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THE GRAND ENERGY TRANSITION

World scenarios and the European RES way to the transition

Alessandro Clerici—Honorary Chair WEC Italy—Chair WEC Study Group on RES Integration

AIEE Energy Symposium - Milan 2016 - Plenary session Dec.2

World Energy Scenarios

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Modern Jazz

Unfinished Symphony

Hard Rock

Pre-determined Elements of the Grand Transition

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	Factors shaped world energy 1970 - 2015	Pre-determined elements 2015 - 2060
Population / Workforce	▪ Global population grew 2x (1.7% p.a.)	▪ Global population will grow 1.4x (0.7% p.a.)
New Technologies	▪ ICT revolution ▪ Productivity growth rate of 1.7% p.a.	▪ Pervasive digitalisation; productivity paradox
Planetary Boundaries	▪ 1,900+ Gt CO_2 emissions from beginning of industrial revolution	▪ In order to have 1,000 Gt CO_2 emissions to 2100 for the 2°C target
Shifts in Power	▪ Rapid economic rise of developing nations ▪ Growing role for global institutions, e.g. UNFCCC, IMF, WTO, G20	▪ 2030: India is most populous country ▪ 2035-45: China is the world's largest economy

Three Scenarios

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Modern Jazz

Market-driven approach to achieving individual access and affordability of energy through economic growth

- Market mechanisms
- Technology innovation
- Energy access for all

Unfinished Symphony

Government-driven approach to achieving sustainability through internationally coordinated politics and practices

- Strong policy
- Long-term planning
- Unified climate action

Hard Rock

Fragmented approach driven by desire for energy security in a world with low global cooperation

- Fragmented policies
- Local content
- Best-fit local solutions

Critical Uncertainties of the Grand Transition

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	Modern Jazz	Unfinished Symphony	Hard Rock
Productivity / Economic Growth	▪ GDP 3.3% p.a. (2015–2060) ▪ Digital boost ▪ Tech innovation ▪ GDP per capita 2060 US$ 30,600	▪ GDP 2.9% p.a. (2015–2060) ▪ Sustainable growth ▪ Circular economies ▪ GDP per capita 2060 US$ 25,200	▪ GDP 1.7% p.a. (2015–2060) ▪ Fragmented markets ▪ Local content ▪ GDP per capita 2060 US$ 14,700
Climate Challenge	▪ Cumulative carbon emission 2015-60 1,491 Gt CO2	▪ Cumulative carbon emission 2015-60 1,165 Gt CO2	▪ Cumulative carbon emission 2015-60 1,642 Gt CO2
International Governance	▪ Economics focused international governance	▪ Broad-based international governance	▪ Fractured and weak international system
Tools for Action	▪ Markets	▪ States	▪ Patchwork of states and markets

Implications for Energy Sector

1 THE WORLD'S PRIMARY ENERGY DEMAND GROWTH

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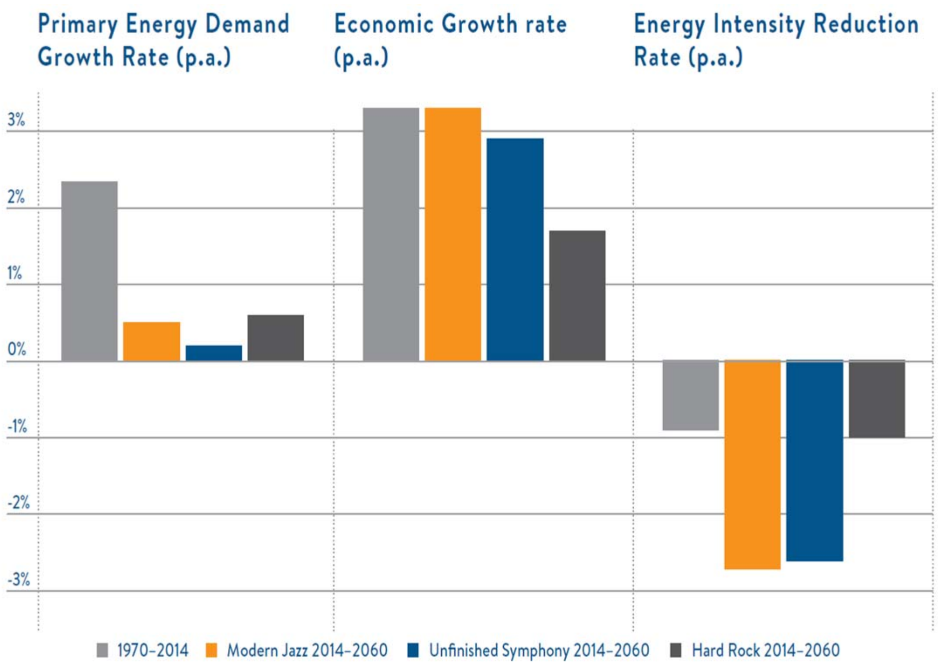
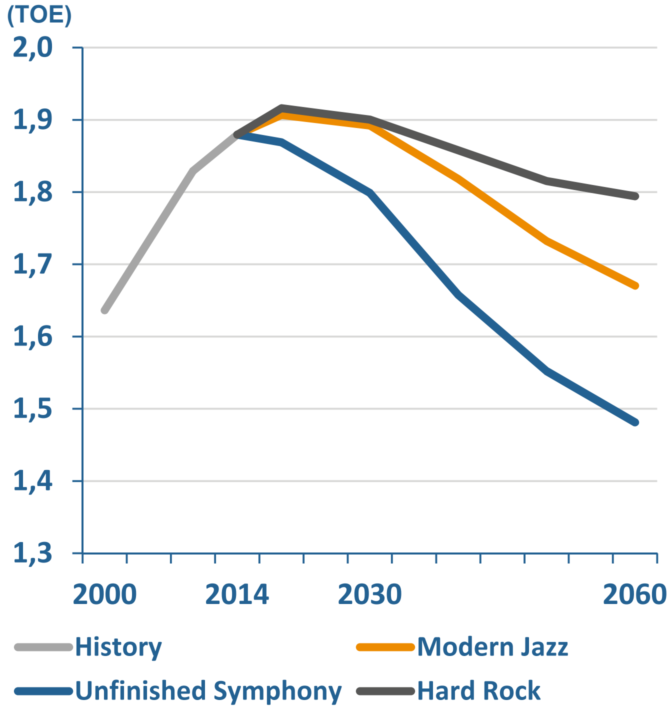
... will slow and per capita energy demand will peak before 2030 due to unprecedented efficiencies created by new technologies and more stringent energy policies.

Slower Primary Energy Demand Growth



Per Capita Primary Energy Demand



2 DEMAND FOR ELECTRICITY

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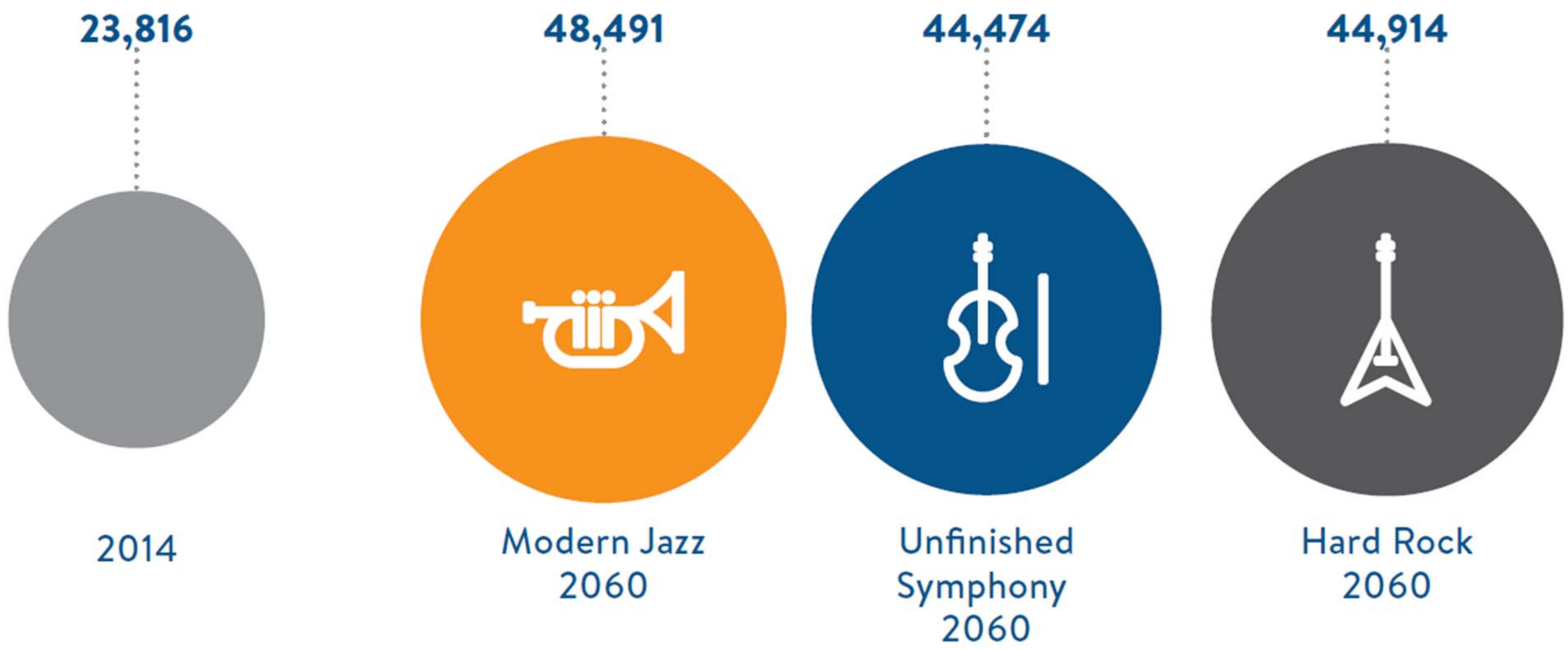
… will double to 2060. Meeting this demand with cleaner energy sources will require substantial infrastructure investments and systems integration to deliver benefits to all consumers.

