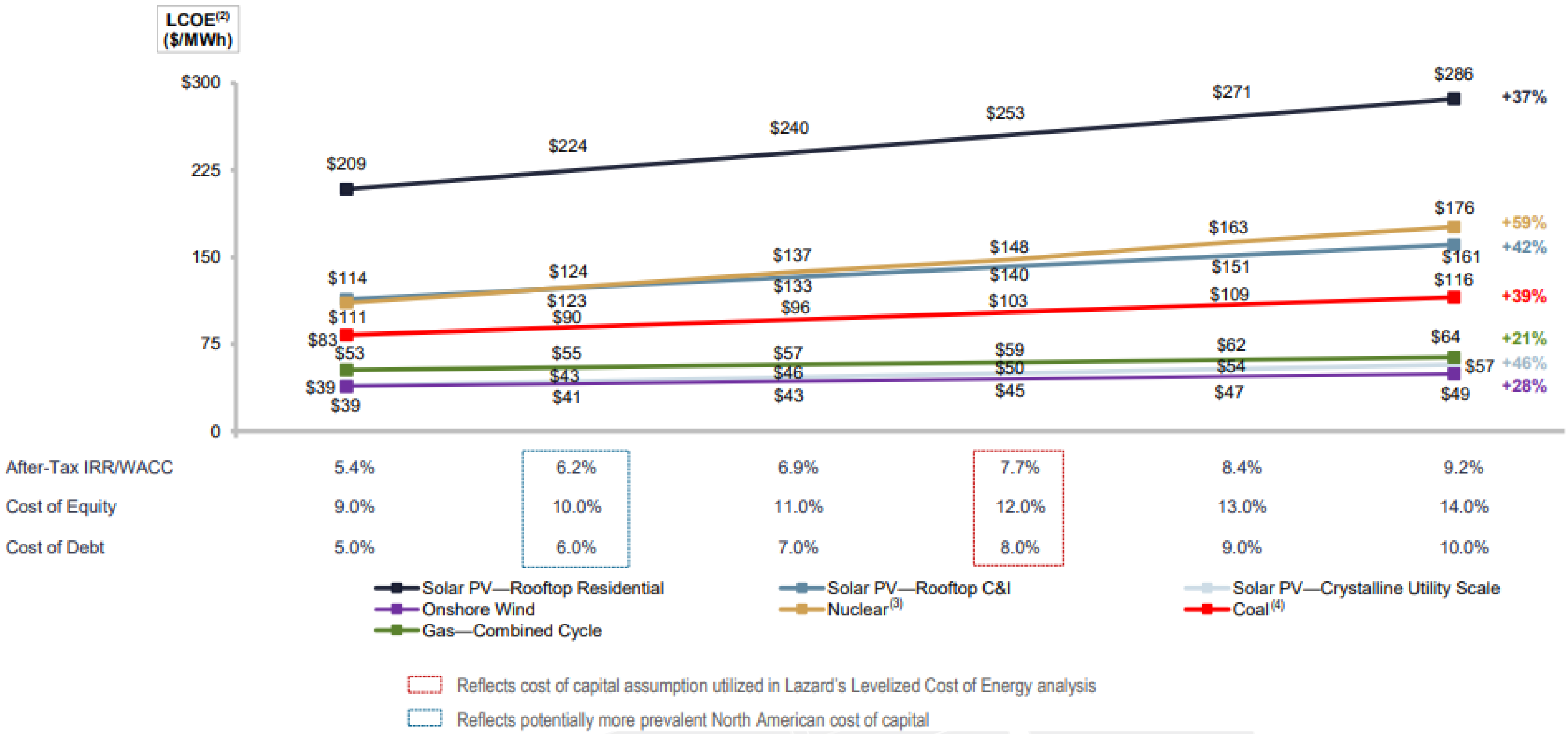


Source: Lazard estimates

While capital costs for a number of Alternative Energy generation technologies (e.g., solar PV, solar thermal) are currently in excess of some conventional generation technologies (e.g., gas), declining costs for many Alternative Energy generation technologies, coupled with uncertain long-term fuel costs for conventional generation technologies, are working to close formerly wide gaps in electricity costs. This assessment, however, does not take into account issues such as dispatch characteristics, capacity factors, fuel and other costs needed to compare generation technologies

Lazard, *Levelized cost of energy analysis—version 11.0*, November 2017.

Levelized Cost of Energy—Sensitivity to Cost of Capital



A key issue facing Alternative Energy generation technologies is the impact of the availability and cost of capital on LCOEs (as a result of capital markets dislocation, technological maturity, etc.); availability and cost of capital have a particularly significant impact on Alternative Energy generation technologies, whose costs reflect essentially the return on, and of, the capital investment required to build them

Lazard, *Levelized cost of energy analysis—version 11.0*, November 2017.

LCOE - *Levelized cost of energy*

- The **LCOE** is the $/MWh measure of power generation costs that accounts for the capital costs, operations and maintenance costs, capacity factors, and fuel costs of a given technology, averaged over its lifetime.
- It enables an apples-to-apples cost comparison of different energy resources