



Wind – challenges, opportunities, and PCS

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Vestas

Vestas

Industry Perspective

Challenges & Opportunities

PCS in Wind

...if I had more time, I would have written a shorter letter...Goethe

Vestas:
The largest wind turbine manufacturer in the world

TOP 10 GLOBAL WIND MANUFACTURERS 2005, 2010 (RANK ORDER BY PRODUCTION)

2005			+25% per year	2010		
Company	Country	Production (GW)	Company	Country	Production (GW)	
1. Vestas	Denmark	3.2	1. Vestas	Denmark	6.3	
2. Enercon	Germany	2.7	2. GE Wind	US	6.0	
3. Gamesa	Spain	1.9	3. Sinovel	China	5.3	
4. GE Wind	US	1.3	4. Gamesa	Spain	4.4	
5. Siemens	Denmark	1.1	5. Goldwind	China	3.6	
6. Suzlon	India	0.9	6. Suzlon	India	3.5	
7. Repower	Germany	0.9	7. Enercon	Germany	3.4	
8. Goldwind	China	0.7	8. Dongfang	China	3.0	
9. Nordex	Germany	0.5	9. Repower	Germany	2.9	
10. Ecotecnica	Spain	0.3	10. Nordex	Germany	2.4	

■ Europe
 ■ US
 ■ China
 ■ Other Asia

Vestas in Top 10 Markets

Ranking

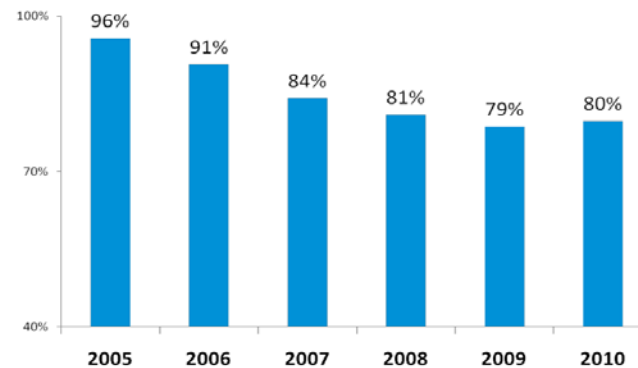
Market	MW	No. 1	No. 2	No. 3
China	18,928	Sinovel	Goldwind	Dongfang
USA	5,115	GE Wind	Vestas	Siemens
India	2,139	Suzlon Group	Enercon-India	Vestas
Germany	1,551	Enercon	Vestas	Suzlon Group
UK	1,522	Siemens	Vestas	Gamesa
Spain	1,516	Gamesa	Vestas	GE Wind
France	1,186	Enercon	Suzlon Group	Vestas
Italy	948	Gamesa	Vestas	Suzlon Group
Canada	690	Siemens	GE Wind	Enercon
Sweden	604	Vestas	Enercon	Siemens

