IFC - ESMAP - RENEWABLE ENERGY TRAINING PROGRAM

Wind Module

I. Technology Overview, Market Analysis and Economics

Washington DC, June 16th 2014

Index

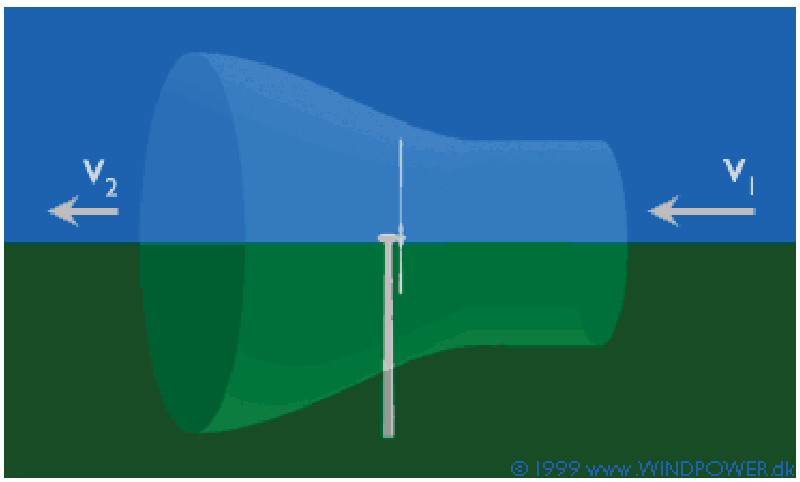
Wind Technology Overview, Market Analysis and Economics

- **Introduction and Technology Overview**
- Market Analysis and Perspectives
- Support Schemes and Price Forecasting
- Grid Integration and System Flexibility
- Challenges and Competitiveness

Wind Power Generation

Wind power generation:
Conversion of wind energy into electricity using wind turbines

Max Power output for a wind speed:



$$W_m = \frac{1}{2} \cdot \rho \cdot A \cdot v^3 \cdot C_p(\lambda, \beta)$$

- ρ= 1,225 kg/m³ → density of the air
- A= swept Area
- V= wind Speed
- Cp= Power Coefficient

Wind - Power Coefficient

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Power Coefficient:

Efficiency of a wind turbine transforming wind power into electricity

$$C_p = \frac{W_{generated}}{W} = \frac{\text{Electricity produced by wind turbine}}{\text{Total energy available in the wind}}$$

Betz Limit:

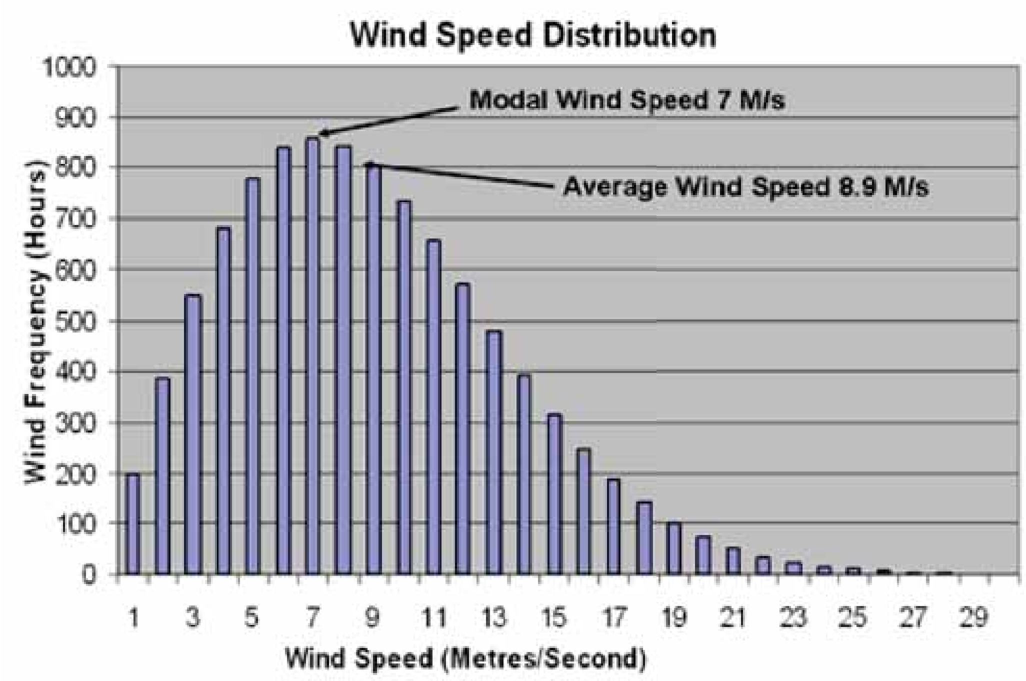
Maximum Power Coefficient of an ideal wind turbine

$$C_{p\,max} = \frac{W_{max\,generated}}{W} \Rightarrow C_{p\,máx} = 0{,}5925 \approx \mathbf{60\%}$$

For commercial turbines, Cp is typically between 40-50%

Wind - Weibull Distribution

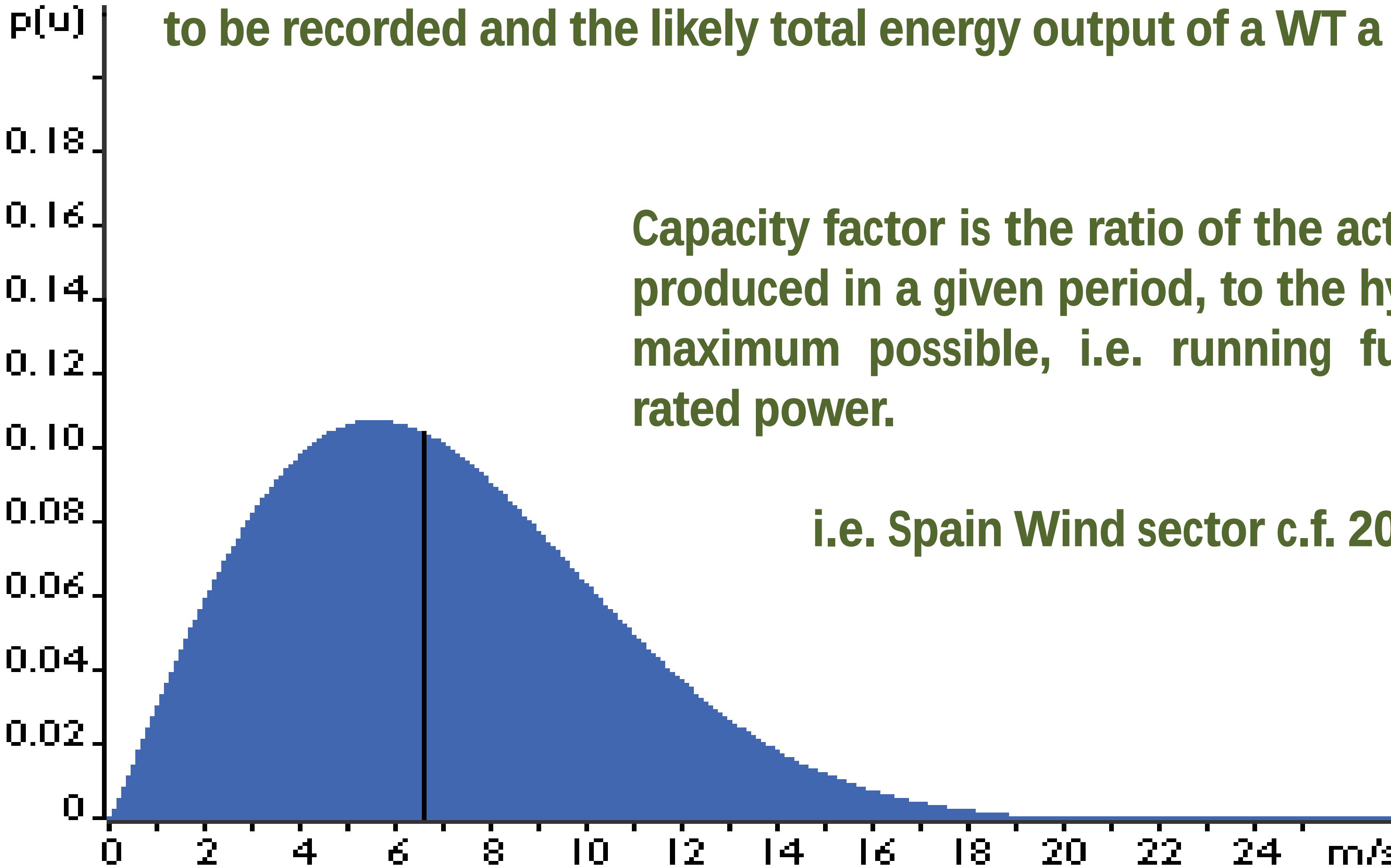
Wind speeds can be modeled using the Weibull Distribution. This function represents how often winds of different speeds will be observed at a location with a certain average wind speed.



The shape of the Weibull Distribution depends on a parameter called *Shape*. In Northern Europe and most other locations around the world the value of *Shape* is approximately 2, then the distribution is named Rayleigh Distribution.

Wind - Capacity factor

Weibull Distribution of Wind Speeds for a site with an average wind speed of 7m/s. It demonstrates visually how low and moderate winds are very common, and that strong gales are relatively rare. It is used to work out the number of hours that a certain wind speeds are likely to be recorded and the likely total energy output of a WT a year.



Capacity factor is the ratio of the actual energy produced in a given period, to the hypothetical maximum possible, i.e. running full time at rated power.

i.e. Spain Wind sector c.f. 2013 ≈ 24%

Wind - Resource maps (1)

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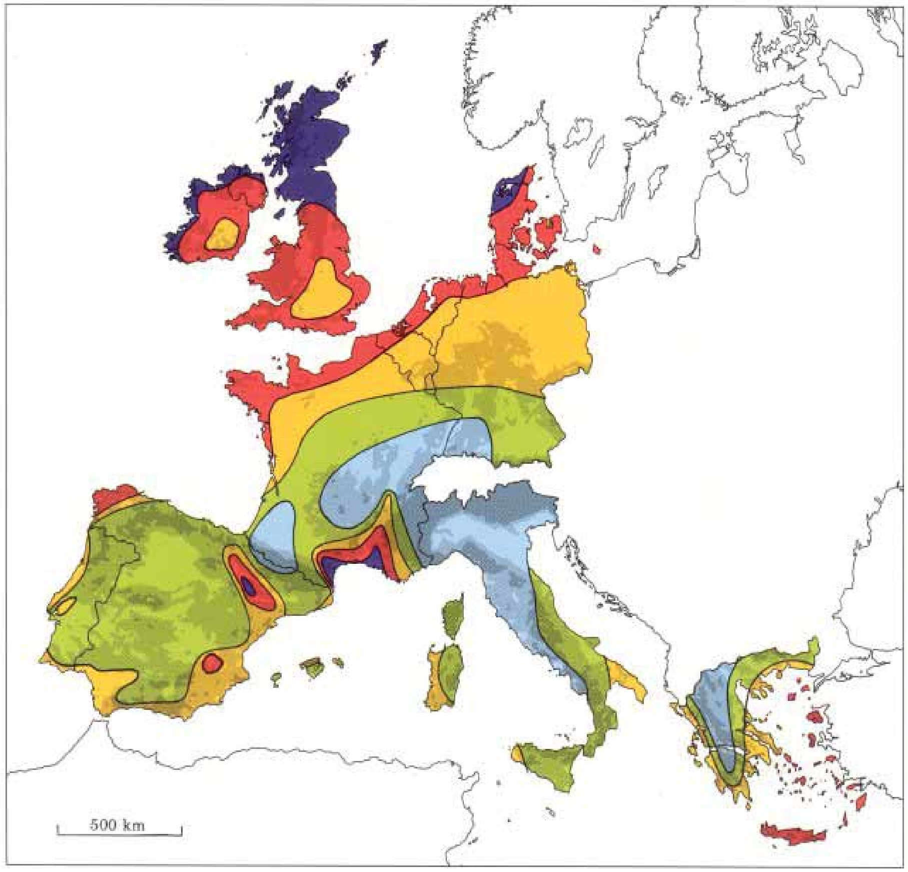
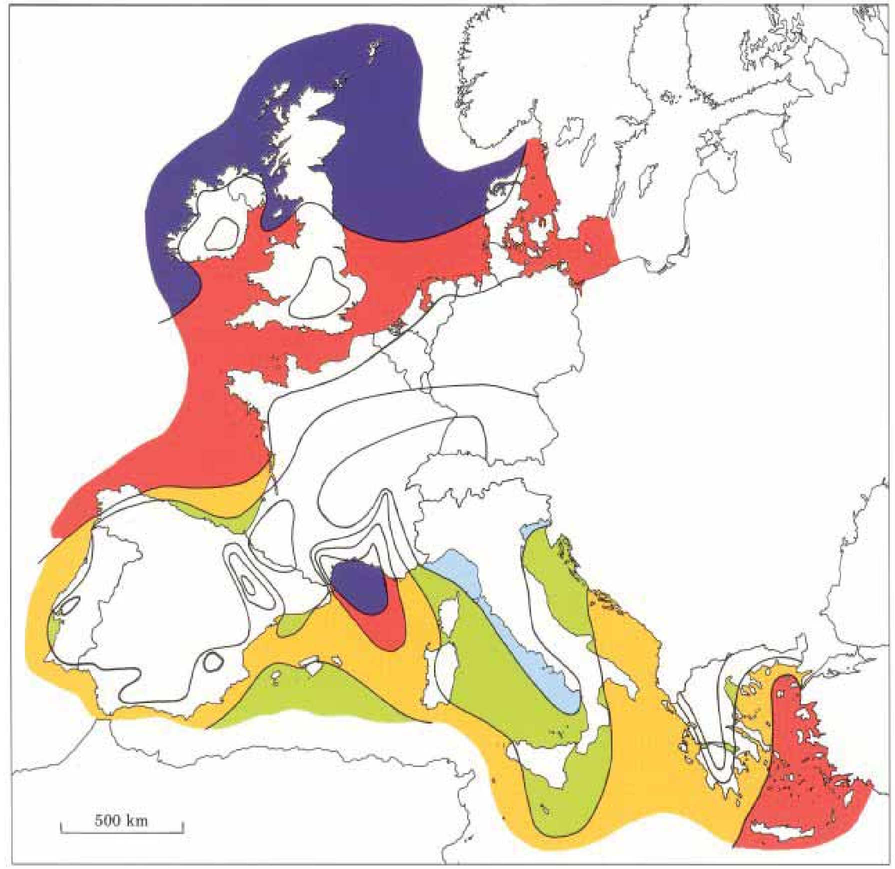
Europe Onshore



Wind resources[1] at 50 metres above ground level for five different topographic conditions										
	Sheltered terrain[2]		Open plain[3]		At a sea coast[4]		Open sea[5]		Hills and ridges[6]	
	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}
	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0- 8.5	400- 700
	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

Europe Offshore

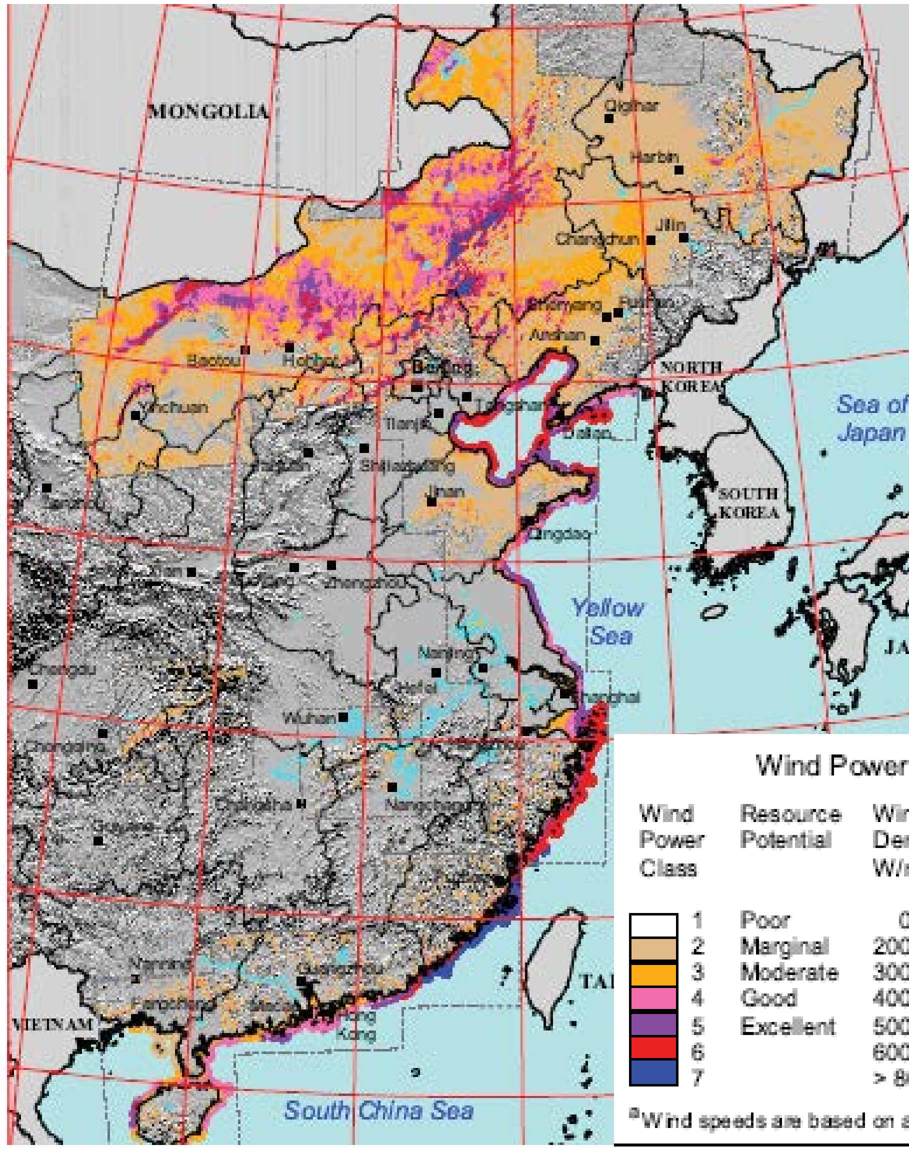


Wind resources over open sea (more than 10 km offshore) for five standard heights										
	10 m		25 m		50 m		100 m		200 m	
	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}
	> 8.0	> 600	> 8.5	> 700	> 9.0	> 800	> 10.0	> 1100	> 11.0	> 1500
	7.0-8.0	350-600	7.5-8.5	450-700	8.0-9.0	600-800	8.5-10.0	650-1100	9.5-11.0	900-1500
	6.0-7.0	250-300	6.5-7.5	300-450	7.0-8.0	400-600	7.5- 8.5	450- 650	8.0- 9.5	600- 900
	4.5-6.0	100-250	5.0-6.5	150-300	5.5-7.0	200-400	6.0- 7.5	250- 450	6.5- 8.0	300- 600
	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 6.0	< 250	< 6.5	< 300

Source: Risø National Laboratory, Roskilde, Denmark

Wind - Resource maps (2)

China Onshore & Offshore



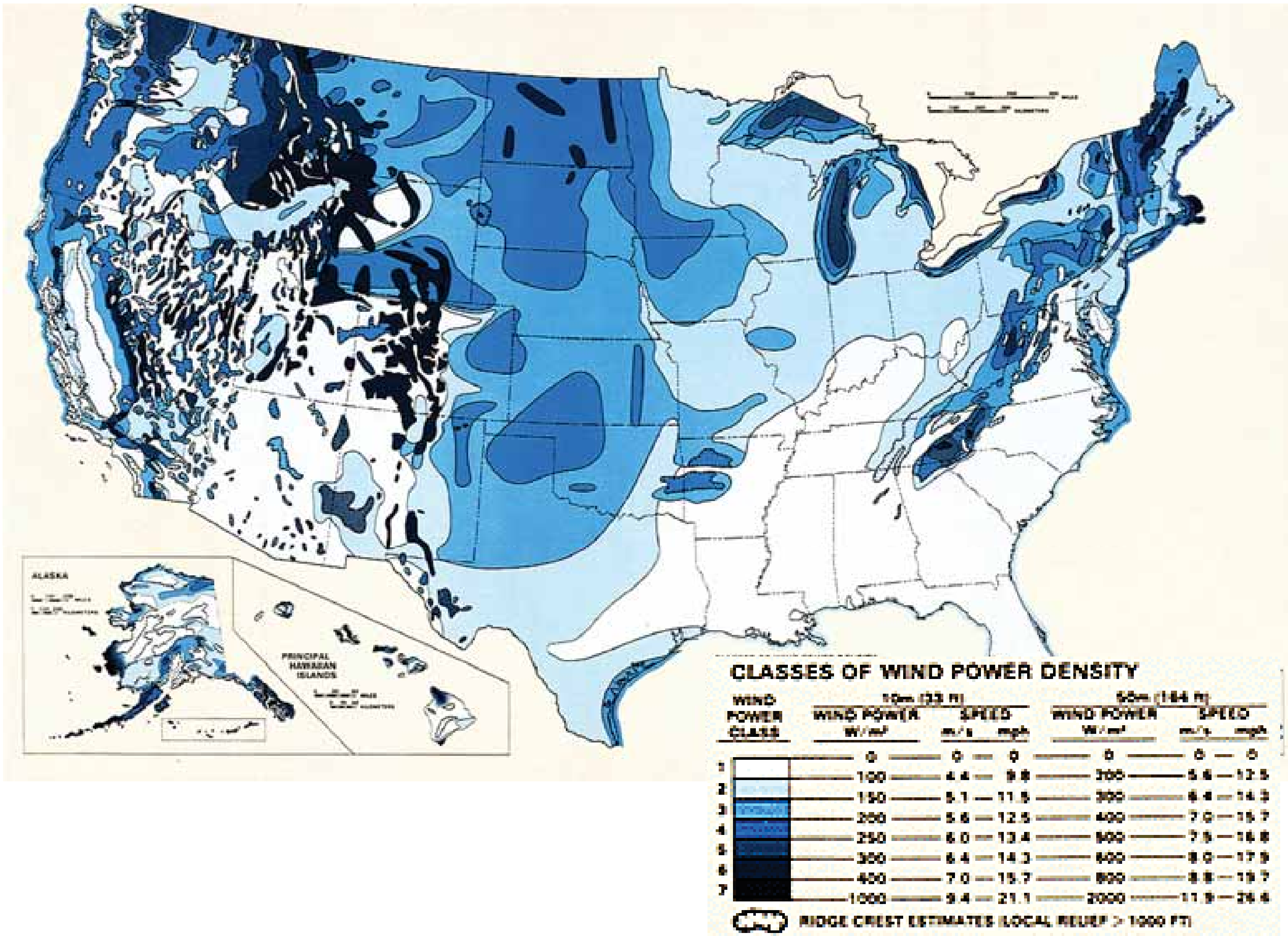
Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed[a] at 50 m m/s
1	Poor	0 - 200	0 - 5.6
2	Marginal	200 - 300	5.6 - 6.4
3	Moderate	300 - 400	6.4 - 7.0
4	Good	400 - 500	7.0 - 7.5
5	Excellent	500 - 600	7.5 - 8.0
6		600 - 800	8.0 - 8.8
7		> 800	> 8.8