Electricity Generation
(TWh)



3 THE PHENOMENAL RISE OF SOLAR AND WIND ENERGY

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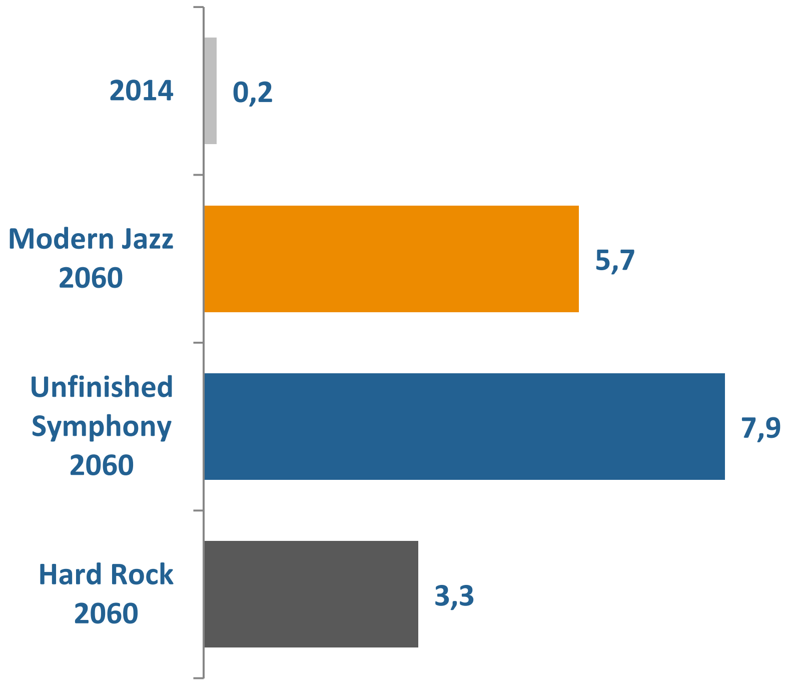
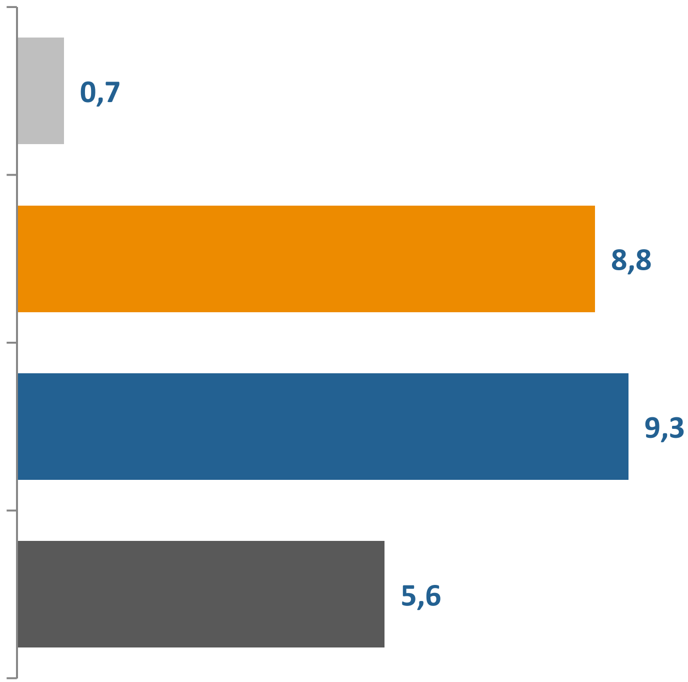
… will continue at an unprecedented rate and create both new opportunities and challenges for energy systems.

Solar Electricity Generation
('000 TWh)



Wind Electricity Generation
('000 TWh)



4 DEMAND PEAKS FOR COAL AND OIL

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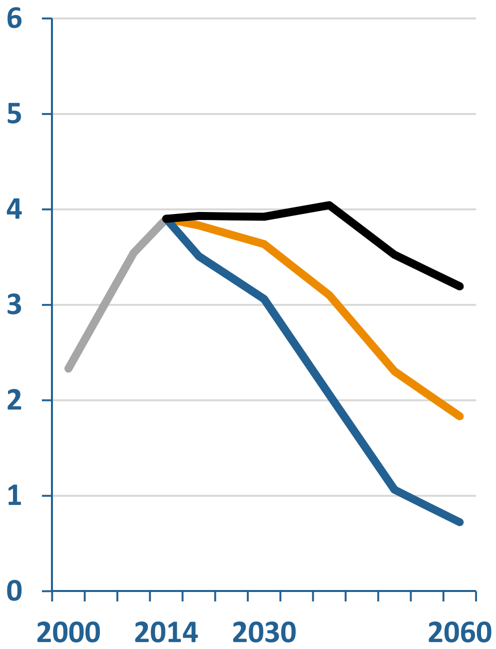
… have the potential to take the world from "Stranded Assets" to "Stranded Resources".

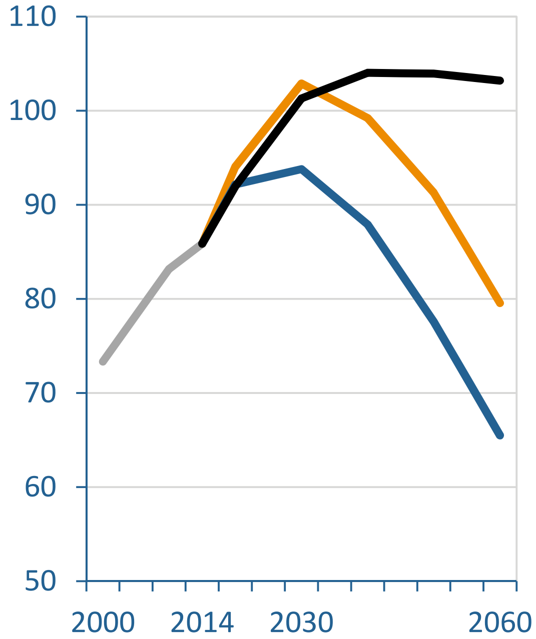
Coal Demand

('000 MTOE)



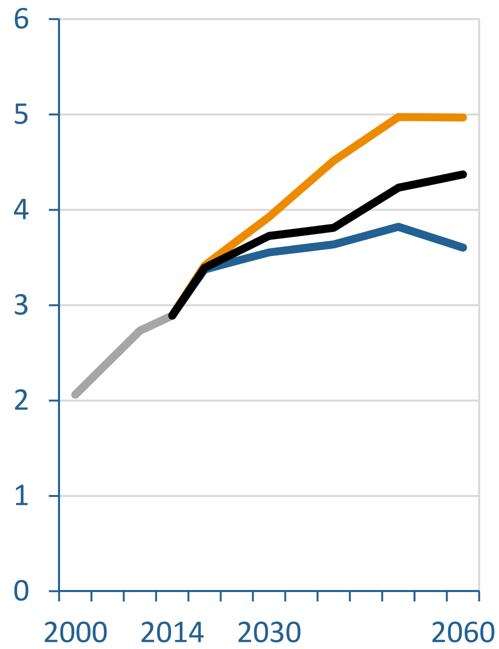
Oil Demand

(mb/d)



Natural Gas Demand

('000 MTOE)



History | Modern Jazz | Unfinished Symphony | Hard Rock

5 TRANSITIONING GLOBAL TRANSPORT…

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… forms one of the hardest obstacles to overcome in an effort to decarbonise future energy systems.

