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VARIABLE RENEWABLES INTEGRATION IN ELECTRICITY SYSTEMS: HOW TO GET IT RIGHT

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ABOUT THE WORLD ENERGY PERSPECTIVES - VARIABLE RENEWABLES INTEGRATION IN ELECTRICITY SYSTEMS: HOW TO GET IT RIGHT

Renewable Energy Sources (RES) offer many benefits, such as CO2 emissions mitigation, fossil fuels import requirement reduction and new jobs creation, just to name a few. At the same time, the recent expansion of variable renewables-based generation also poses certain challenges, both technical and economic and they require short and long-term solutions.

The study identifies these challenges and offers some solutions based on the experience of the industry operators around the world. The conclusions of the study indicate that the complexity and the overall impact of variable renewables integration in national electricity systems are often underestimated both by the consumers and politicians.

Sharing information and experiences between countries, both positive and negative, about different ways to manage certain impacts of variable RES will help ensure each country maximises the benefits and minimises the drawbacks of RES technologies. This has been recognised by the electricity industry and therefore, the World Energy Council established this Knowledge Network (KN).

The work of the KN is supported by the Council's **Global Partner CESI SpA, Italy**, and the Knowledge Network has 48 members representing 32 different countries from five continents

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EXECUTIVE SUMMARY

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In the light of the growing importance of renewables and especially Variable Renewable Energy Sources (VRES) all over the world, policymakers and the industry need to address emerging issues to ensure continued growth of variable renewables and their successful integration in electricity systems. Drawing on case studies from 32 countries across five continents, the report *Variable Renewables Integration in Electricity Systems: How to get it right* highlights lessons learnt, identifies critical success factors and extracts practical solutions for success.

KEY FINDINGS

1. RENEWABLES, INCLUDING HYDROPOWER, NOW ACCOUNT FOR ABOUT 30% OF THE TOTAL GLOBAL INSTALLED POWER GENERATING CAPACITY AND 23% OF TOTAL GLOBAL ELECTRICITY PRODUCTION. In the last 10 years, wind and solar PV have witnessed an explosive average annual growth in installed capacity of 23% and 51% respectively, although their combined contribution to the global electricity production is around 4%.

2. RENEWABLES HAVE BECOME BIG BUSINESS: IN 2015 A RECORD USD286 BILLION WAS INVESTED IN 154GW OF NEW RENEWABLES CAPACITY (76% IN WIND AND PV), by far overtaking the investment in conventional generation to which 97 GW were added. There was a general market shift from developed countries to emerging economies. China alone accounted for 36% of global RES investments.

3. THE COMBINATION OF IMPROVING TECHNOLOGIES AND COST REDUCTIONS IS DRIVING DOWN CAPITAL EXPENDITURE (CAPEX) AND OPERATIONAL AND MAINTENANCE (O&M) COSTS of variable renewables, solar PV in particular. The most recent data available suggests the lowest auction value for wind is a tariff of USD28/MWh in Morocco and USD30/MWh for an 800 MW solar PV plant in Dubai. These exceptionally low values cannot generally be projected to other countries with different wind and sun load factors (in continental Europe, for example, they are up to 50% lower) and high local costs.

4. BY 2015, 164 COUNTRIES AROUND THE WORLD HAD RENEWABLE ENERGY SUPPORT POLICIES IN PLACE: 95 of them were developing countries, compared with 15 in 2005.

5. **THE EXAMPLE OF THE EUROPEAN UNION (EU) HIGHLIGHTS THE CONSEQUENCES OF REDUCTIONS IN SUBSIDIES** and other support schemes for investment in renewables: as subsidies decreased, the EU's share of global solar PV installed capacity dropped over the past four years from 75% to 41%, the share of wind from 41% to 33%.

6. **A RIGHT LOCATION WITH HIGH WIND OR SOLAR LOAD FACTORS AND LOW GRID CONNECTION COSTS** is the key to success for new, large variable renewables projects.

7. **A REAL CHALLENGE FOR VARIABLE RENEWABLES INTEGRATION IS TO RAPIDLY MANAGE THE IMPLICATIONS OF VARIABLE NATURE OF WIND AND SUN.**

RENEWABLES IN THE GLOBAL ENERGY SYSTEM

World global power capacity additions and energy production by source 2004-2014.

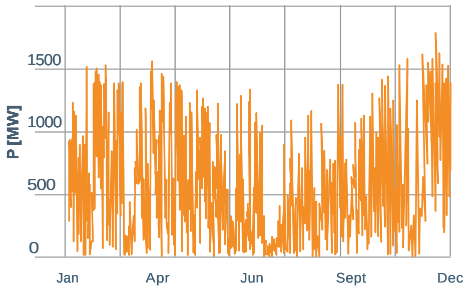
Source	Installed Capacity 2004 [GW] and (%) share		Installed Capacity 2014 [GW] and (%) share		Average Annual Growth Rate (%)	2014 Production [TWh] and (%) share		Average Equivalent Operating Hours [h]
Hydro	715GW	18.8%	1,055 GW	17.1%	4%	3,898TWh	16.6%	3,694
Wind	48GW	1.3%	370GW	6.0%	23%	728TWh	3.1%	1,967
Biomass	39GW	1.0%	93GW	1.5%	9%	423TWh	1.8%	4,545
Solar	3GW	0.1%	181GW	2.9%	51%	211TWh	0.9%	1,168
Geothermal	9GW	0.2%	13GW	0.2%	4%	94TWh	0.4%	7,225
Total Renewables	814GW	21.4%	1,712GW	27.7%	8%	5,353TWh	22.8%	3,127
Total Conventional (Oil, Gas, Coal) and Nuclear	2,986GW	78.6%	4,468GW	72.3%	4%	18,127TWh	77.2%	4,057
TOTAL	**3,800GW**	**100%**	**6,180GW**	**100%**	**5%**	**23,480TWh**	**100%**	**3,799**

Source: CESI S.p.A., based on REN21 2015

The graphs below illustrate the effects of wind variability in Ireland on the global wind fleet power production and the variations of sun on a small PV installation in central Italy.

YEARLY AND DAILY VARIABILITY IN IRELAND OF GLOBAL WIND FLEET POWER PRODUCTION

YEARLY



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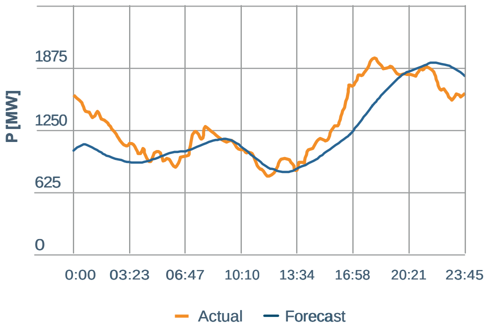
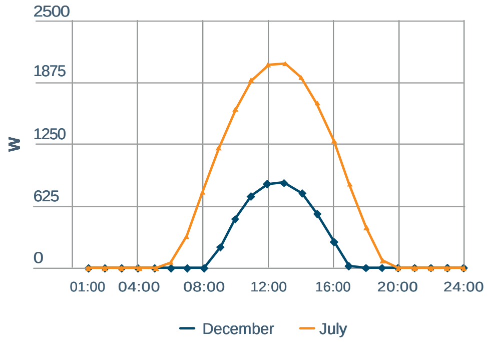


SEASONAL AND DAILY VARIATION OF THE POWER GENERATION FOR A SMALL PV PLANT IN CENTRAL ITALY

SEASONALITY



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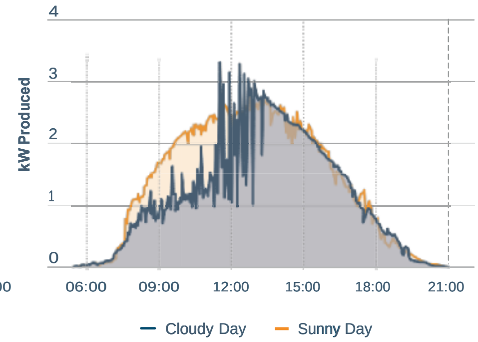


Source: CESI S.p.A

RECOMMENDATIONS

The increasing use of variable renewables still presents a number of challenges. Effective and affordable technology solutions will help decrease or eliminate these challenges. Appropriate policies, including regulation and market design play a fundamental role in both development of variable renewables and their efficient integration in electricity systems.

Solutions for the main challenges can be divided into two complementary categories **Policies** and **Technologies**.

• POLICIES AND MARKET DESIGN

- **A holistic and long-term approach** to system design is key when planning variable renewables integration. Each country's power is unique depending on its primary energy sources, location and size of power plants, transmission and distribution (T&D) systems, financial conditions, costs and consumer behaviour.
- **Market redesign:** Policymakers must design market rules to ensure a more sustainable energy system in line with the objectives of the Trilemma, including clearly defined CO_2 emissions regulations.
- **Introduction of capacity markets** can help ensure security of supply, as energy-only based markets are often insufficient to guarantee supply in systems with a large share of variable renewables.
- **Adjustments to existing market design** can be efficient, for example:

    Larger balancing areas: Sharing the implications of variability and load forecast errors across a broader region provides a natural reduction in the system balancing costs.

    Aggregating the bids of different plants in the market can facilitate a reduction in the overall variability of electricity supply and thus reduce the forecast errors and system balancing needs.

    Ancillary services can be provided by variable renewables, even in the absence of sun and wind, with help of new inverter technologies. Responsibilities for system balancing have to be shared fairly among market participants, including variable renewables generators.

Hourly and sub-hourly scheduling: Taking into account the technical limitations of conventional plants for more efficient use of available transmission and generation capacity.
Nodal pricing demonstrates the benefits of an appropriate selection of location for renewables power plant and as a result, smoother integration of intermittent renewable generation technologies.

- **Looking at the costs:** Policymakers and the industry are encouraged to conduct thorough technical and economic analyses with comprehensive assessment which, in addition to VRES CAPEX and O&M, include the associated costs for the complete power system.

TECHNOLOGIES

- **Improving weather forecasts:** Weather forecasting methodologies need further development to achieve better accuracy.

- **Advanced operating procedures to optimise reserve capacity and flexibility of conventional generation** should be introduced to manage intermittency and variability.

- **Demand response,** i.e. the short-term adjustment of demand to address temporary shortage or excess power from variable renewables, must be developed further.

- **Energy storage technologies** can be a game-changer and contribute to addressing the intermittency challenge. See the Council's 2016 report on E-storage **www.worldenergy.org/publications/2016/e-storage-shifting-from-cost-to-value-2016**

- **An expansion of the transmission and distribution grids,** including cross-border interconnections, may be necessary together with an optimum operational cooperation between TSO's and DSO's.

INTRODUCTION

Over two decades ago, the world's electric power sector began its transformation from a highly centralised and integrated industry that was mostly state-controlled towards a more efficient and lean business model, including private ownership. This transformation has been driven by new developments in regulation, profound structural changes in the market, shifts in the technology mix and growing concerns about the environmental impacts of energy production and use. Mounting concerns about global warming and the role of the energy sector require the industry to adjust to the realities of operating in a new carbon-constrained world. The most significant catalysts for the transformation of the electricity industry include:

- Ongoing market restructuring processes and evolving regulation around the world;
- Increased volatility of oil prices where an era of high oil prices over a longer period of time was followed by a drastic collapse in 2014 which influenced all fossil fuel prices;
- The shale gas revolution in the US which reduced coal demand for electricity production and increased the use of gas leading to growing exports of US coal at low prices;
- The Fukushima nuclear accident in Japan, which has practically stalled future development of nuclear power in many countries;
- Increased tensions in the countries that are large exporters of oil and gas, including the Middle East, Latin America and Russia.

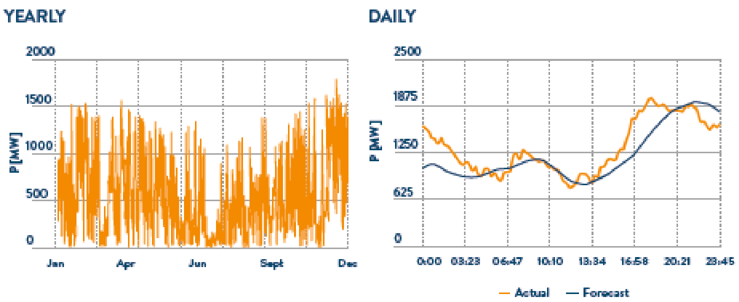
However, first and foremost, it is increased concerns about global warming, the associated environmental regulations and the growing awareness of environmental issues which drive the development of power systems' strategies and projects.

In many countries, this has resulted in new legislation providing support for the development of Renewable Energy Sources (RES), especially wind and solar photovoltaic (PV) which have both experienced a tremendous growth, particularly in the European Union (EU). This growth was also underpinned by a significant reduction in the Capital Expenditure (CAPEX) for wind and solar plant components and projects.

What about the weather? The weather factor plays a leading role in the availability of electricity produced from renewables. Solar PV and wind have a high degree of variability because of the constantly changing wind conditions and sun irradiation rates. This variability leads to seasonal, weekly and daily fluctuations of power and can result in forecast errors in the supply of power to the system.

Figure 1 demonstrates wind patterns in Ireland and their influence on the power delivered to the system by all the wind farms in the country.

FIGURE 1 – YEARLY AND DAILY VARIABILITY IN IRELAND OF GLOBAL WIND FLEET POWER PRODUCTION.



A similar situation based on sun availability is presented in Figure 2 which shows the output of a 3 kW residential solar panel in central Italy and in Figure 3 which shows the effect of daily cloud variations on generation.

FIGURE 2– SUN VARIATION ON THE POWER GENERATION OF A SMALL PV PLANT IN CENTRAL ITALY: YEARLY COMPARISON PER WEEK AND SEASONALITY

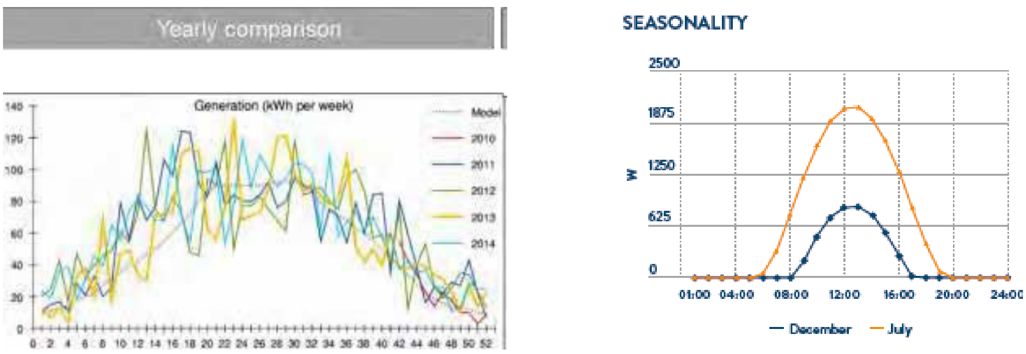
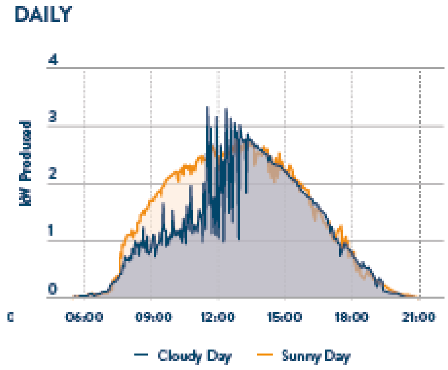


FIGURE 3: CLOUD EFFECT ON THE POWER GENERATION OF A SMALL PV PLANT IN CENTRAL ITALY



Source: CESI S.p.A

The weather dependency of wind and solar PV, especially when they reach a significant share of the generation capacity and energy production, may raise barriers to their smooth integration in the electrical systems which were not originally designed for this type of generation.

The conventional plants used to manage load variability during the day need to adjust to the production variability of large variable renewable energy sources (VRES) plants connected to transmission and sub-transmission systems. They must also accommodate production of a large number of distributed generation units, including households which fall in the "prosumers" category (i.e. both producers and consumers of electricity).

These developments combined with other challenges, such as the requirement for expansion of Transmission and Distribution (T&D) systems, unexpectedly emerging spare capacity at conventional plants and the need for increased flexibility of the generation assets together with VRES impacts on the electricity market have been recognised by the electricity industry at an early stage. To assess the challenges and identify solutions, in 2014 the Councillaunched a study on the Integration of Renewables in Electricity Systems in order to assist the process of energy policies development and increase awareness of the technical, economic and market issues related to integrating VRES into electricity systems.

The work of the Knowledge Network (KN) is supported by the Council's Global Partner CESI SpA from Italy, and the KN has 48 members and contributors representing 32 different countries from five continents (see also Annex 2).

The Council's survey underlying this report was initially based on a questionnaire distributed to a few experts in different countries with a request to validate the concept using a test case of Italy as a template for reporting the electricity system data and other information about the challenges emerging as a result of massive additions of VRES. The reviewed and updated survey questionnaire was distributed to the Council's Member Committees (MCs) across the world. Sharing information and experiences between countries - about the impacts of VRES on the electricity systems was the main scope of the KN.

The objective of this report is to summarise the main results of the research undertaken by the KN focusing on wind and solar PV, and formulate recommendations to decision makers and other stakeholders of electric power systems on how to approach the VRES system integration.

Chapter 1 summarises facts and figures related to the rapid development of VRES worldwide and the associated costs (see also Annex 1). Recent data from auctions held at the end of 2015 through to the first quarter of 2016 confirm a continuing decline of the USD/MWh price of solar PV and wind plants, to levels unimaginable only a year ago.

Chapter 2 presents a summary "lessons learned" from 32 country case studies. These countries represent 89% of the world total variable renewables installed capacity and 87% of the wind and solar electricity production. Different types of incentives are reviewed together with the identified impacts of VRES on the conventional generation fleets, electricity market, T&D grids and the corresponding implications for final consumers.

Chapter 3 is focused on measures for a smoother integration of VRES capacity already in place or under evaluation in a number of countries around the world, both from the technological and market rules perspectives.

Renewable Energy Sources (RES) offer many benefits, including CO_2 emissions mitigation, fossil fuels import requirement reduction and job creation. At the same time, the findings of this study indicate that the total cost and the overall impact of RES on national electricity systems is often underestimated by consumers and policy makers.

In general, the KN found that the rapid growth of renewables together with their priority of dispatch status has led to price reductions but also price increases for some electricity consumers. Final bills do not usually display itemised costs of the direct incentives and additional measures required to accommodate the increasing share of RES. The bills would look significantly different if these costs were itemised. The additional measures are necessary to keep the system running and they include backup/reserve capacity, system balancing costs, additional network investments and other similar outlays. In addition, in some countries, the "state-of-the-art", high efficiency gas-fired generation units are being used less and less frequently and utilities have to write off these stranded assets (see case studies for Germany and Italy); the introduction of a capacity market, are being examined in several EU countries.

How is this study different from other publications and reports on the same topic? First and foremost, it takes the subject beyond academic research and into the practical domain. It introduces a different approach by focusing on actions which are recommended in different conditions and can be used as a “guide book” listing recommendations to take into consideration when evaluating future VRES projects, and the sources for additional information.

Every country’s power system has its specific features, such as type/size, siting of conventional and RES plants, T&D system, consumer behaviour and other factors that make it difficult to draw general conclusions.

Examples of the impacts on the electricity systems in different countries and the associated lessons will be useful for new market entrants to avoid poorly planned VRES integration projects, which could become a liability instead of an asset.

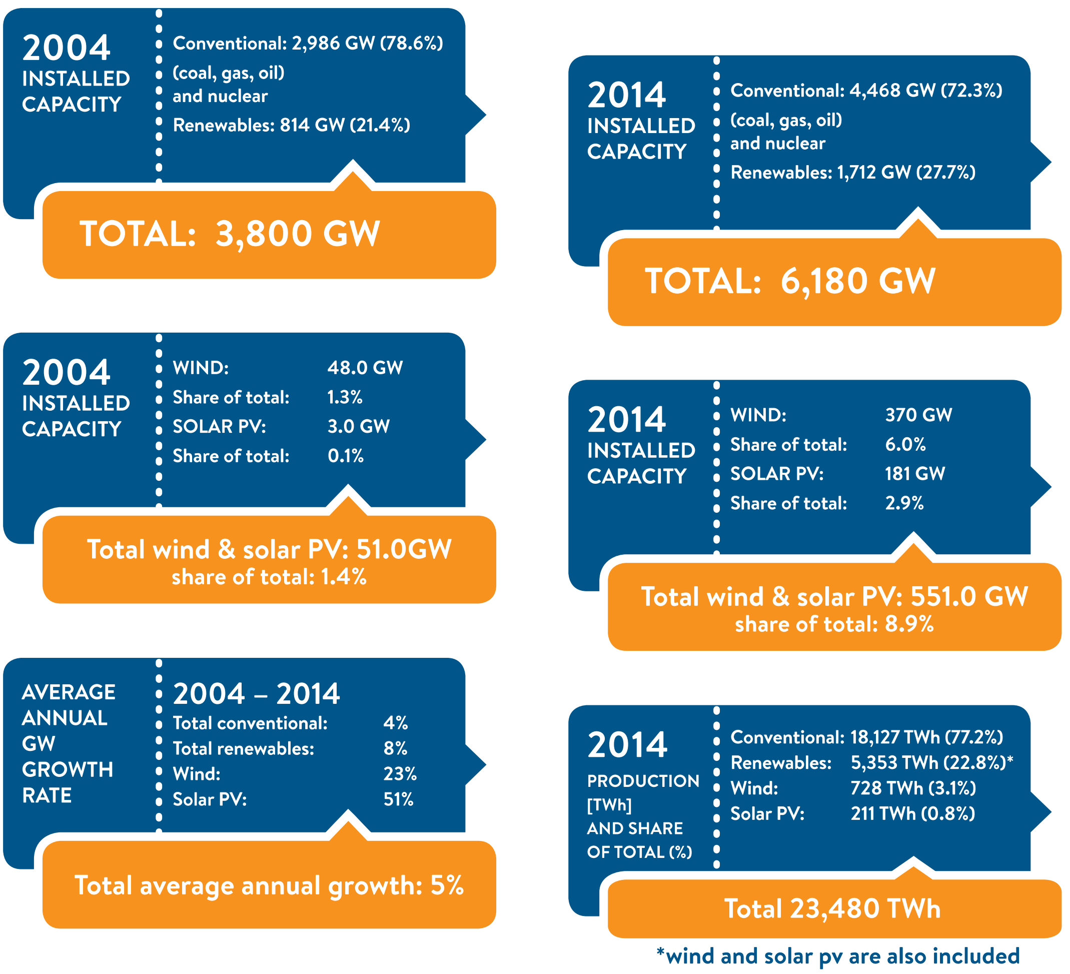
Technical details and cost information in this report are unique because they come directly from the utilities and other relevant sources within each country. Conclusions of the study will help decision makers to develop a better understanding of the complexity of the electricity system setup and operation and suggest factors to be considered when formulating policies and strategies for VRES development.

Chapter 1
Current Status of VRES

By 2015, 164 out of 196 countries in the world had set renewable energy targets, and 138 countries had renewable energy support policies in place. The recent wave of energy policies in support of RES has been led by 95 developing and emerging economies, an increase from only 15 countries in 2005.

The global installed RES capacity has more than doubled over the past ten years, from 814GW in 2004 to 1,712GW by the end of 2014. As Graphic 1 shows, this growth was mainly driven by wind and solar power which increased from 48 GW and 3 GW in 2004 to 370 GW of wind and 181 GW of solar power in 2014, with an average annual growth rate of 23% and 51.0%, respectively.

GRAPHIC 1 - WORLD GLOBAL POWER CAPACITY ADDITIONS AND ENERGY PRODUCTION BY SOURCE 2004-2014



Graphic Source: CESI S.p.A., based on REN21, 2015

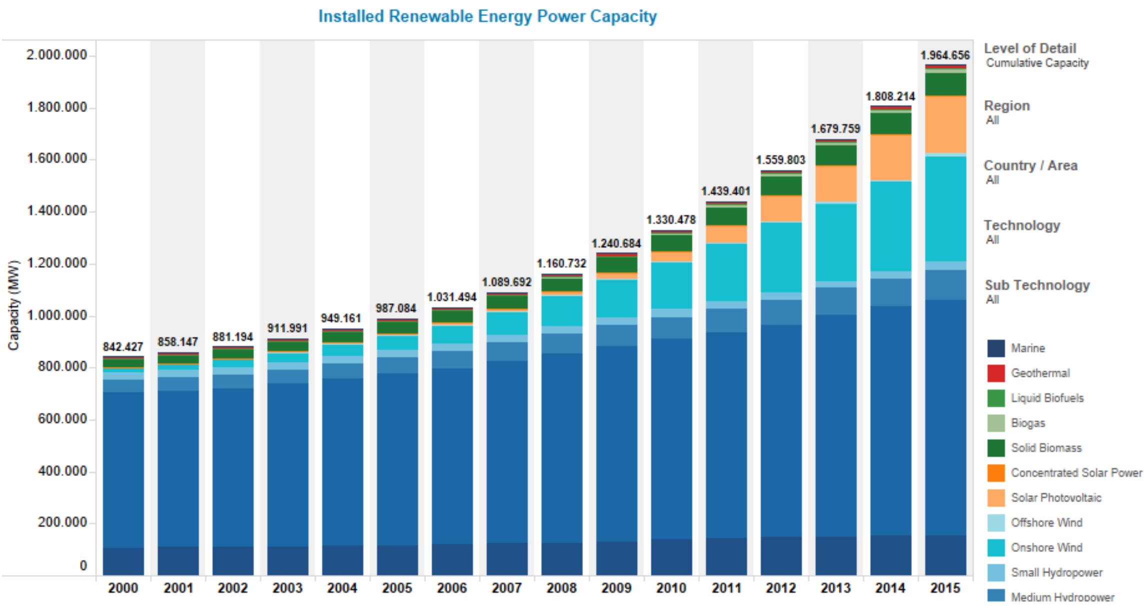
In 2015 alone, 150GW of new renewables capacity were added to global installed generation (Figure 4), more than all other technologies put together, including nuclear, coal, gas and hydro power projects over 50MW. This was equivalent to a share of about 60%.

As in previous years, the growth in renewables in 2015 was dominated by solar photovoltaic and on-shore wind, which together accounted for additional 103 GW. Wind's share was 62GW and solar PV 41 GW, with smaller shares of biomass, geothermal, solar thermal and "waste-to-power" (i.e. recycling of waste products).

In terms of electricity production, RES have reached almost 23% of global annual production in 2014 (Graphic 1). Hydro is still the largest primary renewable energy resource for electricity production, currently accounting for 73% of global RES output. Although the growth in VRES has been spectacular, it is important to note that this growth started from a very low level. Currently, the share of renewables in the total global electricity supply without hydropower is approximately 6.2%.

The relatively low share of wind and solar in the electricity production - 4% of total in 2014 - can be explained by their smaller installed capacity and a lower number of equivalent operating hours per year. World averages of annual equivalent operating hours for different technologies range from 6,300 hours for nuclear to 3,700 hours for hydro, around 2,000 hours for wind and almost 1,200 for solar. This highlights the importance of cost reductions needed for wind and solar technologies to achieve competitive production cost of electricity per kWh.