[a]Wind speeds are based on a Weibull k value of 2.0

Wind - Resource maps (3)

US Onshore & Offshore



Wind - Turbine types

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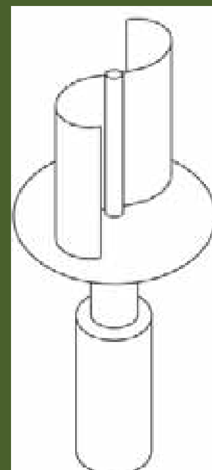
Vertical Axis

Darrieus

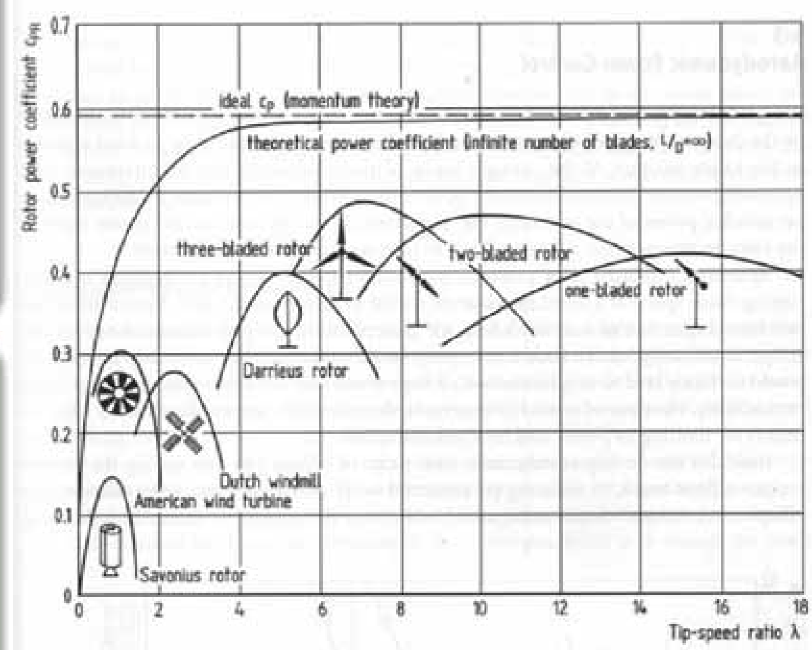
Savonius-Rotor



H-Type

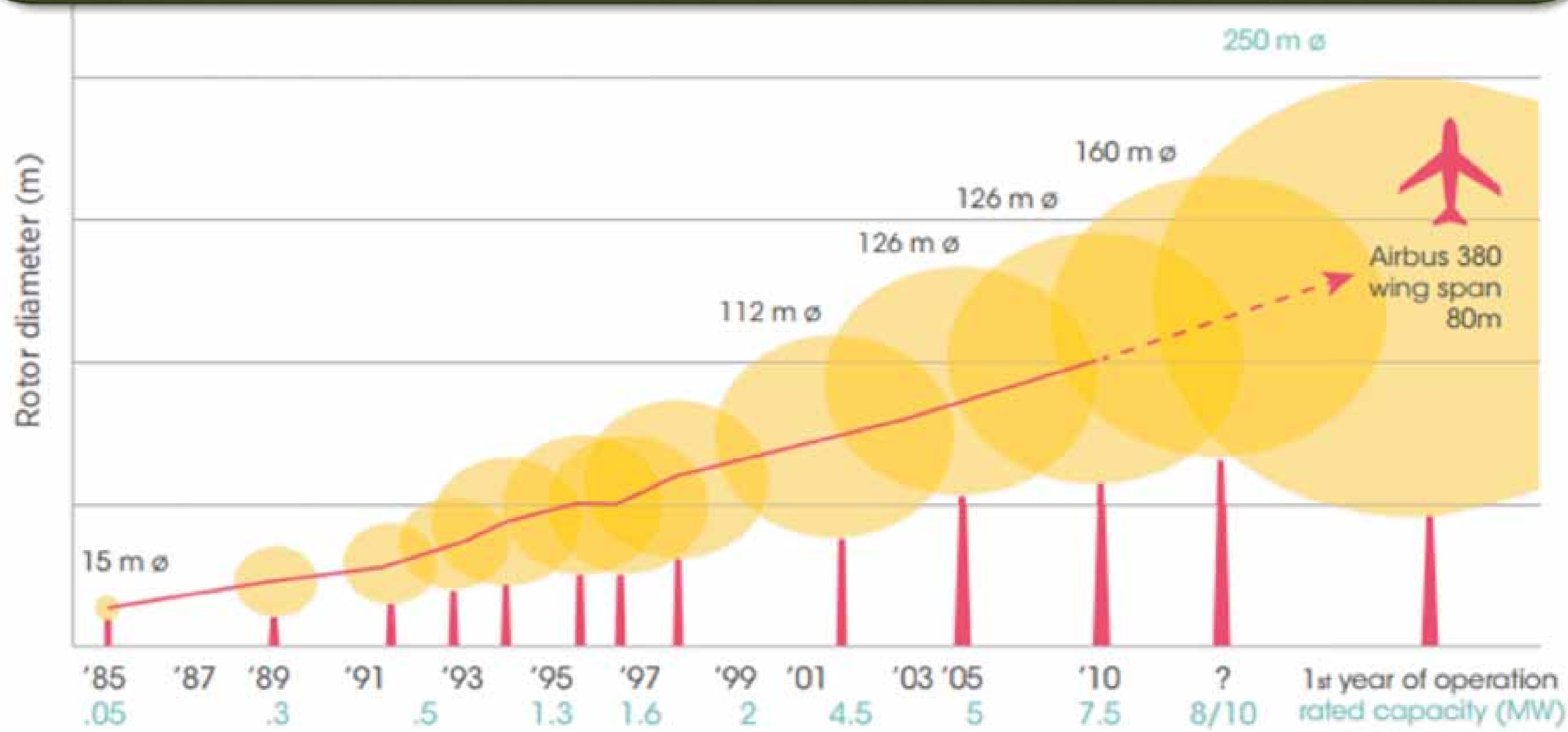
Horizontal Axis

One, two and three blades turbines



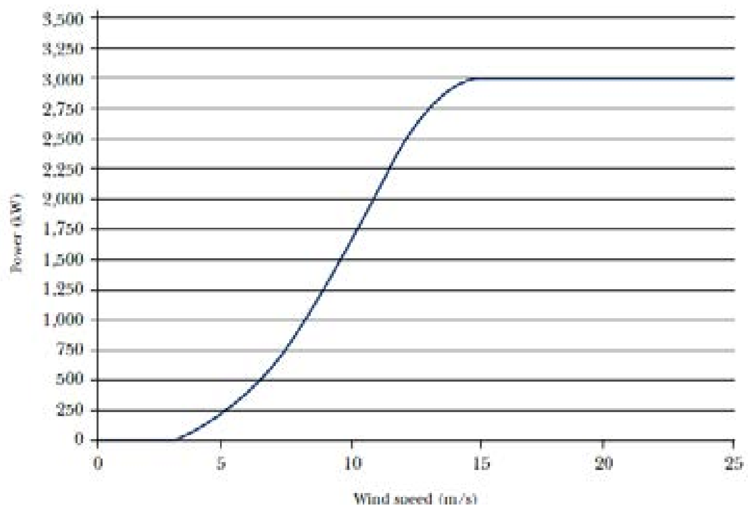
Wind - Turbine size evolution

Land-based supply is now dominated by turbines in the 1.5 and 3 MW range

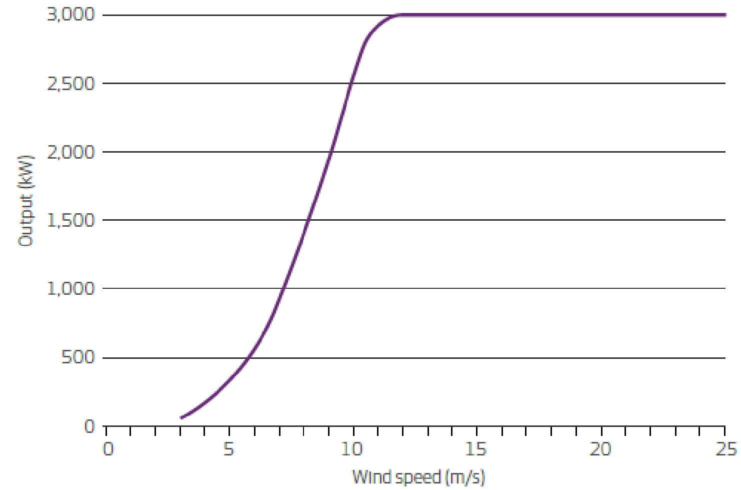


- REpower, exploiting reserve capacity in design margins, has up-rated its 5 MW wind turbine to 6 MW
- BARD Engineering has launched a similar up-rating of its 5 MW design to 6 MW and later 7 MW
- Clipper Windpower is working in two new sizes: 7.5 MW and 10 MW
- Enercon is currently working on a 7.5 MW turbine

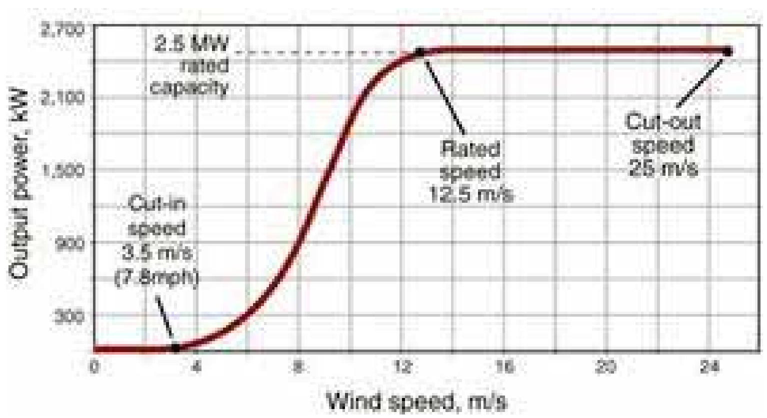
Wind - Power curve (1)



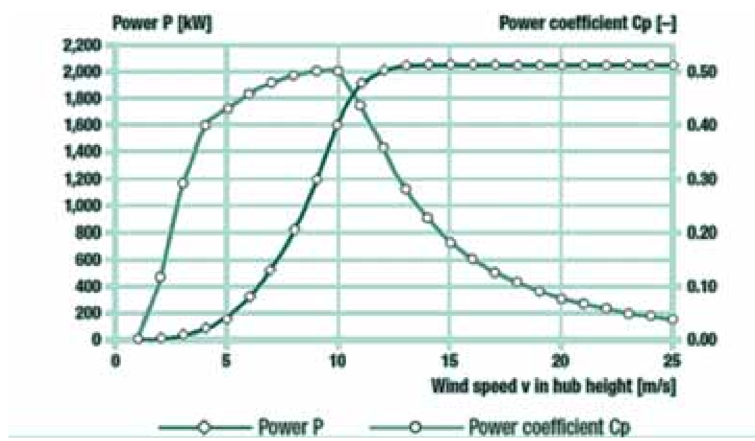
Source: Vestas V90 – 3 MW



Source: Vestas V112 – 3MW



Source: GE Energy – 2.5 MW

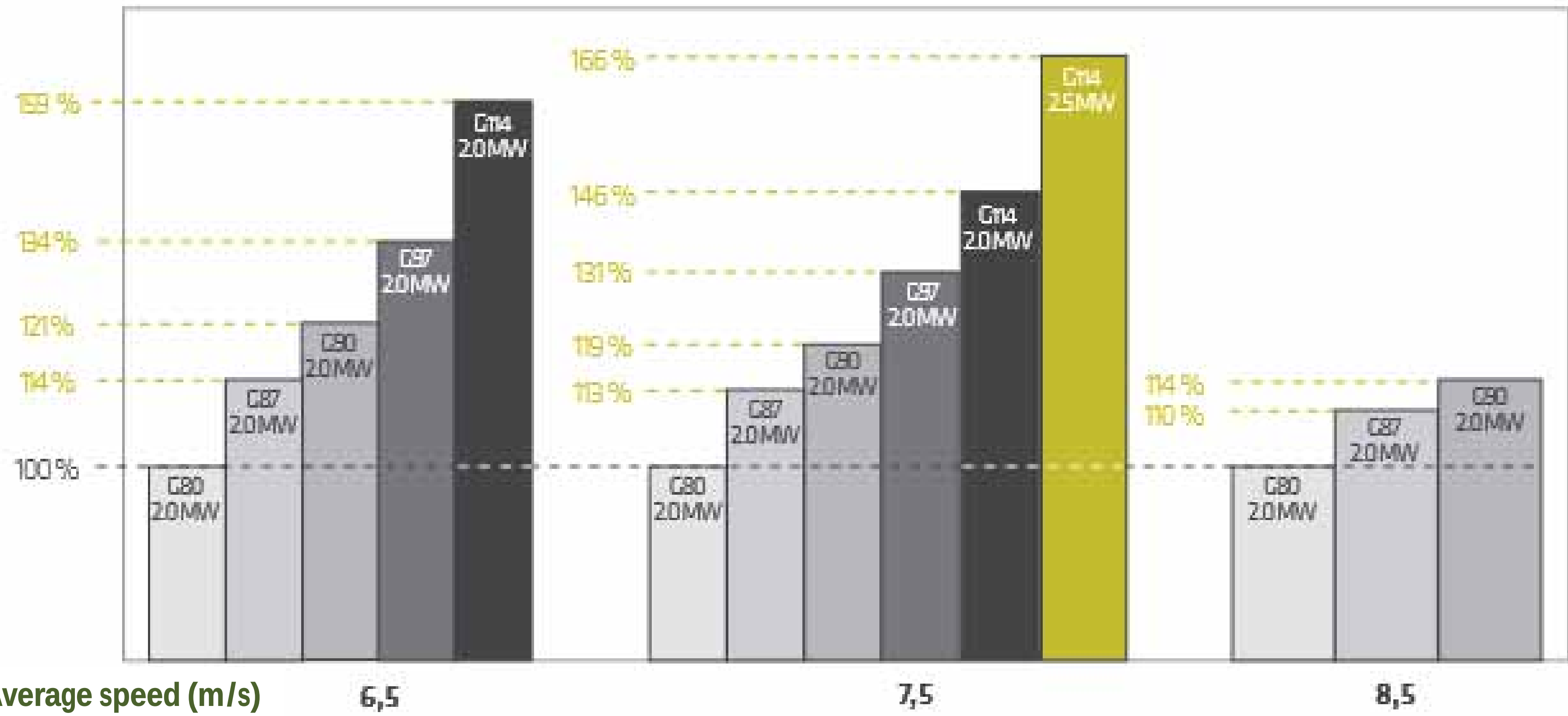


Source: Vestas E-82

Wind - Power curve (2)

Typical generation for a WTG depends on average speed and rotor diameter and not only on WTG nameplate capacity

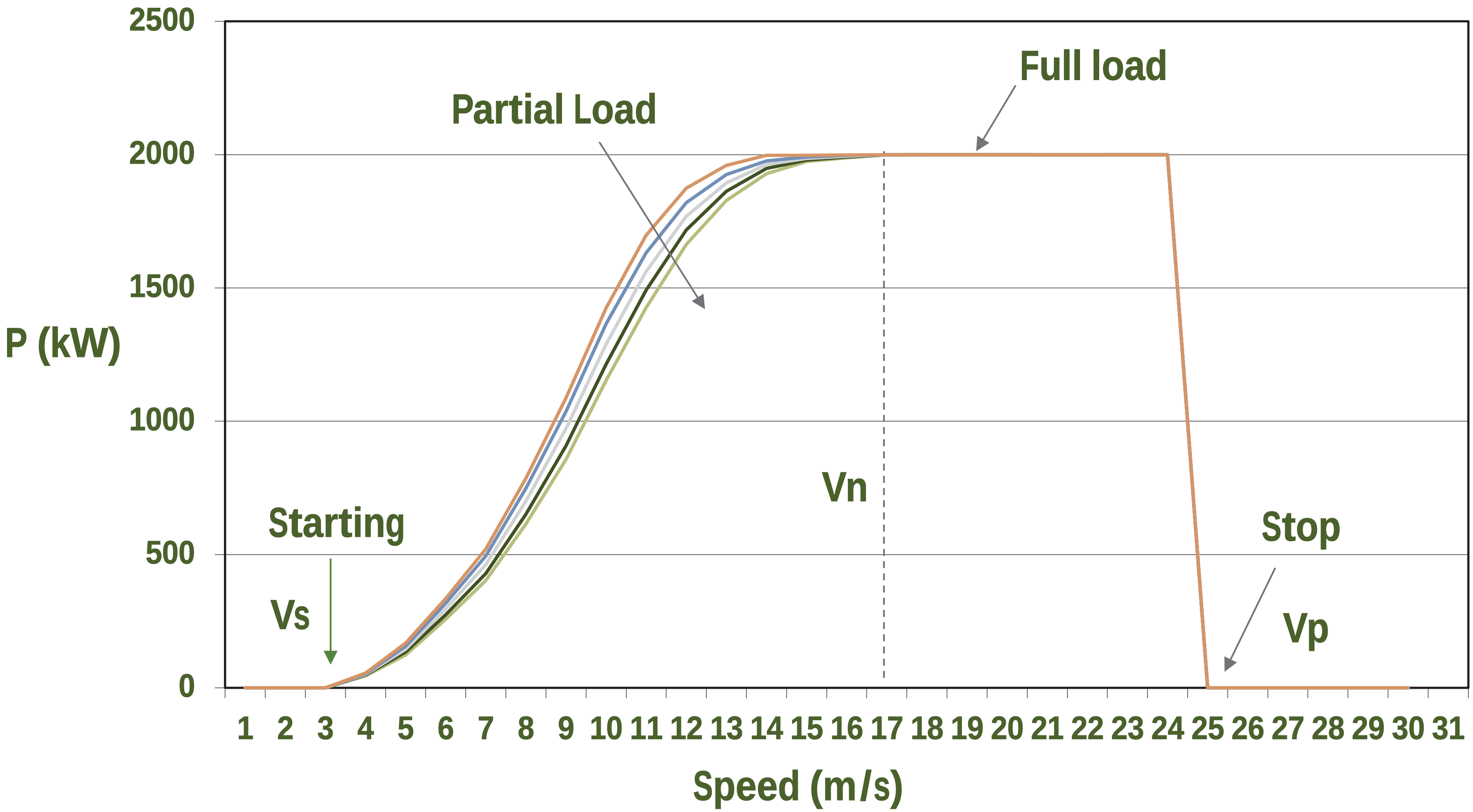
Generation output



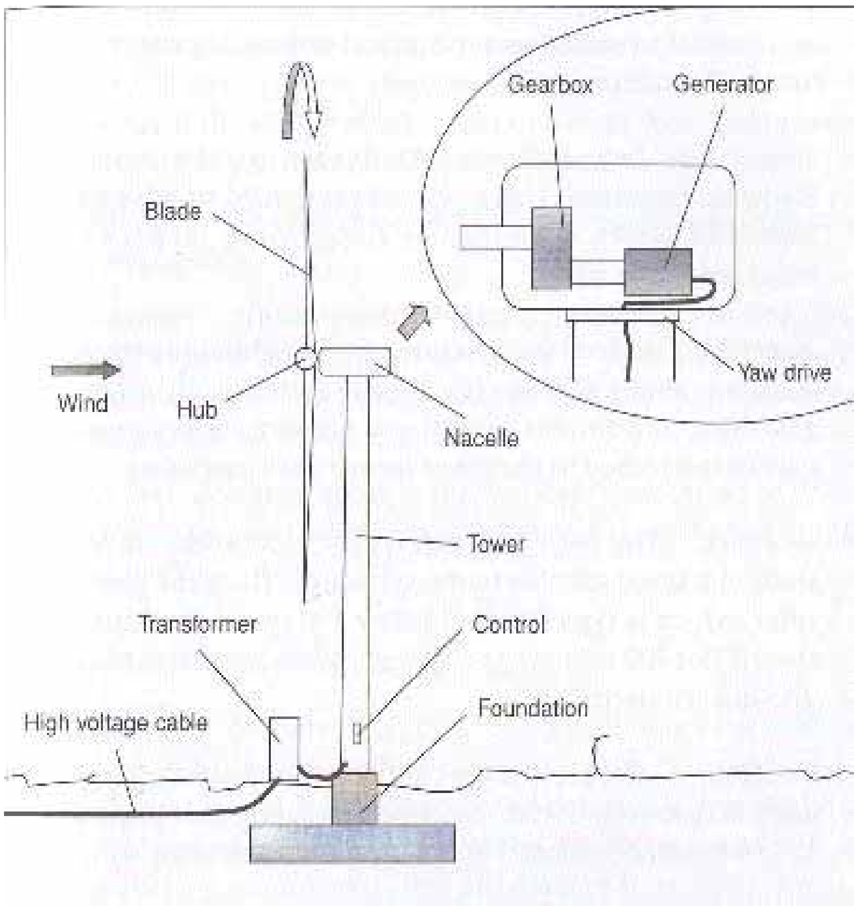
Source: Gamesa

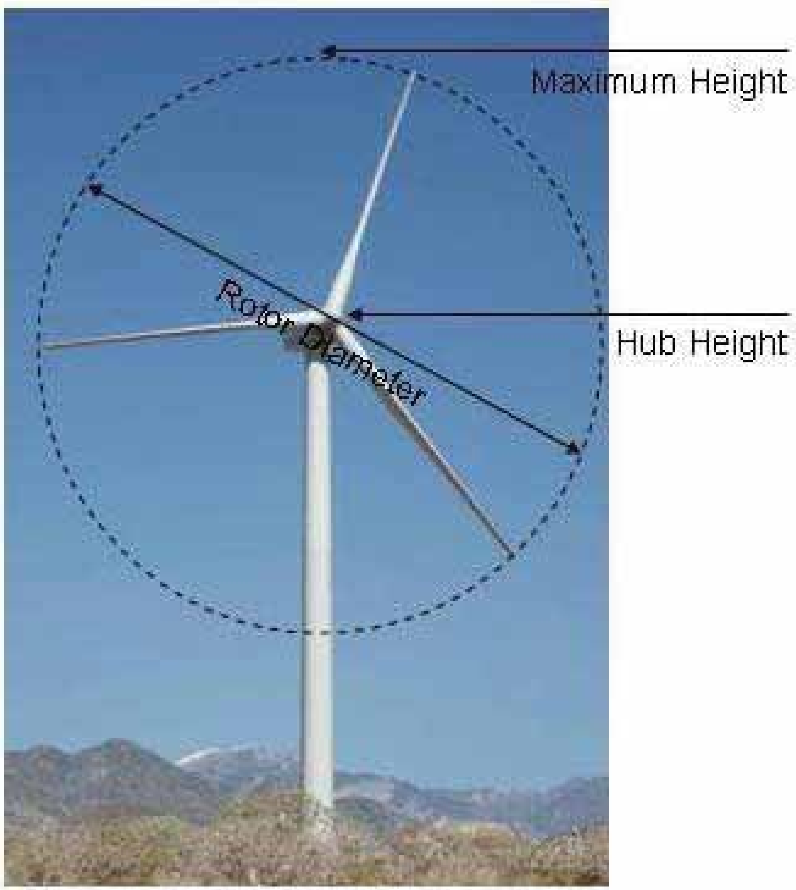
Wind - Power curve (3)