Electric Vehicles of Light-duty Vehicle Fleets

Modern Jazz 2060	Unfinished Symphony 2060	Hard Rock 2060
26% of 3.0 billion	32% of 2.8 billion	9% of 2.9 billion

6 LIMITING GLOBAL WARMING...

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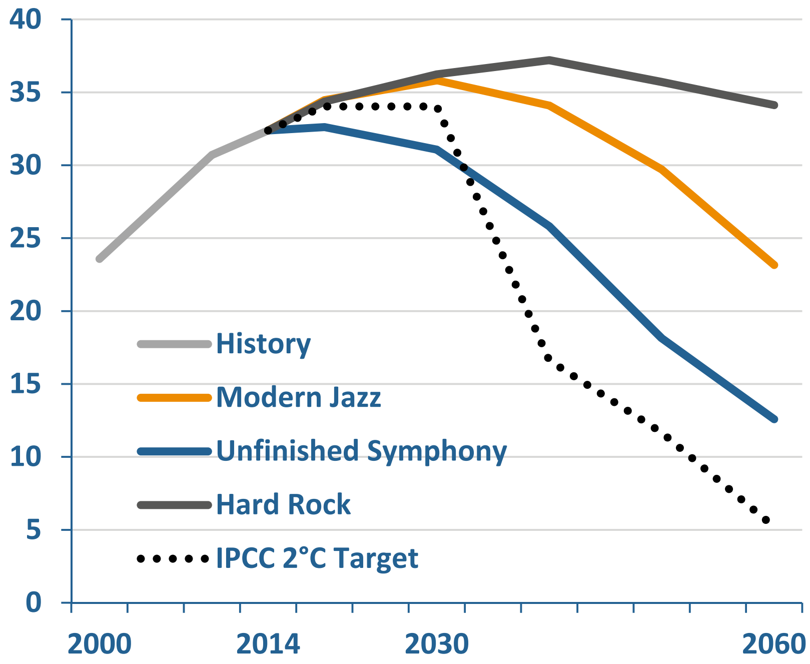
... to no more than a 2°C increase will require an exceptional and enduring effort, far beyond already pledged commitments and with very high carbon prices.

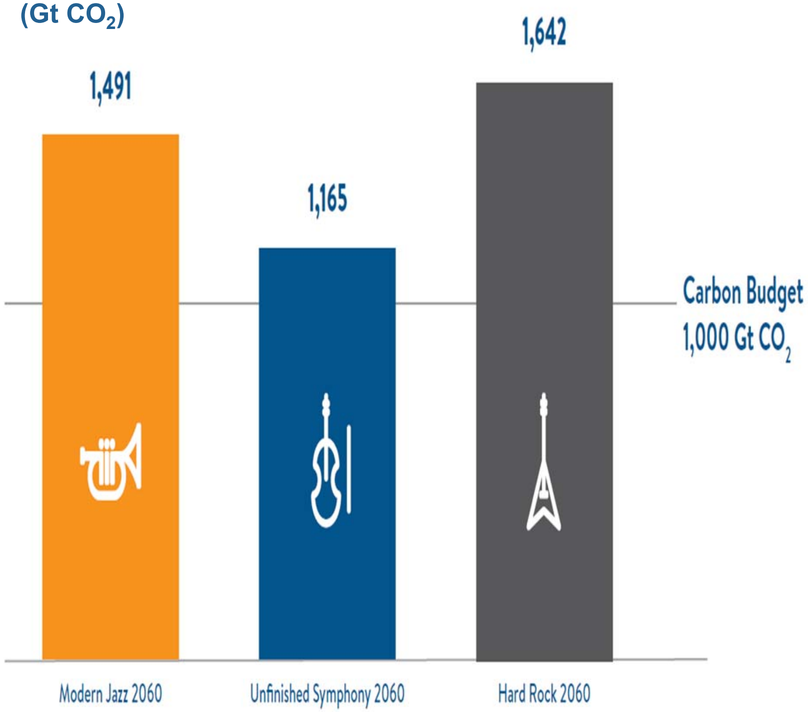
Annual Carbon Emissions

($Gt\ CO_2$)



Cumulative Carbon Emissions 2015-2060

($Gt\ CO_2$)



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7 ENERGY TRILEMMA IN 2060

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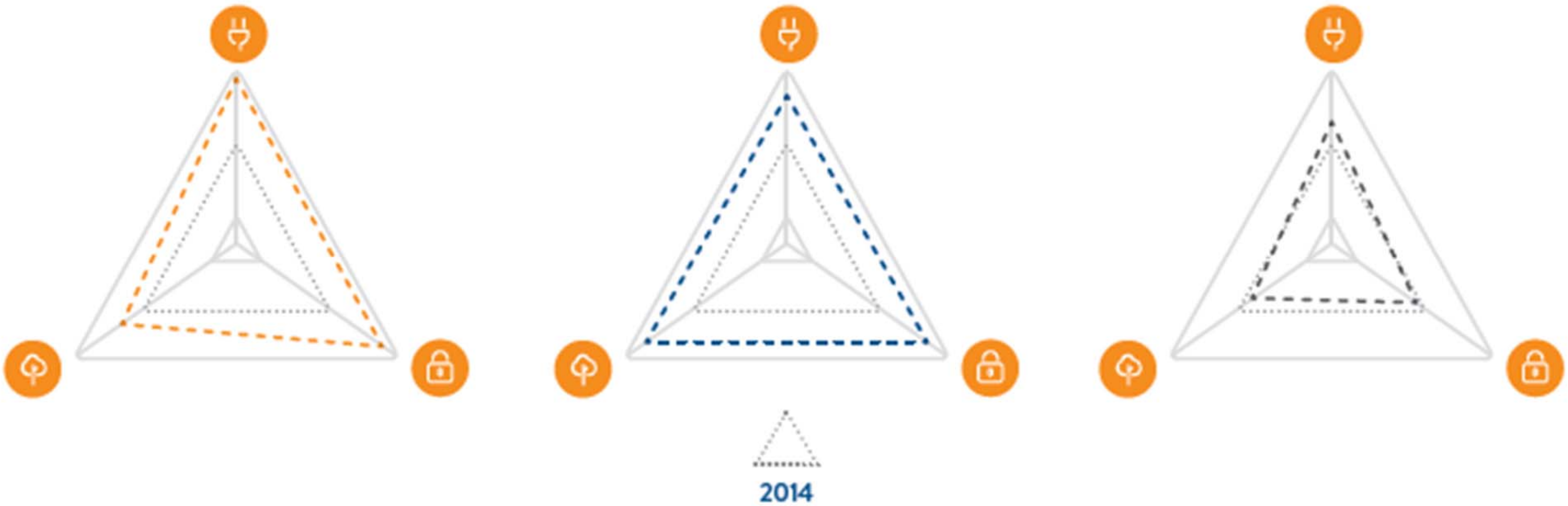
Modern Jazz 2060

Unfinished Symphony 2060

Hard Rock 2060



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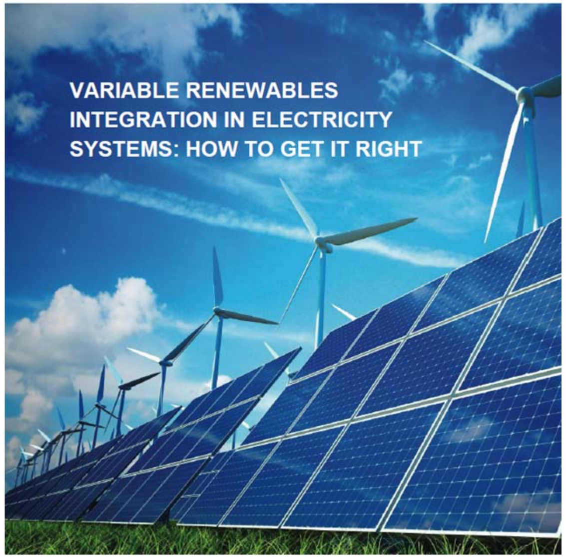
The European RES way to the transition

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

Report from WEC Study Group "RES Integration" launched after 2 years of activities in September 20th 2016- Work supported by WEC Global Partner CESI ,Italy

World Energy
Perspectives

Renewables Integration | 2016



32 COUNTRY CASE STUDIES

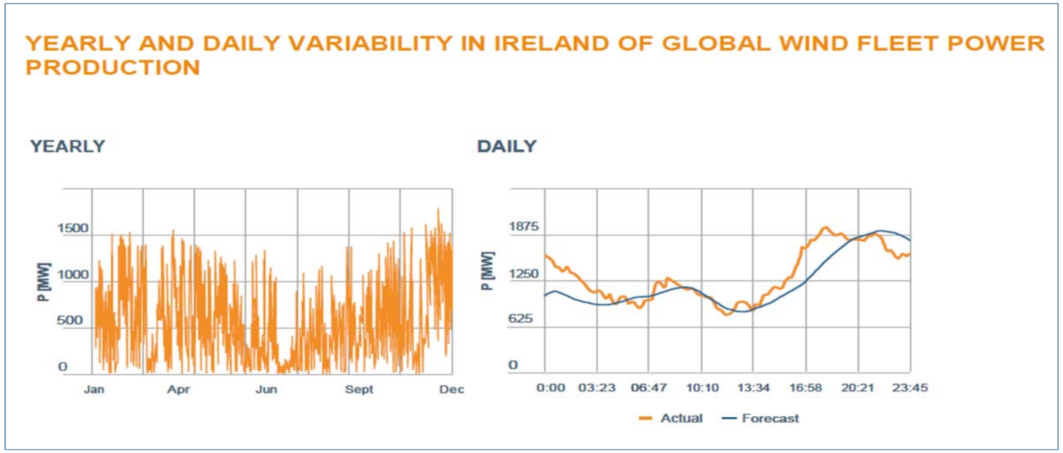
1. Algeria
2. Brazil
3. China
4. Colombia
5. Denmark
6. Ecuador
7. Mexico
8. Egypt
9. France
10. Germany
11. India
12. Indonesia