FIGURE 4: RENEWABLE CUMULATIVE INSTALLED RENEWABLES CAPACITY BY TECHNOLOGY IN THE PERIOD 2001–2015



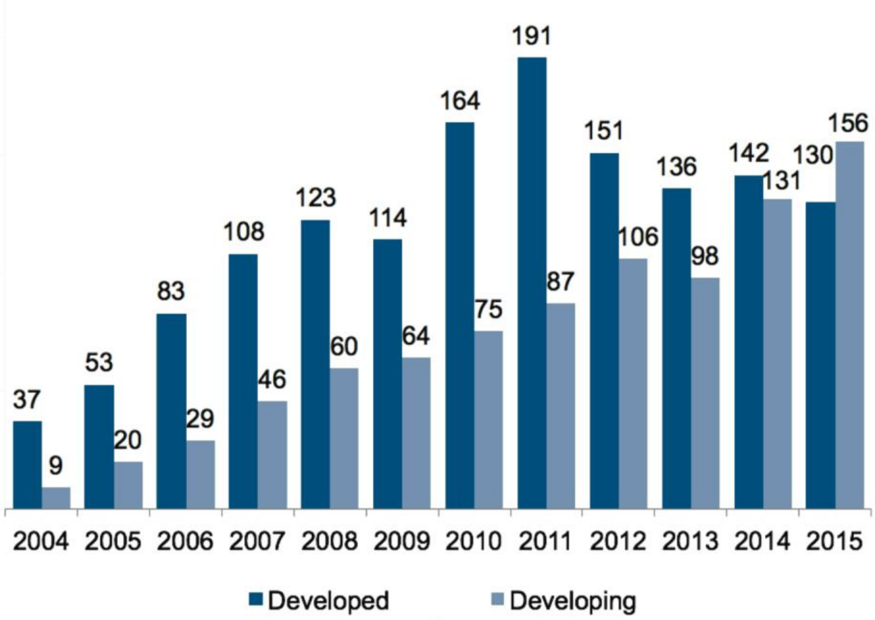
© IRENA
Based on IRENA Estimate, IRENA Questionnaire, Eurostat, EIA, GWEC, Ministry of Mines and Energy (Brazil), ECLAC, Ministry of Energy and Mineral Resources (Indonesia), IEA-PVPS, Bureau of Energy (Chinese Taipei) and more

Source: IRENA

2015 was a historical year in the RES investment (Figure 5) reaching a spectacular amount of USD286 billion with more than half of the total coming from a few developing countries, mainly China, which alone invested USD103 billion that accounts for 36% of the world total. Among developing countries, India was the second largest investor with USD10.2 billion, followed by South Africa (USD4.5 billion), Mexico (USD4billion) and Chile (USD3.4 billion). Morocco, Turkey and Uruguay were also among the major investors with at least USD1 billion each. Generally, developing countries increased their investment in clean energy more than 17 times compared to 2004.

In developed countries, the 2015 investments reached USD 48.8 billion in Europe (21% less compared to 2014), USD 44.1 billion in US and USD 36.2 billion in Japan. These staggering investments especially in Europe underline the business case for VRES, which have grown at a tremendous rate, mostly due to the supportive policies and measures.

FIGURE 5: GLOBAL NEW INVESTMENT IN RENEWABLE ENERGY – DEVELOPED VS DEVELOPING COUNTRIES, 2004-2015 (USD BILLION)



Source: Bloomberg New Energy Finance and UNEP

The downward trend observed over the past 3 years in part was a result of the revisions of RES incentives programmes in a number of EU countries. This decrease was not fully matched by increasing investment in developing countries. Another important factor affecting the decreasing trend was the drop in the investment costs per kW, especially for solar PV (Figure 6).

EU has traditionally been a leader in VRES investment due to its comprehensive CO_2 emissions reduction legislation. The recent decrease in solar PV and wind installations in Europe highlighted in Table 1 shows the EU's share of global solar PV cumulative capacity falling from 75% to 43% over the last four years and wind capacity share falling from 40% down to 33%.

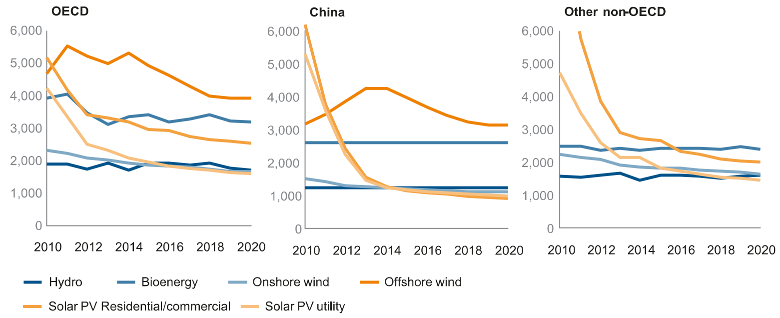
TABLE 1: WIND AND SOLAR PV CUMULATIVE INSTALLED CAPACITY DEVELOPMENT FROM 2011-2015 IN EUROPE AND GLOBALLY (GW)

		2011	2012	2013	2014	2015
PV	Europe	52	70	81	88	96
	World total	69	100	139	181	222
	EU %	75%	70%	58%	49%	43%
Wind	Europe	95	108	119	131	144
	World total	239	283	318	370	432
	EU %	40%	38%	37%	35%	33%
Total	**Europe**	147	178	200	219	240
	World total	308	383	457	551	654
	EU %	48%	46%	44%	40%	37%

Increasing volumes of RES investment together with significant technology developments have led to a fast reduction in the capital expenditure for many renewable technologies.

Solar PV demonstrates the largest cost decline in the OECD countries, by around 50% between 2010 and 2014 and even more in non-OECD Countries (Figure 6). In some countries, solar PV power plants with capacity above a few MW have engineering, procurement and construction contract values even below 1,000 USD/kW.

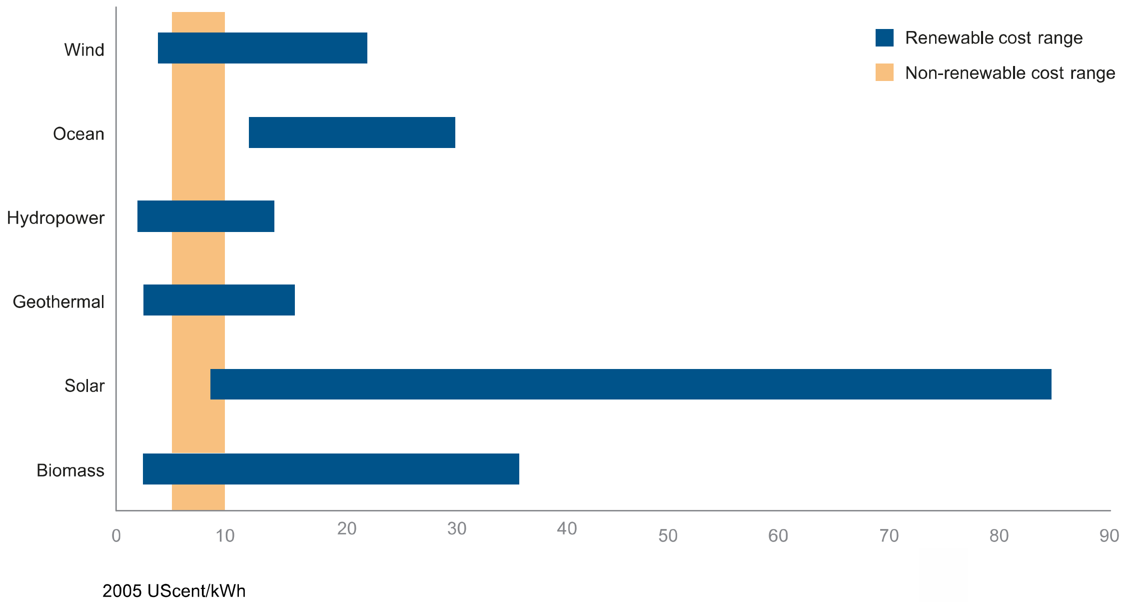
FIGURE 6 – RENEWABLE INVESTMENT COSTS, HISTORICAL AND PROJECTED IN USD/KW



Source: IEA 2015

Figure 7 provides a summary of the worldwide ranges of levelised cost of electricity (LCOE) for RES compared to other technologies. However, the LCOE methodology does not take into account the additional costs to the electrical power system due to the variability/intermittency of wind and solar power. (*See e-storage report* *http://www.worldenergy.org/publications/2016/e-storage-shifting-from-cost-to-value-2016/*)

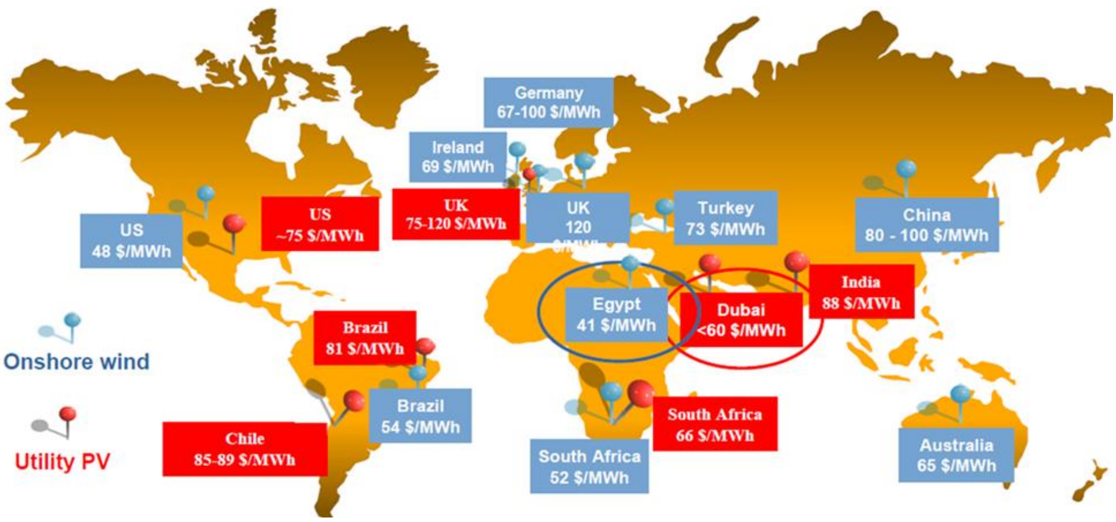
FIGURE 7 – RANGES IN LEVELISED COST OF ELECTRICITY (LCOE) IN USCENT/KWH FOR SELECTED TECHNOLOGIES



Source: REN 21, 2015

A world map in Figure 8 demonstrates a few onshore wind and solar PV prices from long-term contracts updated up to the second quarter of 2015. The combination of technology costs reduction and an appropriate regulatory framework is effectively driving competition and pressing down prices for RES generated electricity worldwide.

FIGURE 8 – LONG-TERM CONTRACT PRICES (E.G. AUCTIONS AND FITS)



Source: IEA, 2015

The lowest values for wind and solar electricity were registered in Egypt (USD41/MWh) and Dubai (USD60/MWh), respectively. **More recently, up to the first quarter of 2016, additional decreases in auction prices have been observed** in Latin America, Africa and Middle East, explained by exceptionally low regional CAPEX & OPEX and extremely high load factors for wind and solar plants.

Load factors for wind at certain locations in Morocco, Egypt, North-Eastern Brazil, Mexico, US and other places are on average around or even exceeding 50% which brings auction tariffs down to 28 USD/MWh in Morocco, 38 USD/MWh in Peru and in the range of 40-55 USD/MWh in Egypt, Mexico, South Africa and Brazil.

Obviously, it is not possible to replicate these prices in continental European countries where on shore plants achieve load factors in the range of only 20-30%.

In the same way, solar PV plants in sunny areas have load factors approaching 30% and this has produced - in the first quarter of 2016 - tariffs at auctions as low as 30 USD/MWh in UAE, 35 USD/MWh in Mexico and ranging 48-55 USD/MWh in Peru and South Africa.

This leads to a first general conclusion: **to secure a short payback time and favourable economics, new VRES projects should be located in places with high wind and/or solar PV load factors and low grid connection costs.** Annex 1 contains examples of detailed economic information for solar PV and wind plants in a number of countries around the world collected by KN.

Chapter 2
Lessons learned from the Country Case Studies

The summaries of the country case studies are included in Annex 2, and the complete country case studies can be downloaded from World Energy Council's website http://www.worldenergy.org/publications/

These individual country reports outline specific implications of VRES developments for their electricity systems. The country reports add their own flavour to the descriptions and practical examples of technological and market developments related to VRES.

The main actions are recommended to help guide the developments based on reviews in the country reports.

The case studies include the following countries:

1. Algeria
2. Brazil
3. China
4. Colombia
5. Denmark
6. Ecuador
7. Egypt
8. France
9. Germany
10. India
11. Indonesia
12. Ireland
13. Italy
14. Japan
15. Jordan
16. Kazakhstan
17. Korea
18. Mexico
19. New Zealand
20. Nigeria
21. Philippines
22. Poland
23.Portugal
24. Romania
25. Russia
26. South Africa
27. Spain
28. Thailand
29. Tunisia
30. United Kingdom
31. USA
32. Uruguay

2.1 Power mix of the 32 country case studies

The Council's Survey shows data for the 32 countries which accounted worldwide for:

- 89% of total installed VRES generating capacity
- 87% of VRES electricity production

The data on the installed capacity for 2015 (Table 3) and electricity generation (Table 4) using different energy sources were collected in each country to highlight VRES penetration including the incidence of VRES percentage on Country peak load (Figure 9).

The top four countries in the study with the highest absolute values of installed wind capacity at the end of 2015 were China (145 GW), US (73 GW), Germany (45 GW) and India (25 GW).

For wind energy production in terms of the percentage of total national production, Denmark is leading with 50%followed by Ireland 23%.

The top four countries in the study with the highest absolute values of solar PV installed capacity at the end of 2015 were China (43 GW), Germany (40 GW), Japan (33 GW) and the United States (26 GW).

For PV energy production in percentage terms of total national production, Italy is leading with 9% followed by Germany 6%.

The top four countries in the combined absolute values of VRES - wind plus solar PV - installed capacity were China (188 GW), US (98 GW), Germany (85 GW) and Japan (36 GW).

In terms of the percentage of total VRES national production, Denmark leads with 52% followed by Portugal (24%).If one considers Denmark in 2015 has had a net import of electricity larger than 20% of national production, the VRES reached about 42% of the total electricity consumption.

The highest equivalent operating hours at peak power (total electricity production per year divided by installed capacity) for wind plants were found in Denmark and UK with around 2,800 hours (load factor 32%), while for solar PV plants Spain has around 2,500 (load factor 28%) equivalent operating hours.

With reference to the potential impact of VRES on the overall national electricity system Germany and Denmark (Figure 9) have a VRES installed capacity practically equivalent to 100 % of the maximum peak demand, followed by Spain at 70% and by Portugal, Romania, Uruguay and Italy close to about 50%. The situation can be even worse considering periods of low demand.

TABLE 2 – 2015 INSTALLED CAPACITY BY COUNTRY AND BY RES AND VRES (GW)

Continent	Country	Peak Demand [GW]	RES installed capacity [GW]	VRES installed capacity [GW]	Wind installed capacity [GW]	Solar PV installed capacity [GW]
AFRICA	Algeria	10.9	0.5	0.3	0.0	0.3
	Egypt	26.1	3.5	0.6	0.6	0.0
	Nigeria	4.5	2.1	0.0	0.0	0.0
	South Africa	35.5	5.1	2.5	1.1	1.4
	Tunisia	3.3	0.3	0.2	0.2	0.0
AMERICA	Colombia	9.6	11.7	0.0	0.0	0.0
	Mexico	39.0	17.6	3.3	3.1	0.2
	United States	723.0	219.3	98.1	72.6	25.5
	Brazil	85.0	114.2	8.7	8.7	0.0
	Ecuador	3.5	2.6	0.0	0.0	0.0
	Uruguay	1.9	2.7	0.9	0.8	0.1
ASIA	China	830.0	519.7	188.2	145.1	43.1
	India	148.2	82.1	30.1	25.1	5.0
	Indonesia	53.8	8.3	0.0	0.0	0.0
	Japan	159.1	90.1	36.3	3.0	33.3
	Jordan	3.0	0.2	0.1	0.1	0.0
	Kazakhstan	15.0	2.8	0.2	0.1	0.1
	Philippines	11.8	6.2	0.5	0.4	0.1
	Korea Rep. of	76.5	12.7	4.1	0.9	3.2
	Thailand	26.9	8.4	1.8	0.2	1.6
EUROPE	Denmark	6.1	7.3	5.9	5.1	0.8
	France	82.5	44.3	16.9	10.4	6.5
	Germany	83.0	105.0	84.6	45.0	39.6
	Ireland	6.3	3.1	2.5	2.5	0.0
	Italy	59.0	54.8	28.0	9.1	18.9
	Poland	25.5	8.4	5.2	5.1	0.1
	Portugal	10.3	11.9	5.6	5.1	0.5
	Romania	9.3	11.3	4.5	3.2	1.3
	Spain	38.7	51.5	27.8	23.0	4.8
	United Kingdom	52.5	33.1	23.0	13.9	9.1
	Russia	155.0	52.0	0.5	0.1	0.4
OCEANIA	New Zealand	6.4	7.0	0.7	0.6	0.0
TOTAL 32 Countries			**1,499.7**	**581.4**	**385.1**	**195.9**
2015 TOTAL WORLD			**1,985.1**	**654.3**	**431.9**	**222.4**
% 32 Countries of TOTAL			**76%**	**89%**	**89%**	**88%**

Source: Country Cases and public sources

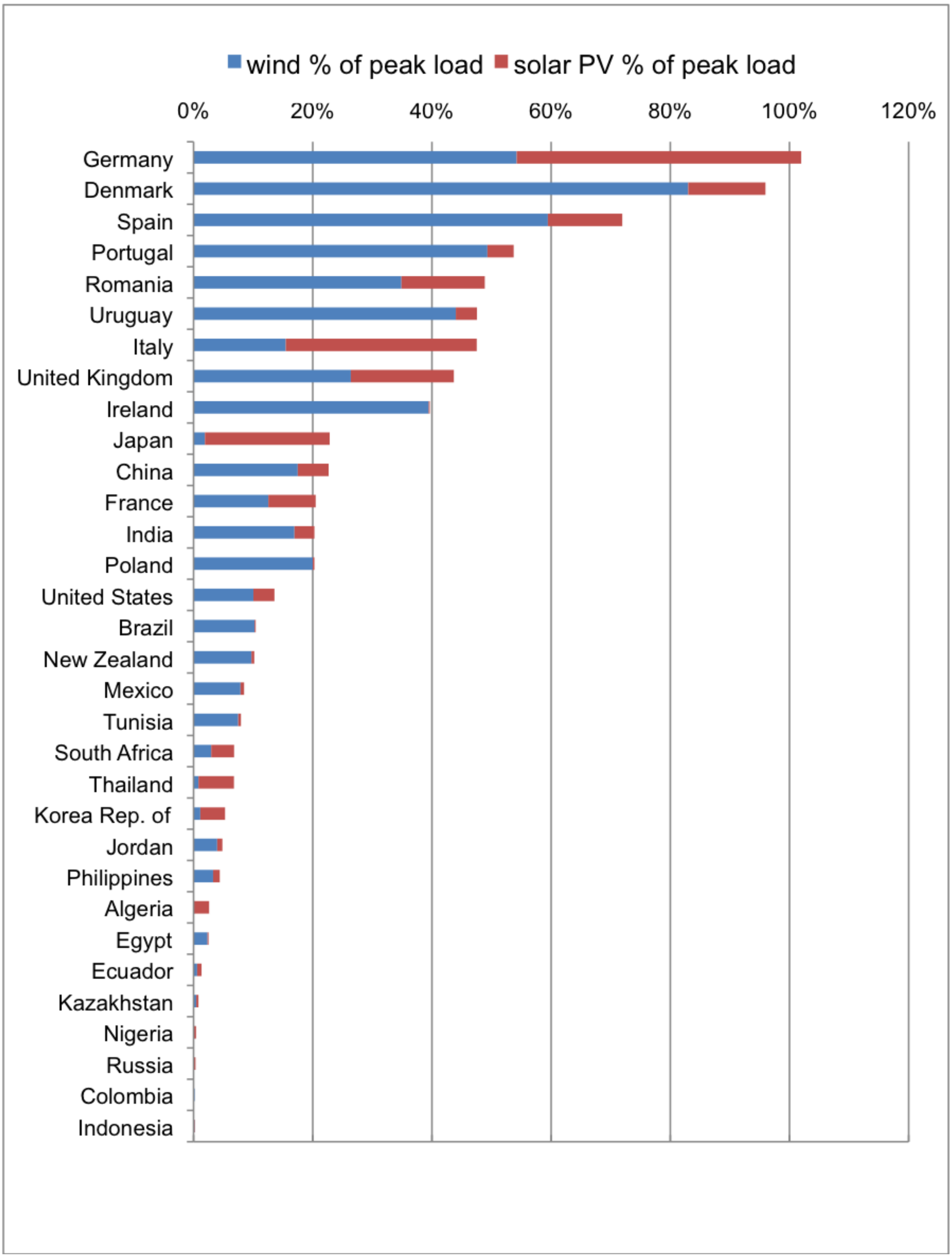
TABLE 3 – 2015 ELECTRICITY NATIONAL PRODUCTION BY COUNTRY AND BY RES AND VRES (TWH)

Continent	Country	Total Gen [TWh]	RES gen [TWh]	VRES gen [TWh]	Wind generation [TWh]	Solar PV gen [TWh]	Ratio VRES/Total gen [%]
AFRICA	Algeria	68.5	0.2	0.1	0.0	0.1	0.1%
	Egypt	180.6	14.6	1.6	1.5	0.1	0.9%
	Nigeria[1]	29.5	5.4	0.0	0.0	0.0	0.0%
	South Africa	249.7	5.3	4.0	2.1	1.9	1.6%
	Tunisia[1]	18.3	0.4	0.4	0.4	0.0	2.3%
AMERICA	Colombia	77.0	46.3	0.1	0.1	0.0	0.1%
	Mexico	306.7	45.6	8.2	7.9	0.3	2.7%
	USA	4.303.0	570.8	231.9	192.9	39.0	5.4%
	Brazil	579.8	432.8	21.7	21.7	0.0	3.7%
	Ecuador	25.9	13.6	0.1	0.1	0.0	0.5%
	Uruguay	12.1	11.2	1.9	1.8	0.0	15.4%
ASIA	China	5.810.6	1.403.6	224.3	185.1	39.2	3.9%
	India	1.304.8	192.9	48.0	41.4	6.6	3.7%
	Indonesia	234.7	26.5	0.0	0.0	0.0	0.0%
	Japan	1.035.5	160.6	36.3	5.4	30.9	3.5%
	Jordan[1]	18.0	1.0	0.1	0.1	0.0	0.6%
	Kazakhstan	91.1	8.0	0.1	0.1	0.0	0.1%
	Philippines	82.6	21.7	0.7	0.6	0.1	0.8%
	South Korea	522.3	16.0	5.4	1.6	3.8	1.0%
	Thailand	177.8	13.7	2.8	0.4	2.4	1.6%
EUROPE	Denmark[2]	28.7	18.9	14.9	14.3	0.6	51.8%
	France	568.8	88.6	27.5	20.2	7.3	4.8%
	Germany	647.1	195.9	126.4	88.0	38.4	19.5%
	Ireland	28.7	7.8	6.6	6.6	0.0	22.9%
	Italy	281.8	108.8	39.9	14.7	25.2	14.2%
	Poland	164.7	22.2	10.9	10.8	0.1	6.6%
	Portugal	51.9	24.2	12.4	11.6	0.8	23.9%
	Romania	65.6	25.9	9.0	7.0	2.0	13.8%
	Spain	278.5	95.8	63.2	49.3	13.9	22,7%
	United Kingdom	337.7	83.3	48.0	40.4	7.6	14.2%
	Russia	1,063.4	170.5	0.1	0.0	0.1	0.0%
OCEANIA	New Zealand	44.3	35.3	2.2	2.2	0.0	5.1%
TOTAL 32 Countries		**18.690**	**3.868**	**949**	**728**	**221**	**5.1%**
2015 TOTAL WORLD		**24.098**	**5.559**	**1.094**	**841**	**253**	**4.5%**
% 32 Countries of TOTAL		**78%**	**70%**	**87 %**	**87%**	**87%**	

[1]2014 values [2]Net import represents more than 20% of its production TWh, the VRES reached 42% of the total consumption in 2015.

Source: Country Cases and public sources

FIGURE 9-2015 VRES CUMULATIVE INSTALLED CAPACITY BY COUNTRY IN PERCENT OF THE NATIONAL PEAK LOAD



2.2 RES regulations, policies and economics

VRES regulation and policies present differences in the 32 Countries, but VRES enjoy priority of dispatch in most of them.

The use of various support and incentive schemes has a strong impact on the VRES development and success.

New Zealand is an exception, as it has a unique market arrangement based on a carbon price which avoid incentives to RES, combined with a nodal price that takes into account eventual additional costs on the T&D (e.g. losses and congestion) due to plants localization.

Financial incentives have been widely used for promotion of VRES. The most popular form is Feed in Tariffs (FIT) that are in used in many countries and are fixed for specified time periods (e.g. 20 years in Germany and Italy). The costs incurred by this system are typically passed on to the end-consumer. Some energy intensive businesses and production processes are exempt from this levy.

Green Certificates have been or are presently used in a number of countries. The quantity of green certificates is usually different for each type of RES technology, where electricity suppliers must each year purchase a number of green certificates proportional to the amount of electricity produced.

Tender auctions are becoming more widespread. Other incentives used include Feed-in-Premiums, tax credits and a levy on fossil fuels (e.g. oil in Algeria and coal in India). India's coal tax charge is 1.10 USD/tonne of coal, equivalent to a tax of approximately 1 USD per tonne of emitted CO2.

Below some key examples from Country Cases have been reported to provide a flavour on different approaches.

Italy – Reduction and withdrawal of incentives

Incentives for VRES in Italy used to consider Green Certificates, FIT, FI premium tariff. PV incentives introduced in 2005 amounted to 450 €/MWh and were among the highest in the world and this resulted in an impressive growth in new installations over a few years. As soon as the incentives were drastically reduced or withdrawn, the annual growth of VRES slowed down from 10 GW in 2011 to around 0.5 GW of new capacity additions in 2015.Now there are only auctions for very reduced global yearly capacity of large plants and tax deductions for small plants.

Germany – Reduction in Feed-in-Tariffs-Introduction of auctions

The FIT has been the basic incentive. The reduction of PV-feed-in tariffs has been a continuous instrument used by the German government and has resulted in reduced capacity additions in recent years (Figure 10). Moreover, a cap on the installed PV capacity of 52 GW has been introduced. Once this cap is reached, new PV units will no longer be supported by the EEG-feed-in tariff. In 2014 auctions for PV have been introduced for plants above 6MW each (see recent results in Annexe 1); auctions also for wind plants will be introduced in 2017.

Romania Green Certificates

Green certificates have been the basic type of incentive for the development of VRES-Decrease of incentives has caused significant reduction in VRES additions.

Japan – Feed-in-Tariffs

Feed in tariff for wind and solar falls in the range between 300–350 USD/MWh and now up to 450 to push VRES development considering nuclear concern and strong reduction in its production.

Korea-Green certificates and special incentives for Energy Storage Systems

It is mandatory for power generators to produce each year 2% of their total production from RES or buy from other generators Green Certificates-Additional certificates will be added to utilities which install wind power plants combined with Energy Storage Systems; this to support stable renewable supply systems, minimizing additional costs created by VRES.

Egypt-Bilateral agreements and tenders-Tax exemptions

Introduction of long term PPA's and competitive auctions which have produced tariffs for large wind plants in the range 38-45 USD/MWh (see Annexe 1). RES equipment and spare parts are exempted from custom duties and sales taxes.

South Africa-Auctions for large PV and wind plants

The auction procedure started in 2010 and the 4th series has been issued in 2015 (see Annexe 1); continuous reduction of the tariffs of around 25% from one auction to the next one.