Power curve:
WT output power characteristic

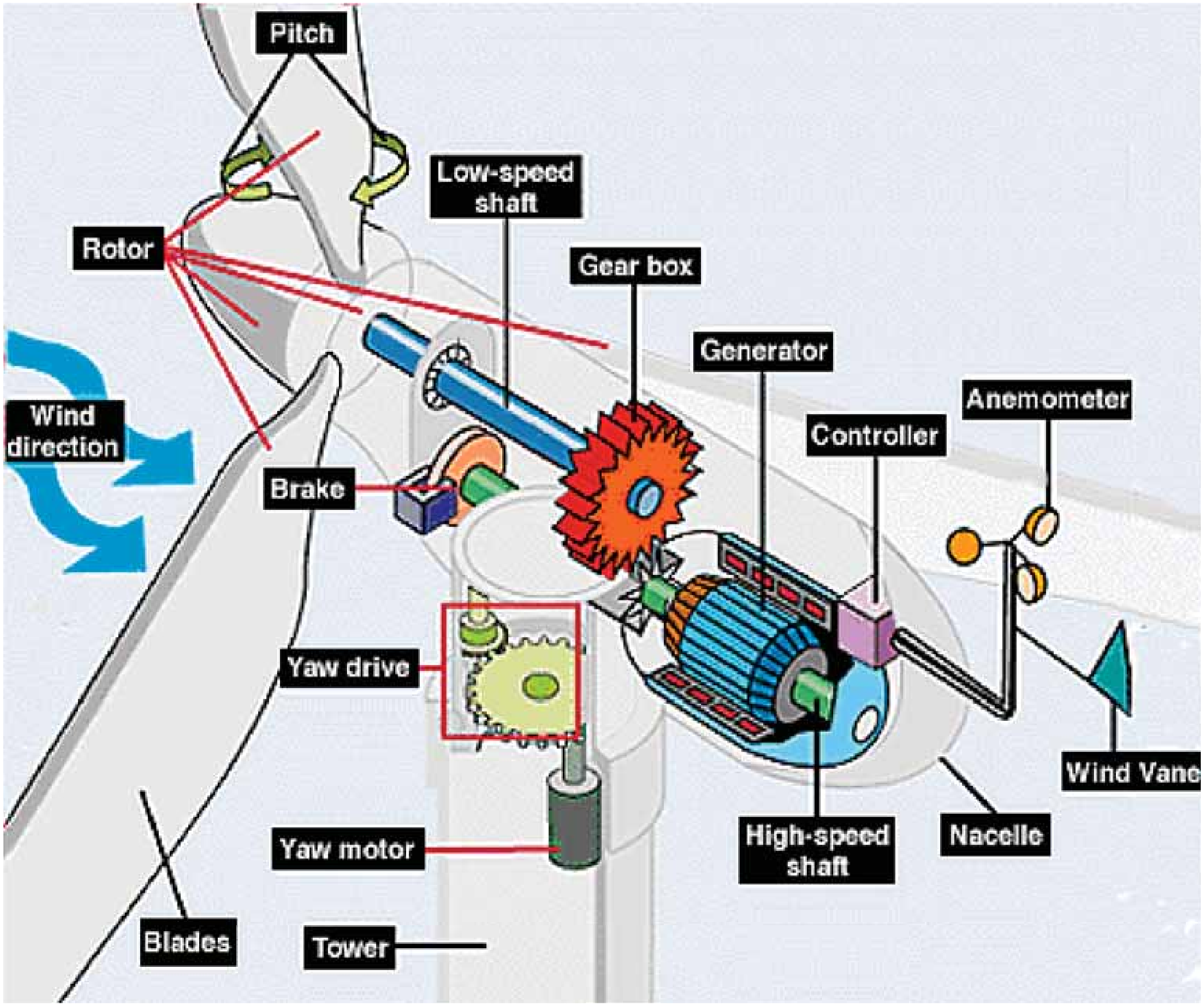


Wind turbine components (1)

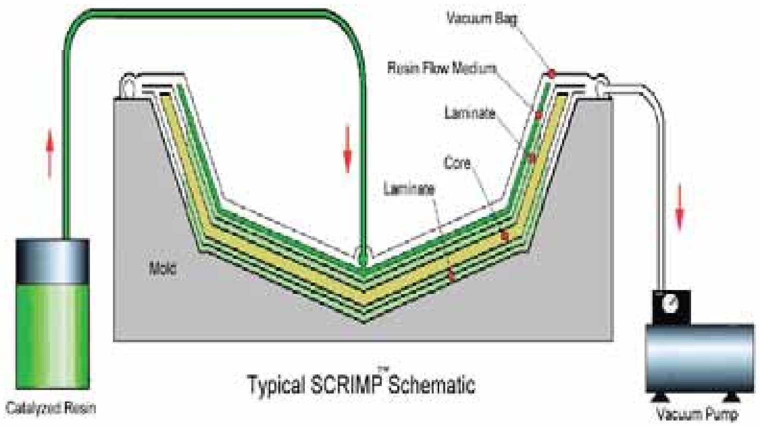


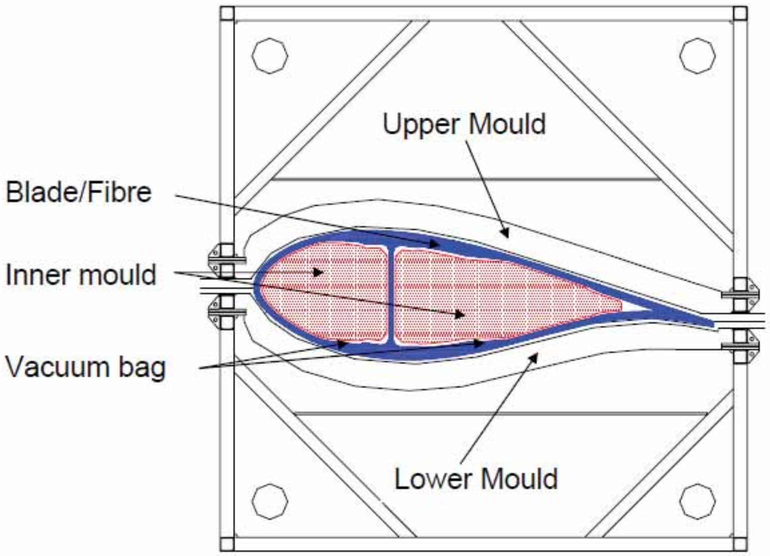


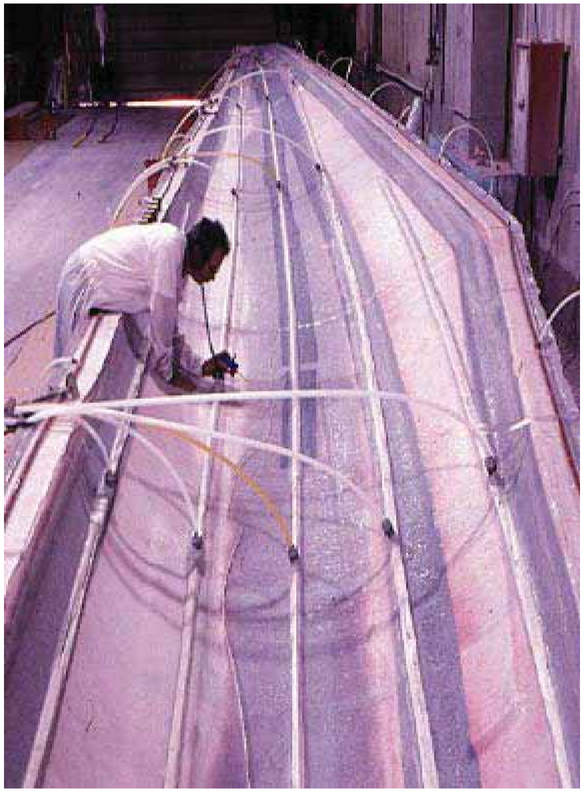
Wind turbine components (2)



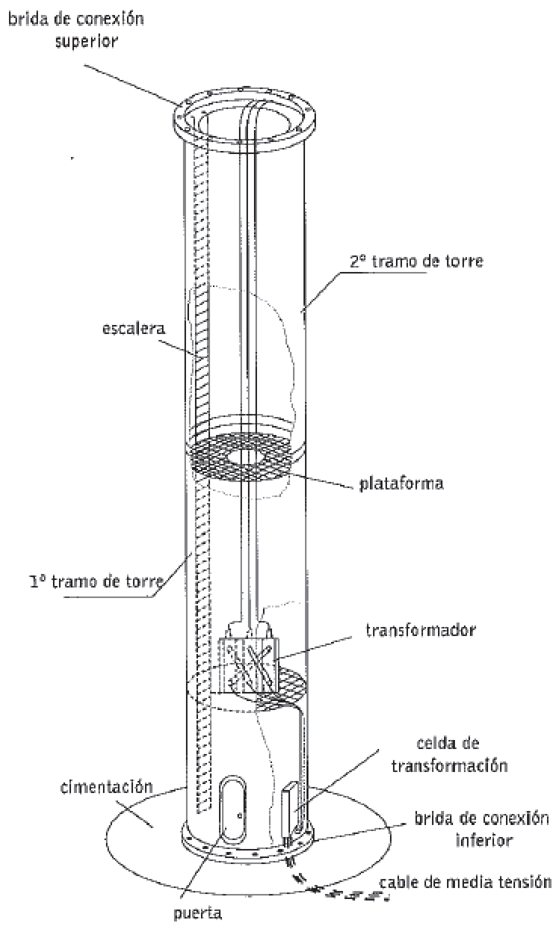
Blades manufacturing

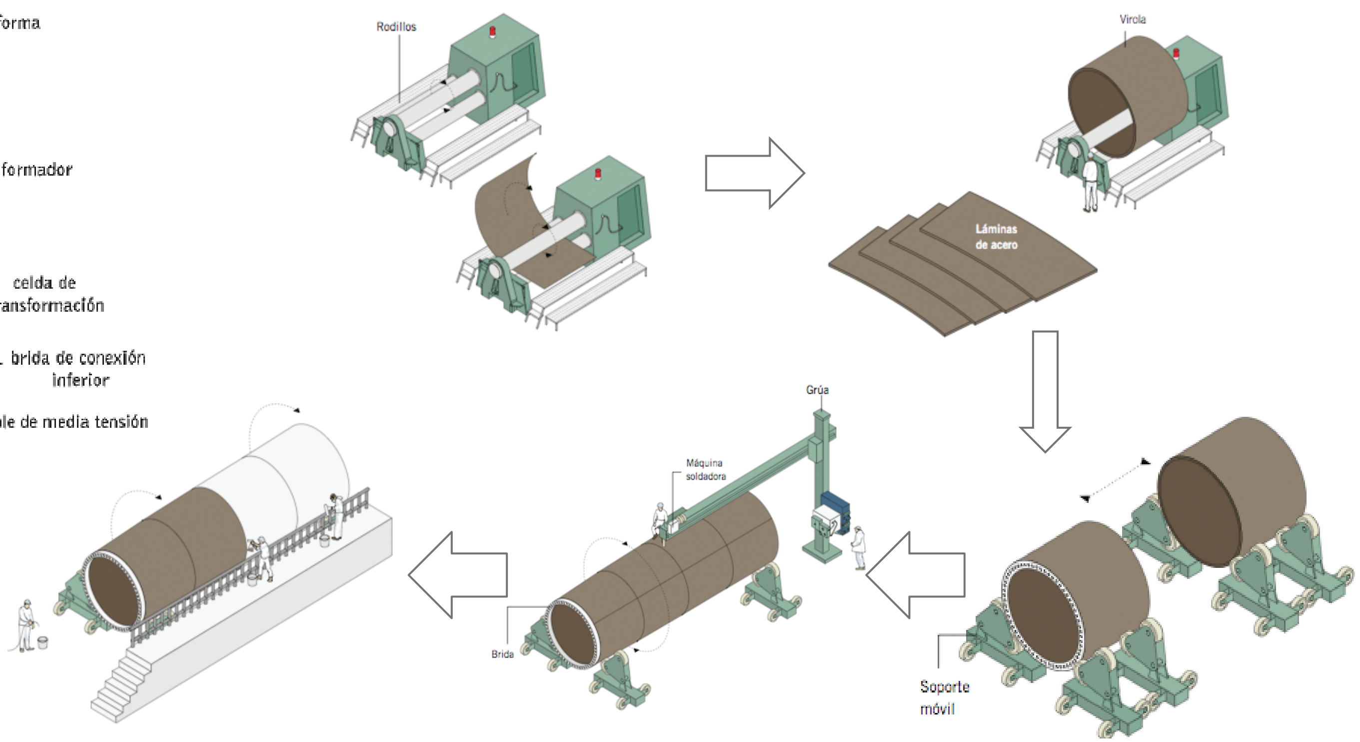






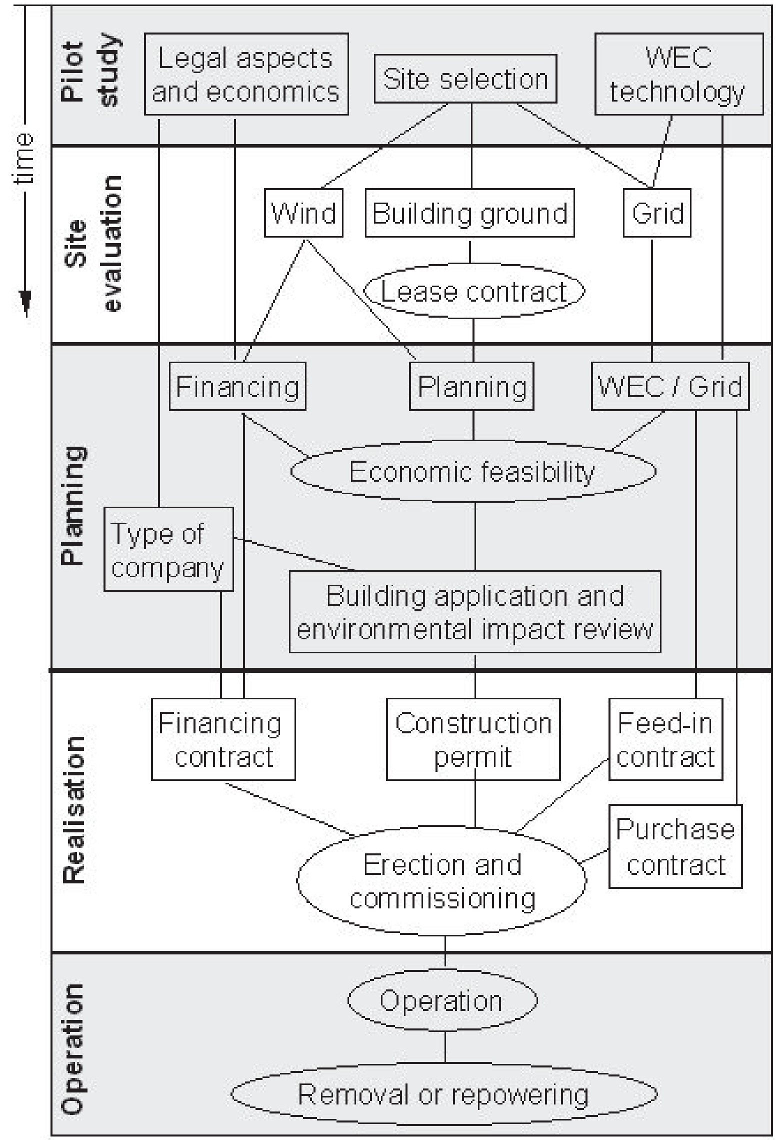
Tower manufacturing and installation





Wind farm flowchart

1. **Wind resource assessment**
2. **WT Selection: restriction of wind turbine type**
3. **Micrositting: output (MWh/year)**
4. **Maximum installed capacity (due to grid connection capability)**
5. **Distance to point of connection**
6. **Technical constraints of the grid (voltage dips, reactive power)**
7. **Environmental constrains**
8. **Factors affecting turbine location**



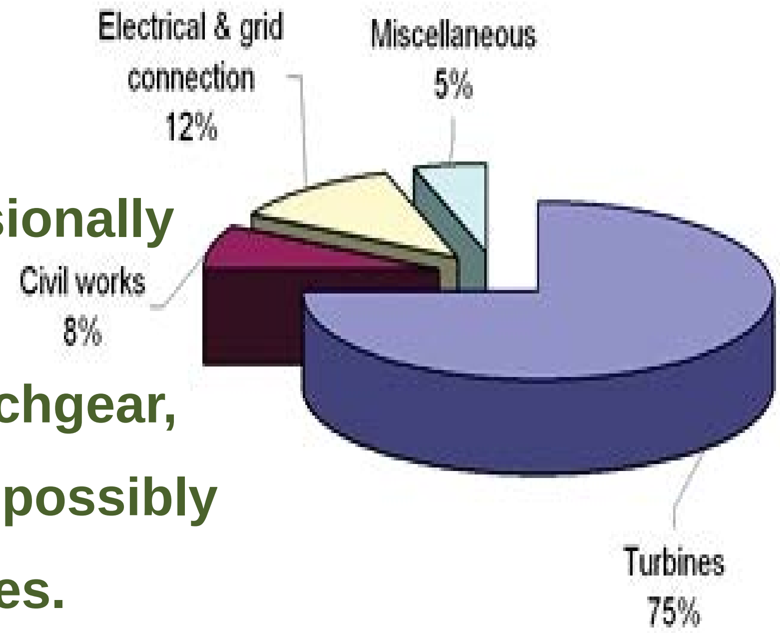
Wind - Factors affecting turbine location

1. Maximum installed capacity (due to grid connection or Power Purchase Agreement terms);
2. Site boundary;
3. 'Set back' - distances from roads, dwellings, electric lines, ownership boundaries and so on;
4. Environmental constraints;
5. Location of noise-sensitive dwellings, if any, and assessment criteria;
6. Location of visually-sensitive viewpoints, if any, and assessment criteria;
7. Location of dwellings that may be affected by 'shadow flicker' (flickering shadows cast by rotating blades) when the sun is in particular directions, and assessment criteria;
8. Turbine minimum spacing, as defined by the turbine supplier (these are affected by turbulence, in particular); and
9. Constraints associated with communications signals, for example, radar.