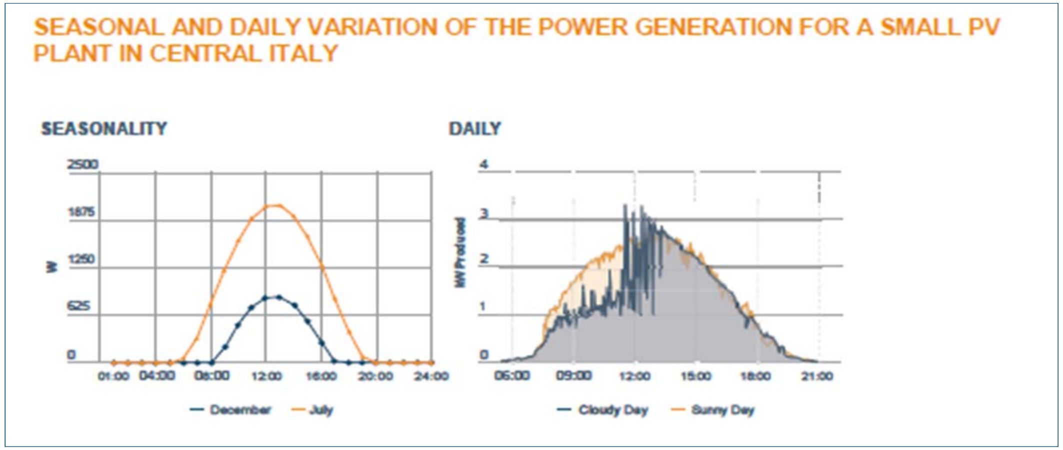
12. Ireland
13. Italy
14. Japan
15. Jordan
16. Kazakhstan
17. Korea (Rep.of)
18. Mexico
19. New Zealand
20. Nigeria
21. Philippines
22. Poland
23. Portugal

24. Romania
25. Russian Federation
26. South Africa
27. Spain
28. Thailand
29. Tunisia
30. United Kingdom
31. United States of of America
32. Uruguay

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

Variable Nature of Wind and Sun





Source: CESI

Global new investment in RES plants lower than 50 MW-Growing importance of developing countries

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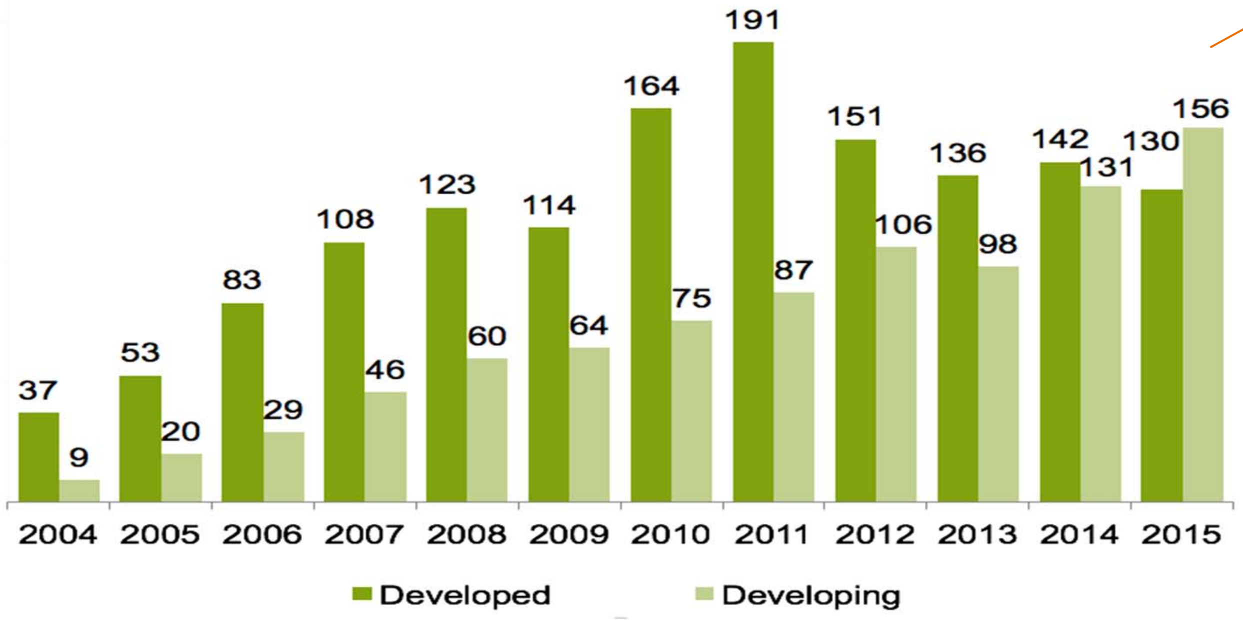
– Developed vs developing countries, 2004-2015 (USD billion)



EU is loosing its leading position to ASIA. China accounts 36% of the total RES investments

(46) (73) (112) (154) (183) (178) (239)(278) (257) (234) (273) (286)

Source: BNEF, 2015

Wind and solar PV reached new lows in June 2015(IEA 2016)

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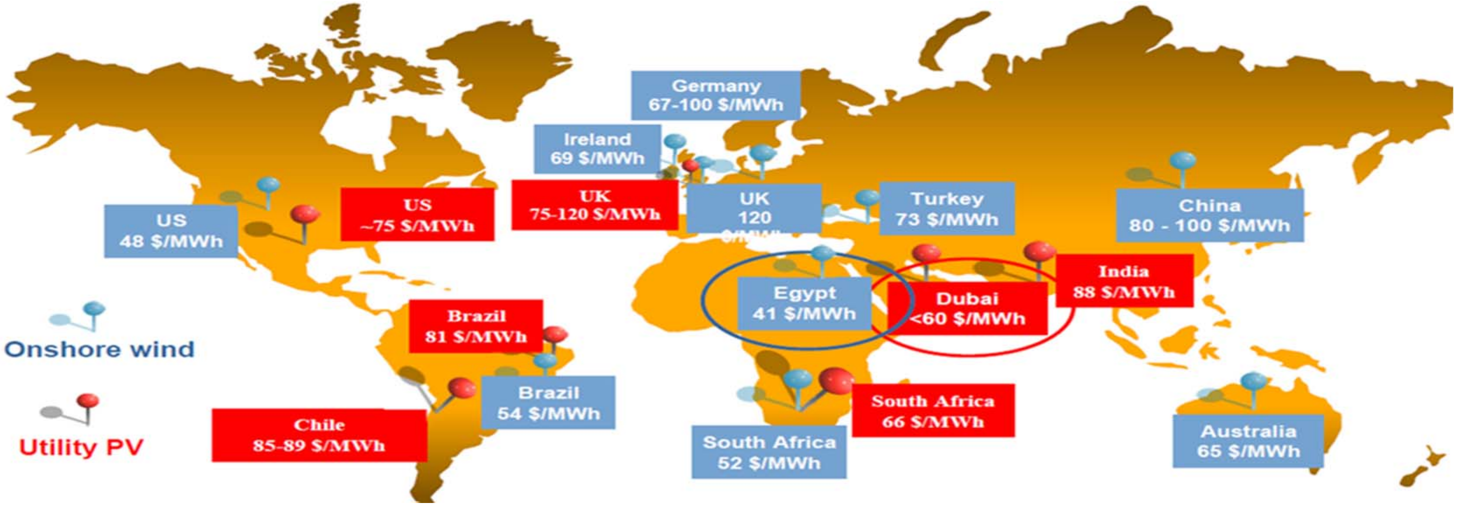
Long-term contract prices (e.g. auctions and FITs) at June 2015



- Rapid reduction in capital costs due to high volume of RES investments and fast technology development.
- Solar PV show the greatest reduction of prices, by 50% between 2010 – 2014 in OECD and even greater in non-OECD countries
- In some countries solar PV power plants with capacity above a few MW the minimum EPC contract value is around 1,000 USD/kW.