USA-Differences for different utilities and regions

Policies for development of RES are Federal (Tax Credit and Production Tax Credit), State (e.g. Net metering) and Local (rebate and financing options, green power rates)

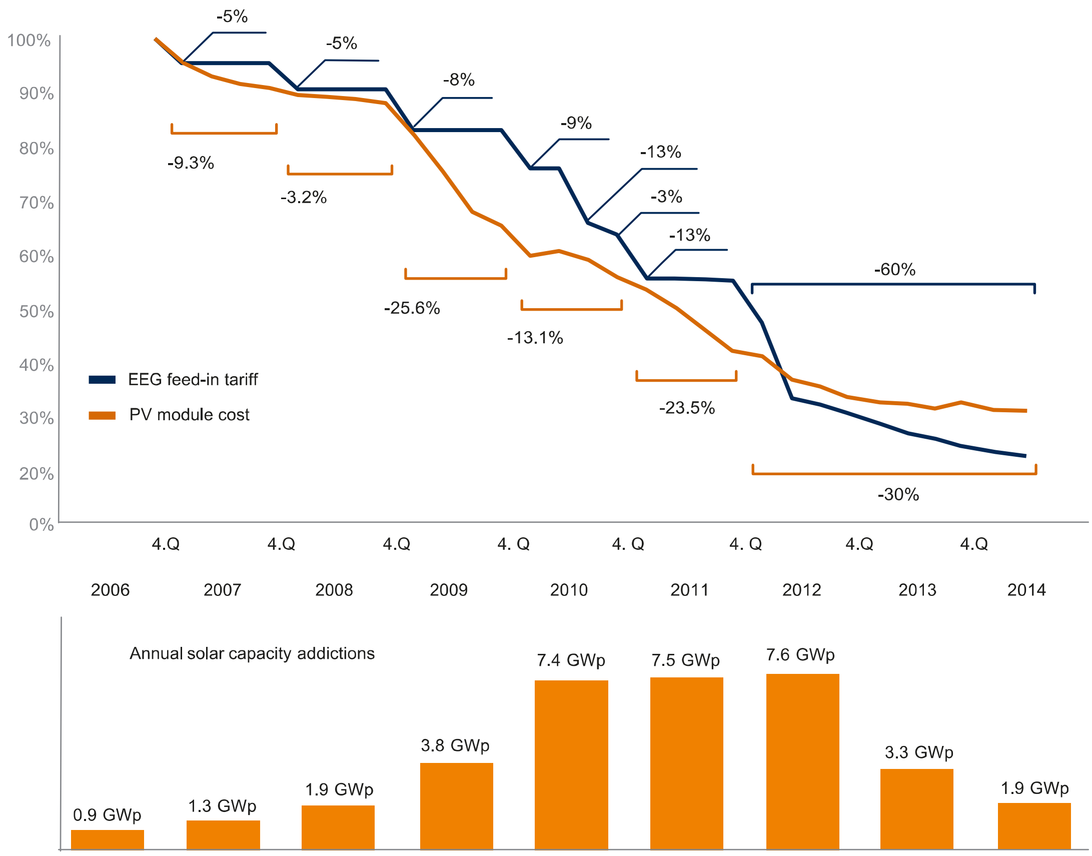
Brazil – Country-wide auctions

The current regulatory frameworks are based on auction mechanism for all types of power sources for long term contracts (Power Purchasing Agreements). In 2014, wind power was the second cheapest electricity source with 60 USD/MWh, but in 2015 auctions reached even below 50 USD/MWh, placing wind as the cheapest source of electricity (see Figure 11 and Annex 1).

Thailand – Feed-in-Tariffs

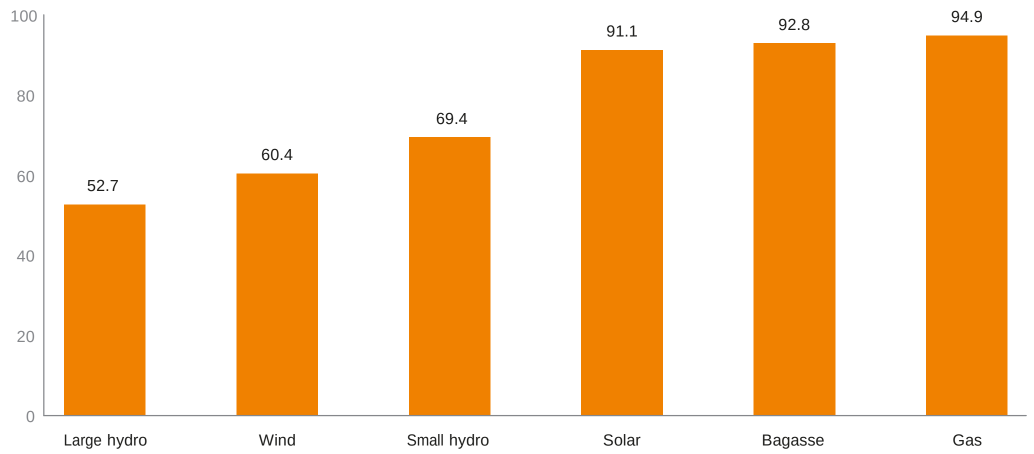
The feed-in tariffs for solar PV in Thailand for a 25-year period are ranging from 160 USD/MWh for large plants (> from 90 MW) to 195 USD/MWh for residential consumers and/or replacement of diesel in certain areas.

FIGURE 10 – DEVELOPMENT OF PV FEED-IN TARIFFS FOR PLANTS < 100KW, MODULE COSTS AND CAPACITY ADDITIONS IN GERMANY



Source: BSW-Solar, Beta

FIGURE 11 – AUCTIONED CONTRACTED PRICES WITH POWER GENERATORS IN BRAZIL IN 2014 (USD/MWh)



Recent financial data for onshore wind and solar PV systems in a number of countries is presented in Annex 1 and it includes CAPEX (**capital expenditure)** values, annual O&M (**operations and maintenance)** costs and when available LCOE (Levelised Cost of Electricity), and results of auctions up to first quarter of 2016 which refers mainly to large plants with financial backing by big energy players.

The values reported are relevant to the projects without special grants or subsidies and include complete generating systems with installation. Clearly both CAPEX and O&M costs are affected by the location of plant, transport and labour costs, local duties and taxes and other outlays.

It should be noted that some CAPEX data may include development costs, and this must be taken into account. It is also worth mentioning that in some cases the CAPEX values may be affected by hidden subsidies to contractors and to equipment suppliers and also by local import taxes for machinery and equipment. A more detailed analysis should be performed also for the data reported by various agencies, in particular when comparing their results.

CAPEX is usually presented in USD/MW or USD/kW and the O&M services are usually expressed in terms of Euro/or USD per installed MW. When expressed in terms of MWh, both CAPEX and O&M are strongly influenced by the load factor of the plant since the annual cost per MW must be divided by the equivalent hours of production (proportional to the load factor).

For wind farms the O&M costs usually increase with time. For a complete scope of services, cost after 5 or 10 years is often in the range of 30-40 USD/MW, while initial contracts in Europe are often in a range of 25-30 USD/MW. The O&M costs therefore for both wind and solar PV plants in locations with low load factors, may reach up to 15-20

USD/MWh for wind farms with 2,000 equivalent operating hours and close to 35 USD/MWh for PV systems with 1,250 equivalent operating hours.

Prices at auctions in many countries around the world have collapsed over the past 1-2 years. Tariffs for both solar PV and wind plants compared to the usual FIT values adopted to subsidise development of RES have decreased significantly. Africa, Latin America and Middle East are the regions leading the price drop where the lowest values were recorded at the end of 2015 and first quarter of 2016.

The lowest value for wind has been registered in Morocco with a tariff of 28 USD/MWh followed by Peru at 37 USD/MWh and by Mexico, Egypt, South Africa and Brazil in the range 40-49USD/MWh.

The lowest value for solar PV has been achieved in UAE 30 USD/MWh, followed by Mexico with 35 USD/MWh followed by Peru at 48 USD/MWh and South Africa with 55 USD/MWh.

It should be noted that such low values cannot be projected to other areas/countries where solar insolation and wind load factors are much lower and employment costs much higher than in the above mentioned countries. Another factor affecting prices is different rules for auctions in different countries and relevant penalties for not compliances in guaranteed performances.

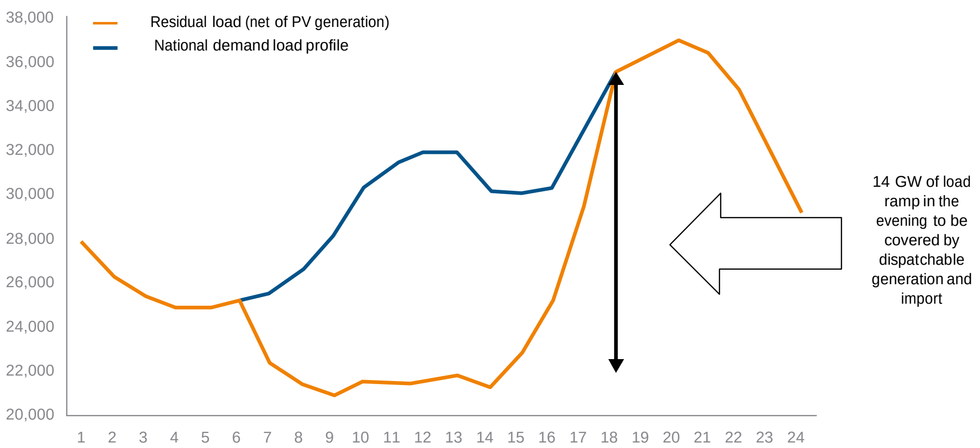
In Europe, for example, auctions in Germany, France and UK have reached 80-125 USD/MWh for solar PV and for onshore wind plants 125 USD/MWh. It will be interesting to review in a few years the low values achieved at recent auctions and find out whether the projected financial performance of the winning bidder was based on accurate estimates or overestimates of load factors and underestimates of actual CAPEX and OPEX costs.

2.3 Impacts of VRES on the electrical power system

IMPACTS ON TRADITIONAL FLEETS

The growth of VRES systems has had a significant influence on the operation of traditional electricity generation fleets (thermal, nuclear and hydro). Many efficient units built for base-load operation are today being used inefficiently, since the dispatch priority is given to VRES. As solar irradiation or wind speed vary, conventional generation units are required to ramp up and down and in many cases, beyond their flexibility limits. The possible implications for conventional units in Italy are presented in Figure 12.

FIGURE 12 – ITALIAN DEMAND AND VRES EFFECT



Source: Terna

VRES unpredictability forces TSO to increase reserve capacity that stands ready to provide additional power when VRE generation produces less power than the forecast and vice versa.

In Germany, an extended network reserve has already been established to stabilise the power system in times of severe grid constraints. It consists of conventional power plants contracted by TSOs especially for such situations. The network reserve must increase spare capacity to 6 GW in 2015/2016 and to 7 GW in 2016/2017.

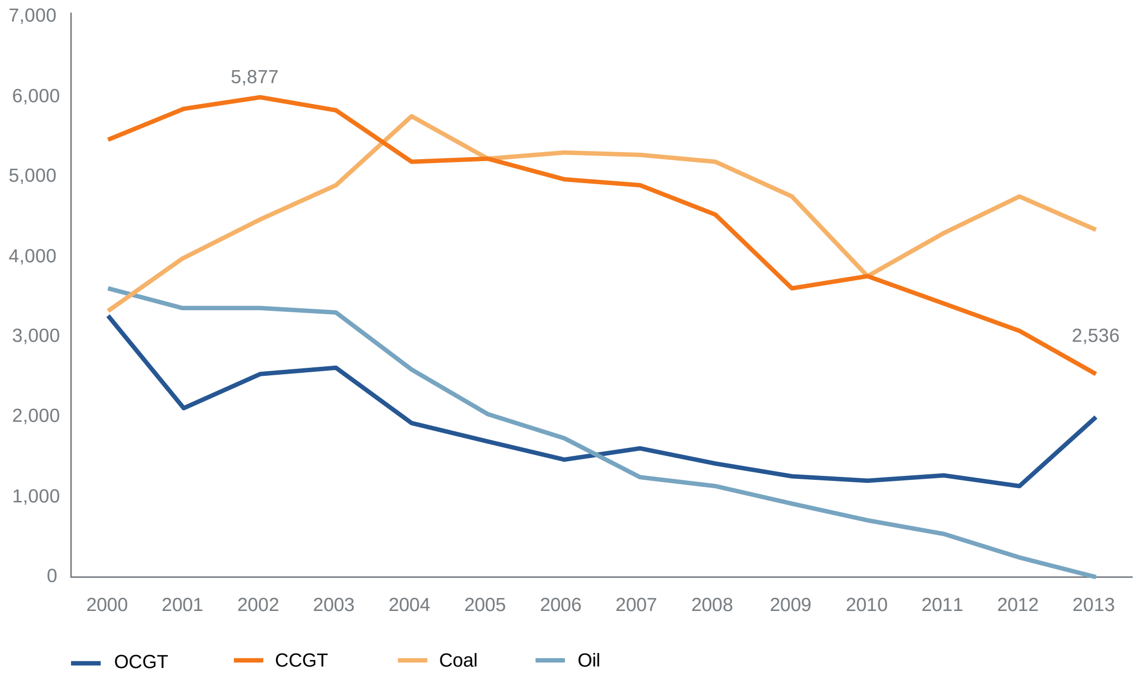
Generation from wind is irregular, but also changing cloudy weather can result in the same variability for PV with short time intervals. TSOs have to balance these variations through automatic primary regulation and by adjusting secondary generation regulation to keep frequency and voltage within a stable range.

Conventional power plants usually have installed primary frequency controllers and in order to bring the system frequency back to the equilibrium (i.e. 60 Hz in the US and 50 Hz in Europe) there is automatic control, while wind generators usually do not have the same capabilities.

The requirement for flexible power supply has also affected combined heat and power (CHP) associated with industrial and district heating uses. These technologies are extensively used in Denmark, Romania, Austria and Russia. In particular, the reduction of electricity generation due to unexpected VRES increase may pose limits to CHP electrical flexibility and thus affect its output. More significantly, the overall efficient and reliable performance of CHP plants may be jeopardised by excessive flexibility in the electricity output which would impact the heating system.

As VRES capacity grows, the associated reduction of operating hours for conventional power plants leads to insecurity in terms of new investments and operating costs as clearly demonstrated in the country reports for Germany, Italy, Romania and Denmark. Conventional power producers, the traditionally large investors in the electricity sector, have been particularly affected because of simultaneously decreasing power prices and shrinking operating hours for supplying the residual load (Figure 13). Reduction in demand has made the situation even worse, especially in some EU countries.

FIGURE 13 – SHRINKING OPERATING HOURS OF CONVENTIONAL POWER PLANTS IN ITALY



Source: CESI

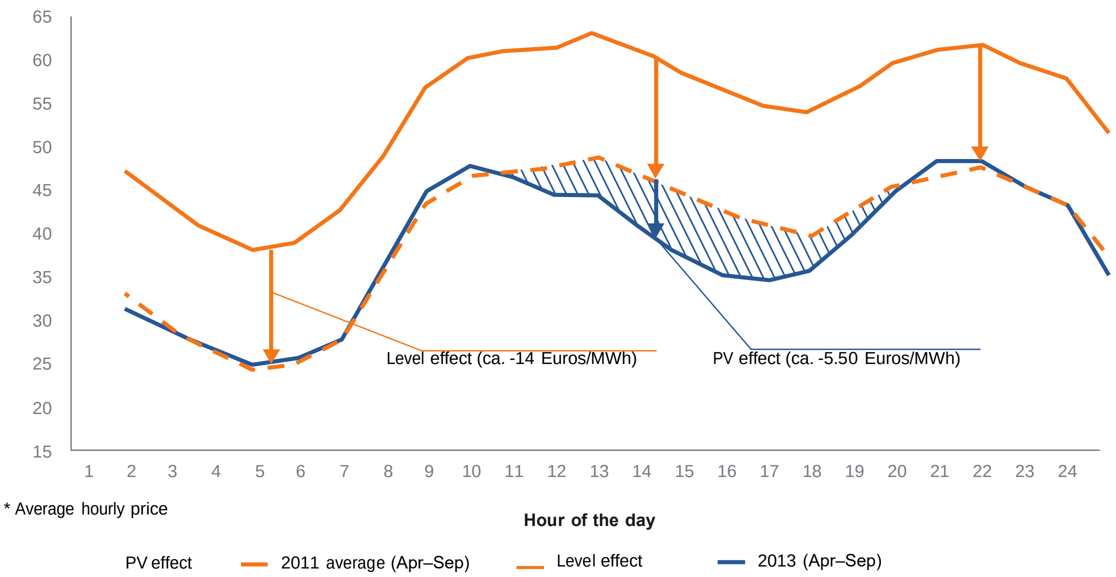
To reduce the implications associated with fast VRES expansion, policy makers and the industry should approach VRES investment with due diligence to avoid extensive boom and bust – cycles that have previously occurred in some OECD countries.

A clear effect of excess of VRES capacity in a specific system is the **overgeneration of VRES compared to demand, especially during low demand days. This leads to curtailment of VRES generated power,** see Italy, Germany and Japan case studies. In other words, when VRES generation exceeds the amount of energy which can be accepted by the network without compromising its security level, and excess energy must therefore be discarded, the VRES producer is still paid for it.

IMPACTS ON THE ELECTRICITY MARKET

The growth of VRES has also had a strong influence on electricity markets in many countries. For example, Italy, Germany and Japan have witnessed sudden and unexpected **wholesale price reduction, new merit order related to VRES dispatching priority** (Figure 14), **changes in ancillary services and balancing costs** (Figure 15). Requirements for re-dispatch are also growing in parallel with increasing renewable power supply (Figure 16).

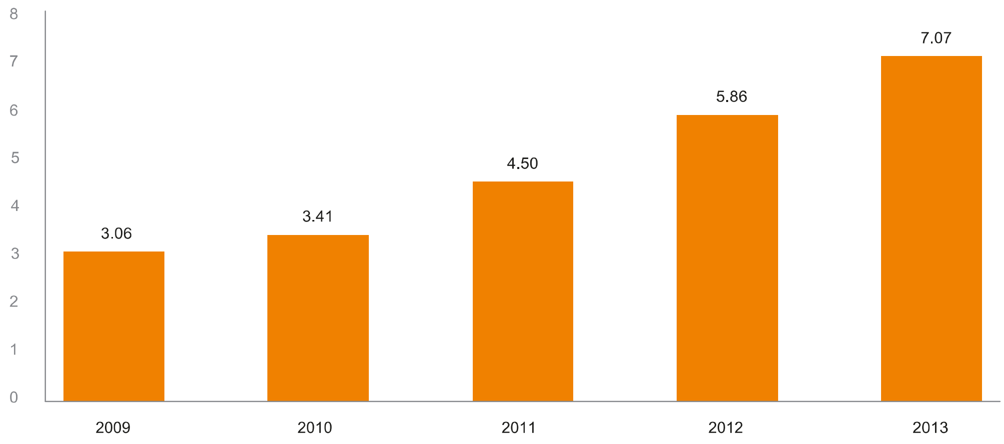
FIGURE 14 –GERMANY: COMPARISON OF AVERAGE HOURLY WHOLESALE POWER PRICES (PHELIX BASE YEAR FUTURE) IN SUMMER 2011 AND 2013



Source: European Energy Exchange (EEX)

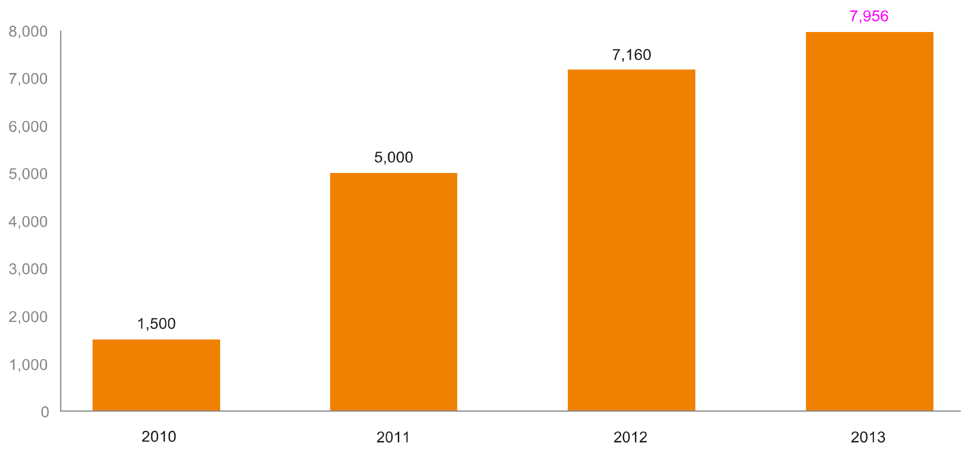
Figure 14 shows the effects on the wholesale price due to massive connections to the network of VRES plants from 2011 and 2013: the so called “level effect” disregarding PV is -14 €/MWh and the PV effect during sunny hours is up to additional – 5.5€/MWh

FIGURE 15 – DISPATCHING COSTS "UPLIFT" INCLUDING ANCILLARY SERVICES AND BALANCING COSTS IN EURO/MWH-ITALY



Source: Terna

FIGURE 16 – HOURS OF RE-DISPATCH MEASURES IN GERMANY 2010–2013



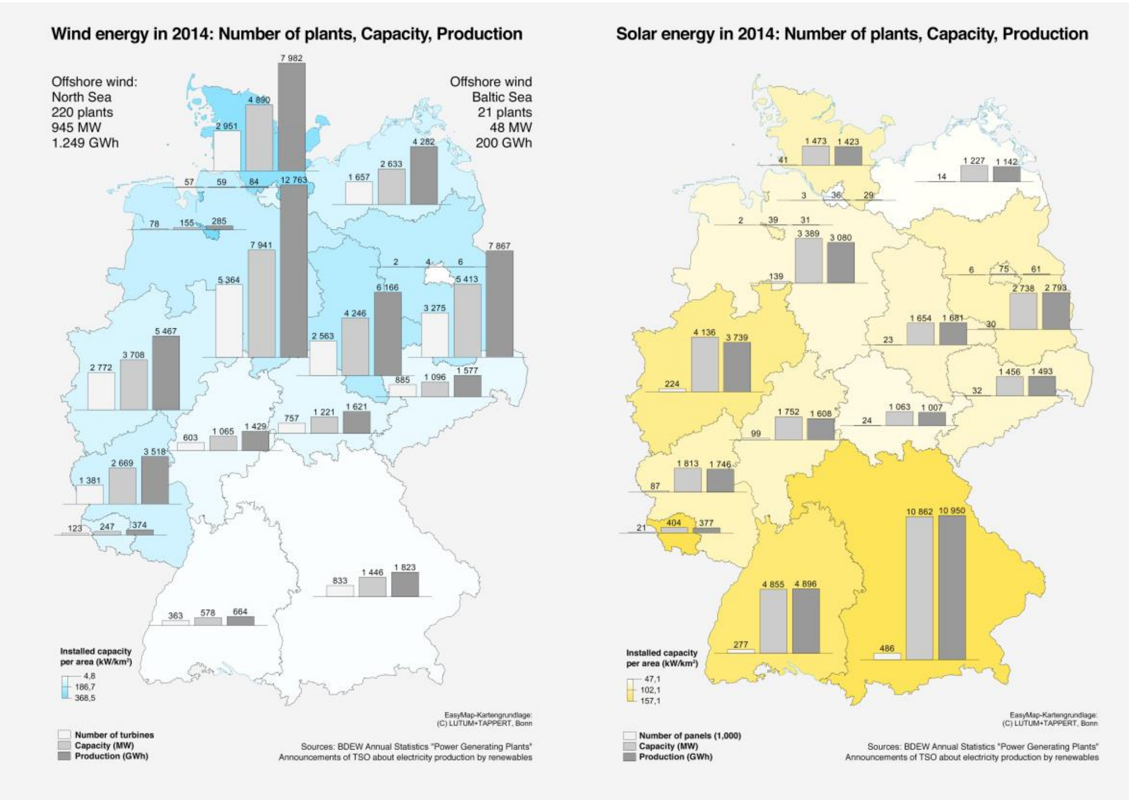
Source : statista/Zeit; TSOs, BNetzA

IMPACTS ON THE TRANSMISSION AND DISTRIBUTION GRID

The growing challenges in electricity supply are accompanied by strong impacts on the electricity transmission and distribution systems of the studied countries. The majority of country case studies demonstrate that there was a need for expansion of both transmission and distribution grids in order to reduce the bottlenecks associated with increasing VRES production. The impacts are amplified by the geographical locations of large VRES power plants, usually far from demand centres.

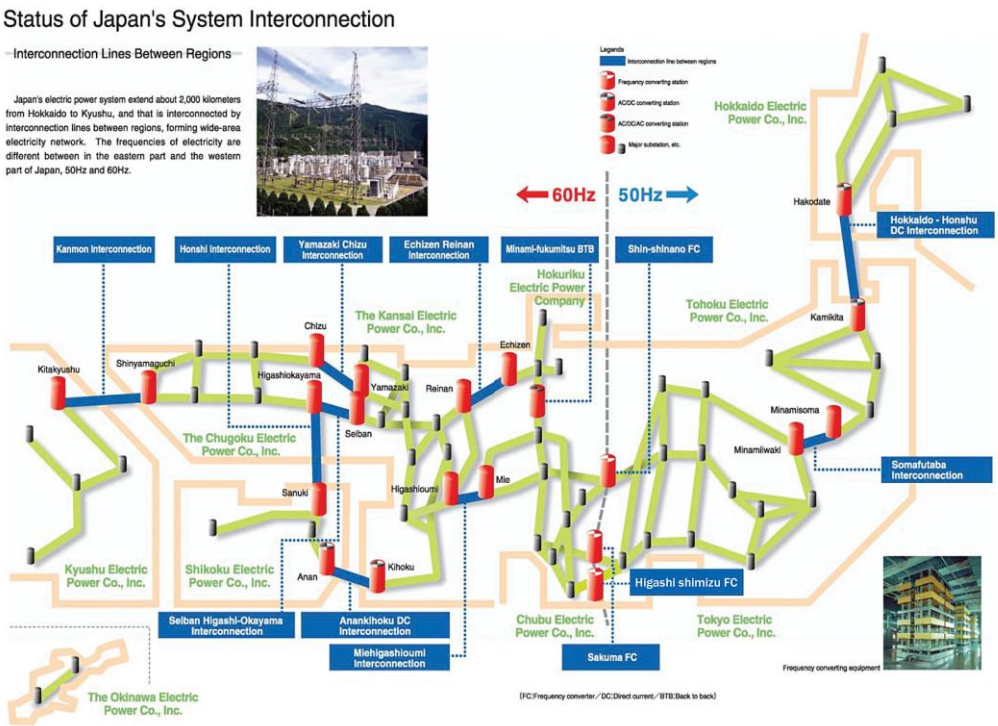
It is worth noting that appropriate selection of RES location would definitely minimize the problem and is cost effective. A clear example is Germany's transport of electricity from North to South and vice versa as shown in Figure 17 which poses huge challenges. Italy is facing the same challenges with its longitudinal transmission system where large newly built RES installations are located in the South whilst the main demand is in the North.

FIGURE 17 – DISTRIBUTION OF 2012 GERMAN WIND AND SOLAR PV CAPACITY IN GERMANY



Source: BDEW

FIGURE 18 SHOWS JAPAN’S TRANSMISSION GRID SYSTEM WITH SEVERAL INTERCONNECTIONS TO PROVIDE SUPPLY FLEXIBILITY AND REDUCE BOTTLENECKS DUE TO THE PROPOSED MASSIVE DEVELOPMENT OF RENEWABLES UP TO 70 GW BY 2030.

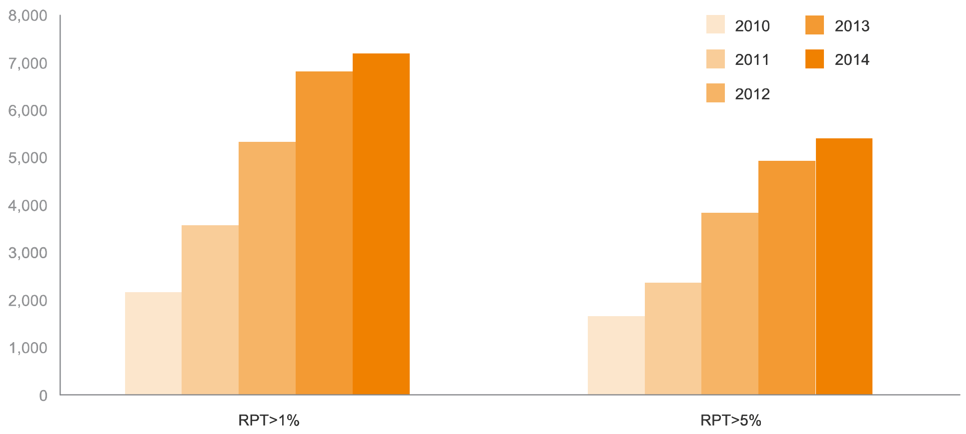


Source: Electric Power System Council of

In general, an increasing number of small-scale electricity generation connected to medium voltage (MV) and low voltage (LV) networks puts a large burden on the distribution grid systems that was originally designed for a one-way power flow.

In Italy, 80% of the **PV installations** are **in MV and LV levels** which **makes it particularly challenging to control them from the national dispatch centre and this leads to an increase of the reverse power flow in the primary and secondary substations** increasing pressure on the existing measuring and protection systems and on voltage reactive power control (Figure 19).