Optimize process ↔ Minimize risks

Wind farm cost breakdown

1. **Civil works:**
   - **Roads and drainage;**
   - **Wind turbine foundations;**
   - **Met mast foundations (and occasionally also the met masts); and**
   - **Buildings housing electrical switchgear, SCADA central equipment, and possibly spares and maintenance facilities.**



2. **Electrical works**
3. **Supervisory Control and Data Acquisition (SCADA) system**

The civil and electrical works are often referred to as the Balance of Plant (BOP)

Wind – Onshore vs Offshore (1)

Onshore	Offshore
Influence of local topographical effects	Limited influence of topographical effects
Constant roughness on surface	Surface roughness varies with sea conditions
Hub always at same height	Hub height varies with tidal
More natural turbulence	Laminar regimen but with more dissipation difficulty
Capacity factor 20%-30%	Capacity factor >30%

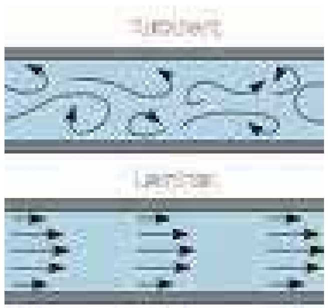
Wind – Onshore vs Offshore (2)

Turbines are very similar to onshore wind turbines, but there are important differences:

- **Installation Phase**
- **Protection and specific isolation required**
- **O&M: access is key**
- **Bigger turbines**

Wind resource

Specific studies

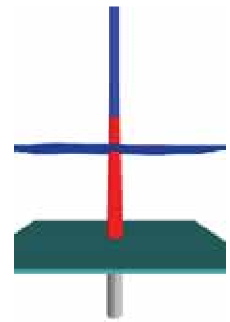


Laminar wind profiles

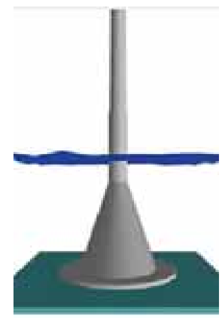
Construction & logistics

Specialized vessel fleet

Foundations



Monopiles



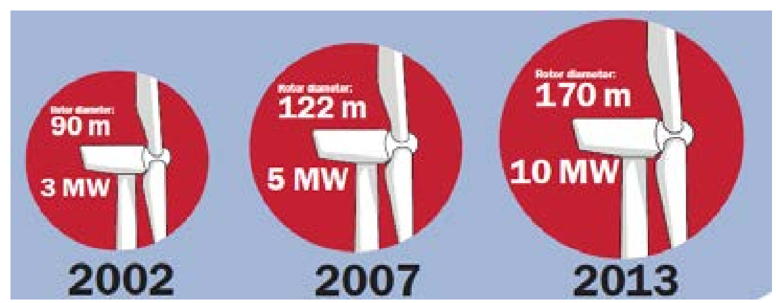
Gravity

Jacket

O & M

Marine environment brings larger risks and costs

Turbines



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Wind Technology Overview, Market Analysis and Economics

Wind – Global current situation

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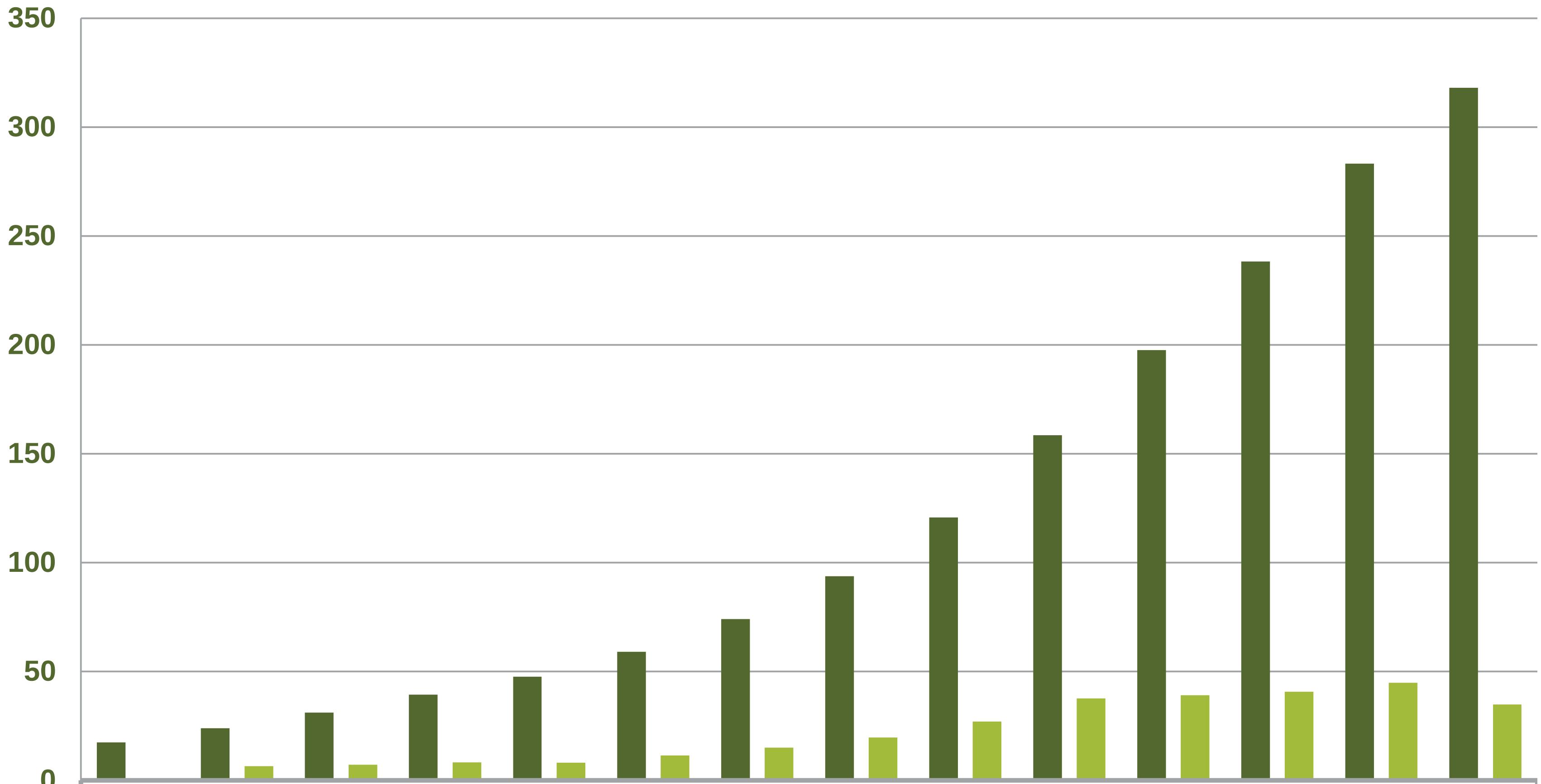
Global cumulative installed capacity 2000-2013

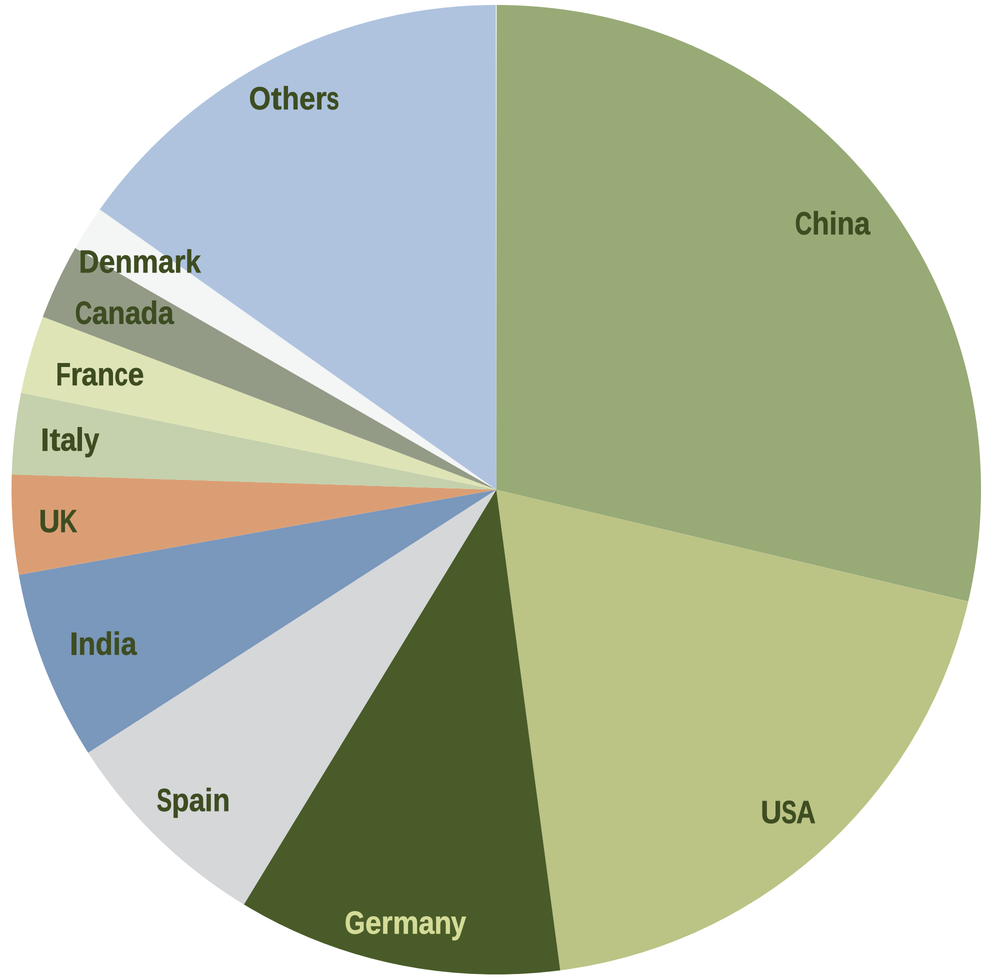


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
GW	17.4	23.9	31.1	39.4	47.6	59.1	74.1	93.8	120.8	158.5	197.6	238.4	283.2	318.1
GW/year		6.5	7.2	8.3	8.2	11.5	15	19.7	27	37.7	39.1	40.7	44.8	34.9

Source: GWEC

Wind – Current situation per country

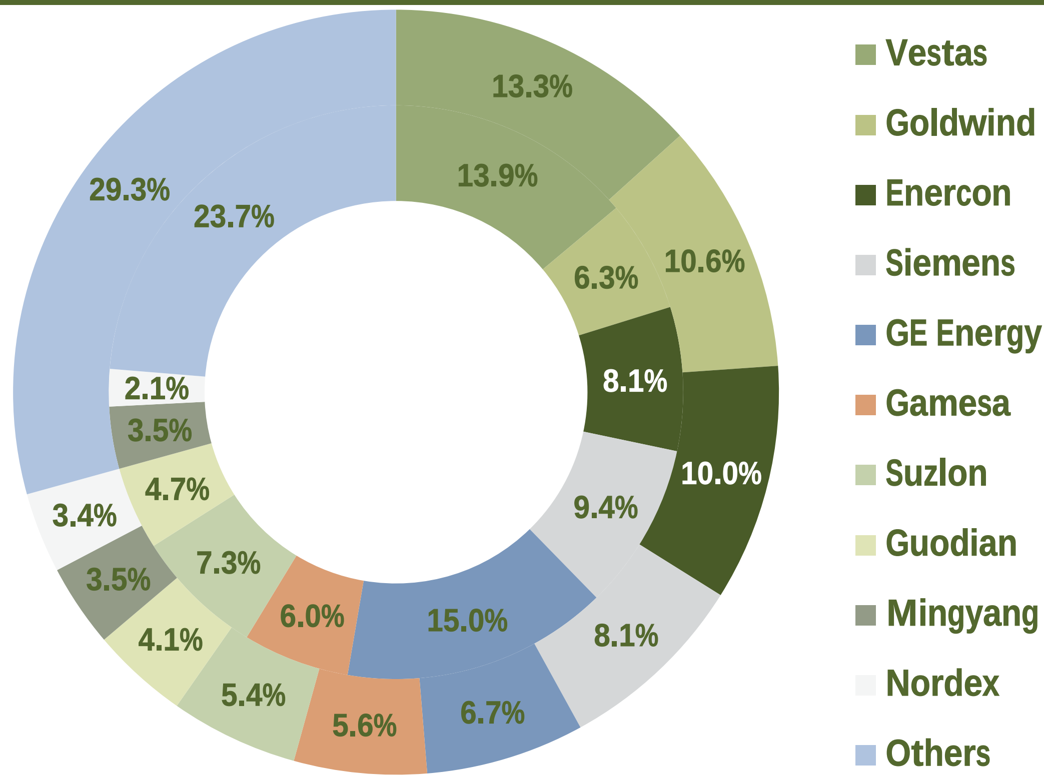
Countries	MW (end of ´13)	%
China	91,412	28.7
USA	61,091	19.2
Germany	34,250	10.8
Spain	22,959	7.2
India	20,150	6.3
UK	10,531	3.3
Italy	8,552	2.7
France	8,254	2.6
Canada	7,803	2.5
Denmark	4,772	1.5
Others	48,332	15.2
TOTAL	318,105	



Source: GWEC

Wind – Onshore WTG manufacturers

Global wind turbine market share evolution: 2012–2013

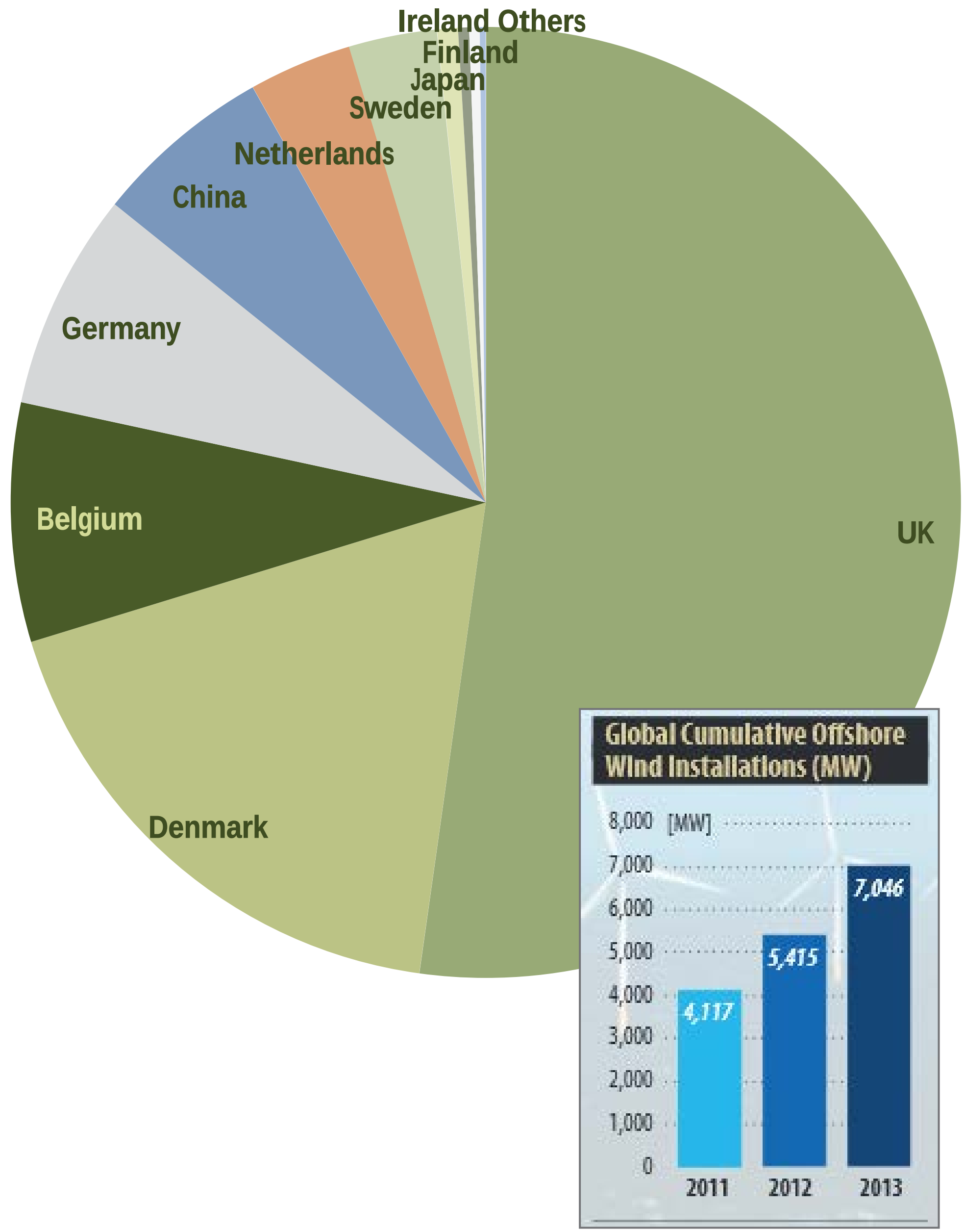


- 2013 was a challenging year for the global wind turbine market.
- A severe drop in US deliveries and increased demand in China shaped last year's market for wind turbine equipment manufacturers.
- Down from 43.6 GW in 2012, about 36.7 GW of wind turbines were shipped globally in 2013.

Source: IHS

Wind – Global offshore capacity

Countries	MW (end of ´13)	%
UK	3,681	52.2
Denmark	1,271	18.0
Belgium	572	8.1
Germany	520	7.4
China	429	6.1
Netherlands	247	3.5
Sweden	212	3.0
Japan	50	0.7
Finland	26	0.4
Ireland	25	0.4
Others	14	0.2
TOTAL	7,046	



Source: GWEC

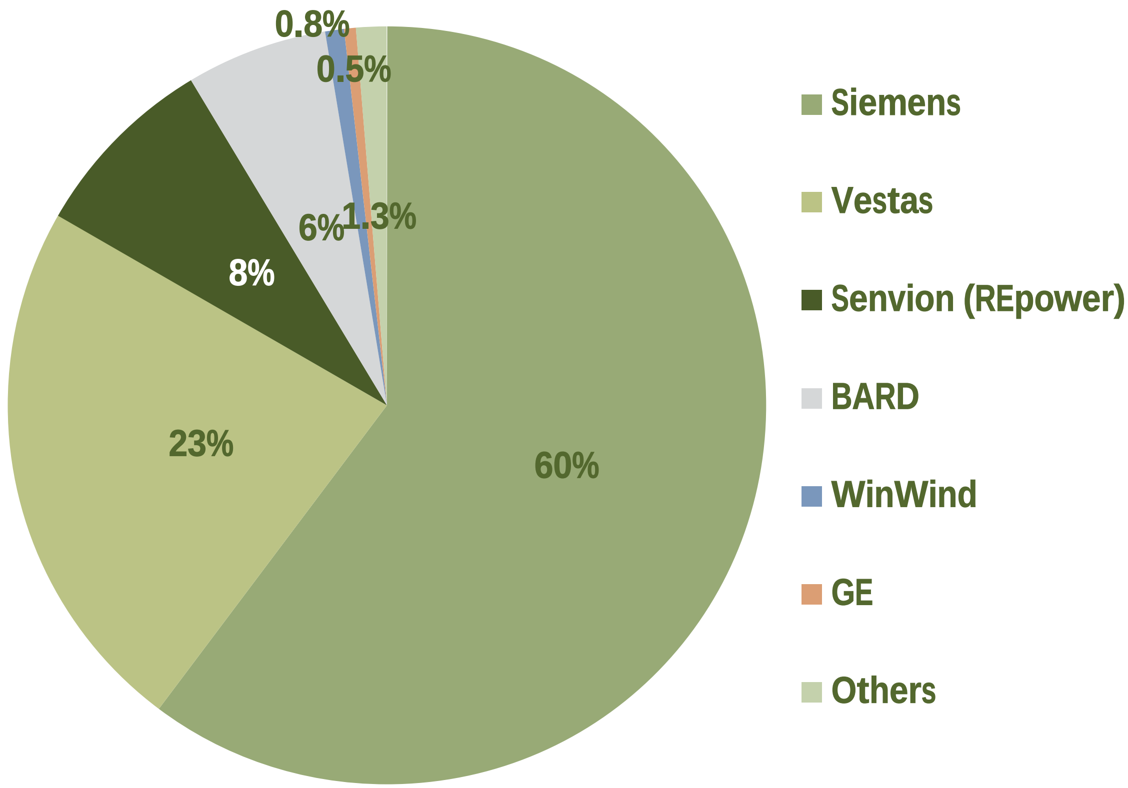
Wind – Offshore capacity evolution

Offshore capacity growth drivers:

- **2000-2003:** offshore market impulse caused by Denmark take off
- **2004-2005:** UK (Round 1) contributes to market growth
- **2006-2010:** UK + new EU countries (Sweden (Lillgrund), Germany (Alpha Ventus), Denmark (Horns Rev II) and The Netherlands (Egmond aan Zee)) support offshore development
- **2010-2012:** first relevant offshore projects in Asia (China and Japan)
- **2012-2014:** UK (Round 2) drives worldwide offshore growth. China speeding up growth

Wind – Offshore WTG manufacturers

YE 2013 Offshore WTG Market Share



Note: Figures for Europe

- **Siemens is the lead offshore wind turbine supplier in Europe with 60% of total installed capacity**
- **Together with Vestas (23%) they accrue the majority of the installed offshore capacity**
- **Siemens secured the most offshore wind deals, accounting for 1.7 GW (62%) of all announced orders in 2013. Europe accounted for almost 80% of announced deals, underlining the relative maturity of the region**

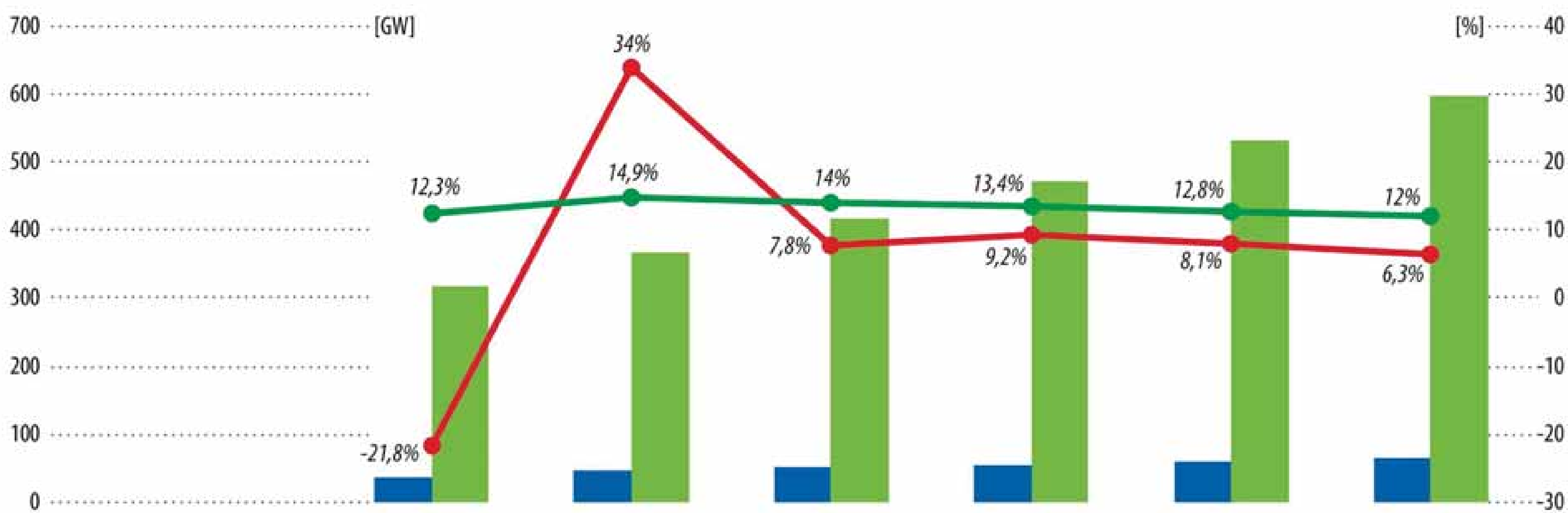
Source: EWEA Offshore Statistics, 2013

Wind – Perspectives

- The market diversification trend which has emerged over the past several years and intensified during 2013 is expected to continue to do so over the next several years.
- New markets outside the OECD continue to appear, and some of them will begin to make a significant difference to overall market figures.
- Inside the OECD, as wind power approaches double digit penetration levels in an increasing number of markets, and as demand growth either stalls or goes backwards, incumbents feel increasingly threatened.
- The fight for market share and policy support in these markets is becoming more and more intense. As a result, most of the growth in the coming years will be in markets outside the OECD.