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But wind and solar PV reach new lows in 2016

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At May 2016 ,auctions:

-**Morocco wind 28 $/MWh** **-UAE PV 30 $/MWh**

- **Cannot be used as average values**, since they **are affected by the local costs and load factor values for wind and solar plants**.
- **Morocco high wind load factor close to 60%** (the average in Italy is 18-24%).
- Solar PV plants in Dubai have load factors which are **more than double of those in the UK**

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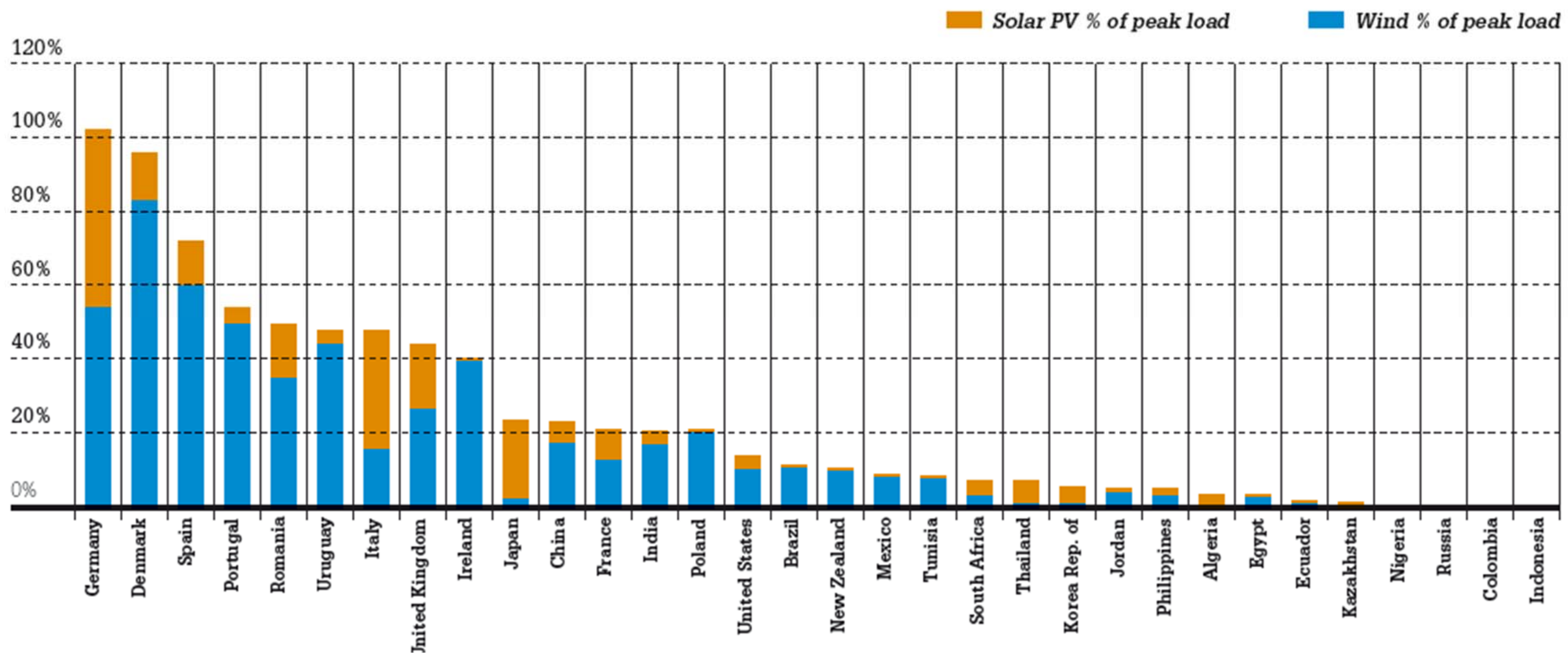
VRES INSTALLED CAPACITY HAS SIGNIFICANT PROPORTION ON THE DEMAND IN VARIOUS COUNTRIES-EU COUNTRIES BY FAR LEADING

VRES cumulative installed capacity by Country in percent of the national peak load



Source: WEC Report

WIND AND SOLAR PV CUMULATIVE INSTALLED CAPACITY DEVELOPMENT FROM 2011-2015.

EUROPE HAS FACED A DECLINE IN % OF WORLD GLOBAL BUT HAS BEEN THE STARTER OF EVOLUTION EVEN IF AT HIGH COSTS

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

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Regulation policies and economics

- **Brazil** Country-wide **auctions for all types of power sources** for long term contracts (Power Purchasing Agreements). **In 2015, wind power was the cheapest** electricity **source with 50 USD/MWh**.
- **Egypt Bilateral agreements**. RES equipment and spare parts are **exempted from custom duties and sales taxes.**
- **Germany The FIT has been the basic incentive**. The **reduction of PV feed-in has resulted in reduced capacity additions** in recent years. 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 feed-in tariff. **In 2014 auctions for PV have been introduced for plants above 6 MW each**; auctions also **for wind** plants will be introduced **in 2017.**
- **Italy** Incentives for VRES in Italy used to consider **Green Certificates, FIT, FI premium tariff. PV incentives** were introduced **in 2005 with high FI premium tariff of 450 €/MWh;** impressive growth in new installations. **As soon as the incentives** for both wind and PV **were drastically reduced or withdrawn**, the annual growth of **VRES decreased from more than 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**.

Regulation policies and economics

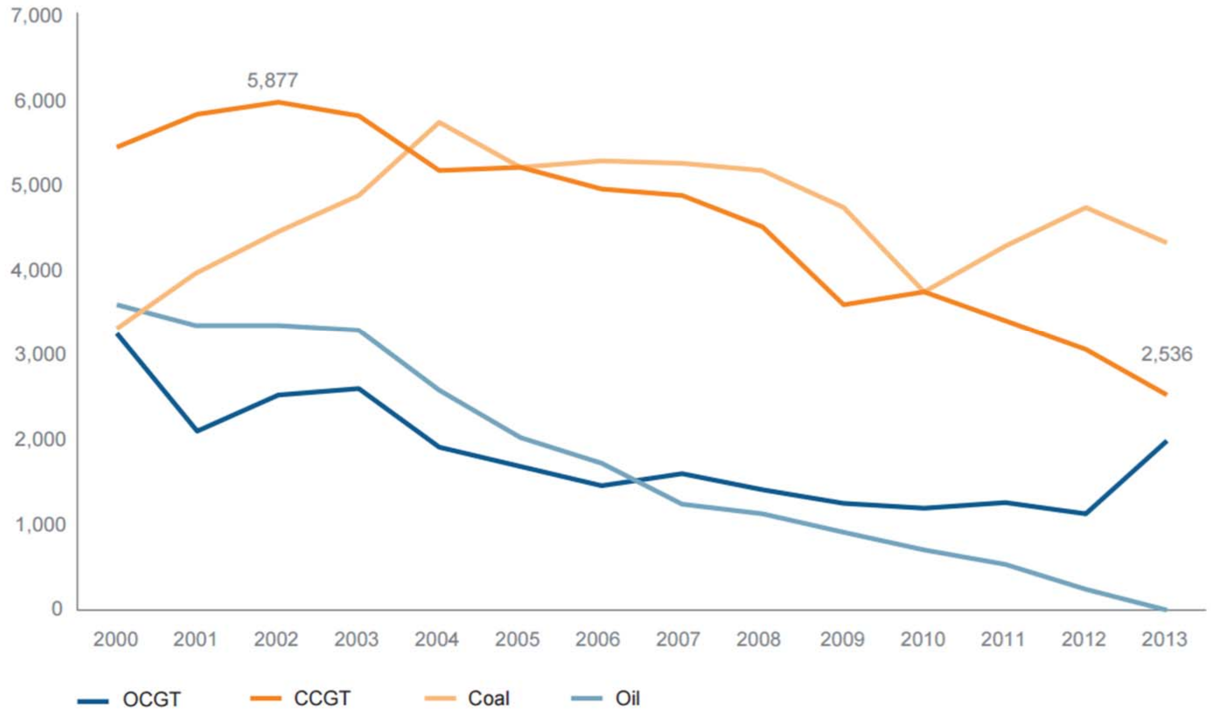
- **Japan Feed in tariff** for wind and solar falls in the range **between 300–350 USD/MWh and now up to 450** to push VRES development **considering nuclear concern** and strong reduction in its production.
- **New Zealand A unique market arrangement based on a carbon price which avoid incentives to 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**.
- **South Korea Additional green certificates** are **added to utilities which install wind power plants combined with Energy Storage Systems.**
- **USA Differences for different utilities and regions**: incentives are **Federal** (Tax Credit and Production Tax Credit), **State** (e.g. Net metering) and **Local** (rebate and financing options, green power rates).