FIGURE 19 – NUMBER OF SUBSTATIONS AFFECTED BY REVERSE POWER FLOW FOR DIFFERENT REVERSE FLOW TIME "RPT" IN THE ITALIAN DISTRIBUTION SYSTEM OF ENEL

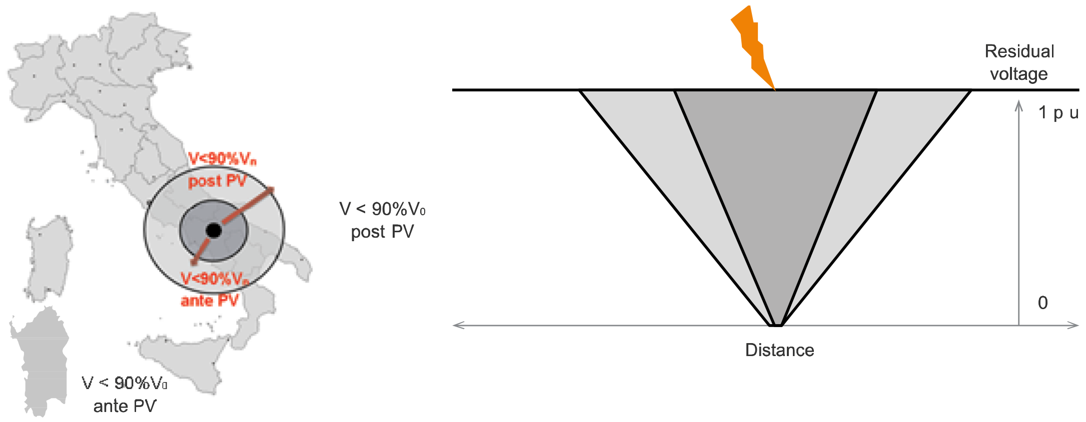


Source: Enel Distribution

The grid system must be able to withstand unplanned events and manage their impacts on the network, thus reducing the risk of cascading effects and decreasing quality of supply.

During operation with a high percentage of VRES connected to the network through inverters, the system is weaker (lower short circuit power) and less able to react to emerging faults. Figure 20 shows an example of a voltage drop caused by a fault in Italy, where the voltage drop post PV installations spread over a wider area **impacting supply quality** hundreds of kilometres away from the event.

FIGURE 20 – POTENTIAL IMPACT ON SYSTEM SECURITY AND QUALITY OF SUPPLY: VOLTAGE DIPS ON TRANSMISSION GRID IN ITALY



Due to reduction of rotating machines connected to Transmission grid, there is less Short-circuit-Power available and therefore voltage dips generated at T-level have larger impact. (In this simulation the spatial distribution of DG has been assumed homogenous.)

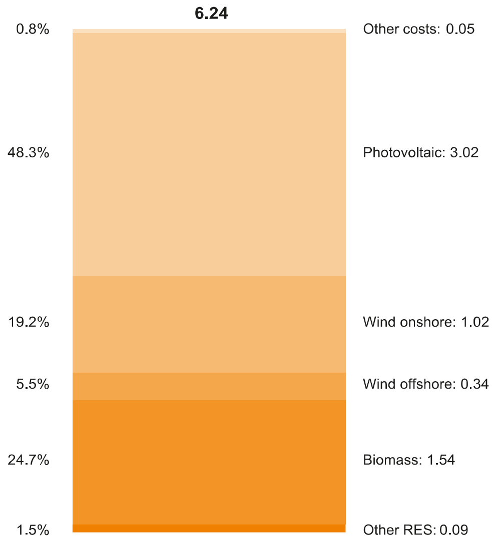
Source: Terna

IMPACTS ON CONSUMERS

Many of the additional costs incurred by the system due to expansion of VRES are generally fully passed on to the end-consumers of electricity, and this in addition to the direct incentives. This is of particular concern in many countries and appreciable price increases have so far been witnessed in Germany (Figure 21), Italy, Japan, and Romania. In 2014, the German Renewable Energy Act (Erneuerbare-Energien-Gesetz EEG) resulted in a price increase of 6.24 Eurocent/kWh for consumers.

FIGURE 21 – 2014 PRICE INCREASE OF 6.24 EUROCENT/KWH IN GERMANY, DUE TO RES INCENTIVES BY DIFFERENT SOURCES (EUROCENT/KWH)

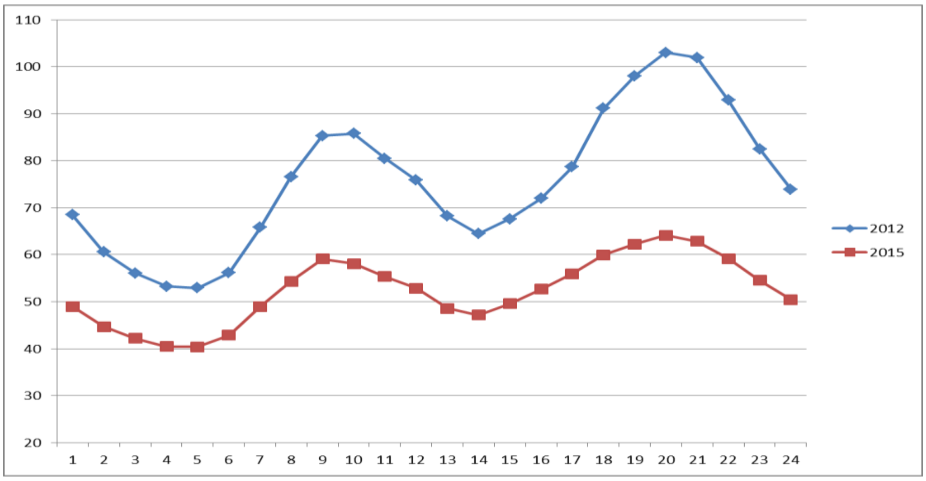
The proceeds from the introduction of EEG in 2014 totalled 23.6 billion Euros and will be used 100% for the promotion of renewables. 97.4% goes directly to the operators of the EEG plants, 1.8% to direct marketing of the EEG power and 0.8% to cover the necessary administrative costs.



Source: BDEW

In any case it should be mentioned that the increase of energy from VRES leads to reduction of the wholesale price along with the 2015 fuel prices drop (Figure 22 for Italy). However, this price drop is lower than the energy bill increase for the end user due to the incentives and additional costs to system for VRES.

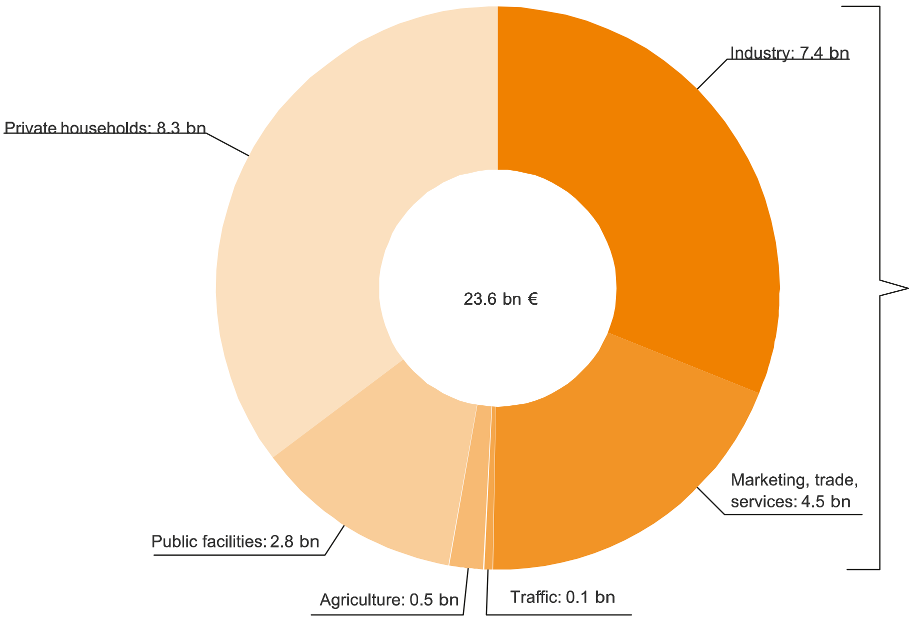
FIGURE 22 – YEARLY AVERAGE HOUR WHOLESALE PRICE 2012 VS 2015 EURO/MWH IN ITALY



Source: GME

Many energy intensive industries have long-term supply contracts for low-priced electricity, and therefore non-energy intensive consumers, residential and commercial will have to pay more for their electricity consumption (Figure 23).

FIGURE 23 – CONTRIBUTION BY SECTOR IN FINANCING THE EEG-LEVY 2014, GERMANY



Source: BDEW

For example, in Italy in 2014, only incentives for VRES passed on to consumers as a component of their electricity bills, amounted to around 13 billion Euro or over 50Euro/MWh, (approximately USD58/MWh) for residential and commercial consumers. This is excluding the additional balancing costs and T&D investments required by VRES integration.

Chapter 3
Measures for a smoother VRES integration

Although VRES may still pose a number of challenges as highlighted in the previous Chapter, affordable solutions will help to decrease or eliminate the challenges and solutions can be divided in two categories: technologies and market redesign.

TECHNOLOGIES

The case studies demonstrate a number of "technological" solutions which have been deployed to address the various challenges posed by the integration of VRES in the electric power system. These solutions include:

1. **Improved Forecasting**: better forecasting accuracy can help minimize VRES integration cost and allow grid operators to schedule VRES and reduce the need for operating reserves and balancing costs. The cost of forecasting has dropped over the last couple of years making it a popular and frequently used mitigation solution. Forecasting accuracy can be further improved by other mitigation strategies, such as faster scheduling and larger balancing areas.
2. **Greater Flexibility of Generation**: flexibility is needed for generation to respond rapidly to the changing load conditions that has required short start-up and shut-down times compared to steady base-load operation. The need for fast ramp up and down mode imposes additional costs, including a quicker equipment wear and increased fuel consumption, and thus higher overall emissions. This option may be costlier compared to other options. Compensation and/or regulatory measures for new generation are important for successful implementation of VRES.
3. **Dynamic Transfers**: to transfer electronically, in real-time, the control responsibility for generation from the balancing area/country in which the generator physically resides to another balancing area. However, available transmission capacity for the amount of energy which can be transferred between balancing areas could be an issue. Dynamic transfers can ease the integration of VRES, but can also provide benefits to customers even without VRES. This option is used for ancillary services, real-time and balancing energy dispatch.
4. **Transmission Expansion**: transmission expansion will provide access to more geographically diverse resources which can help improve system flexibility. Shortage of transmission capacity can be a significant impediment to new utility-scale renewable energy plants. However, transmission can take a long time to develop in many countries due to local opposition to new transmission infrastructure. India, for example, is planning to realize green energy transmission corridors, fairly remunerated, to transport massive RES.
5. **Distribution expansion/modification**: is needed to eliminate bottlenecks to energy from RES connected to MV and LV and to counteract reverse power flows due to increasing connection of distributed generation.
6. **Increased visibility of Distributed Generation**: Distributed generation (DG) is usually "invisible" to system operators, as they do not receive dispatch commands. DG is projected to grow rapidly in the coming years and this growth can cause

scheduling conflicts. Better coordination between DSOs and TSOs in liberalised markets is mandatory.

7. **Demand Response**: i.e. the short-term adjustment of demand to address temporary shortage or excess power from variable renewables, must be developed further.
8. **Energy Storage**: The most established, although geographically limited, energy storage technology is pumped hydro storage which requires transmission capacity and takes a long time to build. There are many types of energy storage using different technologies such as battery, flywheel or compressed air energy storage. Energy storage can help to use load shifting, shorter-term balancing and fast-acting instantaneous supply solutions. Type, characteristics and location of Battery Electrical Storage Systems for instance depend on the type of service they are required for and on the type and location of RES and conventional plants and electricity transmission facilities to avoid T&D bottlenecks and up and down ramps to conventional fleets.

MARKET REDESIGN

The market rules established before the large expansion of VRES now need to be adjusted. The energy market alone does not provide price signals which are sufficiently strong and effective for long-term planning and security of supply. Effective market redesign practices until now have included the following:

1. **Capacity payments:** Capacity payments remunerate generators for being available to participate in the energy markets. Capacity markets can take many forms, including bilateral contracts and centralised auctions run by system operators who clear the market. Capacity markets are needed to provide sufficient revenue and ensure reliability where reliance on energy market revenues alone may not cover the long-term cost of generation. This issue is the subject of great debates going on in Europe. In general, an energy only based market is insufficient to ensure security of supply in the systems with large VRES.

2. **Emission Trading Scheme revision:** an appropriate price for carbon emission would support the deployment of low carbon technologies lowering the needs for generous VRES incentives and priority of dispatching.

3. **Faster scheduling of the electricity market:** hourly and sub-hourly scheduling, with due consideration to conventional plants limits, allows a more efficient use of available transmission / generation capacity, lower reserve requirements thanks to a shorter and more accurate forecast of VRES.

4. **Negative market price:** Negative prices are price signals on the wholesale power market when highly inflexible power generation meets low demand. Inflexible power

generating units cannot be shut down and restarted in a quick and cost-efficient manner. In certain circumstances, negative prices indicate the advance of coming sudden oversupply and the urgent need for the operators to deal with this oversupply of energy by sending relevant market signals to reduce production. At this stage, generators have to compare their costs of stopping and restarting their plants with the costs of selling their energy at a negative price (which means paying instead of receiving money). If their generation units are sufficiently flexible, they will stop producing for a period of time which will prevent or buffer the negative price on the wholesale market and ease the pressure on the grid. In France, Germany and Austria this practice is already in place, thus the prices can fall below zero. An appropriate adjustment of incentive to VRES should be re-analysed in this specific condition. *(Again, refer to e-storage report).*

5. **Nodal pricing:** is a method of determining prices in which market clearing prices are calculated for a number of locations on the transmission grid nodes. The price at each node represents the local value of energy, which includes the cost of the energy, but also the cost of delivering it, taking into account losses and congestions. The New Zealand and US experiences with nodal pricing demonstrate the benefit of a better location of RES power plants and the smooth integration of intermittent renewable generation technologies. This is one of the incentive tools that can help select appropriately RES location. The same could be applied to local auctions.

6. **Larger balancing areas:** Consolidating balancing areas and sharing the variability of the VRES and load forecast errors across a broader region provides a natural aggregation impact. There are strong benefits to consolidation/coordination even in the absence of wind and solar.

7. **Pooling:** unlike wind variability, some aspects of solar variability are predictable (for example, sunrise and sunset). Other aspects, such as intermittent cloud cover, are much less so. However, aggregating the bids of different VRES plants on the electricity market can lead to a reduction in overall variability and thus reduce the forecast error and balancing costs.

8. **Ancillary services:** An important aspect of balancing is the approach to procuring ancillary services. Ancillary services refer to a range of functions which TSOs contract so that they can guarantee system security. These include black start capability (the ability to restart a grid following a blackout); frequency response (to maintain system frequency with automatic and very fast responses); fast reserve (which can provide additional power when needed); the provision of reactive power and various other services. VRES can provide some ancillary services such as voltage reactive power regulation and using new inverters technology can provide services also in absence of sun and wind, see for example, New Zealand. In any case balancing responsibilities have to be shared fairly among market participants including VRES

Chapter 4
Key messages

- Renewable energy sources, in particular variable wind and solar PV have grown rapidly over the past ten years and this growth is expected to continue.

- RES and especially wind and PV have become a big business overtaking investments in conventional generating plants.

- Combination of technology improvements and increasing volumes are driving down CAPEX and OPEX of variable VRES.

- Variability and average low equivalent hours of operation per year of PV and wind, pose challenges to their large-scale development. This affects conventional power generating equipment, T&D grids, electricity markets and economics of power supply for consumers.

- The report identifies main solutions to overcome these challenges through technologies and market redesign initiatives.

- A holistic approach to overall electrical system design is a key to success.

- Each country power system is unique, even if some general recommendations can be drawn. Sophisticated technical, economic and regulatory analysis on a project basis must be conducted over an adequate period of time.

- The implications of reduction in subsidies or other support schemes must be carefully analysed to avoid a drastic reduction in VRES investment as result of incentive reductions (e.g. some EU countries)

- The right location with high wind and solar load factors and low grid connection costs for new large VRES projects is a key to success.

- Regulatory bodies have a fundamental role in both development of VRES and the typology of measures to smooth their impact on the power system.

- VRES can serve as a pathway for climate change mitigation, but also as investments that reduce dependence on imported fuel, improve air quality, increase energy access and security of supply, promote economic development, and create jobs.

- In countries with electricity markets, VRES have contributed to the overall reduction of wholesale price, but for most of customers this has not avoided significant increase of their bills.

- It is misleading to project specific aspects of VRES operation to other countries, in terms of auction prices for kWh or similar indicators as countries have the different levels of wind and insolation and local costs.

- Working together, the main energy stakeholders will be able to meet all current challenges facing RES integration in electricity systems by learning from each other about both positive and negative experiences in their countries.

Annex 1
Examples of costs of wind and solar PV systems and results of recent auctions

1 INTRODUCTION

It is difficult to get accurate financial data and detailed information about the conditions and clauses relevant to actual PV and wind plants that are not published or available publically. This data is considered to be commercially and politically sensitive in various countries, which has limited the Knowledge Network (KN) enquiry.

This annex includes data relevant to new plants for onshore wind and solar PV systems in different countries, in terms of:

- recent CAPEX values, yearly O&M costs and when available LCOE.
- results of auctions up to mid May 2016 based on power purchasing agreements (PPAs).

The values reported are relevant to those projects which exclude possible special grants or subsidies and comprise complete generating systems, including installation. Clearly both CAPEX and O&M costs are affected by the location of plant, transport and labour costs, local duties and taxes, plant power capacity, financial costs etc. and should be extrapolated with caution.

Further caution is due with CAPEX data, since the reported values may or may not include development costs. In some cases, the CAPEX values may be affected by hidden subsidies to contractors and equipment suppliers and also by local import taxes for machinery and equipment. We do not have access to this data so this should be extrapolated with caution to other projects.

A deep analysis should be performed also in relation to the data reported by various agencies and their possible comparisons.

CAPEX is usually given in USD/MW or USD/kW and the O&M services are typically contracted in terms of EUR or USD per installed MW; when expressed in terms of MWh, both CAPEX and O&M are strongly influenced by the Load Factor of the plant since the yearly cost per MW must be divided by the equivalent hours of production (proportional to the load factor).

For wind farms the O&M costs typically increase with the age of the windfarms: for a full service scope, while initial contracts are typically in Europe in a 25-30 USD/kW range, O&M contract renewals after 5 or 10 years are more in the 30-40 USD/kW range. Therefore, O&M costs for both wind and PV plants in locations with low load factors and high cost for personnel may have a significant value up to 15-20 USD/MWh for wind farms with 2,000 equivalent operating hours and close to 35 USD/MWh for PV systems having 1,250 equivalent operating hours.

2 DATA BY CONTINENTS

ASIA

JAPAN

The data provided is relevant both to small household (4 kW) PV systems and larger ones (2 MW) and to wind farms of 20 MW. The LCOE has been computed with a life plant of 20 years, a discount rate of 3% and a decommissioning cost as specified for each example. These figures are based on an exchange rate of 1.39 JPY =1 USD.

PV HOUSEHOLD OF 4kW

- Average Yearly Load Factor = 12% (1050 equivalent hours of operation per year)
- CAPEX = 3,345 USD/kW
- Decommissioning cost = 20% of CAPEX
- LCOE= 251 USD/MWh

PV 2 MW

- Average Yearly Load Factor = 14 % (1,225 equivalent hours of operation per year)
- CAPEX = 2,700 USD/kW
- O&M yearly cost = 1.26% of CAPEX (equivalent to around 28 USD/MWh)
- Decommissioning cost = 5 % of CAPEX
- LCOE = 192 USD/MWh

WIND FARM 20 MW

- Average Yearly Load Factor = 20% (1,750 equivalent hours of operation per year)
- CAPEX=2,600 USD/kW
- O&M yearly cost = 2.1% of CAPEX (equivalent to approx.32 USD/MWh)
- Decommissioning cost = 5.3% of CAPEX
- LCOE = 144 USD/MWh

INDIA

India has just awarded an auction for 500 MW PV plants with a tariff valid for 25 years and the most significant results are:

23 MW PV PROJECT	tariff 67 USD/MWh
2 X 75 MW PV PLANTS	tariff 64 USD/kWh
100 MW PV PLANT	tariff 70USD/MWh

JORDAN

An exchange rate of 1 JOD = 1.41 USD has been assumed for the data received relevant to both household PV systems and to large PV and wind systems.

PV HOUSEHOLD SYSTEMS OF 3-15 kW - Average CAPEX = 1,400 USD/kW

3 PV PROJECTS TOTALLING 15 MW (just in service): results of auctions

- average declared CAPEX = 2,200 USD/kW
- average yearly Load Factor = approx. 20% - 25%
- BOO tariff = 78 USD/MWh

4 PV PROJECTS IN NEGOTIATION: preliminary data from auctions

- average yearly Load Factor = between 20% - 25%
- average declared CAPEX =1,600 USD/kW
- BOO tariff = 61 USD/MWh - 77 USD/MWh

WIND PLANT 117 MW: result of auction

- average yearly Load Factor = 30%
- declared CAPEX = 2,010 USD/kW
- BOO tariff = 120 USD/MWh

WIND PLANT 80 MW (in operation in second half 2016: result of auction)

- average yearly Load Factor =30%
- CAPEX =1,875 USD/kW
- BOO tariff =113 USD/MWh

UNITED ARAB EMIRATES

PV 800 MW PLANT

According to May 2016 press releases the best tariff presented for the auction is 30 USD/MWh which is a world record for PV. It is worth mentioning the high local insolation level, low costs for manpower and favourable financial support to local contractors.

EUROPE

ITALY

In Italy the Load Factor for PV plants in operation varies from around 10% in the extreme North to around 17% in Sicily with a yearly average of 13.5%. For existing wind plants the average Load Factor is between 19% and 25%. An exchange ratio of 1.13 USD = 1 EUR has been used to convert local EUR into USD.

HOUSEHOLD PV ROOF TOP 3-10 kW

CAPEX ranging from around 2,000 USD/kW to 2,800 USD/kW depending on location/difficulties for installation.

PV PLANTS WITH CAPACITY ABOVE 2 MW: latest plants

- CAPEX ranging from 1,000 to 1,200 USD/kW
- O&M costs in the range of 20-40 USD/MWh excluding taxes but including land rent (when not included in CAPEX), preventive maintenance, insurances, guards, grass cutting/panel cleaning, spare parts, quick interventions for repairs, administration of plant production/energy sales etc. As already mentioned the value depends on solar local radiation that varies from the South to the North of Italy as to local manpower costs. A deep analysis performed (Energia Elettrica Vol 3, 2014) by companies operating PV plants having an average capacity of 4 MW and 1,350 operating hours have provided the following split of the total 45 USD/MWh, excluding taxes: 56% O&M with spare parts,18% land rental,10% all-risks insurance, TLC/monitoring/auxiliary services consumptions 9%, guards 7%.

WIND PLANTS WITH CAPACITY ABOVE 5 MW: latest plants

- Average Load Factor = 22% - 25%
- CAPEX = 1,350 – 1,600 USD/kW
- O&M costs in the range = 22-34 USD/kW = 10-17USD/MWh

POLAND

3 WIND PROJECTS TOTALLING APPROX. 80 MW: PRIVATE INVESTORS

- Average investment = 1,450 USD/kW
- Load factors = 23% - 28%

GERMANY

A Trial auction system was set by the government in 2014 and relevant to PV plants above 6 MW each and for around 500 MW to be allocated in 2015 -400 MW in 2016 and 300 MW in 2017. In 2017 auctions should be applied also to wind plants. The first 4 subsequent rounds for PV plants, with 2 different auction methods, have seen publications of winning offers from February 2015 to April 2016. The main results are:

1st round : tariff awarded to all winning offers at 91.7 €/MWh (103.5 USD/MWh)

2nd round : auction (uniform pricing) with the highest awarded bid at 84.9 €/MWh

(96 USD/MWh) applied to all winning bids (the average of all winning bids was at 78.2 EUR/MWh).

3rd round : also held with the uniform pricing with the highest winning bid at 80 EUR/MWh

(90 USD/MWh) applied to all winning bids.

4th round : the auctioning method was pay-as-bid. From preliminary results, the average of all bids was 74.1EUR /MWh (83.5 USD/MWh), the lowest bid being 69.4 EUR/ MWh while the highest at 109.8 EUR/MWh

FRANCE

- The French Ministry of Ecology, Sustainable Development and Energy (MEDDE) announced at end 2015 the 212 winning projects from its 800MW solar energy auction that followed the first auctions held 2 years ago. The capacity of projects ranged from 0.4MW to 12MW and the main results are here below, assuming an exchange rate of -1 EUR = 1.13 USD:

- The average tariff for large rooftop solar installations was EUR 129/MWh (USD 146), down 18% from EUR 158/MWh in the previous auction.

- The average price for ground-mounted facilities was EUR 124 (USD 140), down 15% from EUR 146/MWh in the previous auction

UK

1 WIND PROJECT 50 MW -PRIVATE INVESTORS

Average investment around 1,600 USD/kW

Load factor in the range 30%-34%

WIND AND PV PROJECTS IN FIRST ALLOCATION ROUND OF AUCTIONS

- Results published in February 2015 relevant to 15 years' contracts for difference (CFD) allocating:

15 wind projects totalling 750 MW

- Strike prices in the range 124- 128 USD/MWh (1 GBP=1.55 USD)

2 PV projects totalling 19+14 MW

- Strike price 77.7 USD/MWh

3 PV projects totalling 39 MW

- Strike price 123 USD/MWh

AFRICA

EGYPT

Due to high wind load factors up to 49%, recent BOO plants with capacities up to 250 MW have seen very interesting values with tariffs in the range 38- 45 USD/MWh

MOROCCO

Morocco has announced in first quarter 2016 the results of an auction of October 2015 relevant to wind plants. The 850MW Morocco tender includes five plants ranging from 100 MW to 300MW. Commissioning of the wind plants is expected between 2017 and 2020.The resulting tariffs were all close to 30 USD/MWh and presented the lowest price in the world at 28 USD/MWh-Load factors are up to 58.5%.

NAMIBIA

3X3MW PV PROJECTS (Dec 2015)

Load factor range: = 21-27% = Tariffs 79-85 USD/MWh

SOUTH AFRICA

South Africa has adopted auctions for RES since 2011 (first auction round awarded in December 2011) with the last one (4th round) in 2015. With reference to the last round, the main data for PV and wind plants awarded based on an exchange rate of 1USD=12 ZAR are:

PV PLANTS TOTALLING 415 MW

Tariffs down to 55 USD/MWh - load factors range 24-27%

WIND PLANTS TOTALLING 676 MW

Tariffs down to 43 USD/MWh - load factors from 38 - 45%

Considering the exchange rate USD to South African Rand (ZAR) at the awarding date, for wind plants the auction procedures have produced a continuous reduction of the tariffs of around 25% from one auction to the next if expressed in USD/MWh; if expressed in ZAR the reduction is lower.

NORTH AMERICA

UNITED STATES

- It is difficult to assess whether some contract prices are low in an international context since the prices reported do not reflect major policy factors such as investment tax credit (ITC) and production tax credit.
- Some wind tariff values have been down to around USD 25-30 /MWh, although, as mentioned above, these values have been boosted by “reduction tax credits” which have been subject to several up and down modifications.
- A recent auction by the Texas city of Austin, which contracted to build 300MW of large-scale solar PV, has seen a price of less than US USD40/MWh. Even after backing out a tax credit, this is still less than US USD 60/MWh.

MEXICO

Mexico has just disclosed in March 2016 the bidding prices of the first electricity auction within its new policy of RES development. The auction involves 15 years of purchasing agreements combined with 20 years of green certificates for both PV and wind plants. The plants must be in operation within 2018.Differently from other countries, the **PV prices are lower than those from wind. In particular, the PV prices were the lowest in the world up to the last auction in UAE.**

7 PV PROJECTS TOTALLING AROUND 1100 MW

Average tariff = 45 USD/MWh

Lowest tariff = 35 USD/MWh

4 WIND PROJECTS TOTALLING AROUND 600 MW.

Average tariff = 55 USD/MWh

Lowest tariff = 42 USD/MWh

Load factors up to around 40%

SOUTH AMERICA

BRAZIL

Brazilian policy is to have auctions for every type of plant. First auction for RES started in 2009. In November 2014, 31 PV projects and 31 wind projects were awarded with tariffs over 20 years in pace with inflation and with an exchange rate of 1USD=2.48 REALS. The initial application of auctions has drastically reduced the cost of kWh with respect to those with FIT,

31 PV PROJECTS TOTALLING 890 MW

Average investment around 1,600 USD/kW

Average tariff = 86.8 USD/MWh and best 81 USD/MWh

Load factors in the range 19%-23.7%

31 WIND PROJECTS TOTALLING 770 MW

Average investment around 2,200 USD/kW

Average tariff = 57.4 USD/MWh and best 49 USD/MWh

Load factors around 50%, plus in some locations

Considering the exchange rate of Brazilian Real to USD at the auction awarding date, in the three initial auctions (2009-2010-2011) there was a price reduction from 77 USD/MWh to 55USD/MWh but later on a rather regular/flat trend with average values in the range 55-60 up to the last auction was reported. Clearly due to the Real devaluation there was an increase of the values in local currency of about 40% from the 2011 value to the 2014 value.