- 2014 looks to be a record year, with annual market growth of about 33%, to bring the annual market to about 47 GW, with strong installations in North America and Asia, and the Brazilian market really beginning to come into its own.
- Brazil, Mexico and South Africa will figure increasingly strongly in the annual market figures in the years to come.
- After 2014, the market is expected to return to a more ‘normal’ annual market growth of 6-10% out to 2018.
- Cumulative growth will rise to nearly 15% in 2014, but average 12-14% from 2015 to 2018.
- Total installations should nearly double from today’s numbers by the end of the period, going from just over 300 GW today to just about 600 GW by the end of 2018.

Wind – Short-term market forecast



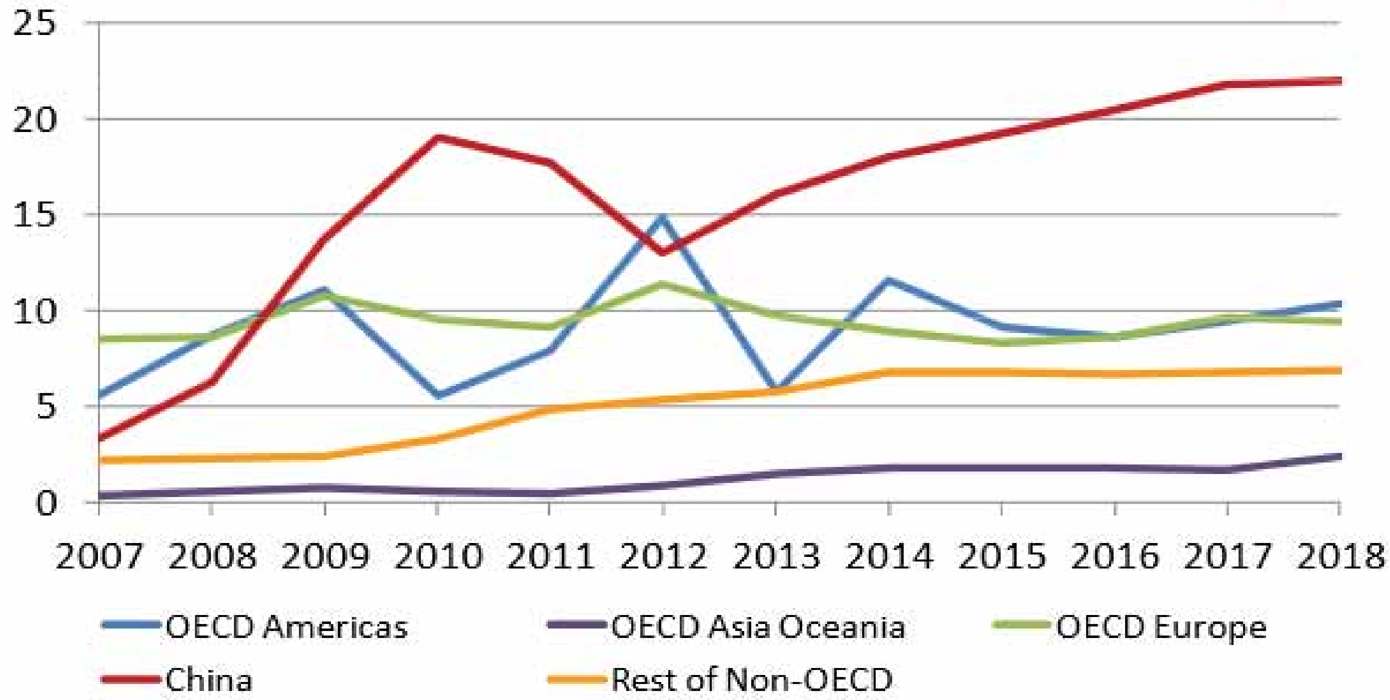
	2013	2014	2015	2016	2017	2018
Cumulative [GW]	318,1	365,4	416,4	472,1	532,3	596,3
Cumulative capacity growth rate [%]	12,3%	14,9%	14,0%	13,4%	12,8%	12,0%
Annual installed capacity ([GW]	35,3	47,3	51,0	55,7	60,2	64,0
Annual installed capacity growth rate [%]	-21,8%	34,0%	7,8%	9,2%	8,1%	6,3%

In 2018, global wind generating capacity will stand at nearly 600 GW, up from 318 GW at the end of 2013.

During 2018, 64 GW of new capacity will be added to the global total, almost the double of 2008 market.

Source: GWEC

Wind – Short-term market forecast



GW	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
World Onshore	19.5	26.0	38.4	36.9	38.9	44.0	36.5	43.8	42.6	42.4	44.2	45.4
World Offshore	0.3	0.4	0.4	1.1	1.1	1.4	2.3	3.3	2.6	3.8	5.1	5.7

The IEA predicts a sustained over 40 GW annual growth. Driven mainly by developments in China and the Americas.

Source: IEA, 2013

Wind – Global market outlook

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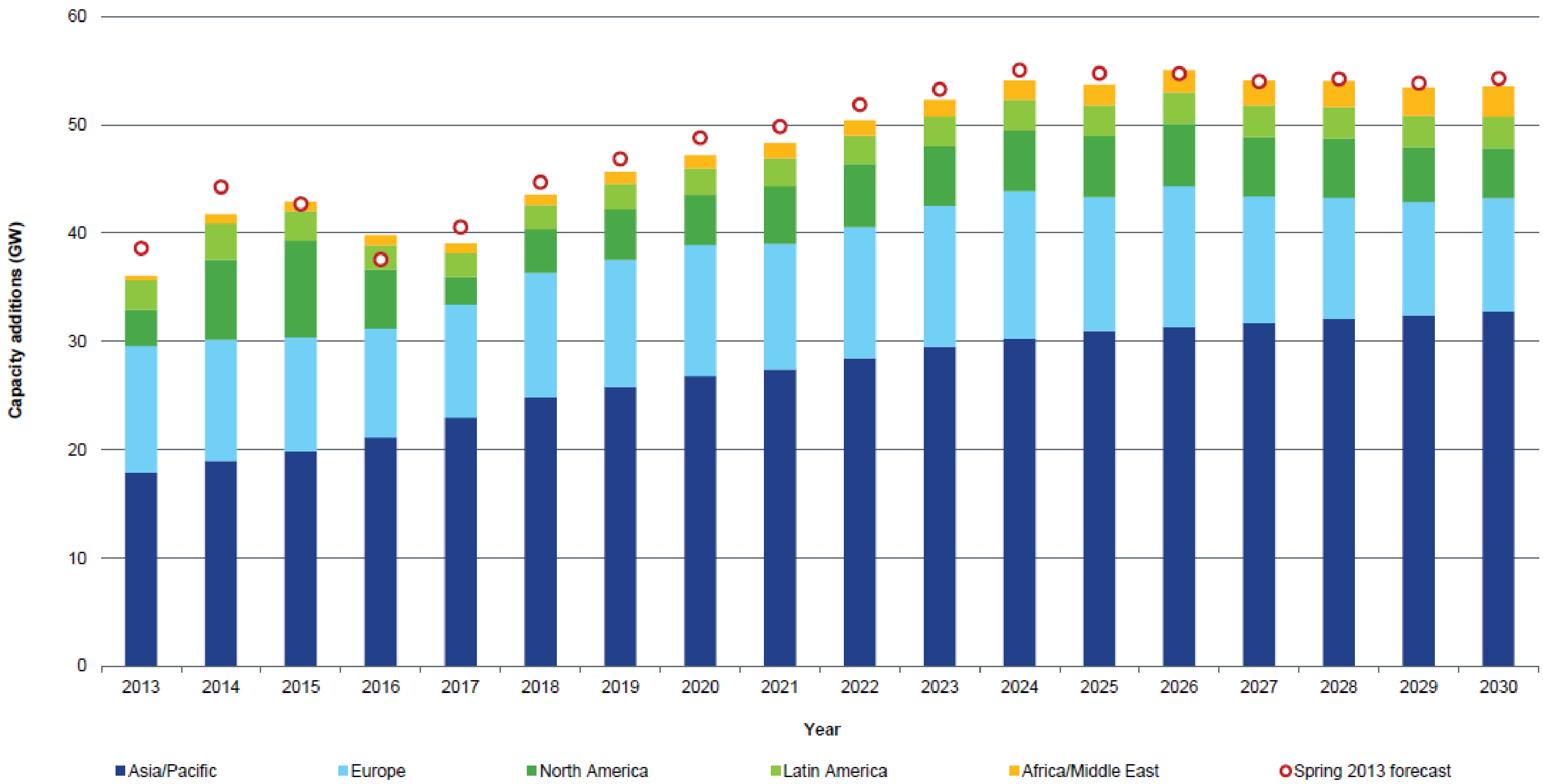
Global wind additions by region: 2013–2030

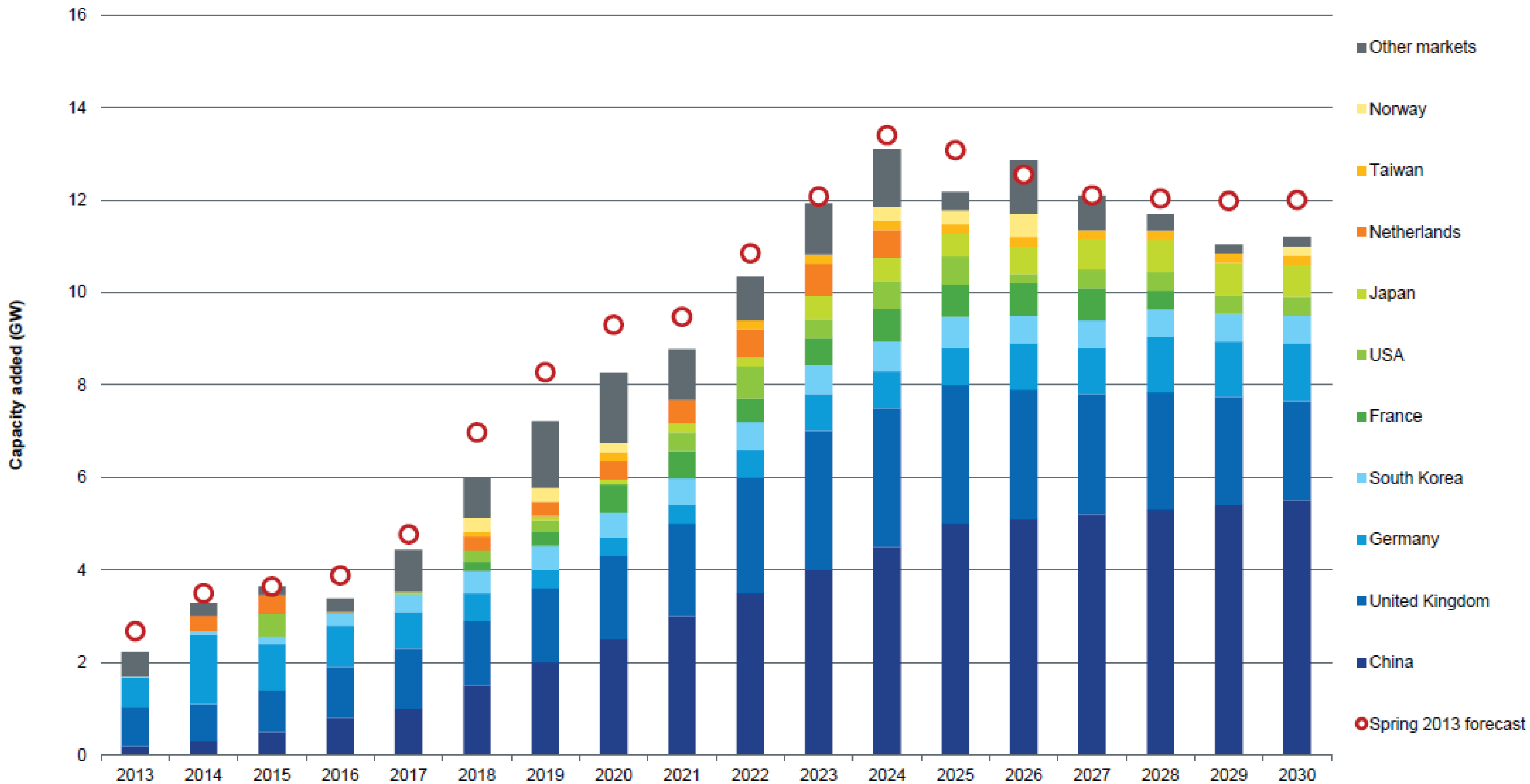


- **The Asia Pacific region continues to drive future demand for wind capacity, accounting for 485 GW, or over half of all global wind additions through 2030**

Source: IHS

Wind – Offshore capacity forecast

Global offshore wind additions by market: 2013–2030



- **Despite an 8.6 GW forecast cut for Germany, global offshore wind additions through 2030 are expected to exceed 153 GW; China, the UK, and Germany together make up 106 GW, or 69% of this capacity**

Source: IHS

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Wind Technology Overview, Market Analysis and Economics

Determining factors for renewable growth

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Economical sustainability	➢ Supporting policies to allow competitiveness of Renewables in the electric system and to protect consumers ➢ Regulatory framework to promote the most competitive technologies, taking into account the added value these represent in terms of benefits and costs
Technical sustainability	➢ Reaching a high level of renewable penetration with sufficient security and reliability conditions for the electric systems ➢ Optimizing the integration and management of renewable generation

Economical sustainability

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TYPES OF SUPPORTING SCHEMES

Feed-In Tariff

Market + Premium

Green Certificates

Tenders

Tax Incentives

Generation-based

Carbon Credits

Quantity-driven

Subsidies

Technical sustainability

Dispatch priority

Reactive and active power control

Voltage control

Balancing services

... among others ...

Keys to price forecasting

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Investments are based in a thorough analysis of regulation and current support schemes

Price analysis are one of the most relevant inputs for the investment decision making

Clear and simple revenues forecasting are a key to attract investment and to match targets

Schemes are composed of different variables that may impact pricing in diverse ways. No one-fit-all solution

Each wind farm is subject to specific variables that may affect potential revenues

Regulation and support schemes are the key driver for providing certainty in terms of future revenues

Price forecasting examples

Price forecast Summary

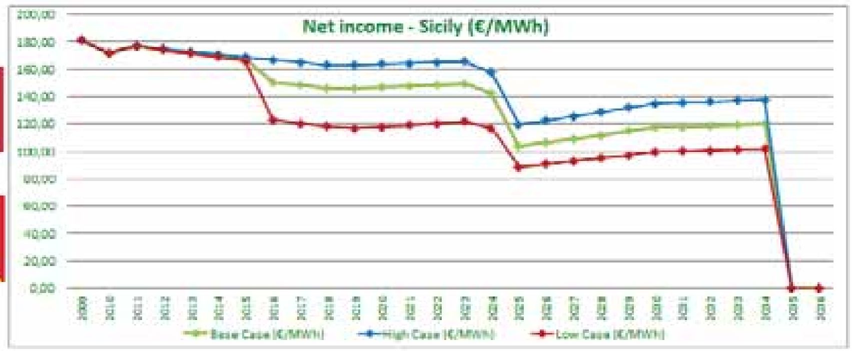
Italy - Sicily

Wind Power

Price Forecast & Risk Scenarios	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Base Case (€/MWh)	181.22	172.05	177.10	174.70	172.30	169.90	167.50	150.32	148.33	146.33	146.28	147.03	147.88	148.78	149.70	142.44	104.19	106.71	109.31	111.97
High Case (€/MWh)	181.22	172.05	177.10	175.07	173.05	171.02	164.99	166.96	164.93	162.90	163.28	163.76	164.23	164.93	165.96	157.96	119.82	122.72	125.70	128.76
Low Case (€/MWh)	181.22	172.05	177.10	174.33	171.56	168.79	166.02	123.00	120.58	118.17	116.92	118.07	119.23	120.48	121.76	116.88	88.56	90.71	92.91	95.17

Facility INPUT DATA	Month	Year
Commissioning Date	10	2009

Enter Commissioning Date (up to 2012)



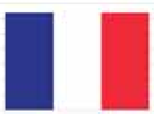
Price Forecast Summary

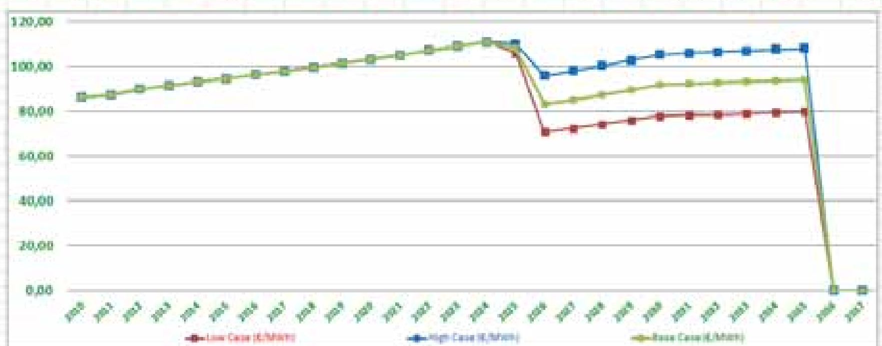
France - Montlouby II

Wind Onshore

Price Forecast & Risk Scenarios	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Base Case (€/MWh)	86,43	87,29	89,92	91,61	93,16	94,75	96,38	98,06	99,79	101,56	103,39	105,26	107,19	109,18	111,21	108,22	83,31	85,33	87,41	89,54	91,73	92,19	92,65	93,11	93,58	94,05
High Case (€/MWh)	86,43	87,29	89,92	91,61	93,16	94,75	96,38	98,06	99,79	101,56	103,39	105,26	107,19	109,18	111,21	110,36	96,84	98,13	100,32	102,97	104,49	106,02	106,56	107,08	107,62	108,15
Low Case (€/MWh)	86,43	87,29	89,92	91,61	93,16	94,75	96,38	98,06	99,79	101,56	103,39	105,26	107,19	109,18	111,21	106,19	70,81	72,53	74,30	76,11	77,97	78,36	78,75	79,15	79,54	79,94

Data Input	
Commissioning date (COD)	01-ago-10
Tariff Fixed in (year)	2009
SEH	2.082





Wind contribution to sustainability

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Benefits		
	Environment	➢ Emissions free ➢ Contributes to emission reduction targets: Kyoto Protocol (1997), Bali Agreements (2007), EU Directives
	Energy Dependency	➢ Local endless energy ➢ Energy dependency reduction ➢ Volatility and growth scenarios for fossil fuels
	Competitiveness	➢ Industrial and socio-economic driver ➢ More competitive generation costs in the longer run

Wind and renewables are ready to face the challenges of the current and future energy context

What makes life easier for developers?

Theoretically ideal scenario

- Clear rules, high legal level: a Law is better than a Decree
- Long term visibility: the forecast is for the whole life time of the asset (20-25 years)
- Country stability, political & social support to RES. Regulatory tradition

Can full certainty be guaranteed? NO

Sources of uncertainty

- Reasonability
- Political stability
- Macroeconomics
- Support mechanism

The effectiveness of support frameworks

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An effective support framework for renewables must be based on four indispensable factors

Economic

- **Profitability**
- **Predictability**
- **Stability**

Technical

- **Adequate Integration**

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Wind Technology Overview, Market Analysis and Economics

Wind generation control capabilities

- Start-up and Stop Controls
- Yaw Control
- Pitching-Speed Control
- Over-speed Control
- Grid Integration:
  - ✓ Power Control
  - ✓ Voltage Control

WTG Control

WTG stop under control

WTG Start-up and Stop Controls

WTG out of control

General concepts: Electrical Grid

Electrical Grid: bundle of interconnected elements (cables, lines, transformers…), with the purpose of providing electricity flowing from generators to consumers, with a certain voltage and frequency.