Impacts of VRES on the electrical power system

1. Traditional fleets
2. The electricity market
3. Transmission and Distribution grid
4. Consumers

Shrinking operating hours of CCGT plants in EU(eg. Italy,Germany)-The Italian Case

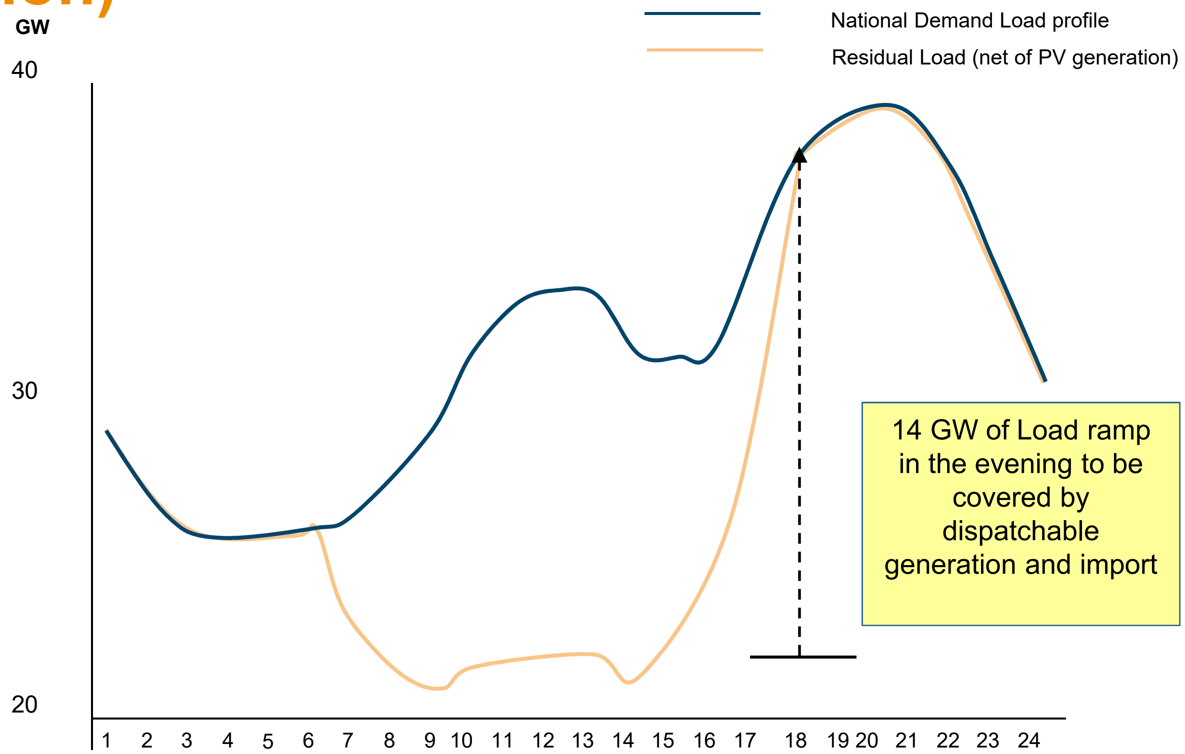
1



Source: AEEGSI

Coping with sharp variation of RES generation can be demanding (eg. Italy in a sunny day :effect on residual load net of PV generation)

1



Source: Terna

Impacts of VRES on the electrical power system

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1. Traditional fleets
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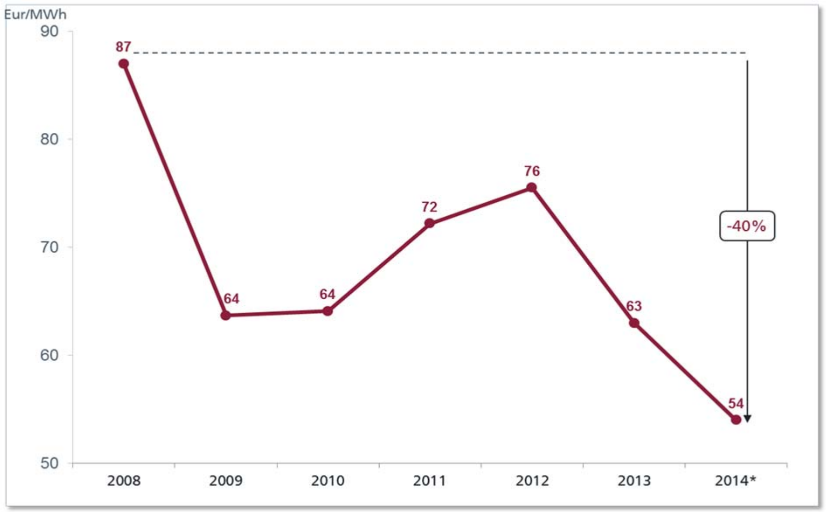
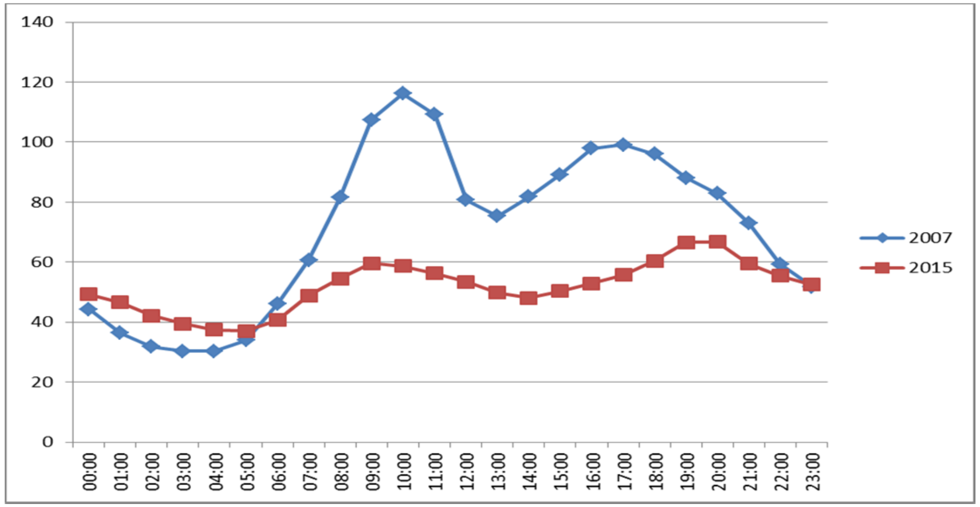
VRES has caused a drastic collapse of national pool price in EU combined also with gas price reduction-
Change in shape of daily price:Max daily price in the evening after sunset –Italy case

2

Average



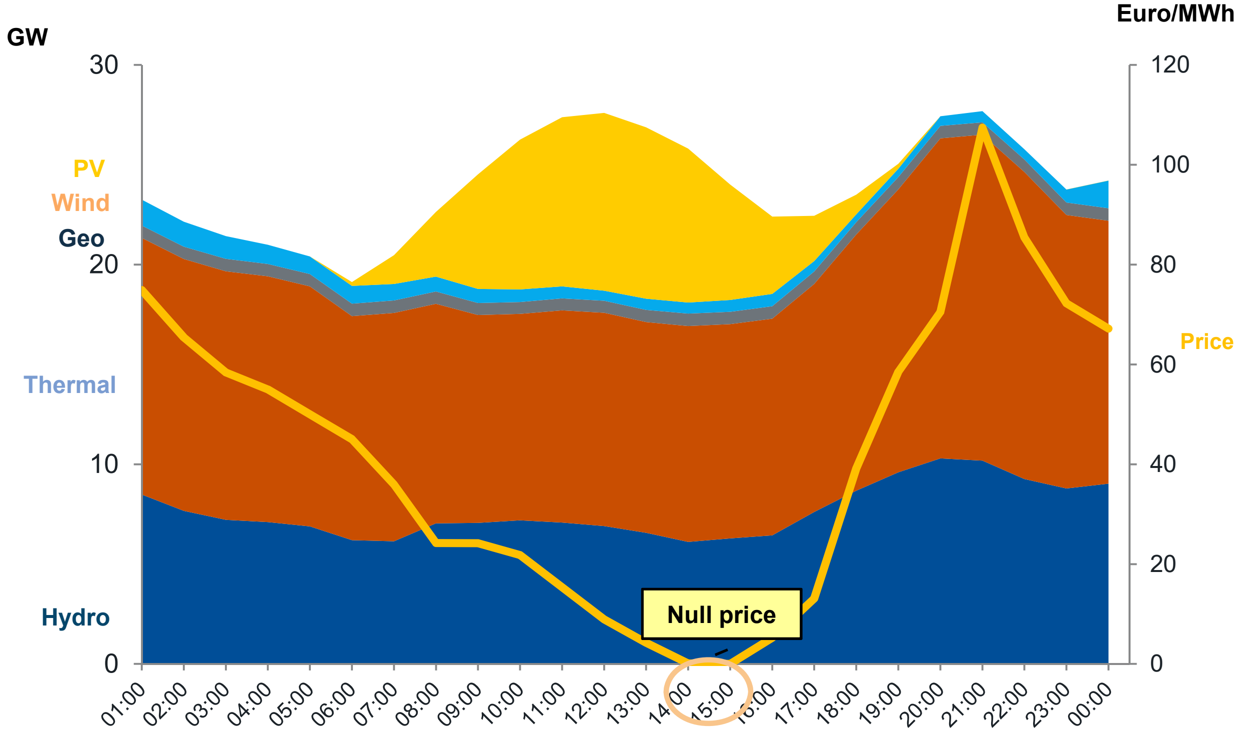
Daily



Source: GME

A null price on the day-ahead market on a sunny summer day (eg. Italy)-And in Germany also negative price