PERU

The Peruvian investment regulatory authority has recently announced the results of its fourth government energy auction since 2009: projects totalling 162 megawatts (MW) of wind energy will receive 20-year PPAs at an average USD37.49 per megawatt-hour (MWh), and 184.5 MW of solar photovoltaic (PV) at an average USD48.39/MWh.

PV

The fourth auction has been the most successful to date. The first one in 2009 closed solar PV deals at USD220/MWh; the second in 2011 managed to cut the price in half to USD110/MWh and now the 2015 tenders announced few weeks ago attracted an average winning solar PV pricing of USD48.39/MWh. The lowest pricing was 48 USD/MWh

WIND

The drop in wind prices from the first Peruvian wind auctions was equally strong. The 2009 auctions were won at USD89/MWh; the 2011 at USD87/MWh, but 2015 winning offers were all under USD38/MWh.

In the first round of the fourth wind auction the largest project, at 126 MW, came in with the lowest overall bid of USD 37.83/MWh.

The second round with two 18 MW projects, minimum offers were of USD 36.84/MWh and USD 37.79/MW

CHILE

PV 55 MW AUCTION: lowest price 65 USD/MWh

3. CONCLUSION

- The spread of CAPEX and O&M costs per kW and consequently the MWh prices in the various countries are very different due to different atmospheric conditions, local costs/taxes, types of regulations and size of plants.

- Auctions in many countries around the world have produced over 1-2 years a substantial collapse in the MWh tariffs for both PV and wind plants compared to the usual FIT values that are adopted to subsidise the development of RES – African, Latin American and Middle East countries are the main actors. The tariffs for auctions in all the countries have seen a constant decrease with respect to those relevant to the first local rounds.

- Sizes of plants for auctions are increasing in capacity and are mainly dealt with by large international investors with high financial strength; this has caused local reactions in some countries. Great disproportion from a great number of bidders and number of winners in some countries has also created problems.

- The lowest value for wind is in Morocco with a tariff of 28 USD/MWh followed by Peru at 37 and by Mexico, Egypt, South Africa and Brazil in the range 40-49USD/MWh.

- The lowest value for PV has been officially reached in Mexico with 35 USD /MWh followed by Peru at 48 and South Africa at 55; but the announcements at end of April report an 800 MW PV plant in UAE with a tariff of 30 USD/MWh.

- It is worth mentioning that these values cannot be extrapolated to other areas /countries with much lower insolation and wind load factors and with personnel costs much higher than the above mentioned countries. In addition, different rules for auctions must be considered together with financial costs.

- In Europe, auctions in Germany, France and UK for PV plants have seen values in the range 80-125 USD/MWh and for on shore wind plants 125 USD/MWh in UK.

- The financial performance of the winners in next years will show possible overestimation of capacity factors for wind or sun and underestimation of real costs in setting low tariff values in the bidding process.

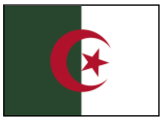
Annex 2
Country Case Studies Summaries

This annex includes key messages from each Country relevant to their situation on power generation and VRES development and policies at the end of 2014 deducted from the detailed case studies; a table has been added to each country with data about installed RES and VRES capacity at end of 2015 (Source: IRENA, RENEWABLE CAPACITY STATISTICS 2016 - Copyright © IRENA 2016).

The detailed case studies can be downloaded from the Council's website (www.worldenergy.org/publications).

1. Algeria
2. Brazil
3. China
4. Colombia
5. Denmark
6. Ecuador
7. Egypt
8. France
9. Germany
10. India
11. Indonesia
12. Ireland
13. Italy
14. Japan
15. Jordan
16. Kazakhstan
17. Korea (Rep. of)
18. Mexico
19. New Zealand
20. Nigeria
21. Philippines
22. Poland
23. Portugal
24. Romania
25. Russian Federation
26. South Africa
27. Spain
28. Thailand
29. Tunisia
30. United Kingdom
31. USA
32. Uruguay

ALGERIA



Algeria's Power Generation – Basic Information (2014)

Total installed generation capacity	**16.00 GW**
Total RES generation capacity	0.26 GW
Total VRES generation capacity	0.26 GW
Peak load (Northern interconnected network)	10.90 GW
Minimum load	10.90 GW
Electricity production	60.50 TWh
Electricity import	686.00 GWh
Electricity export	877.00 GWh

Algeria Renewables (2015)

Total RES generation capacity	**0.54 GW**
Total VRES generation capacity	0.28 GW
Installed solar PV capacity	0.27 GW
Installed wind capacity	0.01 GW

98% of Algeria's electricity system is based on conventional, primarily fossil-fuelled generation with an increasing percentage of natural gas. Algeria's renewable electricity portfolio includes some hydro and only small shares of variable RES. High installation costs and the need for additional reserve capacity have been a barrier for large scale development of solar or wind plants. In 2011, first solar facility was commissioned in a hybrid 150 MW system (25 MW concentrated solar power and 125 MW gas-fired plant). Large solar and wind power potential is in the Southern sparsely populated areas. Future developments of RES are expected to reach up to 22 GW in 2030. Funding for RES comes from a levy on oil tax.

BRAZIL

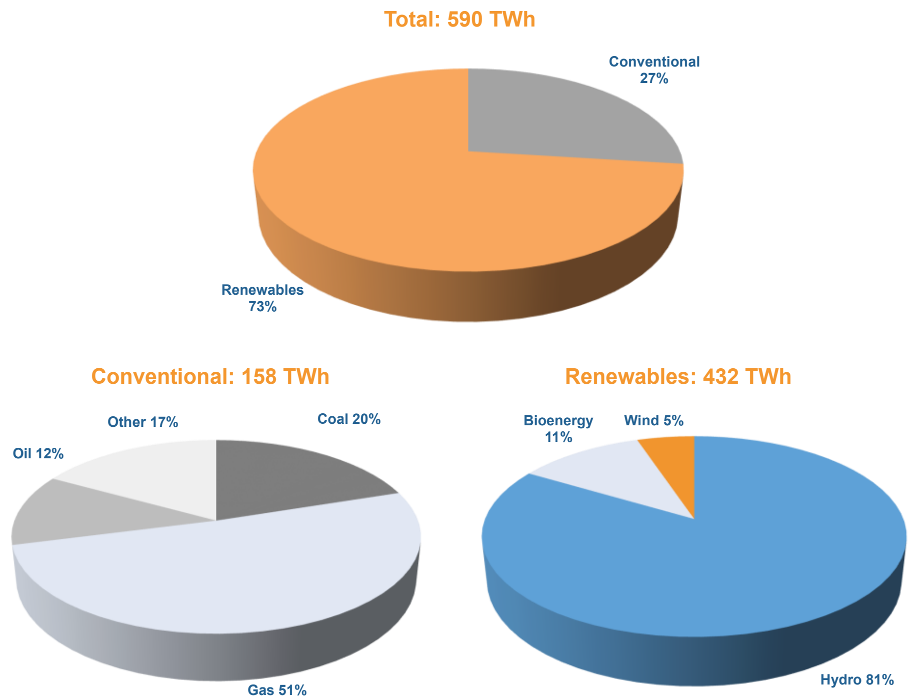
Brazil's Power Generation – Basic Information (2014)

Total installed generation capacity	**133.9 GW**
Total RES generation capacity	106.4 GW
Total VRES generation capacity	5.9 GW
Peak load	85.0 GW
Minimum load	61.1 GW
Electricity production	590.5 TWh
Electricity import	33.8 GWh

Brazil Renewables (2015)

Total RES generation capacity	**114.2 GW**
Total VRES generation capacity	8.7 GW
Installed solar PV capacity	0.021 GW
Installed wind capacity	8.7 GW

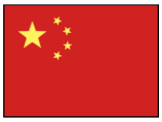
Brazil's electricity production mix (2014)



73% of electricity production in Brazil is based on renewables (mainly hydro). Brazil currently promotes affordable renewable energy at power auctions of different types of supply options with 15 to 30 year contracts. Large-scale bioenergy production is a distinct feature of the country's energy system. Fast development of wind generation capacity has resulted in its increase from 0.2 GW in 2007 to 5.9 GW in 2014, and a drop of auction prices to USD 60/MWh making wind the second cheapest electric energy source after large hydro. Even lower values have been achieved in 2015/2016 (see Annex 1). In 2014

wind accounted for 2% of total electricity production. By 2023 wind capacity is expected to reach 23 GW and solar 4 GW. Seasonal nature of local renewables and further expansion of hydro generation with no reservoirs requires further development of conventional generating plants for security of supply.

CHINA



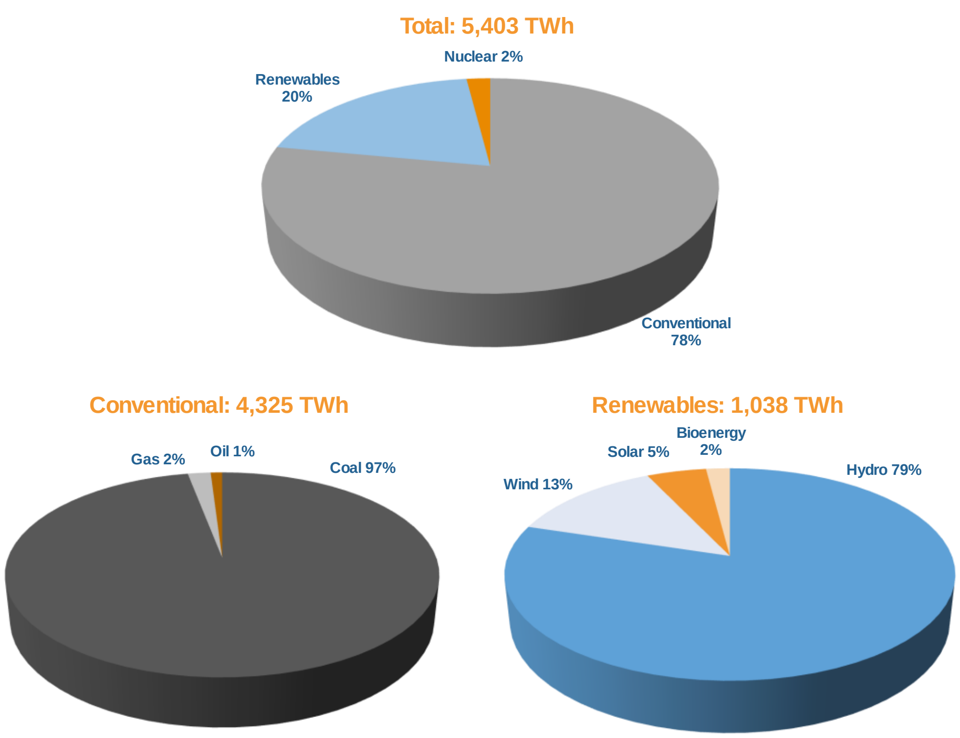
China's Power Generation – Basic Information (2014)

Total installed generation capacity	**1,360.0 GW**
Total RES generation capacity	454.0 GW
Total VRES generation capacity	142.6 GW
Electricity production	5,403.0 TWh

China Renewables (2015)

Total RES generation capacity	**519.7 GW**
Total VRES generation capacity	188.1 GW
Installed solar PV capacity	43.0 GW
Installed wind capacity	145.1 GW

China's electricity production mix (2014)



China is the world leader in installed generation capacity (1,360 GW) and electricity production (5,403 TWh). 78% of it comes from conventional power plants (mainly coal-fired), while the renewable energy portfolio is dominated by hydropower. Wind and solar PV have grown strongly in recent years reaching installed capacity of 114 GW and 28 GW, respectively at the end of 2014. Wind currently accounts for 2% and solar PV for less than 0.5% of total electricity production, but both are growing quickly with the recent annual capacity increases of 19.7% for wind and 17.1% for solar in 2014. Even if the share of variable RES is still low in relative terms, their random fluctuations and lack of flexible conventional power have resulted in significant changes in the power balancing capability of power grid. China has six interconnected grids, and therefore certain consolidated data is not available.

COLOMBIA

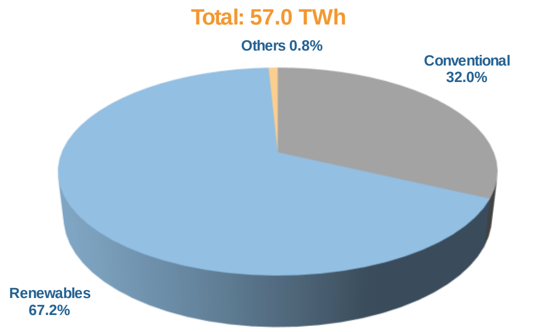
Colombia's Power Generation – Basic Information (2014)

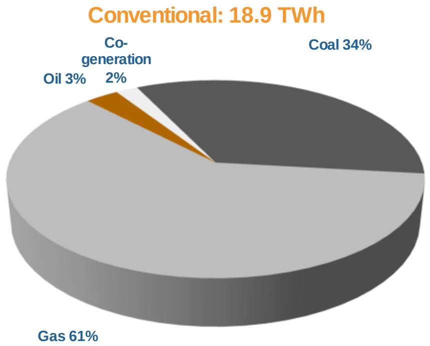
Total installed generation capacity	**15.0 GW**
Total RES generation capacity	11.1 GW
Total VRES generation capacity	18.0 MW
Electricity production	57.0 TWh
Electricity import	715.0 MWh
Electricity export	6.5 MWh

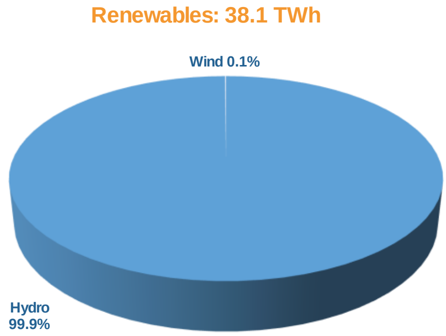
Colombia Renewables (2015)

Total RES generation capacity	**11.7 GW**
Total VRES generation capacity	18.0 MW
Installed solar PV capacity	0.0 MW
Installed wind capacity	18.0 MW

Colombia's electricity production mix (2014)

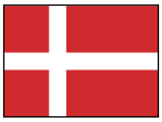






Colombia has a hydropower based electricity sector with a fairly insignificant share of VRES, mainly wind. A number of laws and regulations have been introduced to facilitate and accelerate development of VRES. For example, Law 1715 adopted in 2014 introduces fiscal incentives for renewables, which include Income tax reduction to 50% of total investment during 5 years, accelerated depreciation, reduction of the basic income tax for unconventional energy projects, VAT exclusions for equipment and other discounts. There are also specific tariffs in support for RES, such as “Derechos Arancelarios” tariff exemption, and tariff exemption for machinery, equipment, materials and imports used for unconventional energy projects.

DENMARK



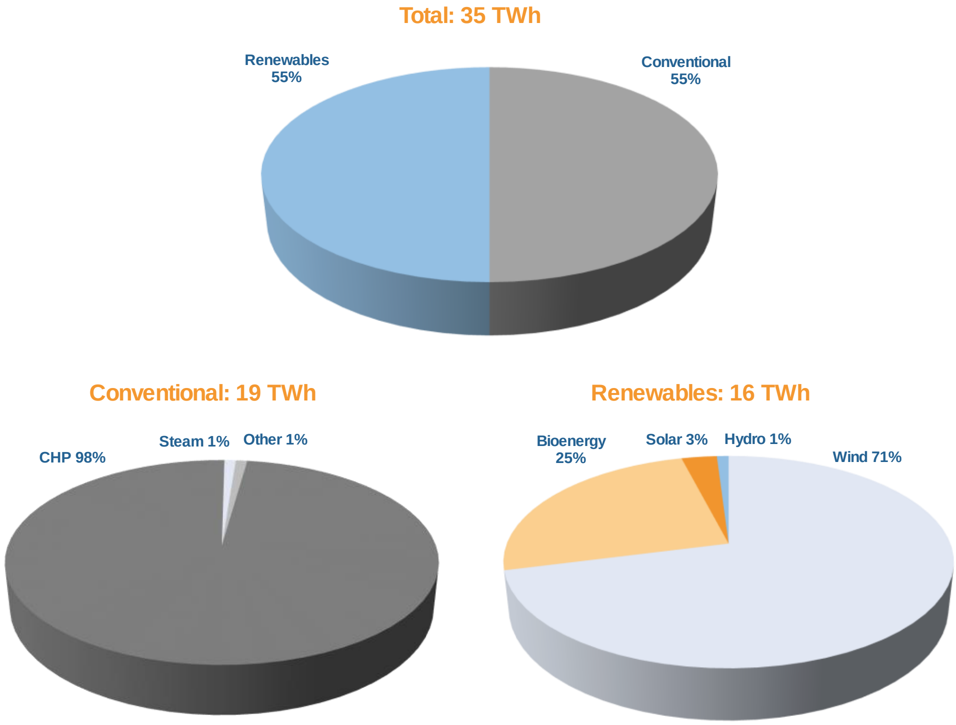
Denmark's Power Generation – Basic Information (2014)

Total installed generation capacity	**13.60 GW**
Total RES generation capacity	7.0 GW
Total VRES generation capacity	5.4 GW
Peak load	6.1 GW
Minimum load	2.3 GW
Electricity production	34.7 TWh
Electricity import	11.5 TWh

Denmark Renewables (2015)

Total RES generation capacity	**7.3 GW**
Total VRES generation capacity	5.9 GW
Installed solar PV capacity	0.8 GW
Installed wind capacity	5.1GW

Denmark's electricity production mix (2014)



Up to 35% of Denmark’s 35 TWh generation of electricity is produced with renewable energy, with wind accounting for 71%. In total, 33% or 11.3 TWh of Denmark’s electricity was produced from variable RES in 2014, achieving the highest VRE penetration in the world in relative terms. At the same time, Denmark imported 11.5 TWh of electricity. Dispatching priorities, feed-in-tariffs, and feed-in premiums for variable RES have been driving growth in VRES. This large share of RES required significant changes to the Danish energy system including interconnectors to neighbouring countries, back-up power units, demand management and energy storage. The target for 2020 is to reach 50% of electricity consumption supplied by wind without any use of coal in Danish plants and by 2050 the entire Danish energy consumption should be supplied by VRES technologies.

ECUADOR

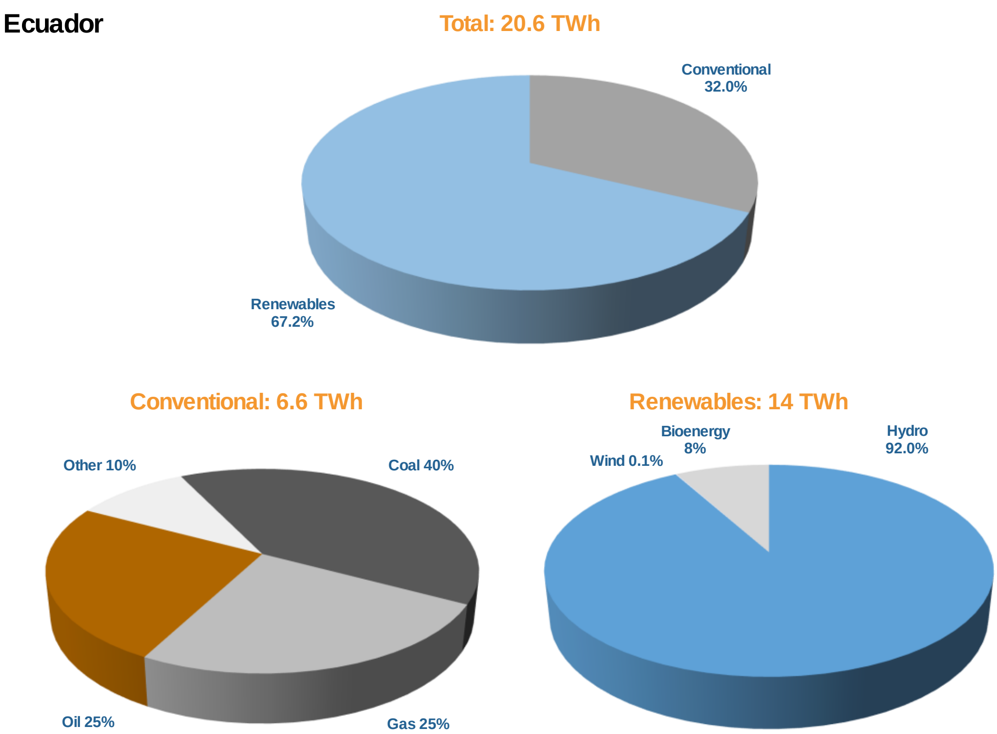
Ecuador's Power Generation – Basic Information (2014)

Total installed generation capacity	**5.3 GW**
Total RES generation capacity	2.4 GW
Total VRES generation capacity	0.05 GW
Peak load	3.5 GW
Electricity production	20.6 TWh
Electricity import	0.90 TWh

Ecuador Renewables (2015)

Total RES generation capacity	**2.6 GW**
Total VRES generation capacity	0.05 GW
Installed solar PV capacity	0.02 GW
Installed wind capacity	0.03 GW

Ecuador's electricity production mix (2014)



Primarily hydropower and coal-fired power plants supply the Ecuadorian electricity network. Ecuador's 47.6 MW total installed capacity of VRES (26.4 MW PV and 21.2 MW wind) are split between wind production in the Galapagos Islands and the Southern regions, and PV solar electricity between production in the North and Central regions. Feed in tariffs for the first 15 years have been in the range around 10 cents USD / kWh for wind and 42 cents USD/kWh for PV. There are no major plans for future large developments of VRES.

EGYPT

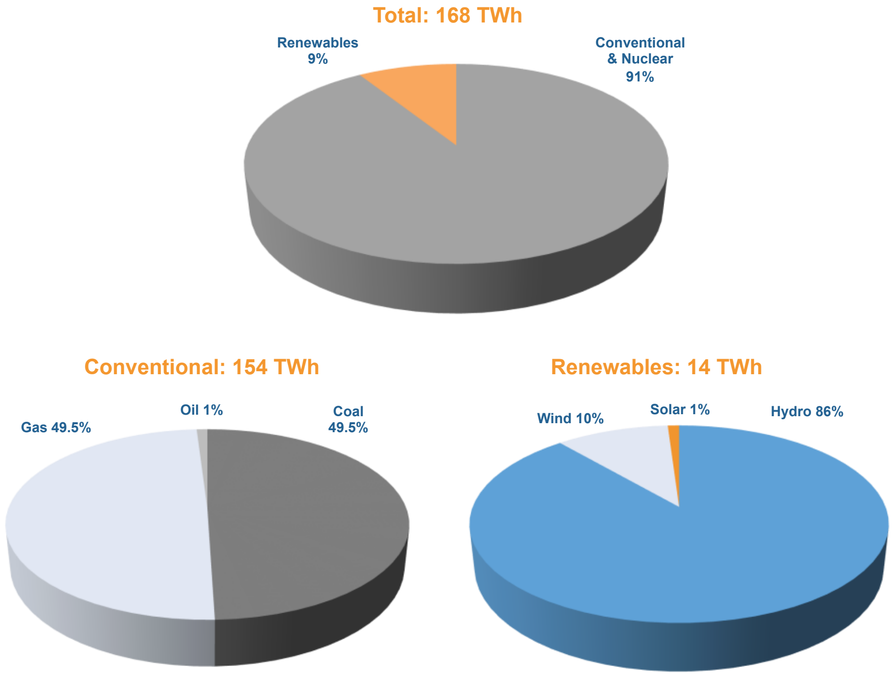
Egypt's Power Generation – Basic Information (2014)

Total installed generation capacity	**32.0 GW**
Total RES generation capacity	3.5 GW
Total VRES generation capacity	0.6 GW
Peak load	26.1 GW
Electricity production	168.0 TWh

Egypt Renewables (2015)

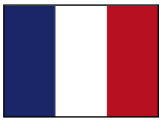
Total RES generation capacity	**3.51 GW**
Total VRES generation capacity	0.64 GW
Installed solar PV capacity	0.03 GW
Installed wind capacity	0.61 GW

Egypt's electricity production mix (2014)



The government strategy approved in February 2008 outlines the objective of RES reaching a 20% share of the total electricity generation by the year 2020. The share of the grid-connected wind power is today about 10% of the total electricity generation in Egypt. It is planned to develop a broad private participation through both the competitive tender and bilateral agreements. This will be supported by the introduction of long-term Power Purchase Agreements. The Government of Egypt will guarantee all financial obligations under the PPA. More than 7,600 square kilometres of desert lands have been allocated for future projects Renewable energy equipment and spare parts are exempt from the customs duties & Sales Taxes .Central Bank of Egypt guarantees all financial obligations of EETC under the PPA. The results of recent auctions are presented in Annex 1.

FRANCE



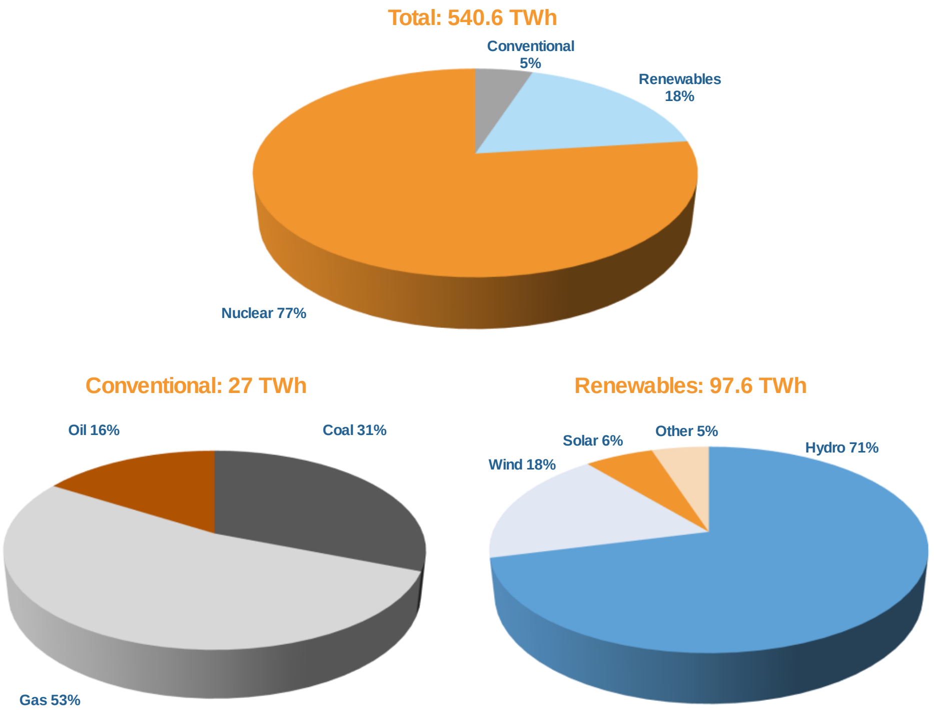
Frances's Power Generation – Basic Information (2014)

Total installed generation capacity	**129.0 GW**
Total RES generation capacity	41.8 GW
Total VRES generation capacity	14.5 GW
Peak load	82.5 GW
Minimum load	29.5 GW
Electricity production	540.6 TWh
Electricity export	92.4 TWh
Electricity import	27.3 TWh

France Renewables (2015)

Total RES generation capacity	**44.2 GW**
Total VRES generation capacity	16.9 GW
Installed solar PV capacity	6.6 GW
Installed wind capacity	10.3 GW

France's electricity production mix (2014)



In 2014, the production from all renewable energy sources provided 18% of French electricity, a slight increase compared to 2013. Renewable energies continued their development assisted by streamlining of the regulatory framework and more favourable economic conditions. Wind and solar PV capacity increased by nearly 1.900 MW in 2014. Currently, France has 9.100 MW of wind and 5.300 MW of solar generation capacity. Electricity generated by renewable energies other than hydropower (28 TWh) outperformed fossil fuel power generation for the first time in 2014. More than half was generated by wind power, with the remainder split between solar PV and biomass.