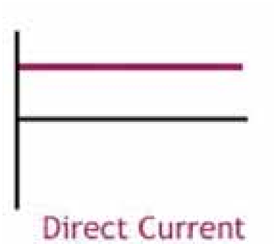
The Electrical Grid is the largest infrastructure ever designed, built and controlled by men.

NETWORK=CONTROL

- AC Grid. **Since 1897.**
- DC Grid. **Offshore Wind Farms.**

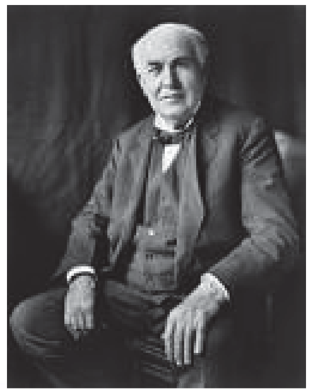
General concepts: Electrical Grid

DC Generator

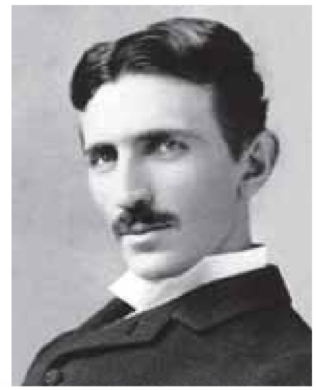


- ✓ **Voltage amplitude**

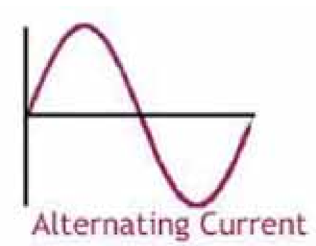
Thomas Alva Edison
1847-1931



Nikola Tesla
1856-1943



AC Generator



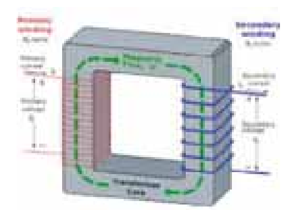
- ✓ **Voltage amplitude**
- ✓ **Frequency**

Main barrier: transmission of electricity across long distances

In 1890 voltage rising was complex

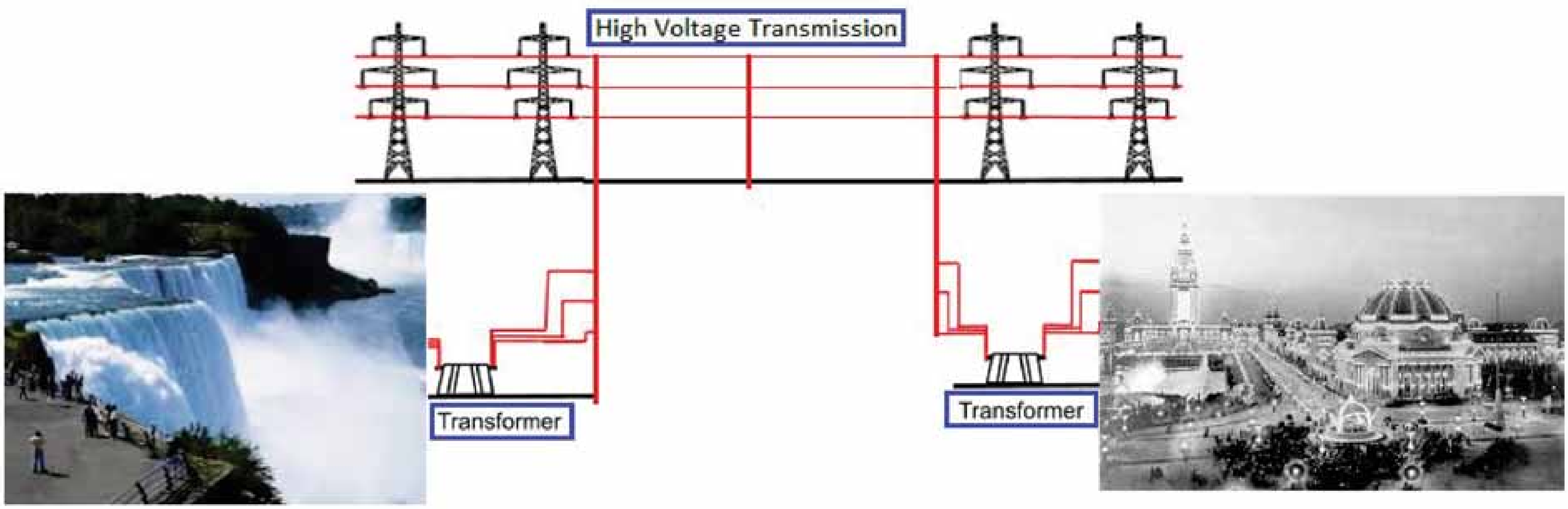
In 1890 voltage rising was simple using Transformers

In 2014, offshore wind farms connected with DC links



General concepts: Electrical Grid

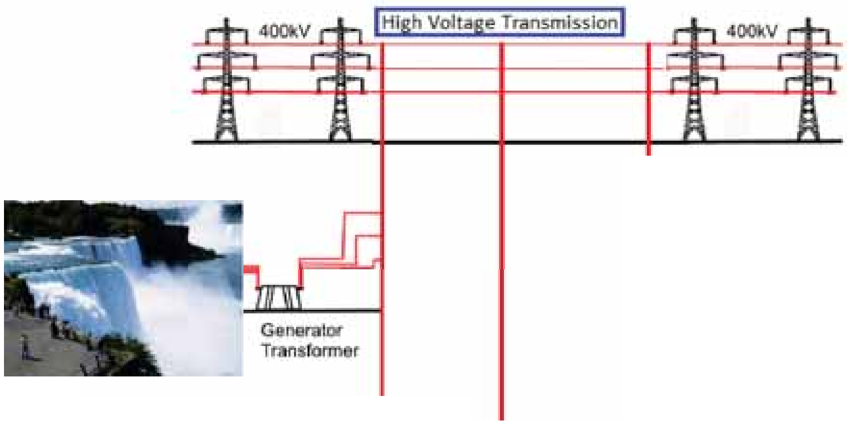
Nikola Tesla´s challenge: first electricity network ever in 1897.

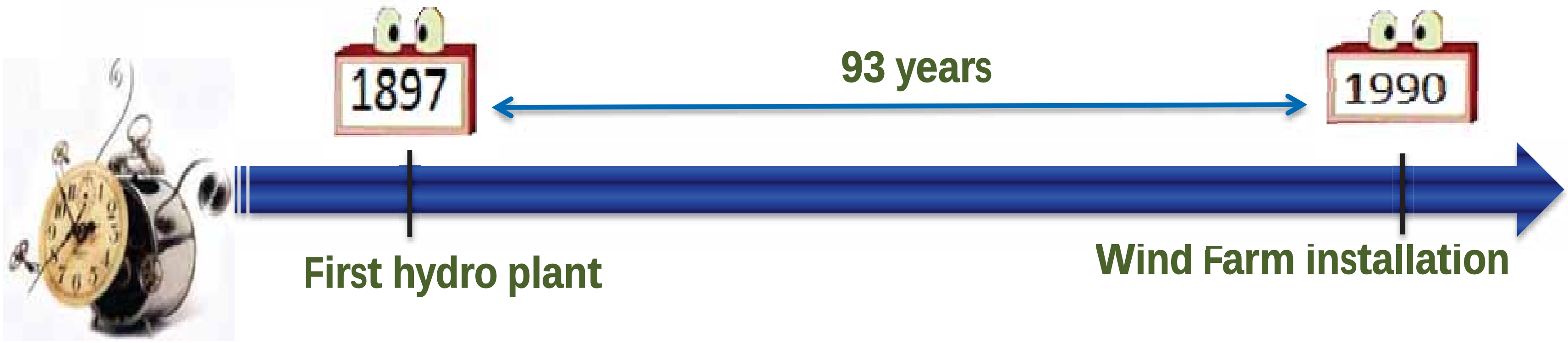


Niagara Falls

Buffalo City

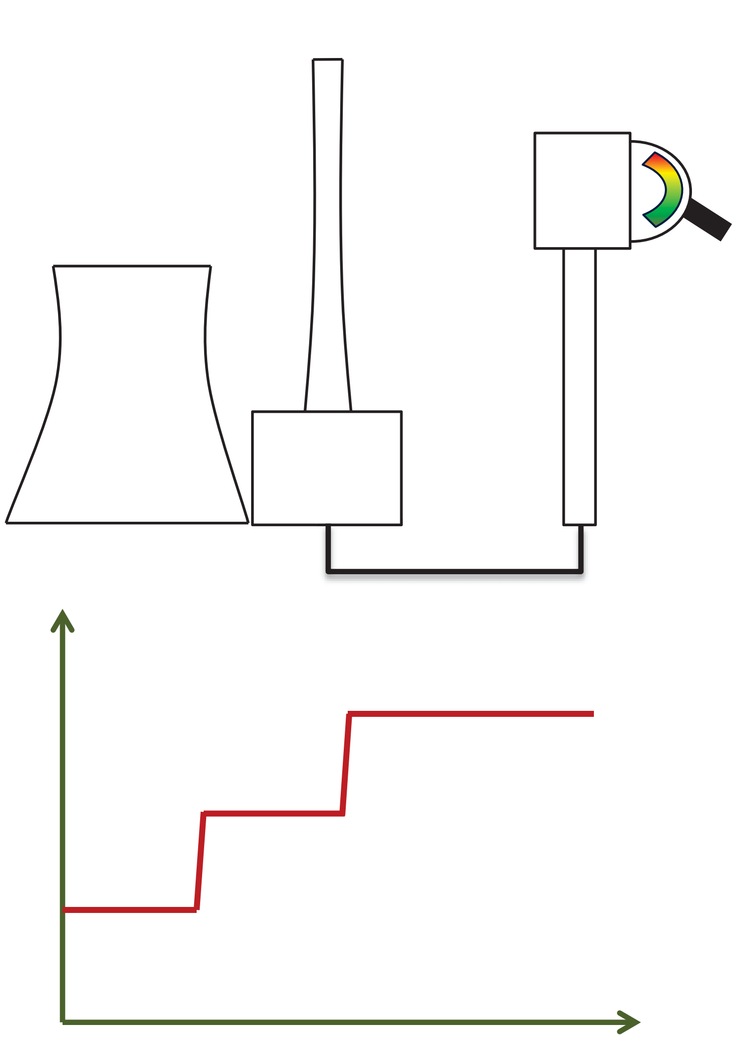
General concepts: Electrical Grid



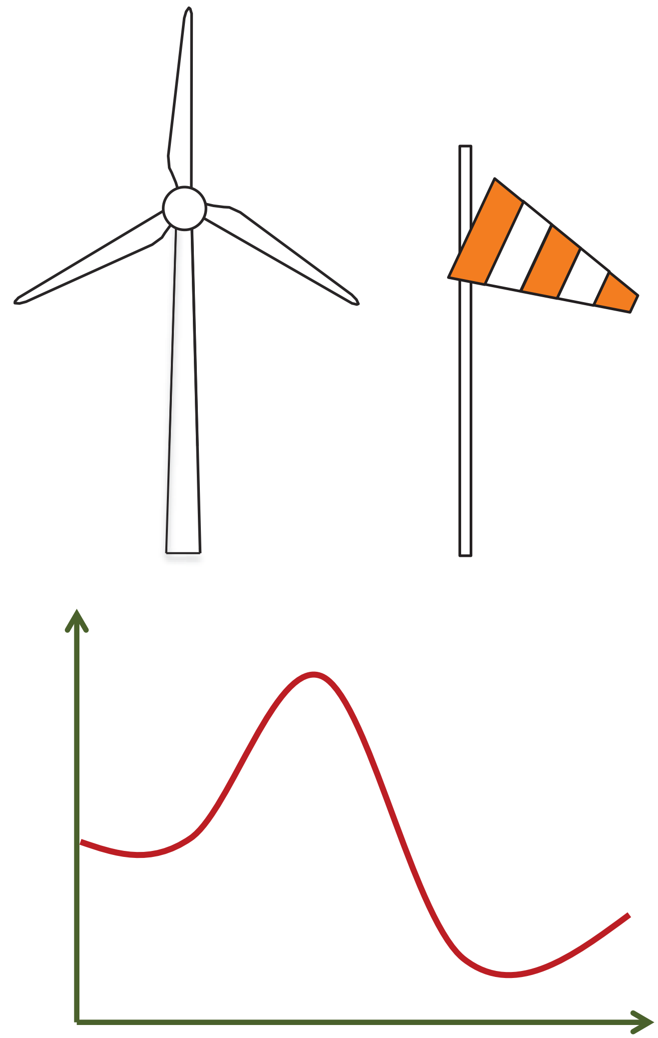


Generation: Dispatchable vs. Variable

Conventional Generation



Wind Generation



General concepts: Electrical Grid

Electricity Networks are complex systems by definition, due to this, sophisticated Control tools must be implemented by TSOs in order to hold grid stability:

- **Keep voltage within certain boundaries**
- **Keep frequency within certain boundaries**

CONTROL CENTERS

TSO

Wind asset operators (CORE → IBERDROLA)

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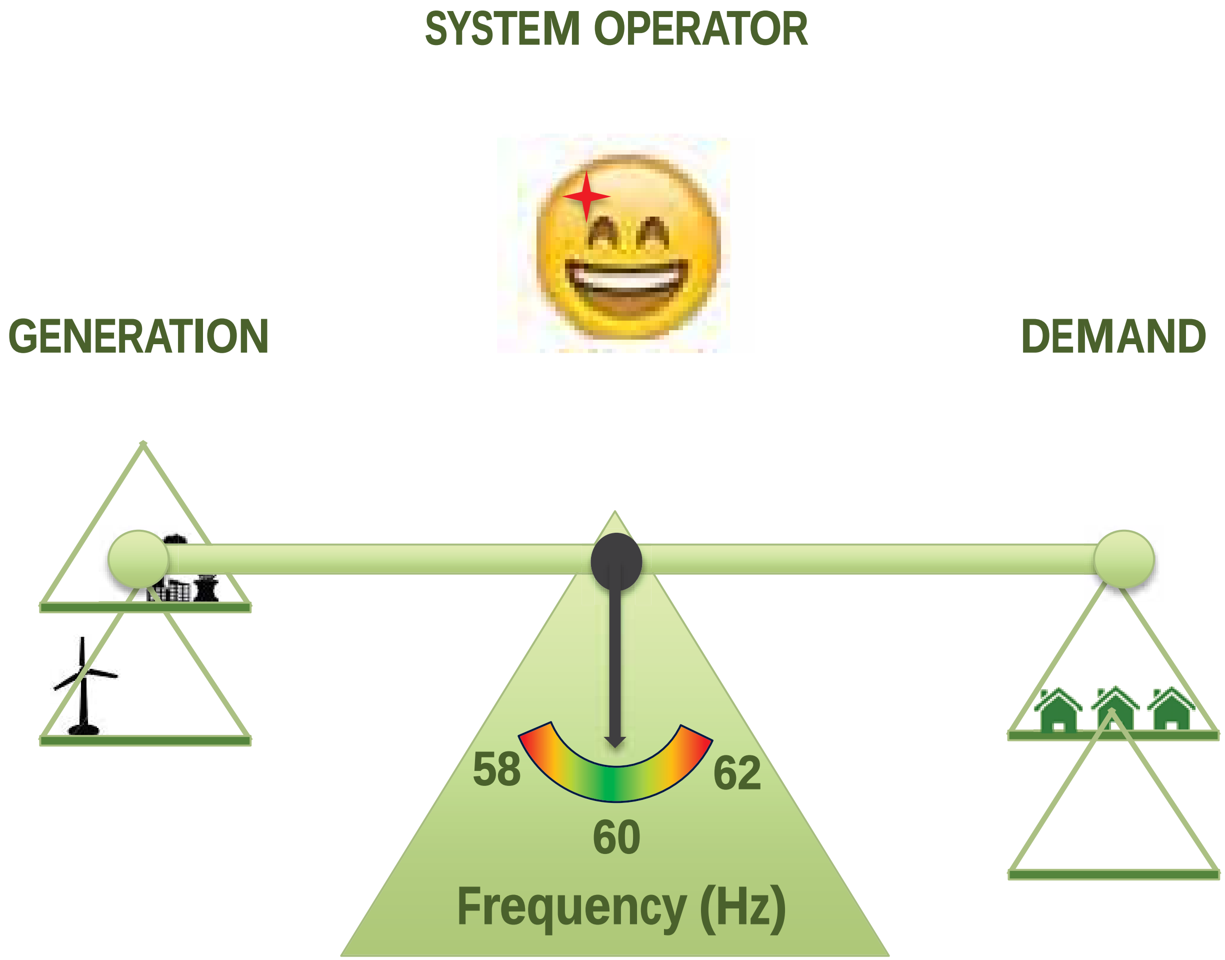
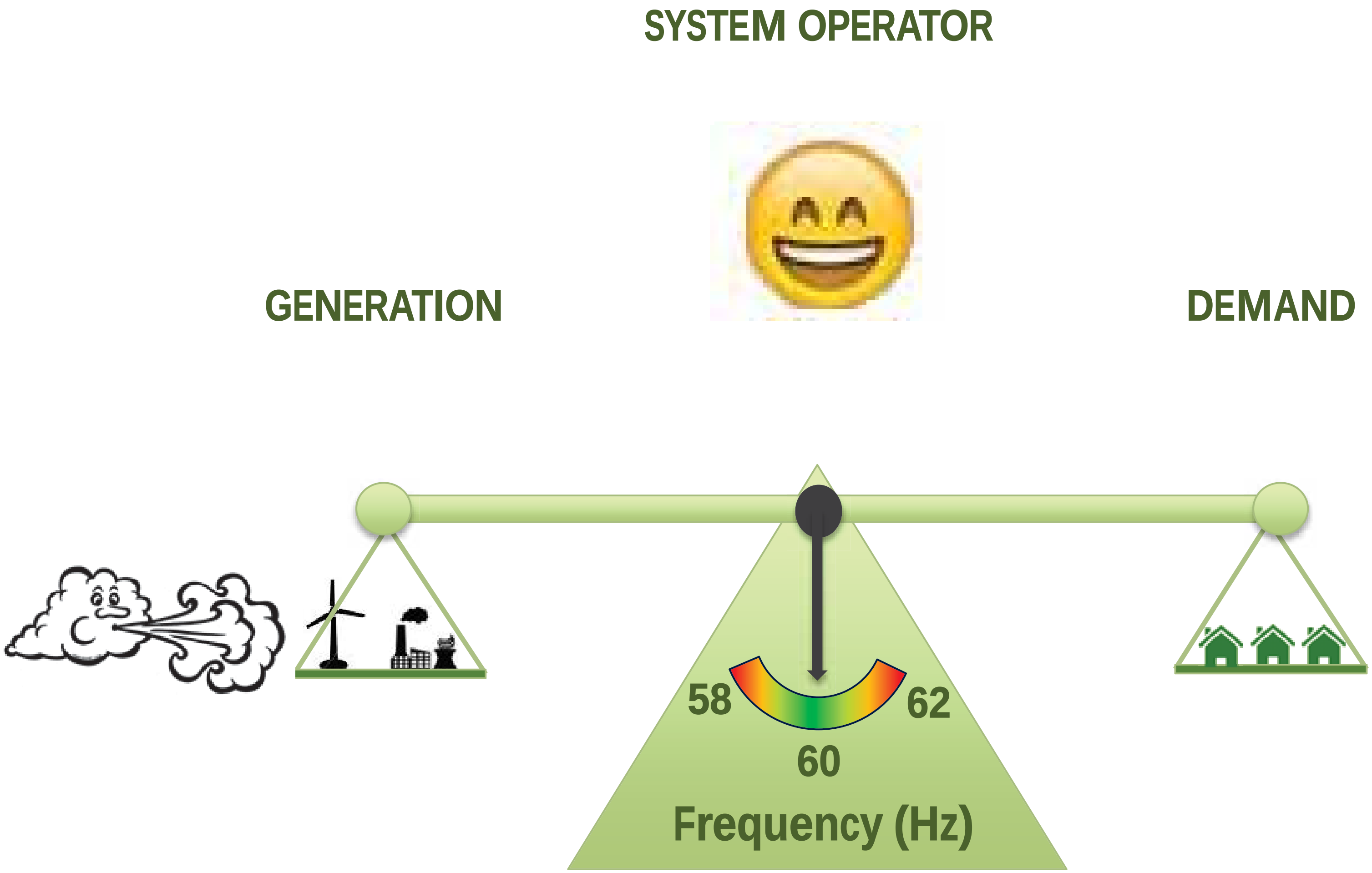
In order to facilitate wind integration in the electric systems and, therefore, maximize variable generation penetration, competing with conventional plants, it is necessary to improve WTG functioning in regards to:

1. **Power control**
   - Dispatchable generation
   - Ancillary services to the TSO
2. **Voltage control**
   - TSO to improve voltage manageability
   - Increase wind penetration