2



Source: Terna, GME

Impacts of VRES on the electrical power system

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1. Traditional fleets
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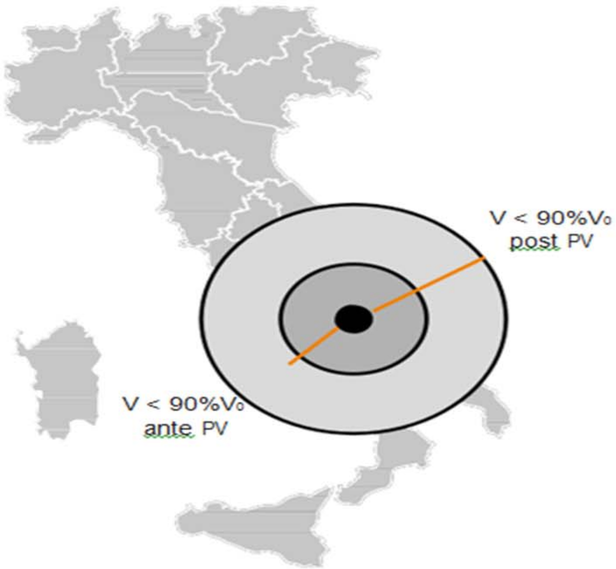
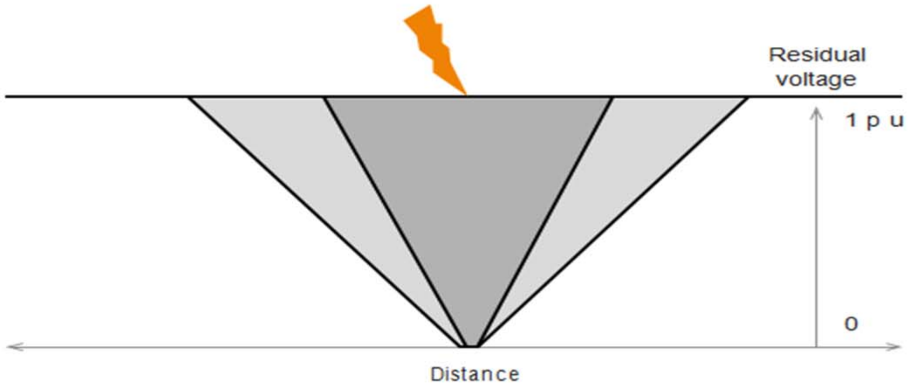
Voltage drops caused by a fault are spread to a wide area, impacting quality of supply even hundreds of km from fault location during hours with high percentage of VRES production

3





Due to reduction of rotating machines connected to Transmission grid, there is less Shortcircuit-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

The increase in the number of primary substations with power flow inversion in EU impacts the existing measuring and protection systems- Example of Italy

3

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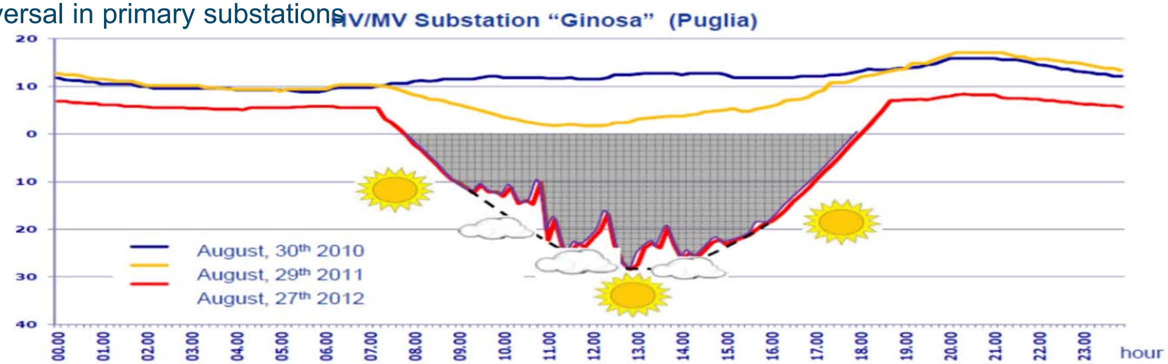
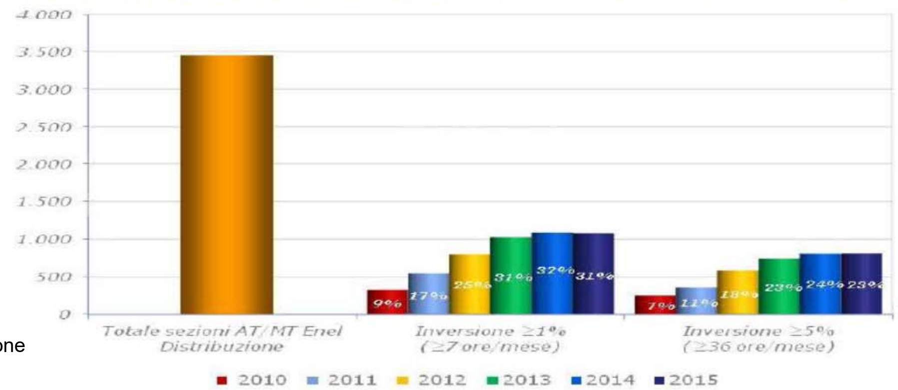
Power flow reversal in primary substations





Source: ENEL Distribuzione

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Impacts of VRES on the electrical power system

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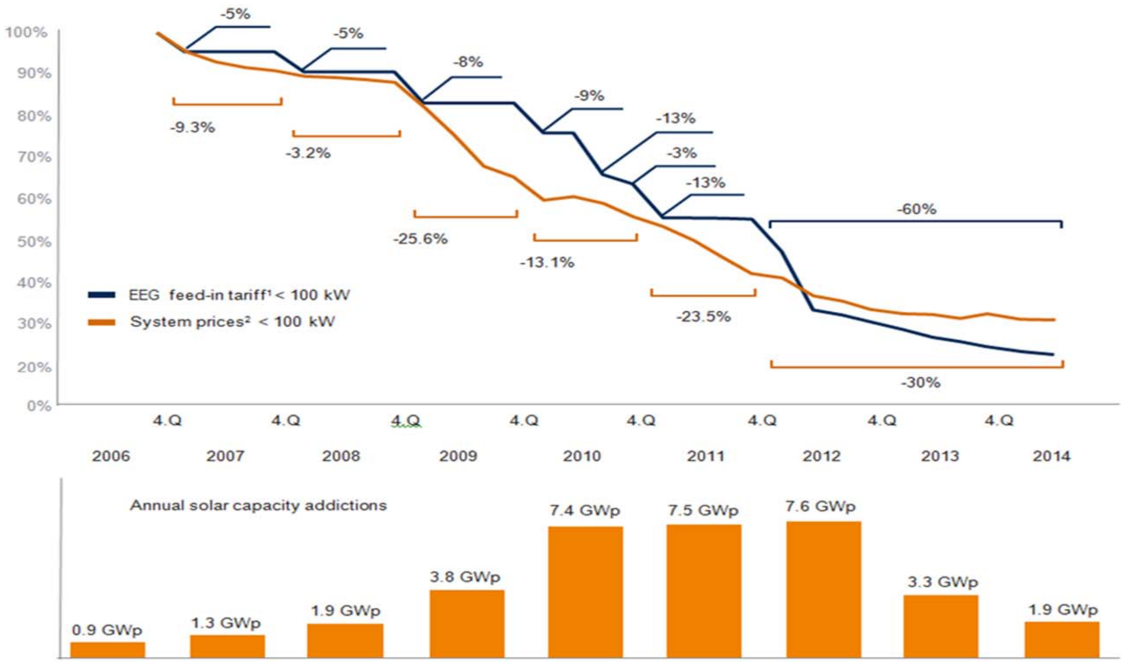
Development of PV feed-in tariffs, module costs and capacity additions (eg. Germany)

4



1 The EEG compensation: the compensation classes were in the second quarter 2012 brought in line with the amended EEG law. Previously until the end of the first quarter 2012, PV installations with the output of 30–100 kWp were included.