Maximum wind power generation was reached on 27 December 2014 with output of slightly over 7.000 MW, representing 80% of total installed wind power capacity. Maximum photovoltaic power generation was reached at 13.30 on 17 May 2014 with output of 3.700 MW. Such levels had never been achieved before. In addition, hydro availability was particularly high in that year, due to heavy rainfall. Output of hydropower at 68.2 TWh was the second highest of the decade after 2013, when it was exceptionally high. All these favourable conditions resulted in the highest level of generation by renewable energies accounting for nearly 20% of French power production. This contributed to the reduction of carbon emissions, already achieved by both energy consumption efficiency programmes and nuclear power plants. Annex 1 presents some data from auctions of VRES.

GERMANY

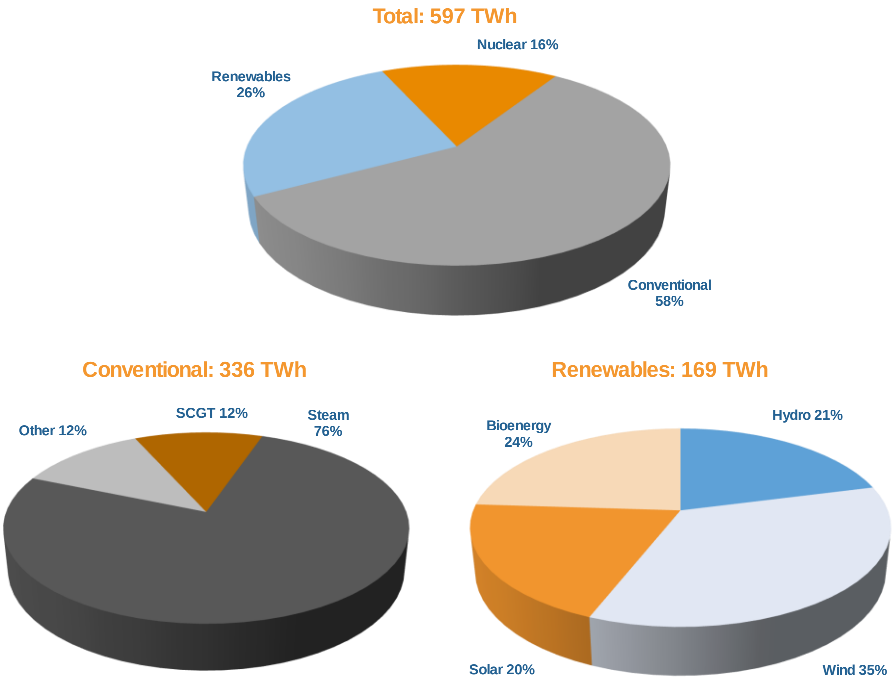
Germany's Power Generation – Basic Information (2014)

Total installed generation capacity	**194.0 GW**
Total RES generation capacity	97.7 GW
Total VRES generation capacity	74.0 GW
Peak load	83.0 GW
Minimum load	32.0 GW
Electricity production (Gross)	614.0 TWh
Electricity production (Net)	597.1 TWh
Electricity export	36.0 TWh

Germany Renewables (2015)

Total RES generation capacity	**105.0 GW**
Total VRES generation capacity	84.6 GW
Installed solar PV capacity	39.6 GW
Installed wind capacity	45.0 GW

Germany's electricity production mix (2014)



Germany has been a front runner in promoting RES development by introducing FIT's with a consequent sky rocketing increase of the share of wind and solar PV up to the present 38% of total installed capacity. The high RES growth has high associated costs. For example, in 2014 alone, 24 billion euros for FIT's (feed-in-tariffs) were passed on end consumers (with exemption of energy intensive industries) accompanied by substantial investments in T&D systems.

The reduction of FIT's has caused a drastic reduction of new variable RES installations, especially solar PV (new capacity additions dropped from 7.6 GW in 2012 to 1.9 GW in 2014). Introduction of pilot auctions will substitute in future FIT's (see Annex 1). Conventional power producers have been hit by the rise in the share of variable RES which has resulted in a drop in both wholesale prices and operating hours of their plants used for residual loads. Four German TSO's, which are also expected to manage the phase out of nuclear, are facing great challenges in transporting electricity from North to South and vice versa. There is a clear need for market rules readjustments. Various technologies and management investments (storage, demand side management etc.) are under development. On the positive side, RES investments have created job opportunities and have contributed to reduction of GHG emissions and fuel imports.

INDIA

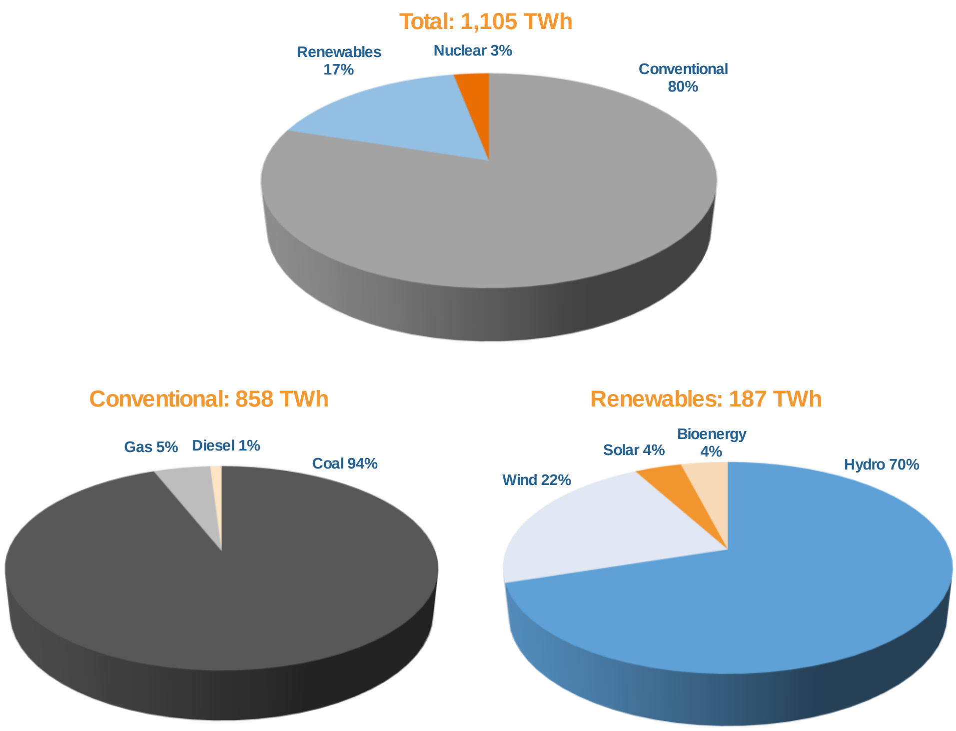
India's Power Generation – Basic Information (2014)

Total installed generation capacity	**271.7 GW**
Total RES generation capacity	77.0 GW
Total VRES generation capacity	27.2 GW
Peak load	148.2 GW
Electricity production	1,105.0 TWh

India Renewables (2015)

Total RES generation capacity	**114.2 GW**
Total VRES generation capacity	30.1 GW
Installed solar PV capacity	5.0 GW
Installed wind capacity	25.1 GW

India's electricity production mix (2014)



India is positioned well for large-scale renewable energy development due to its abundant solar and wind resources which today account for approximately 3.5 % of total electricity with installed wind capacity of 23.4 GW and solar PV of 3.7 GW. Wind has benefitted from accelerated depreciation and generation based incentives. Solar PV enjoys direct capital subsidy; FITs are around USD100/MWh and the allocation of solar PV projects has been through auctions in the recent years. Net metering has been introduced by many states. Several measures, including green corridors are being taken to address technical challenges of increased variable RES with their intermittency. The 2022 targets envisage an installed capacity of 100 GW for PV and 60 GW for wind.

INDONESIA

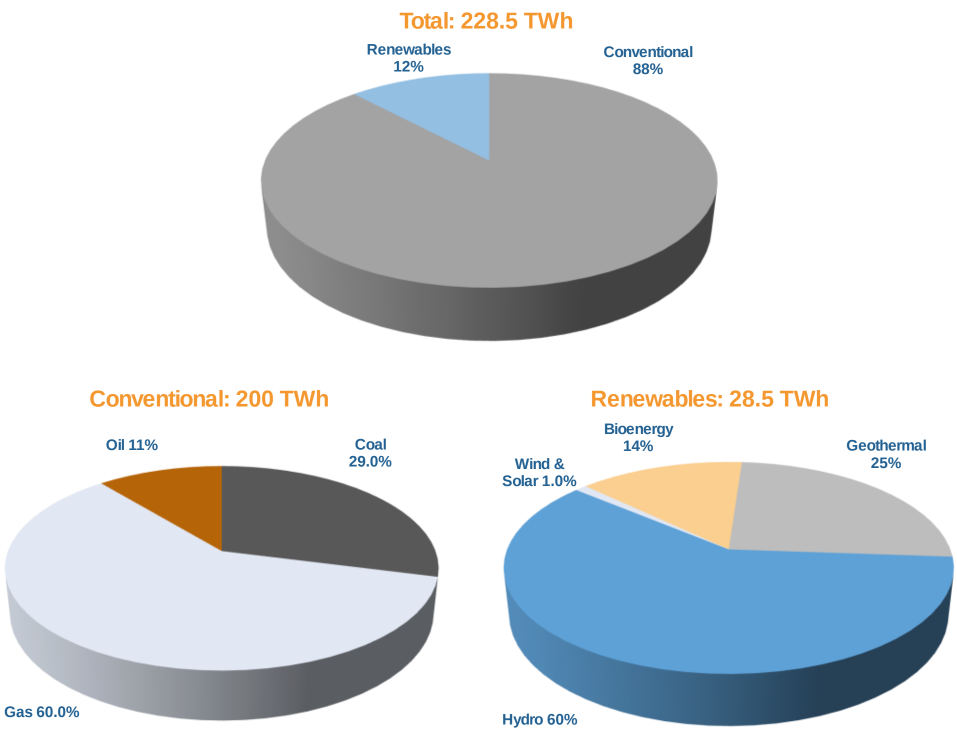
Indonesia's Power Generation – Basic Information (2014)

Total installed generation capacity	**55.0 GW**
Total RES generation capacity	8.30 GW
Total VRES generation capacity	0.01 GW
Peak load	53.8 GW
Electricity production	228.5 TWh

Indonesia Renewables (2015)

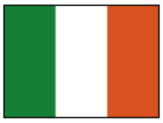
Total RES generation capacity	**8.3 GW**
Total VRES generation capacity	13.0 MW
Installed solar PV capacity	12.0 MW
Installed wind capacity	1.0 MW

Indonesia's electricity production mix (2014)



Today, renewable energy accounts for a small but growing portion of Indonesia's electricity portfolio. The Government of Indonesia (GoI) has announced a medium term target for increasing the share of renewable energy in total energy mix to 25% by 2025. This means that USD38 billion will be invested in the renewable energy sector. Current installed capacity in Indonesia is mostly solar PV home systems. Wind energy development programme in Indonesia up to 2020 amounts to 200MW which are currently still under procurement. The government supports the projects to attract foreign solar cell manufacturers to Indonesia to create jobs and increase the interest in RES.

IRELAND



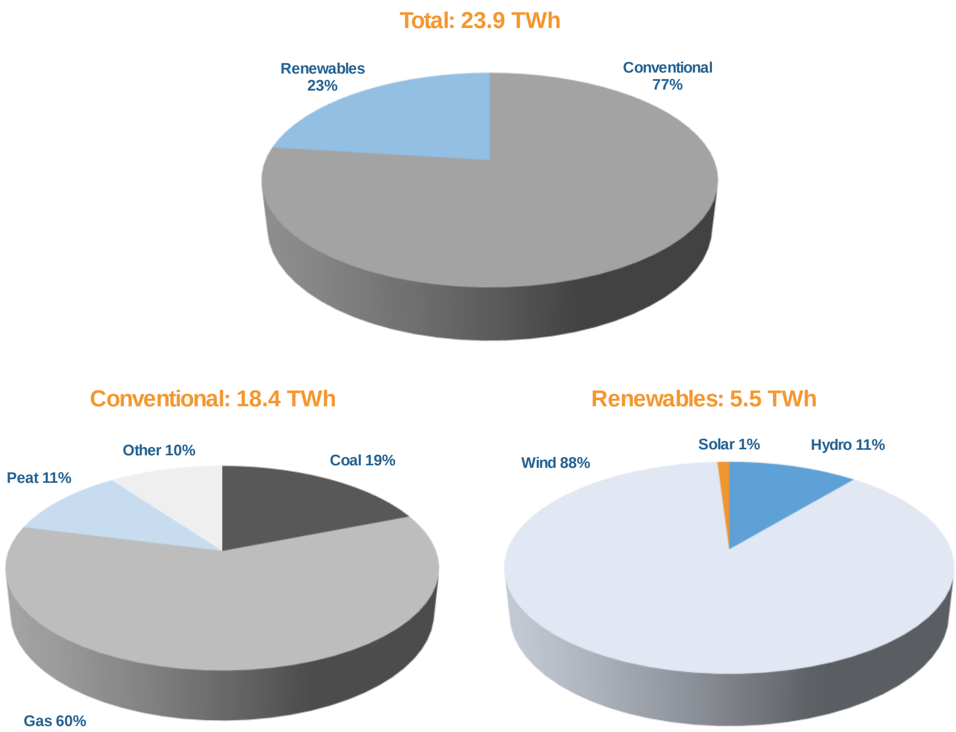
Ireland's Power Generation – Basic Information (2014)

Total installed generation capacity	**9.99 GW**
Total RES generation capacity	3.1 GW
Total VRES generation capacity	2.3 GW
Peak load	6.3 GW
Electricity production (Gross)	23.9 TWh
Electricity export	1.8 TWh

Ireland Renewables (2015)

Total RES generation capacity	**3.1 GW**
Total VRES generation capacity	2.5 GW
Installed solar PV capacity	1.0 MW
Installed wind capacity	2.5 GW

Ireland's electricity production mix (2014)



Ireland has excellent renewable energy resources, which will be a critical and growing component of Irish energy supply to 2020 and beyond. Indigenous renewable energy already plays a vital role in domestic fuel mix. It also increases sustainability through the use of clean power sources and enhances energy security by reducing Ireland's dependence on imported fuels. Wind and solar energy can yield additional opportunities for suppliers and consumers alike. Under the 2009 Renewable Energy Directive, Ireland is committed to produce at least 16% of all energy consumed from renewable sources by 2020. This will be met by 40% from renewable electricity, 12% from renewable heat and 10% from the renewable transport sector. The target to have 40% of electricity consumed from renewable sources by 2020 is one of the most demanding in the world.

ITALY

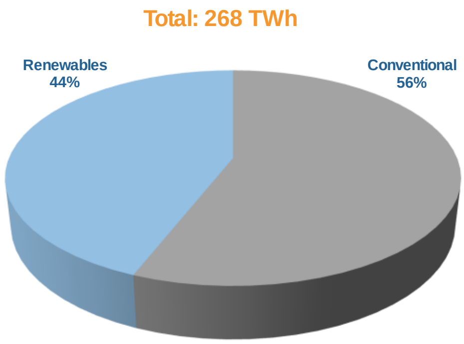
Italy's Power Generation – Basic Information (2014)

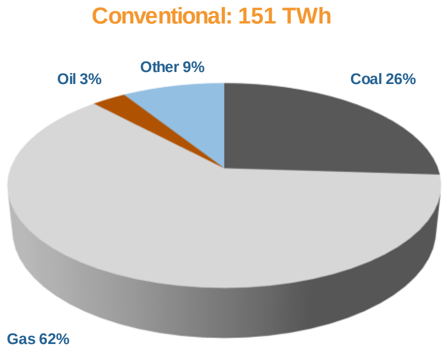
Total installed generation capacity	**125.0 GW**
Total RES generation capacity	53.9 GW
Total VRES generation capacity	27.5 GW
Peak load	54.0 GW
Minimum load	20.0 GW
Electricity production	268.0 TWh
Electricity import	40.0 GWh

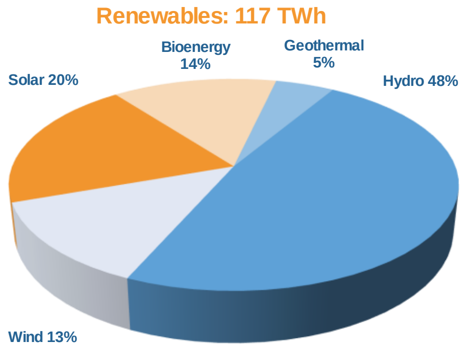
Italy Renewables (2015)

Total RES generation capacity	**54.8 GW**
Total VRES generation capacity	28.0 GW
Installed solar PV capacity	18.9 GW
Installed wind capacity	9.1 GW

Italy's electricity production mix (2014)



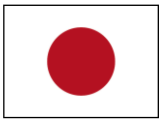




Italy's VRES production is high, 39 TWh (14.5% of the country's electricity generation) using 20 GW of PV and 9 GW of installed wind capacity. The PV production has reached 8% of the total generation (world record). Fast development of RES technologies has been driven by a number of generous incentives such as green certificates and especially FI premium tariffs. The incentives for PV were introduced in 2005 and amounted to 450€/MWh; but now the price is based only on auctions for large plants and tax deductions for small installations. For wind there are currently only a few auctions operating at reduced capacities. The sudden decrease of incentives has resulted in a drastic collapse of annual additions to installed capacity of PV from 9 GW in 2011 to less than 1 GW in 2014 and for wind from 1.2 to 0.3 GW.

A number of side effects related to RES integration have made an impact on the power system and on the market behaviour, including drastic reduction of operating hours for the high efficiency combined cycle fleet. Another contributing factor was strong reduction of demand. Incentives for RES paid by consumers amount to around 13 billion Euros per year, while 6 billion € will be invested into transmission improvements over the next 10 years. Ancillary services market costs are close to 2 billion €/year (doubled with RES introduction). Pilot electrical storage systems both for TSO and DSO grids are already installed or under installation. New market designs are being developed to provide further opportunities for RES investments which in any case contributed to reduction of GHG emissions and import of primary energies, and also created job opportunities. Annex 1 presents some details on recent costs for CAPEX and O&M of PV and Wind plants.

JAPAN



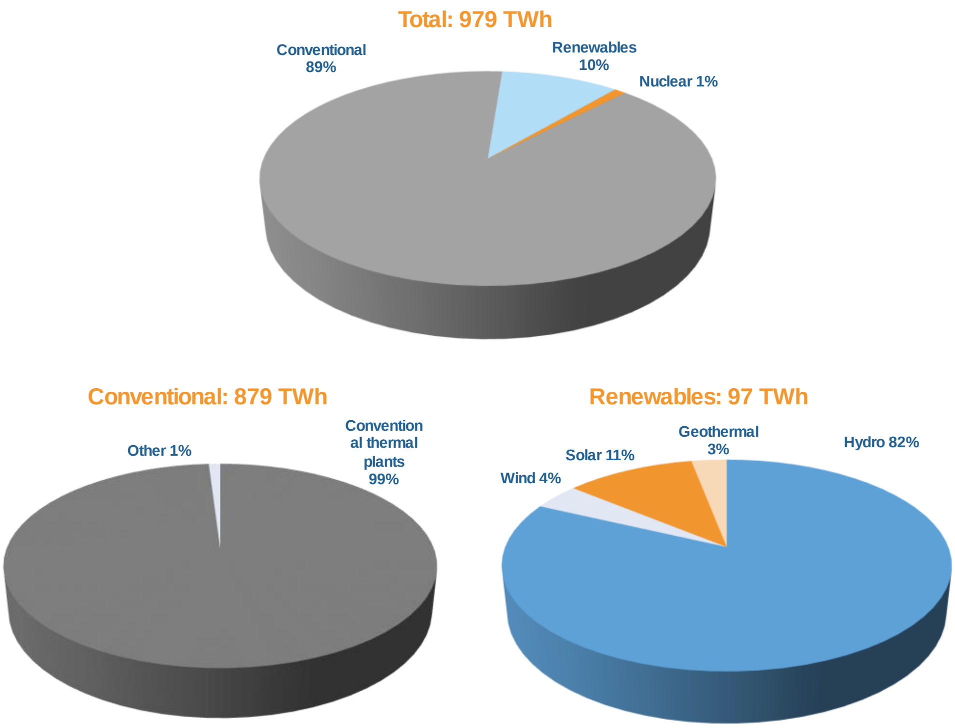
Japan's Power Generation – Basic Information (2013)

Total installed generation capacity	**252.5 GW**
Total RES generation capacity	69.7 GW
Total VRES generation capacity	15.1 GW
Peak load	159.1 GW
Electricity production	979.0 TWh

Japan Renewables (2015)

Total RES generation capacity	**90.1 GW**
Total VRES generation capacity	36.3 GW
Installed solar PV capacity	33.3 GW
Installed wind capacity	3.0 GW

Japan's electricity production mix (2013)



In 2010, before Fukushima, 30% of Japan's electricity production was from nuclear plants which are now shut down, anticipating new safety standards. With renewables contributing only 10% of the country's electricity production whereof 1% solar and 0.5% wind, there is a pressing need to import considerably more fossil fuels and this places a large financial burden on Japan's economy. Therefore, the country is strongly promoting RES; and a FIT premium scheme was introduced in 2012. PV, that had a tariff of 35 US cents/kWh in 2012 (now above 45), has got the highest increase of RES which have a target capacity of 70 GW. This requires significant investments in T&D systems and system balancing issues. The acceptable supply targets for utilities generating power from PV are by far lower than the approved limits for other technologies, and METI has established a Working Group of independent experts to a study of variable RES integration. Financial details are presented in Annex 1.

JORDAN

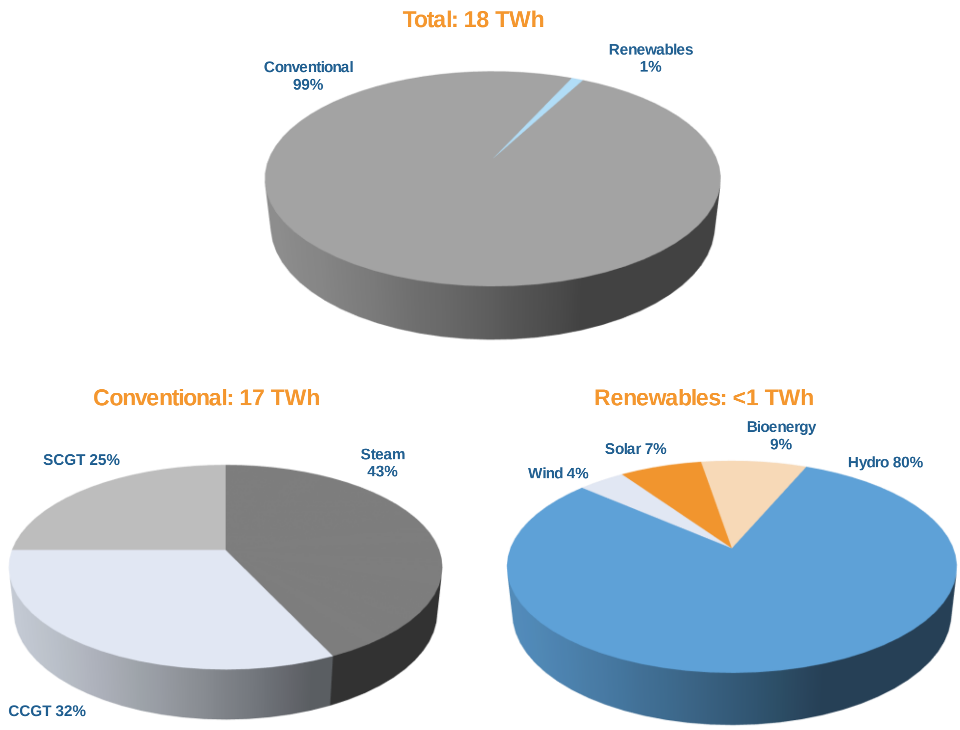
Jordan's Power Generation – Basic Information (2014)

Total installed generation capacity	**4.0 GW**
Total RES generation capacity	26.0 MW
Total VRES generation capacity	11.0 MW
Peak load	3.01 GW
Minimum load	1.2 GW
Electricity production	18.0 TWh

Jordan Renewables (2015)

Total RES generation capacity	**160.0 MW**
Total VRES generation capacity	145 MW
Installed solar PV capacity	26.0 MW
Installed wind capacity	119.0 MW

Jordan's electricity production mix (2014)



Given that RES account for less than 0.5% of RES electricity production, Jordan has made minimal progress in its introduction of renewables. The shares of solar PV and wind energy are 7% and 5% of Jordan's total renewables production, even if in the Southern parts of the country there are suitable sites for development of both wind and PV plants. With 96% of fossil fuels being imported, Jordan plans to increase its RES capacity with the help of generous feed-in-tariffs, with a goal of reaching 10% RE electricity production by 2020.Various wind and PV projects have been contracted with private investors and a "green corridor" for grid support has been established. (See Annex 1 for cost details).

KAZAKHSTAN

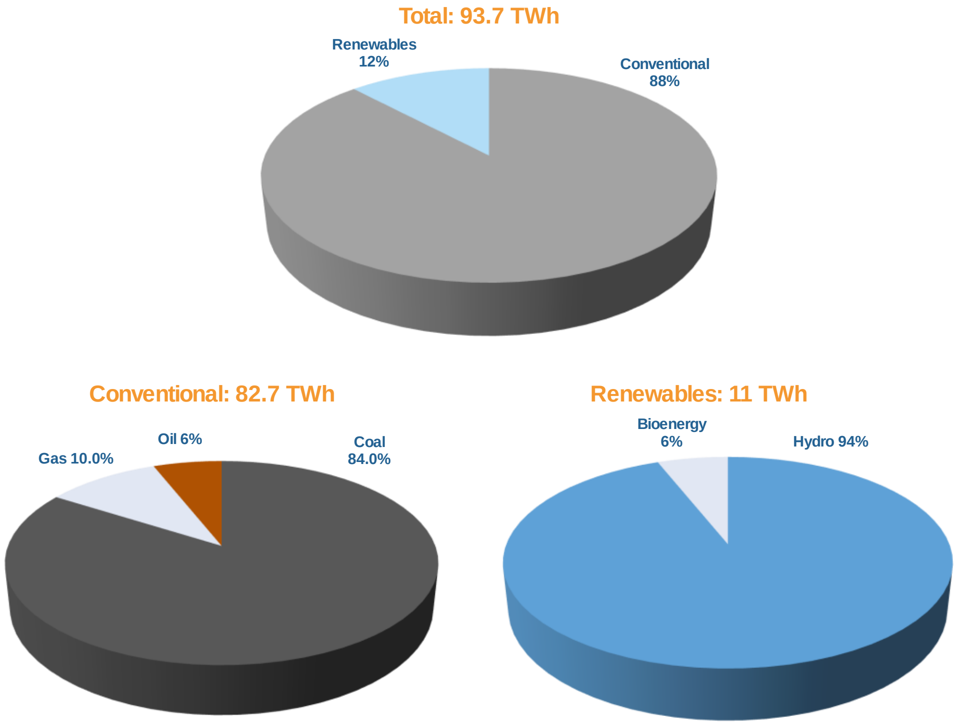
Kazakhstan's Power Generation – Basic Information (2014)

Total installed generation capacity	**19.6 GW**
Total RES generation capacity	2.8 GW
Total VRES generation capacity	0.1 GW
Electricity production	93.7 TWh

Kazakhstan Renewables (2015)

Total RES generation capacity	**2.8 GW**
Total VRES generation capacity	123 MW
Installed solar PV capacity	55 MW
Installed wind capacity	68 MW

Kazakhstan's electricity production mix (2014)



According to government's strategy to 2050, 50% of the installed capacity in Kazakhstan will use renewable energy sources. This is just one component of Kazakhstan's comprehensive initiative to transfer from one of the world's premier hydrocarbon energy producers to a model "green" economy. Wind power has the potential to produce 25 times more energy in a year than Kazakhstan's current production from hydrocarbons. It is estimated that 10-15% of the land in Kazakhstan has average wind speeds of over 6 m/s. Wind power will play a large part of the 2020 goal to expand the renewable energy generating capacity to 1,040 megawatts from 110 megawatts last year. The 2020 goal is to have four solar power plants in operation producing a total of 77MW of electricity. The recently announced solar-power-generating complex in Kyzylorda Province will be generating 65MWh of electricity per year. A major step forward in Kazakhstan's timeline was the opening of the Astana Solar LLP photovoltaic panel production plant in Astana in 2013 to meet Kazakhstan's increasing demand for solar panels.