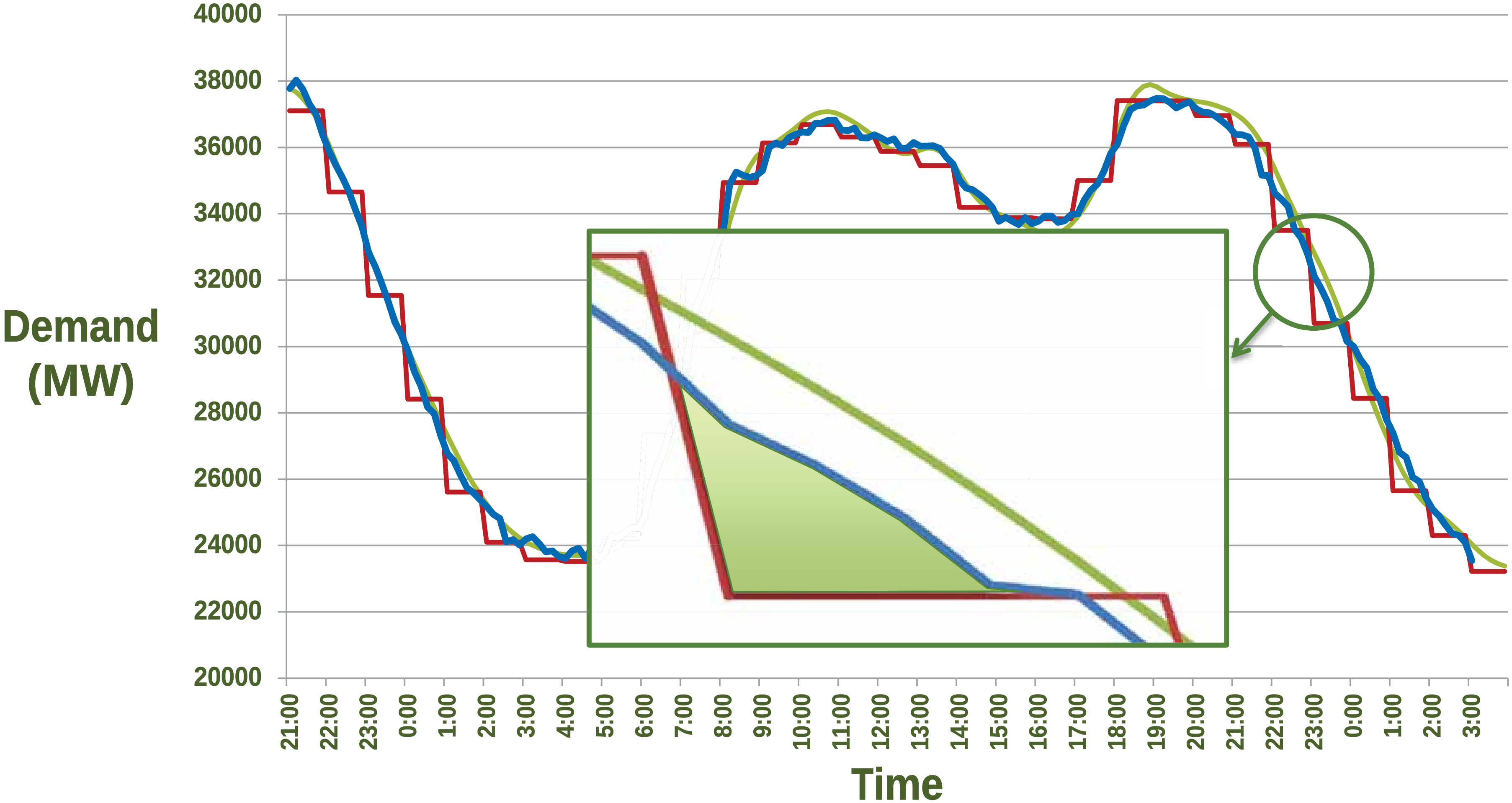
The balance between Demand and Generation



The balance between Demand and Generation



Real-Time generation balancing



Balancing Mechanisms are required to adjust real-time generation

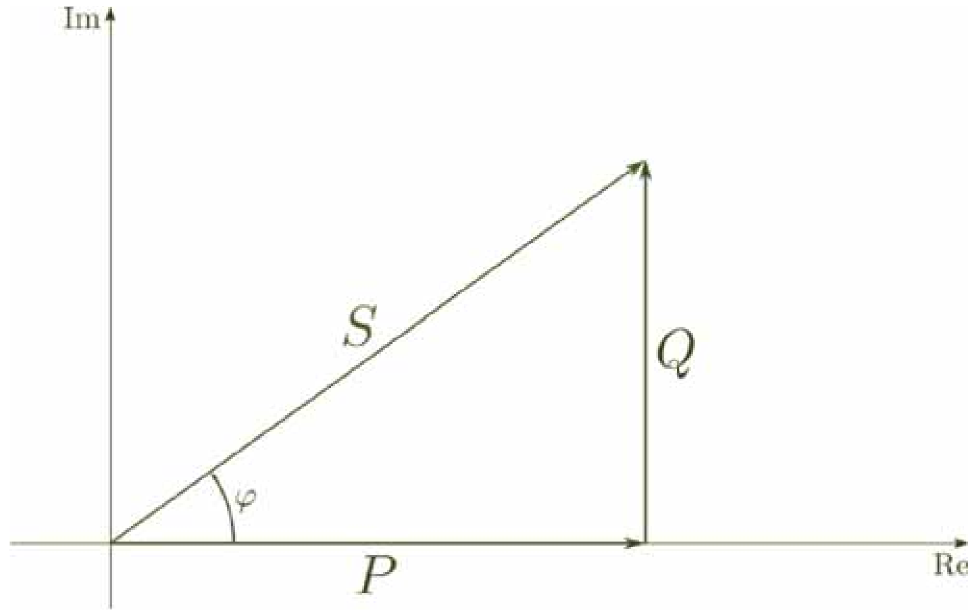
In order to keep demand continuously balanced with generation, three levels of capacity reserves are utilized:

- **Primary Reserve:** very quick response (2 to 15 seconds).
- **Secondary Reserve:** quick response (15 seconds to 15 min).
- **Tertiary Reserve:** slower response (over 10-20 min).

Due to the quick variability of wind, wind energy needs to be backed-up with secondary reserve.

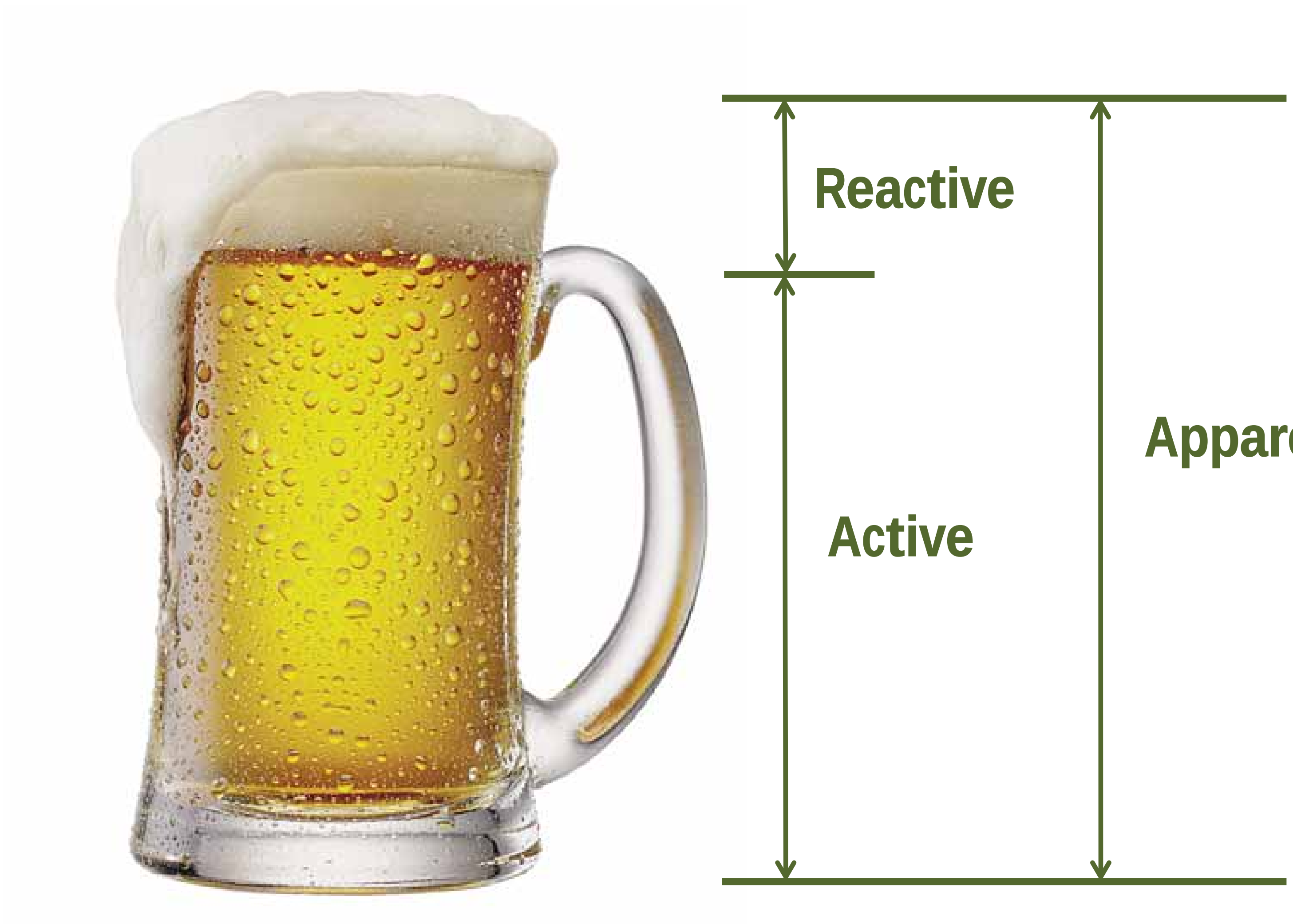
Voltage Control

$$S^2 = P^2 + Q^2$$



- S = apparent power (VA)
- P = real or active power (W) → useful work
- Q = reactive power (VAr) → electromagnetic fields
- Power factor (cos ϕ) → ratio of P to Q

Reactive Power ↔ Active Power

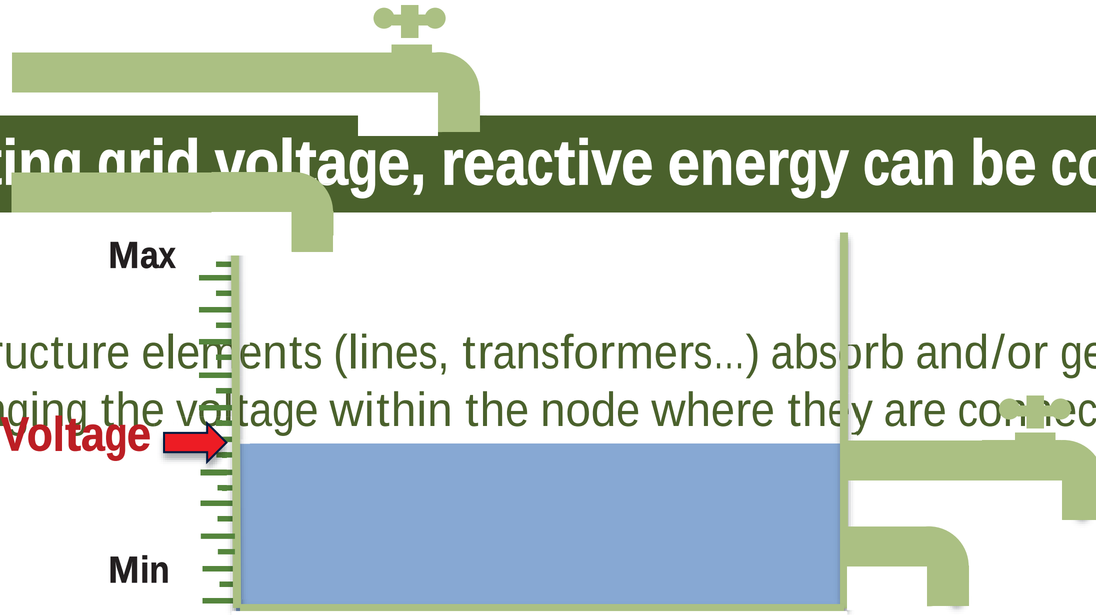


Reactive Power / Voltage Ratio

- Reactive Power in the grid is directly related to voltage. Reactive energy flows from nodes with higher voltage to those with lower voltage.

By setting grid voltage, reactive energy can be controlled

- Grid infrastructure elements (lines, transformers…) absorb and/or generate reactive power, changing the voltage within the node where they are connected.



Main short-term challenges

- **Generally, little challenges across systems at <10% annual shares apart from local 'hot-spots'.**
- **When variable renewables are added to a capacity adequate system:**
  - **Situations of low load and high wind generation**
    - **Wind curtailment if flexibility is insufficient**
    - **Negative market prices due to inflexible generation and renewables support mechanisms**
  - **Grid bottlenecks in regions with high variable density**
    - **Limitations feeding production from the distribution to the transmission grid**
    - **Insufficient evacuation capacity in regions with rapid build out of new wind capacity**

Wind Forecasting

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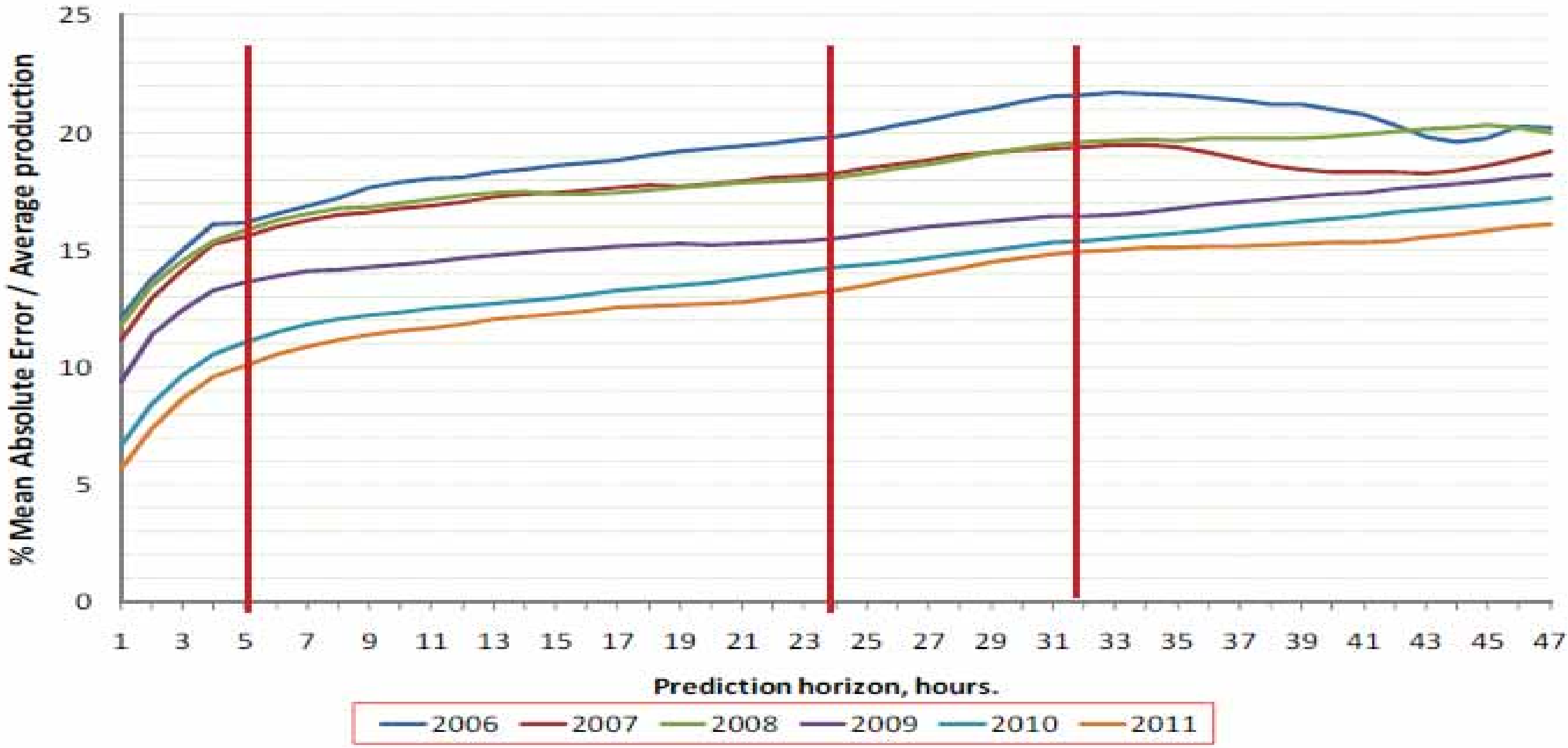
Wind forecasting accuracy above 85%



Forecasting tools have improved continuously during the last years, and are meant to keep improving in the future

Long-term flexibility challenges

Grid infrastructure

Dispatchable generation

Storage

Demand side integration

Flexibility resources

- **Flexible generation:**
  - **Conventional plants and firm renewables adjustable in wide range, very durable, more or less rampable, different lead time and state dependency (nuclear to OCGT)**
  - **Adjustability and durability of wind limited by resource, but within these bounds they are very rampable, little response time, almost no state dependency**
- **Demand Side Integration**
  - **Adjustable (consumption), varying durability, varying rampable, lead time, possibly high state dependency**
- **Storage**
  - **Perfect adjustability, determined durability …**
- **Interconnection**
  - **Can reduce demand and increase supply along all dimensions**

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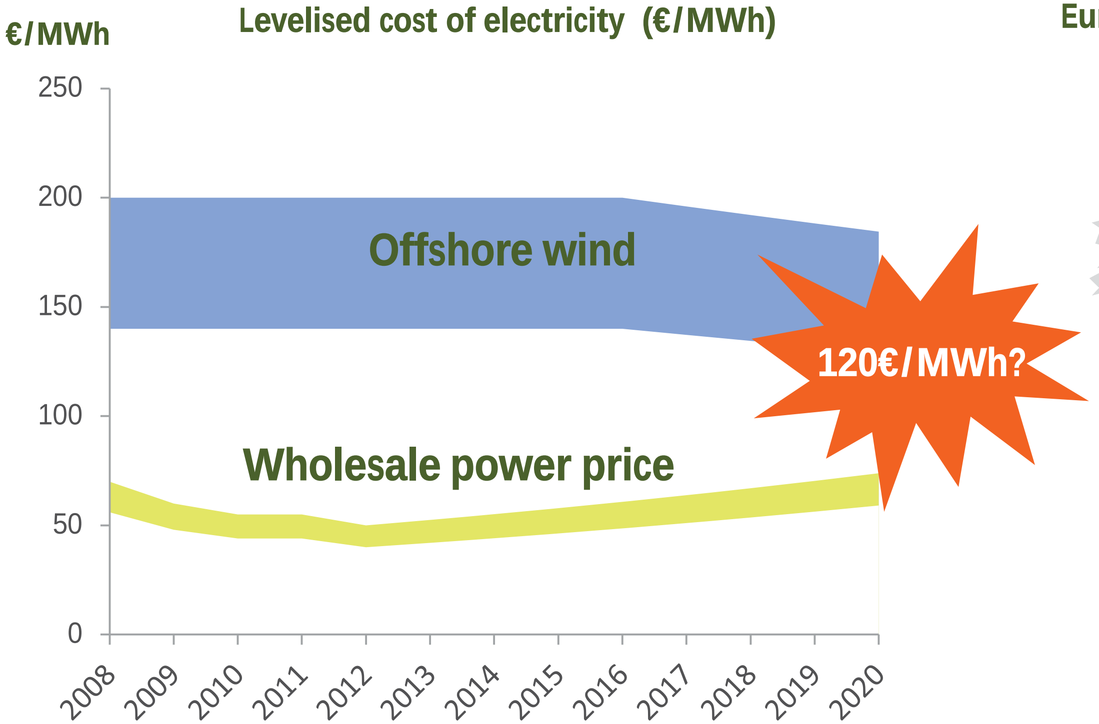
Wind Technology Overview, Market Analysis and Economics

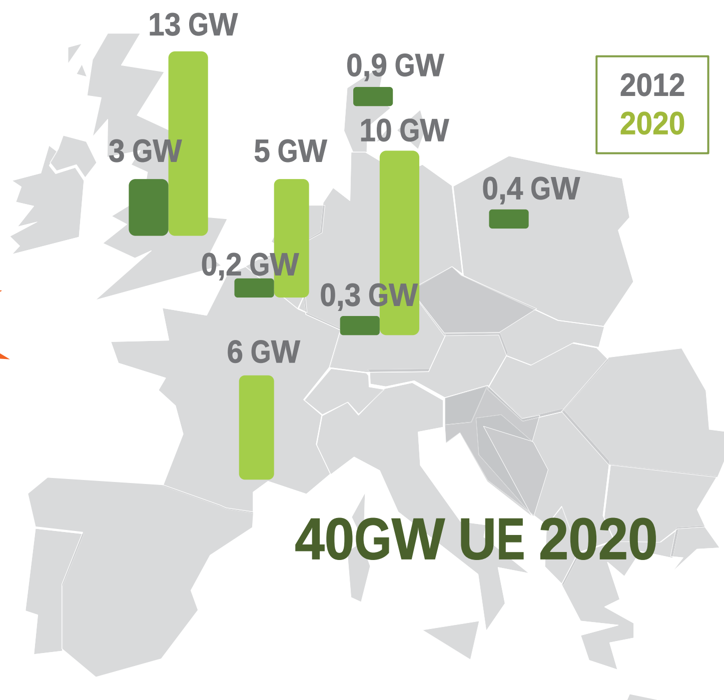
Offshore wind: “make or break”

The industry will have to prove it is capable to reduce costs, or face decline as a non-competitive technology

Levelised cost of electricity (€/MWh)



Europe wind cumulative capacity 2012-2020E (GW)