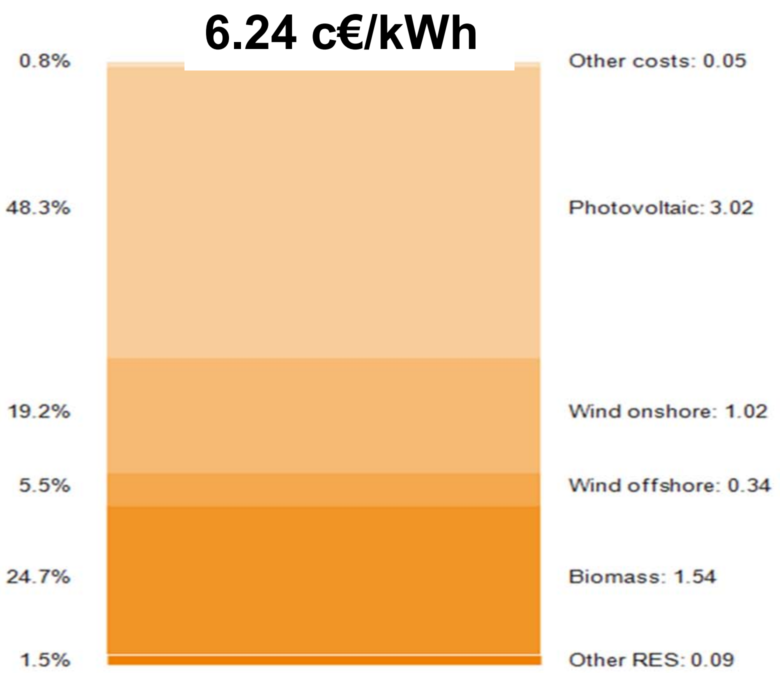
2 System prices: the average price paid by the end user for fully installed roof panels without USt.

Source: BSW-Solar, Beta

EEG-levy 2014 is ca. 6.24 c€/kWh (eg. Germany)

4

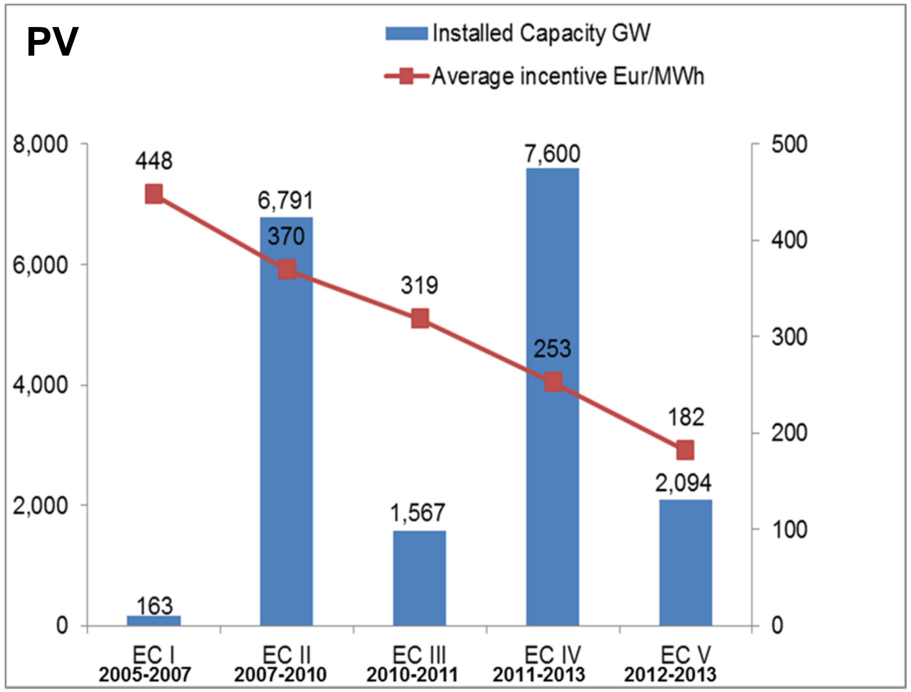
The proceeds from the introduction of EEG in 2014 totalled 23.6 billion Euros and will be used to 100% for the promotion of renewables. 97.4% go directly to the operators of the EEG plants, 1.8% to direct marketing of the EEG power and 0.8% to cover the necessary administrative costs.



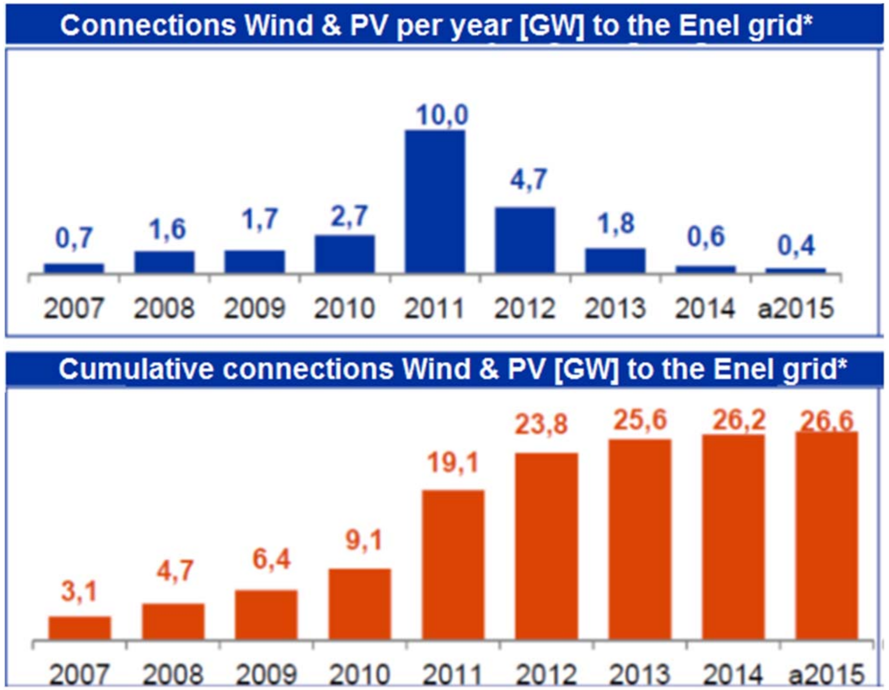
Source: BDEW

Evolution of the PV incentives with different feed-in scheme and effects on connections (Wind & PV) to the Enel distribution system in Italy

4



Source: BDEW



*Enel DSO covers more than 85% of the Italian distribution grid

Measures for a smoother VRES integration

TECHNOLOGIES

- Improved forecasting
- Optimisation of operating reserve
- Greater flexibility of conventional generation
- Dynamic transfers
- Expansion of local transmission and distribution grids
- Cross-border interconnections
- Energy storage systems
- Demand response

MARKET DESIGN

- Revision of emissions trading schemes
- Capacity market
- Sub-hourly market closures
- Negative market prices
- Nodal pricing
- Larger balancing areas
- Aggregate bids of RES power plants
- Green energy transmission corridors
- TSO /DSO’s coordination rules
- Role of private investors

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LESSON LEARNED [1/2]

- RES and particularly variable RES as wind and PV have had are having and will have explosive development
- RES and specifically wind and PV have become a big business overtaking the investments in conventional generating plants
- Combination of technology /construction developments and volumes have driven down CAPEX and OPEX costs of variable VRES
- Variability and average low equivalent hours of operation per year of PV and also in many countries for wind, pose challenges to their extensive development- DSO's, TSO's and conventional plants operators succeeded to manage electrical systems with no impact on reliability even in presence of high % of VRES.
- A holistic approach to overall electrical system design is a key to success –Each country power system is unique even if some general statements can be drawn.
- Sophisticated technical, economic and regulatory analyses on a case-by-case basis must be conducted over an adequate period of time
- The implications of reductions in subsidies or other support schemes must be carefully analysed to avoid a drastic reduction on VRES investments as results of incentive reductions(e.g. some EU countries)

LESSON LEARNED [2/2]

- The right location with high wind and solar factors and low grids connection costs for new large VRES project is a key to success
- Regulatory bodies have a fundamental role in both development of VRES and typology of counter measures to smooth the impact on the power system
- VRES are in any case a pathway for climate change mitigation, but also investments that reduce dependence on imported fuel, improve air quality, increase energy access and security of supply, promote economic development, and create jobs.
- Cautions on extrapolations to other countries of auctions $/kWh values got in nations with very high levels of wind and insolation and very low local costs
- Working together, the main energy stakeholders will be able to meet all current challenges facing RES integration in electricity systems by learning about both positive and negative experiences of other countries

MY PERSONAL COMMENT

OR EU WAKES UP AND INTRODUCES AN ADEQUATE CARBON PENALTY ASAP OR WITH PRESENT ETS SCHEME AT 6 €/TON-CO2 WE WILL FOLLOW WHAT IS HAPPENING IN GERMANY:

-MORE THAN 40% 0F ELECTRICITY FROM LIGNITE/COAL AND CLOSURE OF COMBINED CYCLE PLANTS WHICH PRODUCE 1/3 OF CO2 PER KWH GENERATED……AND IN PARALLEL THE OFFSHORE FARMS IN THE NORTH SEA ARE GRANTED WITH MORE THAN 450 €/TON CO 2 AVOIDED!!!!WHERE IS THE RATIONALE?

IN ITALY IN PAST YEAR THE 23 TWH PRODUCED BY PV PLANTS HAVE GOT AN AVERAGE AROUND 370 €/MWH, EQUIVALENT TO MORE THAN 800 €/TON CO2 AVOIDED-POOL PRICE 40 €/MWH !!!

Further information

Download the free WEC report on RES Integration from the Council's website: https://www.worldenergy.org/publications/

Thank you