KOREA (REP. OF)

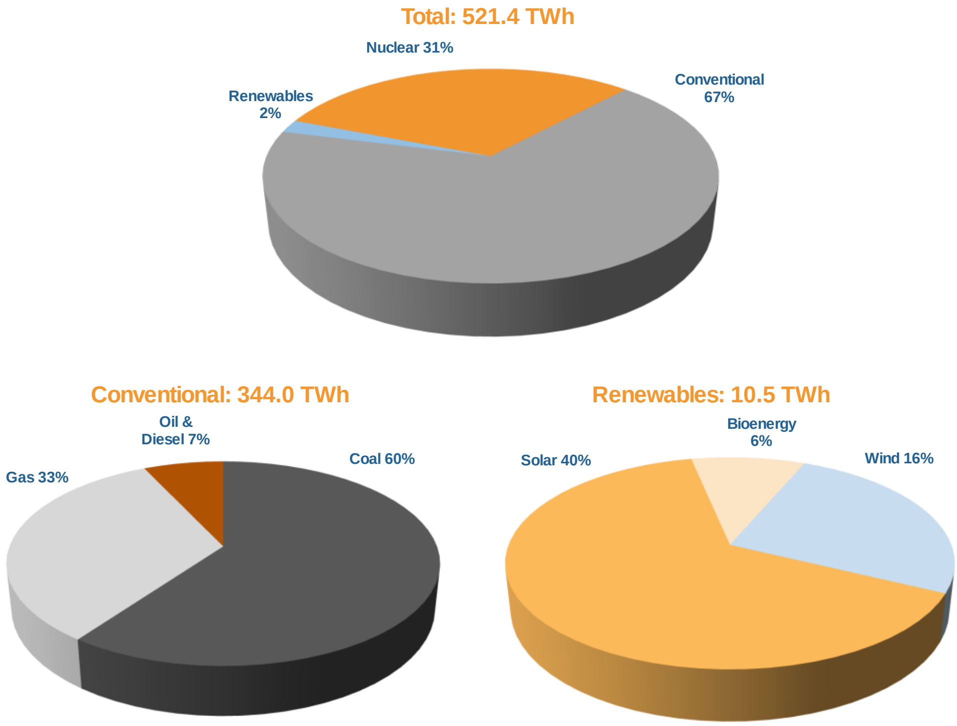
Korea's Power Generation – Basic Information (2014)

Total installed generation capacity	**93.2 GW**
Total RES generation capacity	11.7 GW
Total VRES generation capacity	4.0 GW
Electricity production	521.4 TWh

Korea Renewables (2015)

Total RES generation capacity	**12.7 GW**
Total VRES generation capacity	4.0 MW
Installed solar PV capacity	3.2 MW
Installed wind capacity	0.8 MW

Korea's electricity production mix (2014)



According to the 4th national plan for development and supply of renewable energy in Korea, renewables will reach 13.4% of total installed power generation capacity by 2035 compared to 3.7% in 2012. Solar and wind are expected to increase from 0.5% in 2012 to 7.5% in 2035. Both the public and private sectors, invest actively in research and development of "green" and smart technologies such as Energy Storage System (ESS), smart and micro grids. Certain incentives have been introduced to support the private sector investment in a stable renewable energy supply system. For example, additional Renewable Energy Certificate (REC) points will be added to the utilities who install wind power plants combined with Energy Storage System (ESS). These points can be sold in the REC trading market, and this brings additional profits for renewable energy producers. Korean government adopted the Renewable Portfolio Standards (RPS) in 2012, making it mandatory for power generators to produce each year 2% of their electricity from renewable energy sources. Utilities can run their own renewable energy power plants or buy the points of REC from other generators to meet their annual 2% quota.

MEXICO

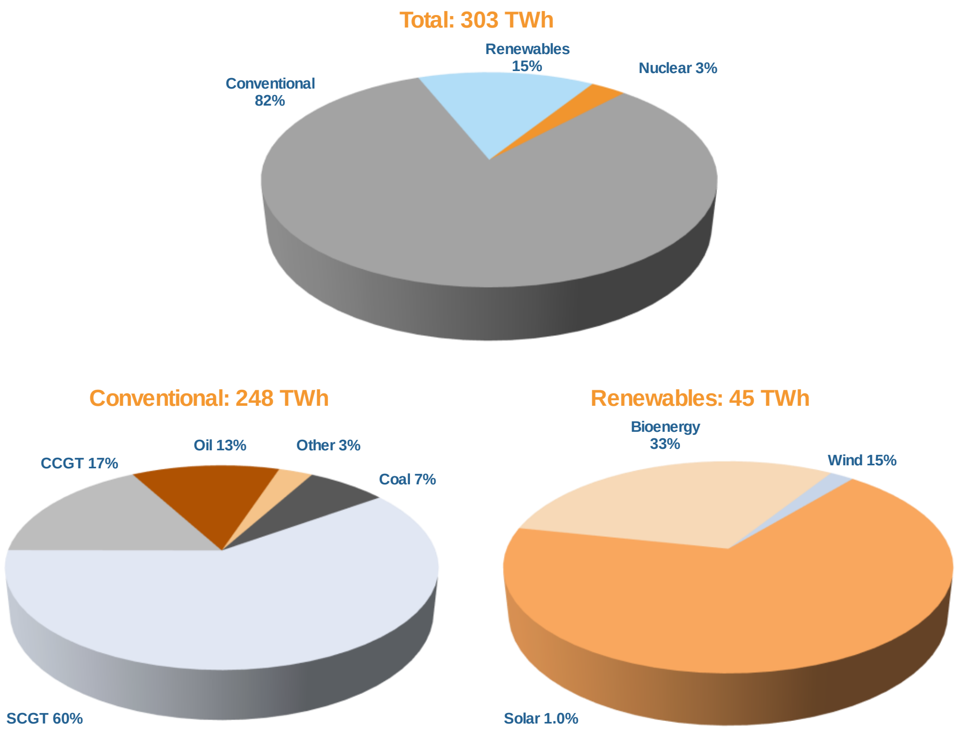
Mexico's Power Generation – Basic Information (2014)

Total installed generation capacity	**65.4 GW**
Total RES generation capacity	16.5 GW
Total VRES generation capacity	3.2 GW
Peak load	39.0 GW
Minimum load	17.1 GW
Electricity production	303 TWh

Mexico Renewables (2015)

Total RES generation capacity	**17.6 GW**
Total VRES generation capacity	3.3 GW
Installed solar PV capacity	0.2 GW
Installed wind capacity	3.1 GW

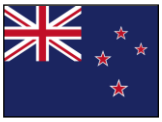
Mexico's electricity production mix (2014)



RES account for nearly 15% of electricity production in Mexico and wind is by far the most developed VRES with a share of 2% of the country's production and of installed capacity. Wind resources are located mainly in the Southeast, while PV is in the Northern regions; however, both are far from important load centres and require development of transmission infrastructure. Average O&M costs are 9 USD/MWh for wind and 12 USD/MWh for PV. Mexico is aiming to increase its renewable electricity production to 25% by 2025 and to 50% by 2050. It is planned to achieve these targets with clean energy certificates, accelerated depreciation, preferential wheeling charges, net metering and other solutions.

Certain approaches that have been used to foster RES integration are transmission reinforcement and there are plans for demand side management through smart grids technologies. Annex 1 presents results of recent auctions.

NEW ZEALAND



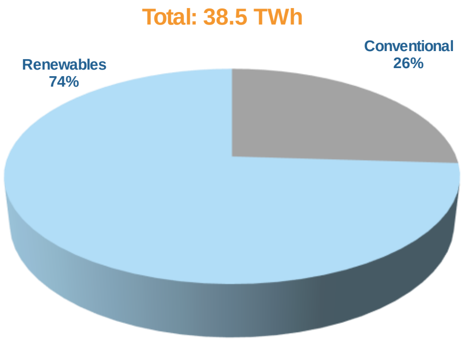
New Zealand's Power Generation – Basic Information (2014)

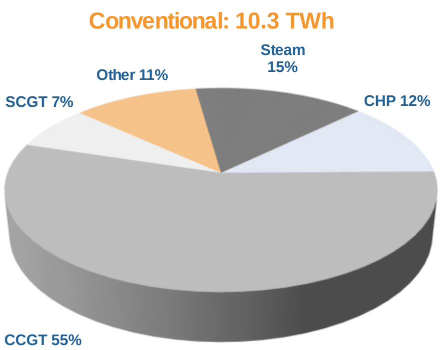
Total installed generation capacity	**11.06 GW**
Total RES generation capacity	7.0 GW
Total VRES generation capacity	0.64 GW
Peak load	6.41 GW
Minimum load	2.84 GW
Electricity production	38.5 TWh

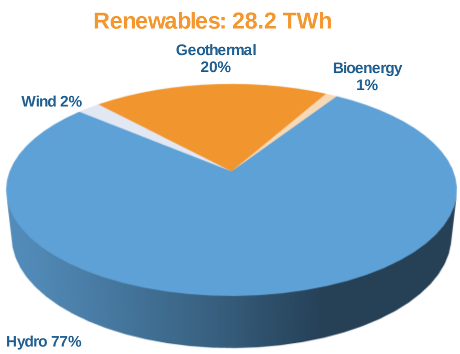
New Zealand Renewables (2015)

Total RES generation capacity	**7.0 GW**
Total VRES generation capacity	0.65 GW
Installed solar PV capacity	0.03 GW
Installed wind capacity	0.62 GW

New Zealand's electricity production mix (2014)

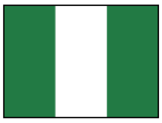






With large water and geothermal resources, the majority of New Zealand electricity production is from renewable energy sources. Wind energy with a load factor 38–43% comprises 2% of these renewables energy and it will cover 40% of next foreseeable capacity additions. PV production is just at the beginning with maximum expected future installed capacity providing 2–3% of country energy. No incentives to RES. New Zealand has a unique market with a carbon price emission trading scheme combined with “location marginal pricing LMP” which includes offer-based merit order dispatch and a nodal price which takes care of losses and congestion. Generators offer energy in real time avoiding balancing payments. Inverters in new windfarms are used to provide voltage support even when there is no wind and the turbines are not generating.

NIGERIA



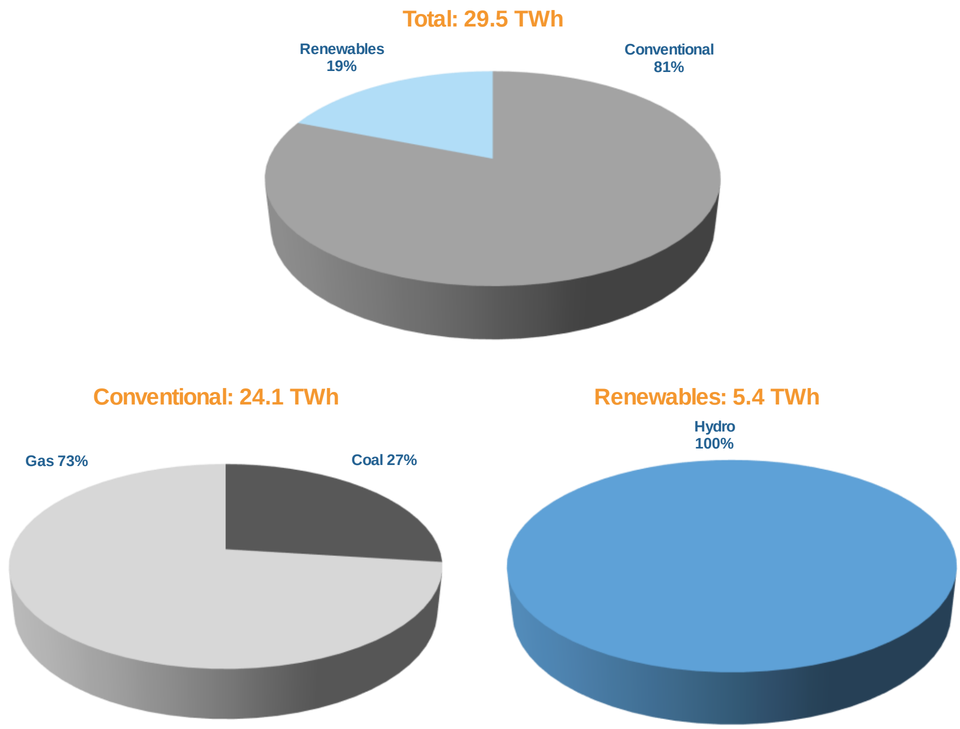
Nigeria's Power Generation – Basic Information (2014)

Total installed generation capacity	**9.9 GW**
Total RES generation capacity	2.0 GW
Total VRES generation capacity	18 MW
Peak load	4.5 GW
Electricity production	29.5 TWh
Electricity import	1.7 TWh

Nigeria Renewables (2015)

Total RES generation capacity	**2.1 GW**
Total VRES generation capacity	19.0 MW
Installed solar PV capacity	17.0 MW
Installed wind capacity	2.0 MW

Nigeria's electricity production mix (2014)



The Nigerian electricity production mix does not include any variable RES technologies, as all of the 22% of renewable electricity within the country is generated through hydropower. Future VRES production is expected to be developed, through investment from the privatization of the electricity industry. Reliability of both conventional and renewable electricity supply will be ensured through the improvement of Nigeria's deteriorated electricity infrastructure and financial incentives through subsidies, grants, low interest loans, and many others. Large obstacles for VRE investment lie in the absence of a market, appropriate policy and regulation.

PHILIPPINES

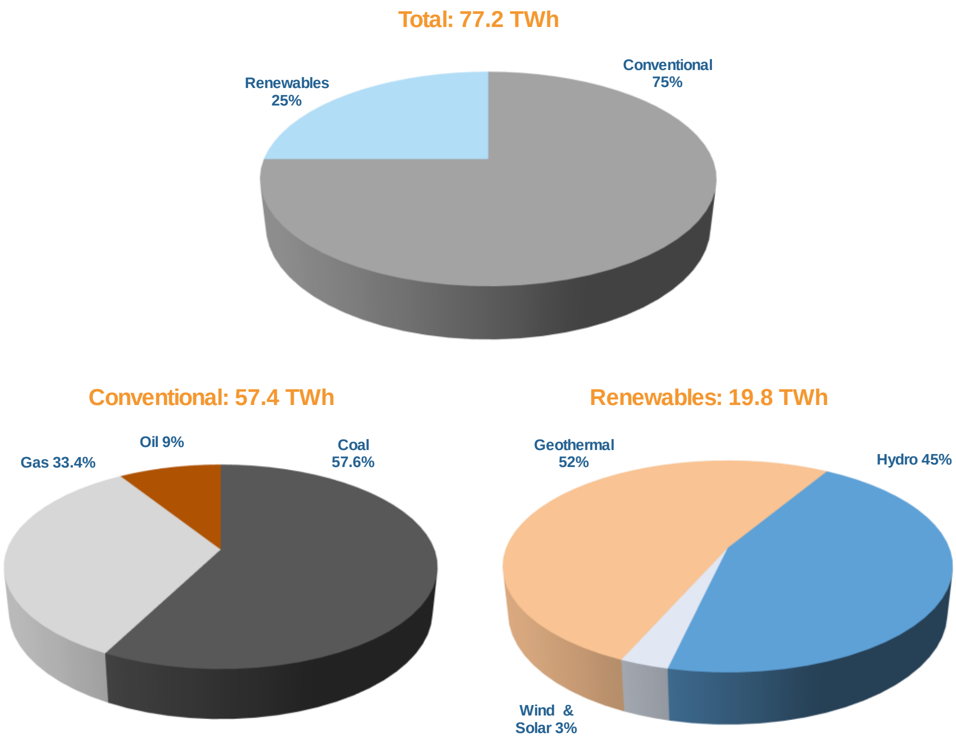
Philippines' Power Generation – Basic Information (2014)

Total installed generation capacity	**17.9 GW**
Total RES generation capacity	5.9 GW
Total VRES generation capacity	0.4 GW
Peak load	11.8 GW
Electricity production	77.2 TWh
Electricity import	23.0 TWh
Electricity export	2.4 TWh

Philippines Renewables (2015)

Total RES generation capacity	**6.2 GW**
Total VRES generation capacity	519 MW
Installed solar PV capacity	132 MW
Installed wind capacity	387 MW

Philippines' electricity production mix (2014)



It is the government's policy in the Philippines to facilitate the energy sector's transition to a sustainable system with a dominant RES capacity. The shift from fossil fuel sources to renewable forms of energy is a key strategy in ensuring the success of this transition. Moreover, current initiatives in the pursuit of this policy are directed towards creating a market-based environment that is conducive to private sector investment and participation and encourages technology transfer and research and development. Thus, current fiscal incentives provide for a preferential bias to RES technologies and projects which are environmentally sound.

POLAND

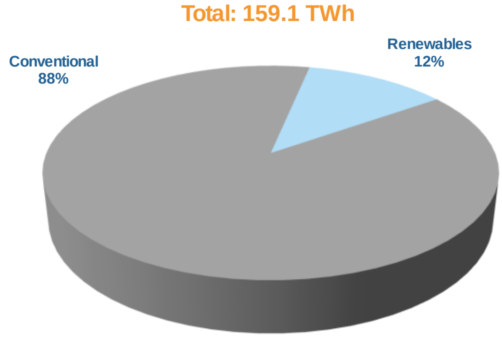
Poland's Power Generation – Basic Information (2014)

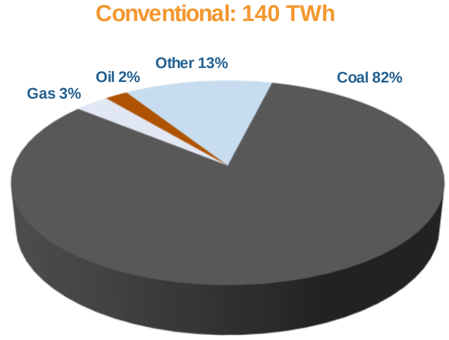
Total installed generation capacity	**39.4 GW**
Total RES generation capacity	7.0 GW
Total VRES generation capacity	3.9 GW
Peak load	25.5 GW
Minimum load	20.5 GW
Electricity production	159.1 TWh
Electricity import	40.0 TWh
Electricity export	0.0 TWh

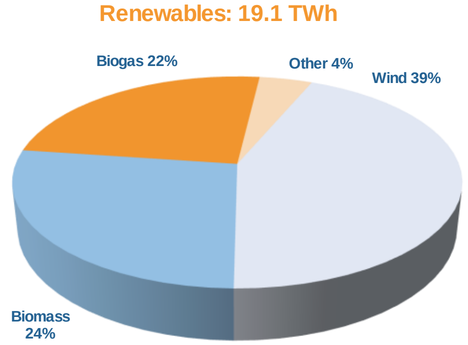
Poland Renewables (2015)

Total RES generation capacity	**8.4 GW**
Total VRES generation capacity	5.1 GW
Installed solar PV capacity	0.07 GW
Installed wind capacity	5.17 GW

Poland's electricity production mix (2014)







The Polish energy sector is historically based on the domestic abundant hard coal and lignite, which are used to produce nearly 88% of Poland's electricity. In the last five years, the Polish power system has experienced rapid development of variable renewable energy (VRES) generation capacity increased from 84 MW in 2005 to 3,863 MW in 2014 and 5,056 MW in 2015. Electricity production from these plants increased from 135.5 GWh in 2005 to 7,683 GWh in 2014. The development is driven by wind energy. At the end of June 2015, there were 981 wind power plants in Poland with a total capacity of 4,117 MW.

Most wind farms are located in North-Western Poland and high potential wind onshore and offshore sites are located in the Baltic Sea region. Polish public policy ensured the achievement of the 20/20/20 objective under the EU climate and the third energy package through generous incentives for VRES. According to the Energy Law Act, connecting to the grid VRES plants with an installed capacity up to 5 MW requires only 50% of the fee, calculated on the basis of actual costs of establishing the connection.

PORTUGAL

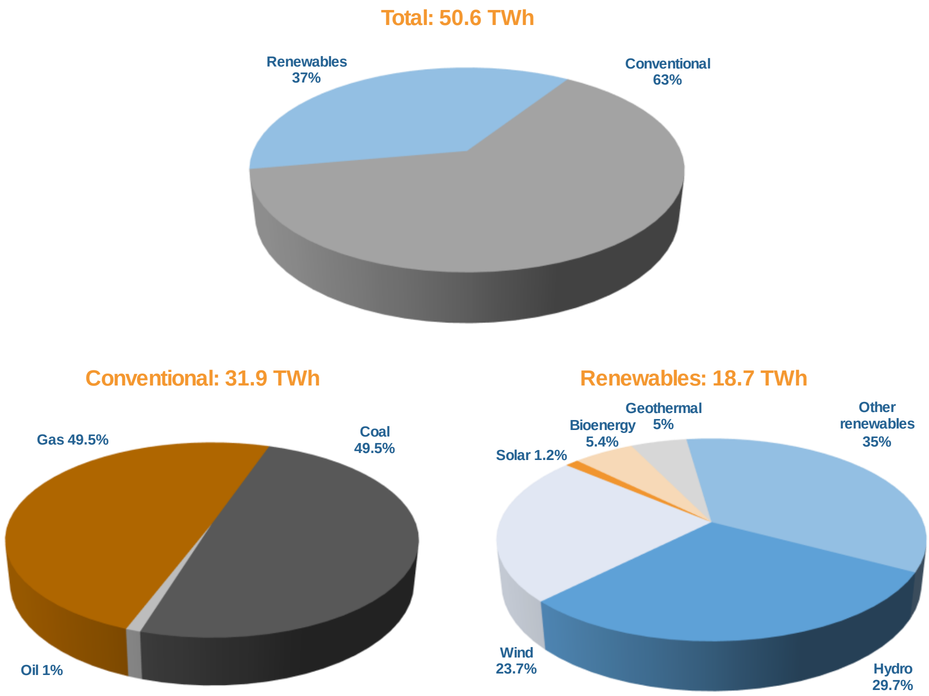
Portugal's Power Generation – Basic Information (2014)

Total installed generation capacity	**19.7 GW**
Total RES generation capacity	11.6 GW
Total VRES generation capacity	5.0 GW
Peak load	10.3 GW
Minimum load	4.7 GW
Electricity production	50.6 TWh
Electricity import	3.1 TWh
Electricity export	4.0 TWh

Portugal Renewables (2015)

Total RES generation capacity	**11.9 GW**
Total VRES generation capacity	5.53 GW
Installed solar PV capacity	0.45 GW
Installed wind capacity	5.08 GW

Portugal's electricity production mix (2014)



At the end of 2014, RES represented 37% of electricity consumption in Portugal mainland, a value above average mainly due to the high precipitation levels along the year. The sector has an important impact on jobs creation and in the Portuguese GDP. Referring to 2014 the sector employed around 43 478 individuals (indirect and direct jobs) and contributed with 2 902 M€ for the GDP. The RES directive 2001/77/CE, implemented through the national decree-law n. º 339-C/2001, December 29th, was the main precursor of RES in Portugal.

In 2013, the Portuguese National Renewable Energy Action Plan (Plano Nacional de Ação para as Energias Renováveis) in accordance with Directive 2009/28/EC on the promotion of the use of energy from renewable sources, was published. This NREP was prepared in accordance with the template published by the Commission, and provide detailed roadmaps of how each Member State expects to reach its legally binding 2020 target for the share of renewable energy in their final energy consumption.

ROMANIA

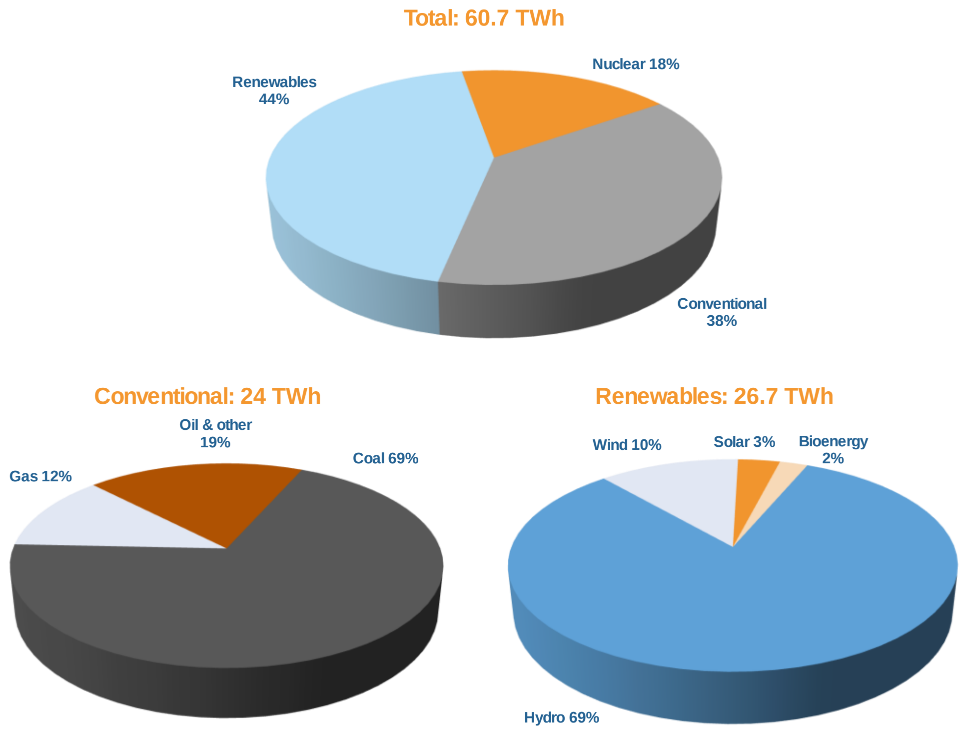
Romania's Power Generation – Basic Information (2014)

Total installed generation capacity	**24.0 GW**
Total RES generation capacity	11.2 GW
Total VRES generation capacity	4.2 GW
Peak load	9.3 GW
Minimum load	4.1 GW
Electricity production	60.7 TWh

Romania Renewables (2015)

Total RES generation capacity	**11.3 GW**
Total VRES generation capacity	4.5 GW
Installed solar PV capacity	1.3 GW
Installed wind capacity	3.2 GW

Romania's electricity production mix (2014)



Given that 44% of electricity generated in Romania comes from renewables, more electricity is produced from renewables than any other energy resource. Variable RES i.e. wind and solar PV, account for 10.1% and 2.6% of country production, respectively. Most of PV installations are connected to medium and low voltage networks, which makes controlling them from dispatch centres fairly challenging. Fast and frequent wind power fluctuations create problems for balancing of the system. Romanian RES production has increased spectacularly because of generous incentives, mainly through tradable Green Certificate Schemes, which are different for each RES technology. The decrease of incentives has caused a significant reduction in annual additions to the installed RES capacity. Future technical and economic policies are under development to ensure further growth of variable RES – moreover, adjustment of the wholesale market is planned, including a fair allocation of balancing responsibilities to all market participants.