High pressure to deliver capacity on large scale

Source: IHS, BNEF, Own Estimates

Attracting billions of dollars

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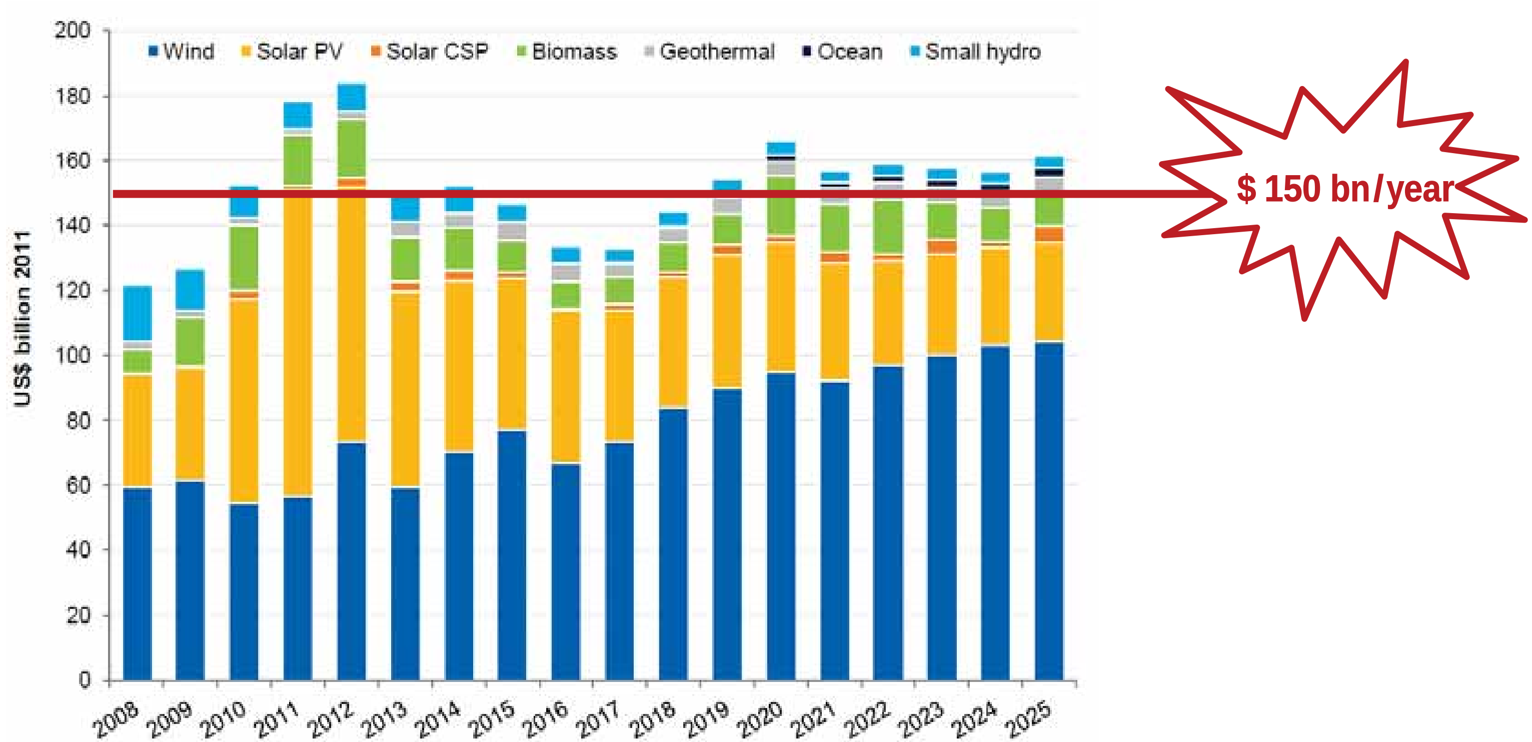
US $150 bn of average annual investment over the next decade

Renewable power investments by technology 2008-2025E



Wind will receive ≈55% of total expected investment; Solar ≈30%

Source: IHS

The effect of the economic crisis…

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In a context of economic difficulties…

- Need to alleviate budget deficits
- Weak electricity demand leading to low electricity prices
- Reductions in bank lending and increased financing costs for projects

…pressure is building up to reduce costs

✓ Governments are reconsidering their priorities

✓ Some countries have announced or already carried out reviews of their renewable support

…leading to regulatory instability

High pressure to limit support for renewables

Reviews of renewables support schemes have been carried out in many markets

Spain: Regulatory moratorium. Elimination of market+premium option and 7% tax to all power generation.

Italy: Switch to tender scheme starting on 2013 and adjustments to solar PV incentives. Unexpected introduction of balancing costs.

Greece: Introduction of new tax on incomes

Bulgaria: Introduction of grid access fees for all installed capacity since 2010. FIT reductions

Germany: Government proposed measures that would reduce incomes both for existing and future installations

Poland: Government proposed measures that would reduce income of existing installations

…challenging renewables growth / whole system stability

Renewables industry facing a turning point

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..... 2000 2013 ?

..... 2000	2013
Early technology deployment of RES	RES technologies maturing fast. Wind most mature renewable technology
Government support driving RES investments	RES generation costs going down
Constant evolution of technology	High penetration levels in many markets
	Massive RES deployment
	Economic crisis . Pressure to limit support for RES
	High costs from solar bubble

Will support mechanisms still be there in the future?

Meeting the challenge of competitiveness

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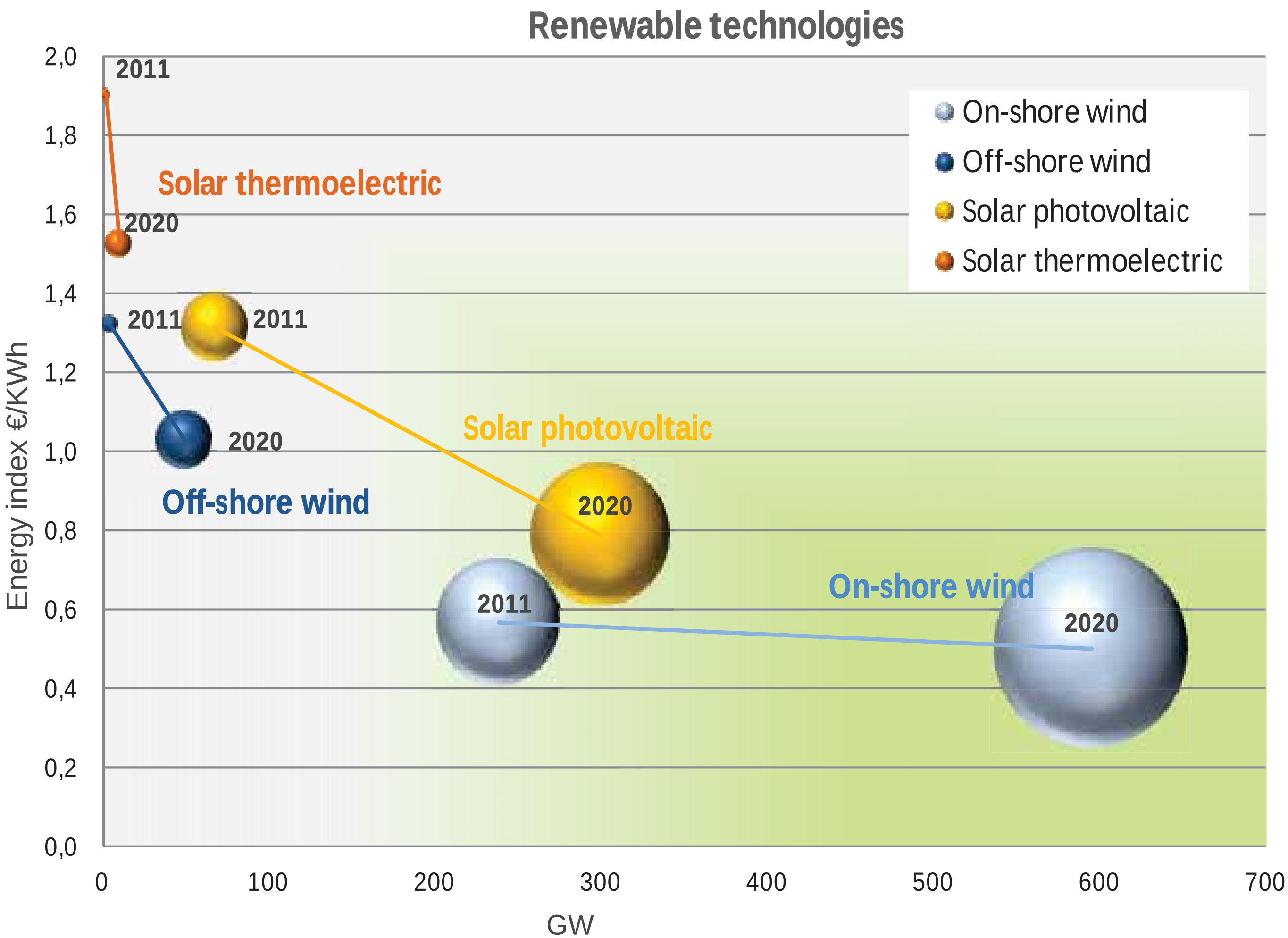
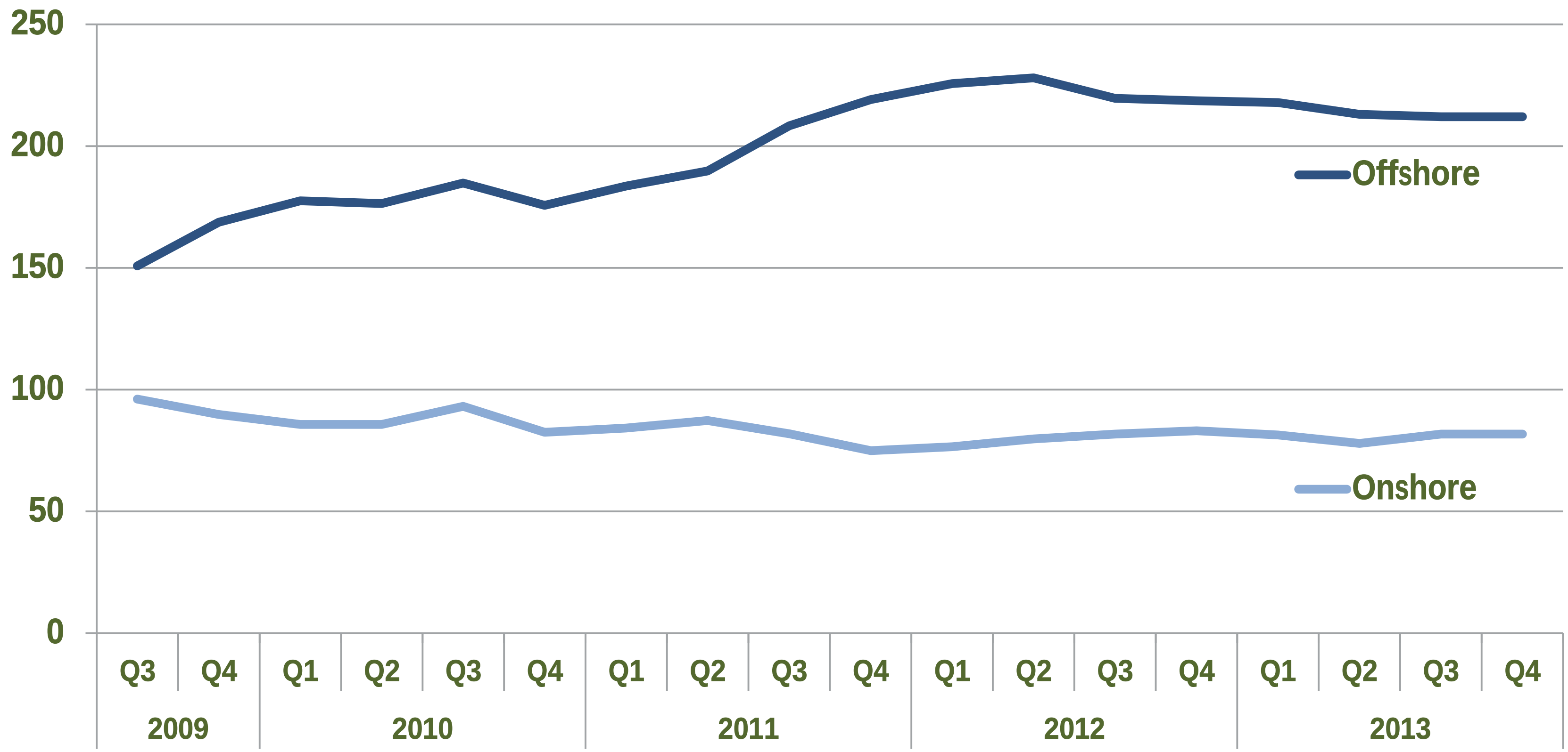
Diverse technology solutions...



Different in terms of..

- **Natural resource availability and growth potential**
- **Efficiency and level of technological maturity**
- **Cost-effectiveness**
- **Integration into the grid and into the system**

Wind – Levelised Cost of Electricity ($/MWh)



Note: Prices are in nominal dollars. Onshore prices are for 'international' turbines as opposed to Chinese-sourced turbines

- **Onshore turbine prices inched up this quarter, resulting in a corresponding increase in our global onshore wind LCOE scenario from $78/MWh to $82/MWh**
- **Offshore wind LCOEs remain stable at $212/MWh, reflecting a scenario for a German offshore farm costing $5.9m/MW and producing at a capacity factor of 42%**

Source: Bloomberg New Energy Finance

Economic sustainability → cost effectiveness

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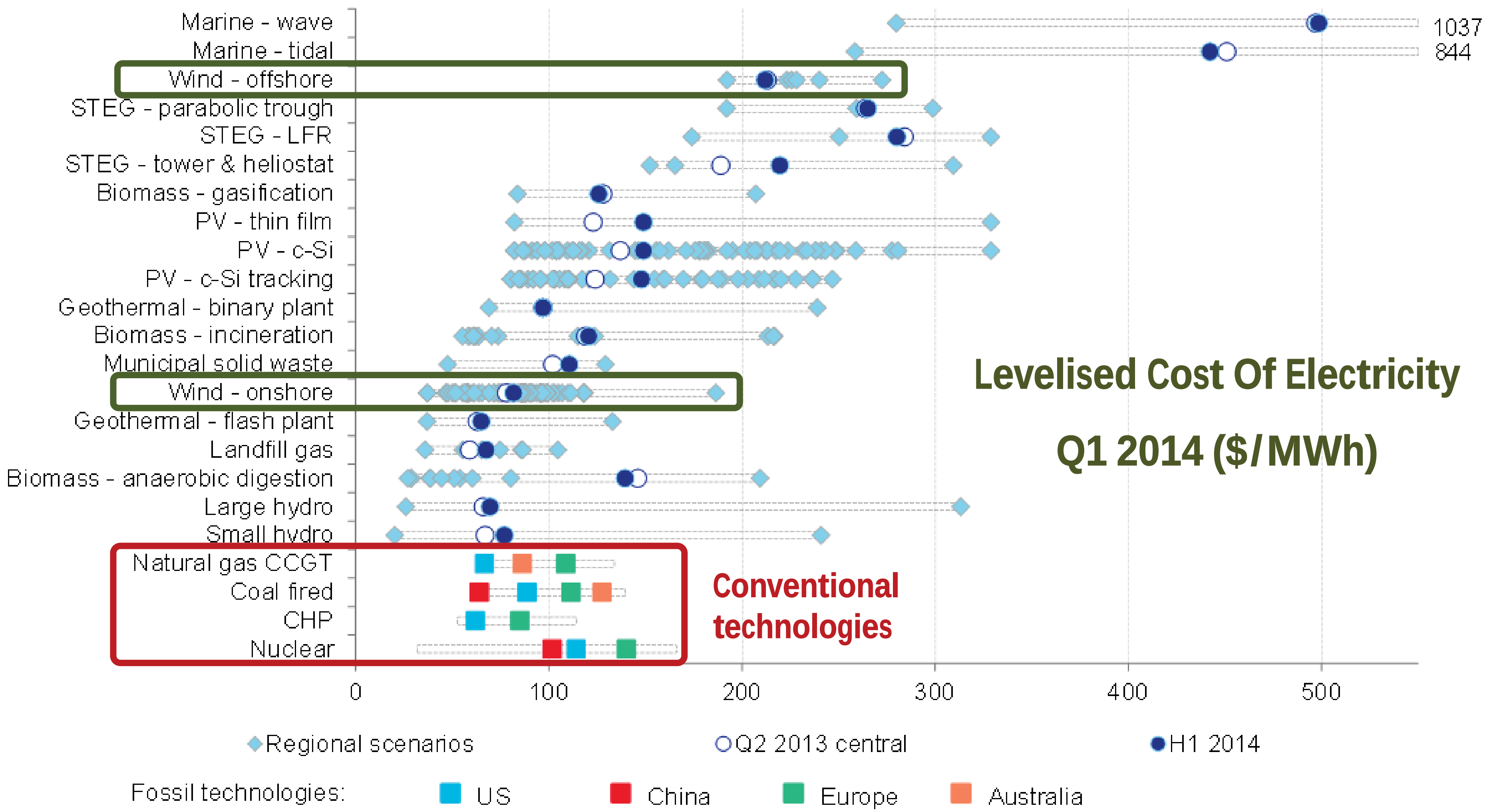


Note: LOCEs for coal and CCGTs in Europe and Australia assume a carbon price of $20/MWh. No carbon prices are assumed for China and US.

Onshore wind is close to competitiveness

Source: Bloomberg New Energy Finance

Classic approach

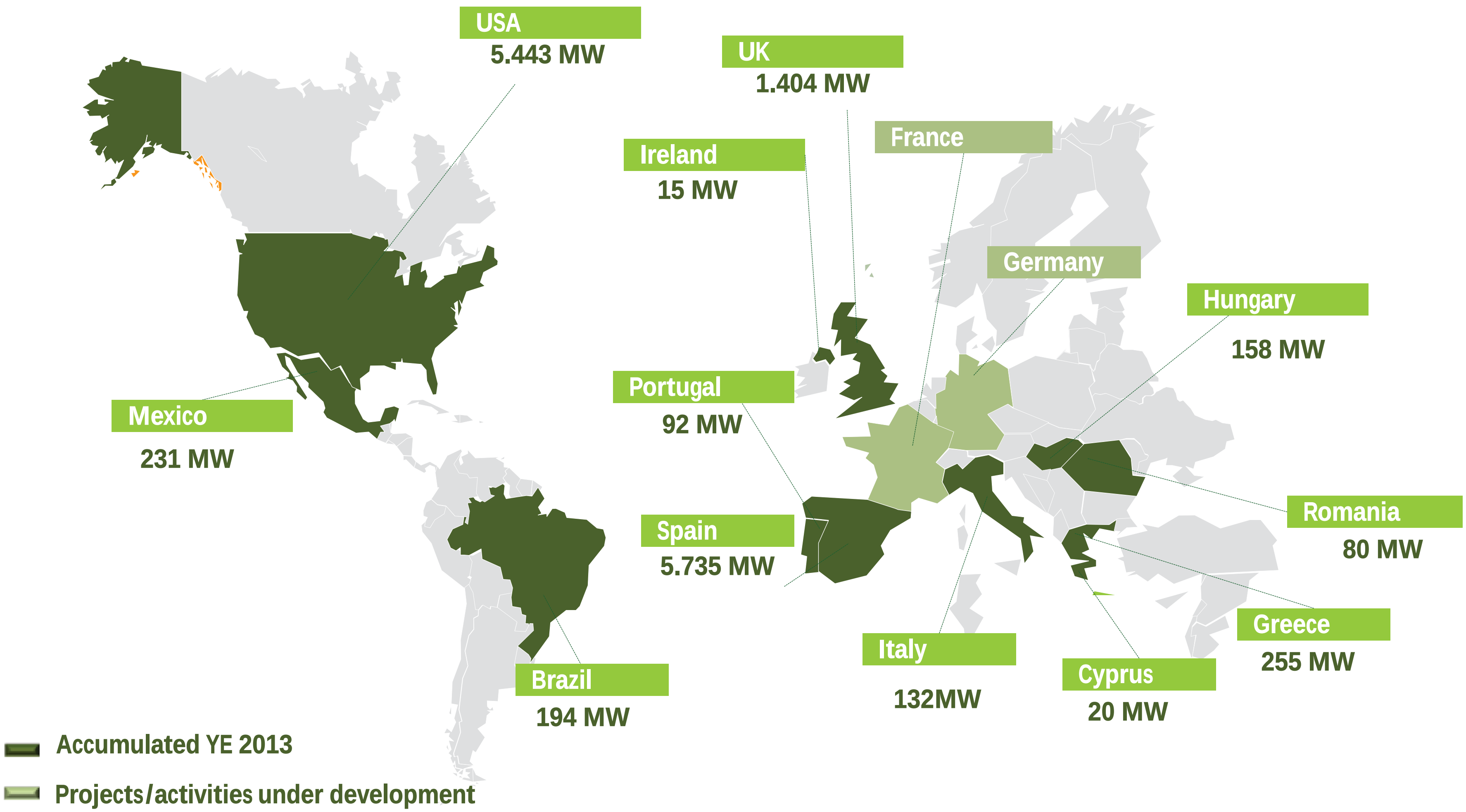
Large renewable developers have typically followed simple business growth approaches:

- Organic and inorganic wind/renewable assets growth
- Greenfield development
- Tendering processes
- Build-to-sell
- Operation and maintenance

TYPICAL SOURCES OF REVENUE

Iberdrola´s renewable assets worldwide

Present in 14 countries with 14 GW of operating wind assets



As of YE 2013

Renewable business growth

There are positive expectations for the growth of renewables worldwide in the following years

- Competitiveness of renewables, specially onshore wind and PV (Grid/Market parity)
- Replacement of old capacity for developed countries
- New capacity required for emerging markets
- Growing interest from institutional investors in renewables

Renewable energies will grow during the next decade

NEW SOURCES OF REVENUE

The expected growth will require expertise to allow an efficient and sustainable development

Renewable solutions provider

A new perspective is addressed by traditional renewables developers, providing technical support as a consultancy firm, as a developer or as an asset manager

Regulatory issues

- ✓ Support of the development of pieces of regulation for renewables

Development of new assets

- ✓ Support of the development of new assets

Assets management

- ✓ Applying the tools developed in-house and the expertise coming from vast experience in managing own assets

IFC - ESMAP - RENEWABLE ENERGY TRAINING PROGRAM

Q & A

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Washington DC, June 16th 2014