RUSSIAN FEDERATION

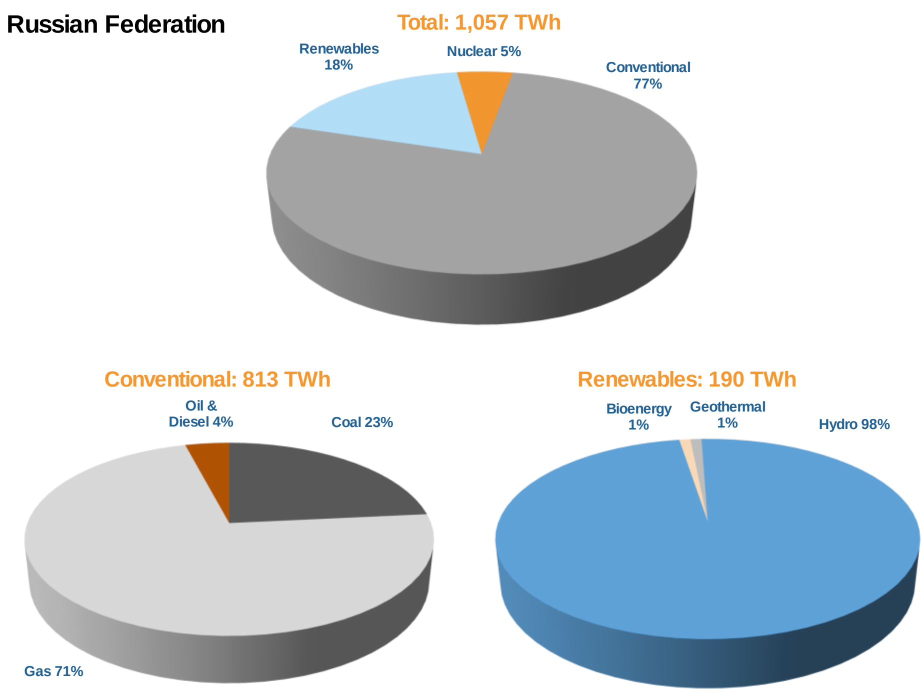
Russia's Power Generation – Basic Information (2014)

Total installed generation capacity	**240.0 GW**
Total RES generation capacity	51.7 GW
Total VRES generation capacity	0.42 GW
Electricity production	1,057 TWh
Electricity import	4.5 TWh
Electricity export	17.5 TWh

Russia Renewables (2015)

Total RES generation capacity	**52.0 GW**
Total VRES generation capacity	0.50 GW
Installed solar PV capacity	0.40 GW
Installed wind capacity	0.10 GW

Russia's electricity production mix (2014)



Given its huge and diverse energy resource base there is little interest in developing renewable energy sources in Russia. In terms of environment, the energy industry has different serious issues with the aging conventional and nuclear plants. The previous administration, with its active promotion of new technologies, was the first in modern Russia's history to set a non-binding renewable energy target of 4.5% of electricity production by 2020. The provisional target of 2.5% by 2010 was however missed and there had been no institutional developments in support of renewables, apart from the Ministry of Energy six-year plan, which includes commissioning of 5.87GW of renewable energy capacity by 2020. Adding to the confusion surrounding renewables in Russia, the plan stipulates that wind energy should become the leading technology for new projects.

So far, out of the 3.6GW wind capacity planned to be installed by 2020, only 190 MW been completed by 2016. Implementation of several renewable energy projects initiated in 2013-2014 has been postponed, as the devaluation of the Russian ruble against hard currency made the projects too expensive.

SOUTH AFRICA

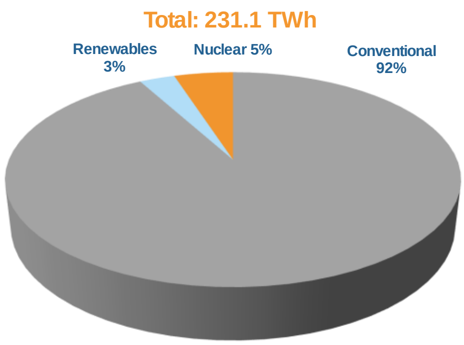
South Africa's Power Generation – Basic Information (2014)

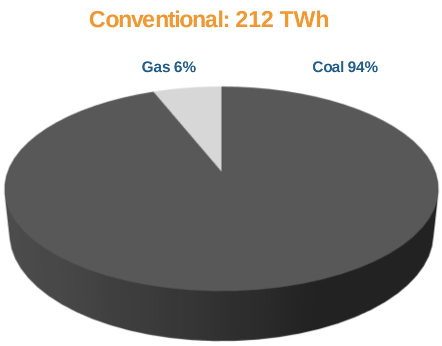
Total installed generation capacity	**44.2 GW**
Total RES generation capacity	4.0 GW
Total VRES generation capacity	1.5 GW
Peak load	35.5 GW
Electricity production	231.1 TWh
Electricity import	12.7 TWh

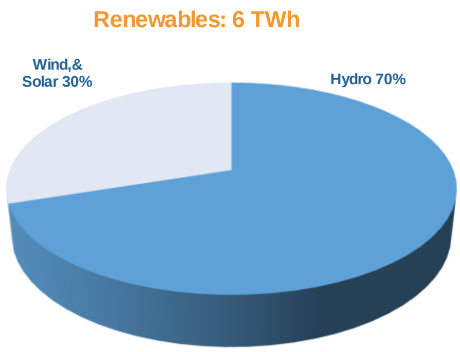
South Africa Renewables (2015)

Total RES generation capacity	**5.12 GW**
Total VRES generation capacity	2.41 GW
Installed solar PV capacity	1.36 GW
Installed wind capacity	1.05 GW

South Africa's electricity production mix (2014)







As a consequence of a readily available supply of low cost coal, South Africa's energy is predominantly coal-based powering a carbon intensive economy. As at 31 March 2014, conventional power sources remain the primary source of energy, but investment in renewable energy has rapidly accelerated as a result of a massive, utility scale, Renewable Energy Independent Power Producer Programme (REIPPPP). Since its inception in 2011, the REIPPPP has enabled rapid development of energy capacity and investment by the private sector, growing South Africa's share of installed RE generation capacity from negligible in 2010 (0%, IRP 2010) to 2.43% in 2014. By March 2014, 21 Renewable Energy-Independent Power Producer (RE-IPP) projects had been successfully connected to the national power grid, contributing 1076 MW of installed capacity. At the end of 2014, three new RE bid rounds were in various stages of completion.

As a result of the REIPPPP, major shifts have been achieved in the energy industry in an exceptionally short space of time, demonstrating the country's commitment to re-orientate the economy towards a sustainable, low-carbon growth trajectory while securing an inclusive and equitable society. Annex 1 presents results of the recent auctions.

SPAIN

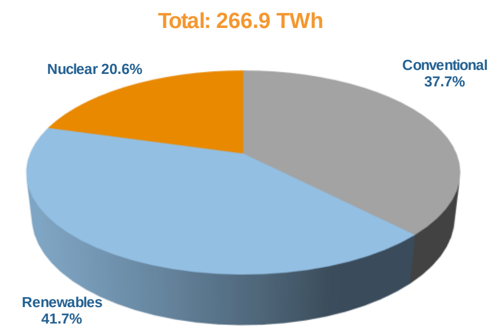
Spain's Power Generation – Basic Information (2014)

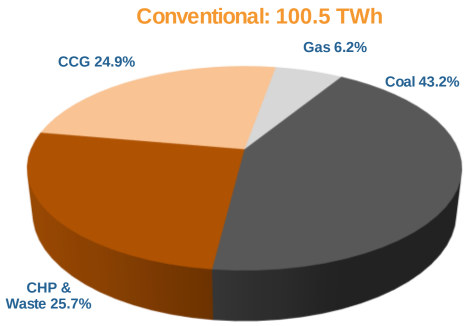
Total installed generation capacity	**105.8 GW**
Total RES generation capacity	50.4 GW
Total VRES generation capacity	27.7 GW
Peak load	38.7 GW
Minimum load	18.1 GW
Electricity production (Gross)	266.9 TWh
Electricity production (Net)	258.1 TWh
Electricity export (Net)	3.4 TWh

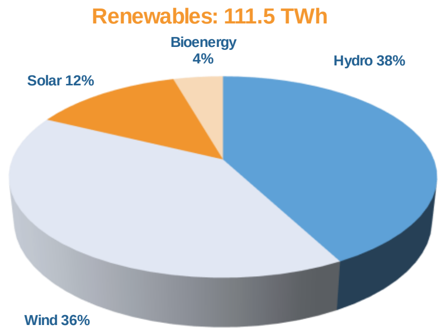
Spain Renewables (2015)

Total RES generation capacity	**51.5 GW**
Total VRES generation capacity	27.8 GW
Installed solar PV capacity	4.8 GW
Installed wind capacity	23.0 GW

Spain's electricity production mix (2014)







Spain holds a leading position within the EU in the renewable energies sector, and it is still above its path of meeting the goals by 2020. The implementation of a FIT's scheme and the development of the power grid have contributed to a significant increasing of renewable electricity generation, reaching 41.7% of total electricity demand in 2014. As a matter of fact, both solar and wind technologies accounted for 28.3% of the overall installed electric power by the end of that year.

Nevertheless, this intense growth entailed a significant extra cost associated with the incentives involving these technologies (primes), contributing meaningfully to generate a high tariff deficit on Spain's electrical power grid, which threatened its sustainable development. Until 2013, this cost reached an accumulated value of € 43,726 million. Since mid-2013, a comprehensive reform of all regulated activities in the electricity system has been carried out with the aim of correcting this imbalance. In particular, for renewable energies, a new remuneration system has been introduced that guarantees a "reasonable return" on investments for efficient and well-managed companies. Renewable electricity is granted priority dispatch in the electricity markets by Law under equal economic conditions, as well as priority to grid's access and connection. Furthermore, in order to implement new plants within the electric system at the lowest possible cost, a competitive auction system has been launched too. The reform has allowed eliminating the tariff deficit along with a progressive reduction of consumer prices. Since 2014 the electrical system is already in surplus (+550.3 million € in 2014). The growth of renewable energies generation contributes to improving self-supply, with the consequent decrease of fossil products imports, and the reduction of greenhouse gas emissions. Likewise, based on lower generation variable costs compared to plants based on conventional technologies, it enables a reduction in the price within electricity production. But on the other hand, it's essential to increase the level of interconnection with the rest of Europe in order to integrate Spain's renewables output as well as to guarantee security of supply and maintain the proper functioning of the system.

THAILAND

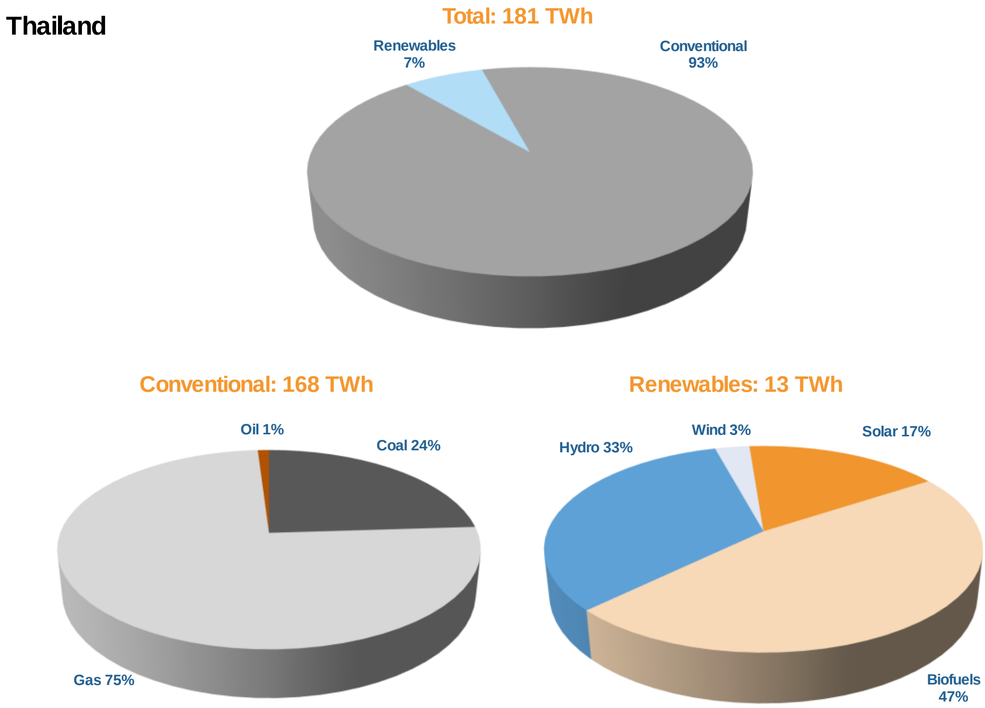
Thailand's Power Generation – Basic Information (2014)

Total installed generation capacity	**35.0 GW**
Total RES generation capacity	7.8 GW
Total VRES generation capacity	1.5 GW
Peak load	26.9 GW
Electricity production	181 TWh
Electricity import	12.2 TWh

Thailand Renewables (2015)

Total RES generation capacity	**8.4 GW**
Total VRES generation capacity	1.8 GW
Installed solar PV capacity	1.6 GW
Installed wind capacity	0.2 GW

Thailand's electricity production mix (2014)



Thailand has a very small share of renewable energy sources for electricity production, mainly hydro power which has a share of 3% only. Starting from 2012, Thailand has been implementing a 10-year development plan to increase renewable electricity production with growth in solar and wind power increasing to 3,000 MW and 1,800 MW, respectively by 2021. This growth will be financed through subsidies from the Energy Service Company Fund and feed-in-tariffs. FIT's for PV for a 25-year period are ranging from 160 USD/MWh for large plants (> from 90 MW) to 195 USD/MWh for residential consumers and/or replacement of diesel in certain areas.

Various measures have been introduced to promote renewables generation, e.g. ESCO Revolving Fund, Adder, Feed in Tariff (FiT), etc.

ESCO Venture Capital (monitored by DEDE)

The Ministry of Energy has established an ESCO Fund to promote private investments in RE/EE projects, with the initial capital from the ENCON Fund. The Fund was launched in October 2008, with an initial capital of THB 500 million (about USD14.7 million) targeted for SMEs; and as a pilot venture capital initiative to address the issue of lack of equity capital for small developers. The Fund provides up to 50% of equity capital.

Feed in Tariff

The National Energy Policy Council (NEPC) has approved the FiTs to promote the electricity generating from Solar PV for the period of 2014-2015 for 25 years for

1. Solar Farms with the maximum installed capacity of ≤ 90 MWp

2. Solar Roof top with different rates for different types of buildings

TUNISIA

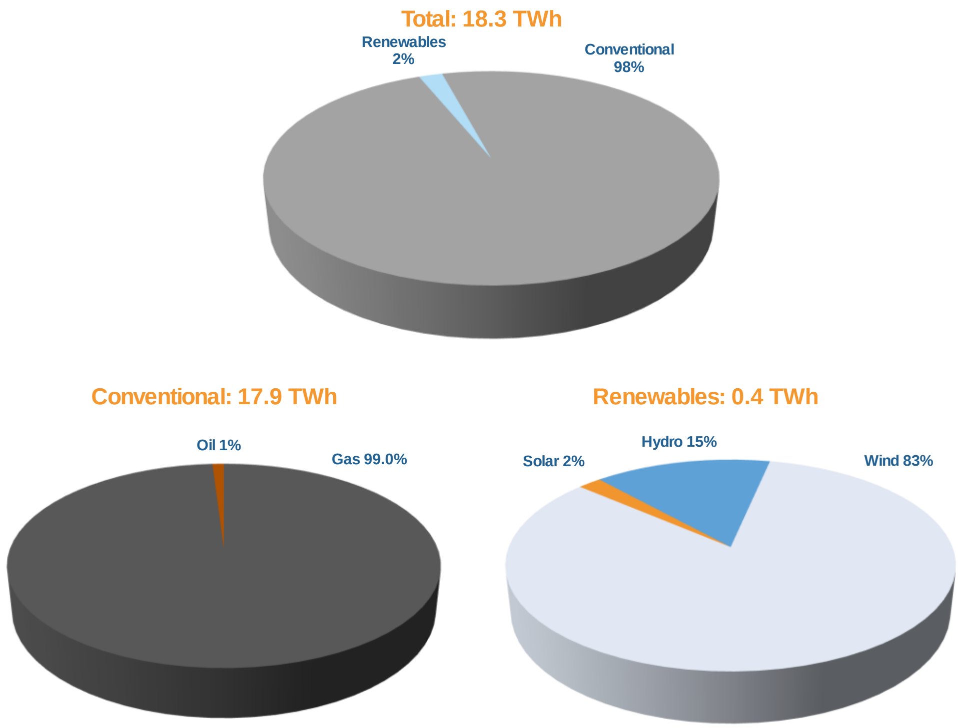
Tunisia's Power Generation – Basic Information (2014)

Total installed generation capacity	**4.2 GW**
Total RES generation capacity	0.3 GW
Total VRES generation capacity	0.2 GW
Electricity production	18.3 TWh
Electricity import	0.1 TWh
Electricity export	0.2 TWh

Tunisia Renewables (2015)

Total RES generation capacity	**0.3 GW**
Total VRES generation capacity	0.26 GW
Installed solar PV capacity	0.02 GW
Installed wind capacity	0.24 GW

Tunisia's electricity production mix (2014)



Reliance on fossil-fuels and a lack of political support has meant that, historically, development of renewable energy has not been a high priority for Tunisia. However, the rapid expansion of the global renewables market, recognition of the country's significant RES potential and a number of major international solar initiatives has resulted in a strong commitment to diversify the country's power generation portfolio, in particular through investment in wind and solar power capacity. The share of electricity generated by RES is around 1%; however, government targets aim to increase this to 25% by 2030. Despite the relatively low levels of current installed RES capacity, it could be argued that Tunisia has in fact spent the last 20 years preparing for the transformation of its energy sector that is currently taking place.

Since 1985, Tunisia has pursued a "Rational Use of Energy" policy and has sought to establish an appropriate institutional and legal framework and financial environment conducive to energy conservation and management, including the development of the National Fund for Energy Conservation (FNME) in 2005. It is obvious that political turmoil in North Africa in recent months is likely to have an impact on the socio economic direction of the region in the short term. Tunisia does not currently offer a specific incentive system for renewable energy comparable to a FIT or REC scheme, but rather uses direct financial and tax incentives to promote green energy. Capital subsidies, grants and rebates (one-off payments by the Government or utility) are available, mainly for the purpose of energy audits and implementation of energy efficiency measures. At present, direct financial incentives are mainly aimed at water heating and small-scale energy substitution rather than large-scale renewables. However, various tax incentives do exist for renewable energy, such as the reduction of customs duty and VAT exemption on the import and local manufacture of raw materials and equipment used for renewable energy generation.

UNITED KINGDOM

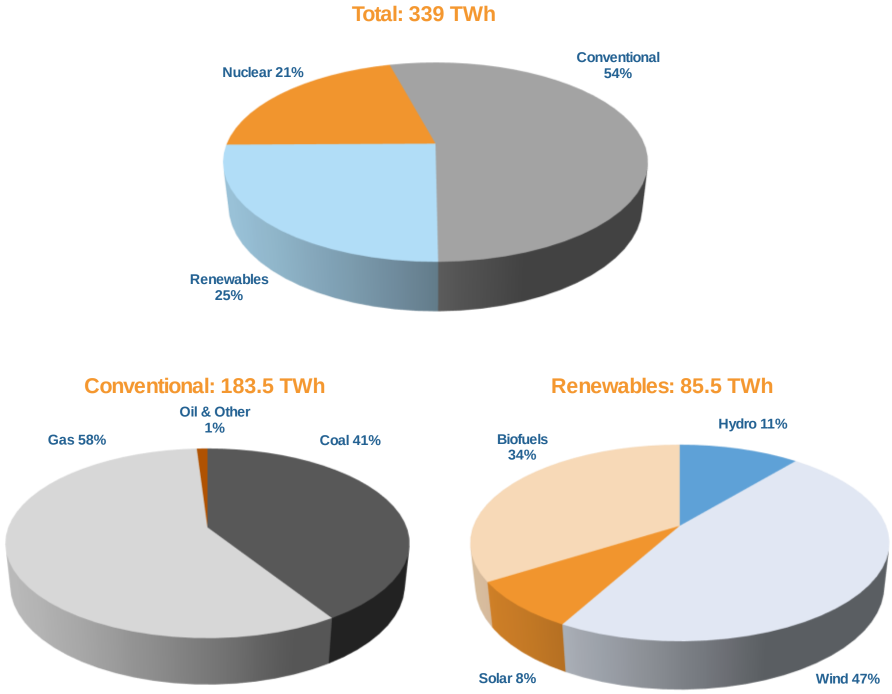
UK's Power Generation – Basic Information (2014)

Total installed generation capacity	**94.0 GW**
Total RES generation capacity	27.7 GW
Total VRES generation capacity	18.3 GW
Peak load	53.8 GW
Electricity production	339.0 TWh
Electricity import	23.0 TWh
Electricity export	2.4 TWh

UK Renewables (2015)

Total RES generation capacity	**33.1 GW**
Total VRES generation capacity	23.0 GW
Installed solar PV capacity	9.1 GW
Installed wind capacity	13.9 GW

UK's electricity production mix (2014)



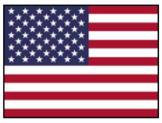
UK is among front runners in the developed energy markets moving towards a low carbon economy. The electricity sector is undergoing rapid transition across the entire value chain. Coal fired generation is decreasing, gas consumption increasing, renewable production grows, with variable renewable technologies leading the growth. This development is driven by the 5th Carbon Budget targets which are legally binding for the UK following from The Climate Change Act announced in December 2015. This binds the UK to a target of 80% reduction from 1990 levels by 2032. UK is on its way to meet the target of 15% renewable generation by 2020, with 7% of its final energy consumption being achieved by electricity sector alone.

The UK Transmission system and the regional electricity distribution systems which have gone through a long period of incentive based regulatory comparative competition on the RPI-X formula has now been adapted to meet the new emerging requirements of managing for energy efficiency, low carbon distributed generation and low carbon foot print. This new mechanism, called the RIIO Model incentivizes network operator Revenues based on performance Incentives+Innovation and Output.

Revenues = Incentives + Innovation + Output is the new RIIO framework.

Mechanisms to connect distributed renewable generation at low voltage levels are being introduced to be able to provide security of supply, optimal grid stabilization and greater efficiencies. At the consumer end, energy efficiencies are evident: peak demand down from 60.11 GW in 2002 to 53.8 in 2014, mainly attributable to the overall slowdown in the economy in recent years. In summary, the UK is in a state of very rapid transition and issues relating to the management of variable renewable energy in power generation are the centre stage. The biggest challenges for UK: to optimize its supply security, deliver low energy costs to the consumer and ensure decarbonisation are going to be implemented through appropriate management and integration of renewables into the changing energy mix. Recent data on PV and solar is presented in Annex 1.

UNITED STATES OF AMERICA - USA



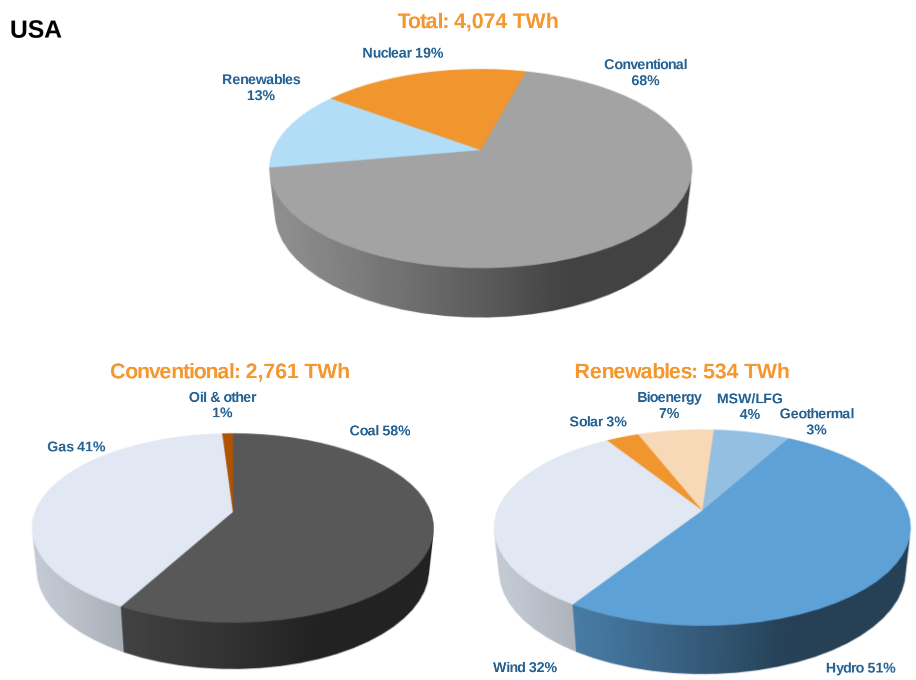
US's Power Generation – Basic Information (2014)

Total installed generation capacity	**1,155 GW**
Total RES generation capacity	203.5 GW
Total VRES generation capacity	84.0 GW
Net Electricity production	4,074.0 TWh
Electricity production (renewables)	534.0 TWh
Electricity import	15.5 TWh

US Renewables (2015)

Total RES generation capacity	**219.3 GW**
Total VRES generation capacity	98.1 GW
Installed solar PV capacity	25.5 GW
Installed wind capacity	72.6 GW

US's electricity production mix (2014)



In the last few years, renewable energy capacity in the United States power system has increased by 40% from 2008, resulting in 13% of electricity production coming from renewable energy sources. Variable RES accounted for the largest increase and their share in the production of electricity is currently at 4% and 0.4% for wind and solar, respectively. Installed wind capacity was 66 GW in 2014 and solar 18 GW. DOE goal for wind is to reach 20% of country production by 2030. States with most wind capacity are Texas, California and Iowa while most solar capacity is concentrated in California, Arizona and New Jersey. RES penetration requires significant investments in T&D systems and costs are different for different utilities and regions. Policies for development of RES are Federal (Tax Credit and Production Tax Credit), State (Net metering) and Local (rebates and financing options, green power rates).

Mitigation measures under implementation or emerging are: improved forecasting, faster scheduling, reserve optimization, greater flexibility from generation, larger balancing areas, transmission expansion, demand response, and energy storage solutions. Annex 1 presents recent data from auctions.

URUGUAY

Uruguay's Power Generation – Basic Information (2014)

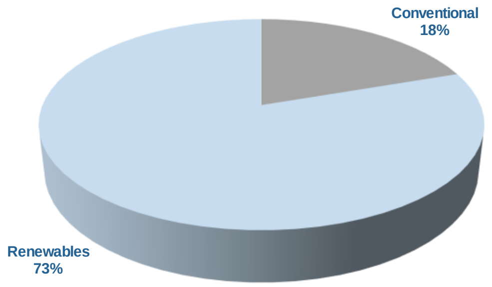
Total installed generation capacity	**3.7 GW**
Total RES generation capacity	2.3 GW
Total VRES generation capacity	0.57 GW
Peak load	1.92 GW
Minimum load	0.66 GW
Electricity production	12.9 TWh
Electricity import	0.0 TWh
Electricity export	1.27 TWh

Uruguay Renewables (2015)

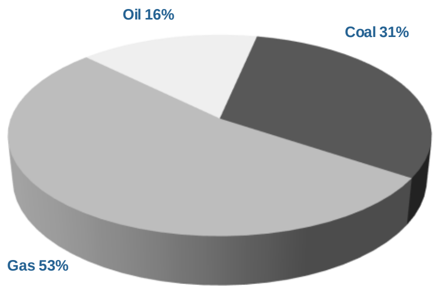
Total RES generation capacity	**2.7 GW**
Total VRES generation capacity	913 MW
Installed solar PV capacity	68 MW
Installed wind capacity	845 MW

Uruguay's electricity production mix (2014)

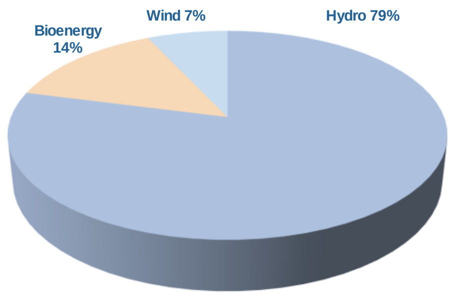
Total: 13 TWh



Conventional: 2.3 TWh



Renewables: 11.7 TWh



Uruguay has a large share of production from renewable energy sources: 82% of total electricity production in the country comes from renewable energy sources, mainly from hydro. The majority of Uruguay’s hydropower has however no storage capacity and production is variable dependent on the yearly and seasonal rainfall. The most important new VARIABLE RES in the country is wind with presently installed capacity of 485 MW (13% of total installed generating capacity) and a planned expansion in 2016 to 1,470 MW (29% of total expected installed capacity) and to 2,300 MW in 2030.The development of wind power is through auctions and at the 2011, the auction price was around 63 USD/MWh. Auctions for PV have shown values of 90 USD/MWh.

Further 200 MW of plant capacity are expected to come online in 2016. Main objectives for the development and integration of wind in electricity systems are to provide flexibility to the existing fleet, expansion of transmission systems and demand side management even if currently Uruguay operate interconnections with Brazil and Argentina.

APPENDIX

LIST OF FIGURES AND TABLES

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GLOSSARY

CCGT	Combined cycle gas turbine
CO2	Carbon dioxide
EU	European Union
EUR	Euro
GHG	Greenhouse gases
GW	Gigawatt
LCOE	Levelized cost of electricity
MW	Megawatt
O&M	Operation and Maintenance
OECD	Organisation for Economic Cooperation and Development
PV	Photovoltaic
RES	Renewables
TWh	Terawatt hours
USD	US dollars
VRES	Variable Renewables

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