Source: BTM Consult – part of Navigant Consulting – March 2011

Source: Bloomberg New Energy Finance

Market share of top 10 suppliers

Per cent



Source: BTM Consult – part of Navigant Consulting – March 2011

Wind. It means the world to us.™

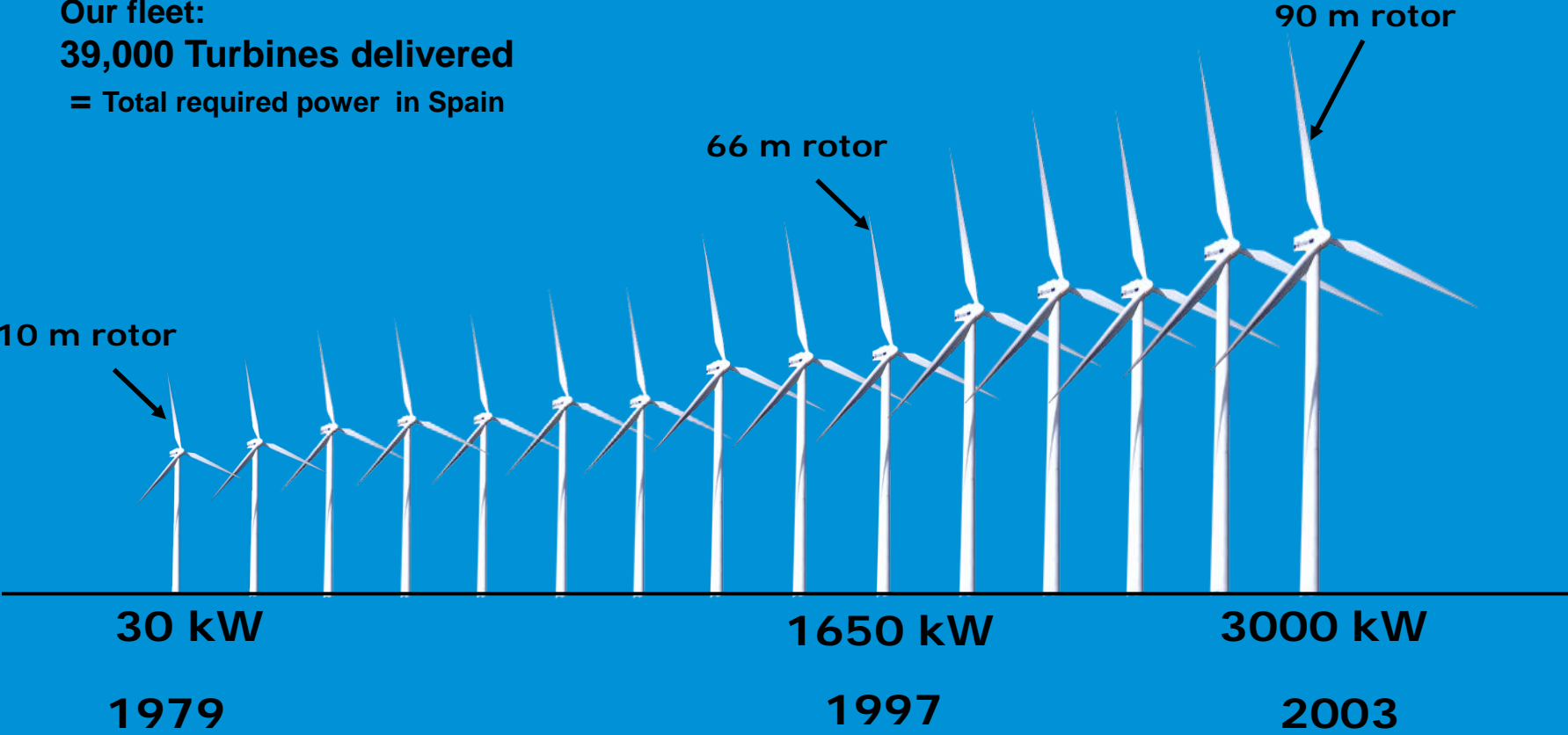
On the way up...

On the way *not* up...

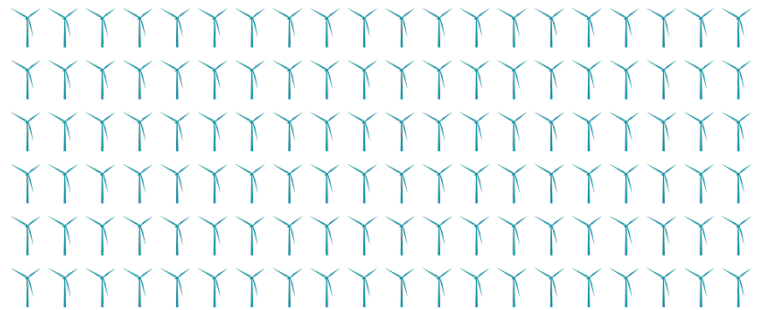
bigger was better...

Over the last 25 years, the output of a single Vestas turbine increased 100x – total annual energy increased 330x

Our fleet:
39,000 Turbines delivered
= Total required power in Spain



Today one turbine produces 3000 kW

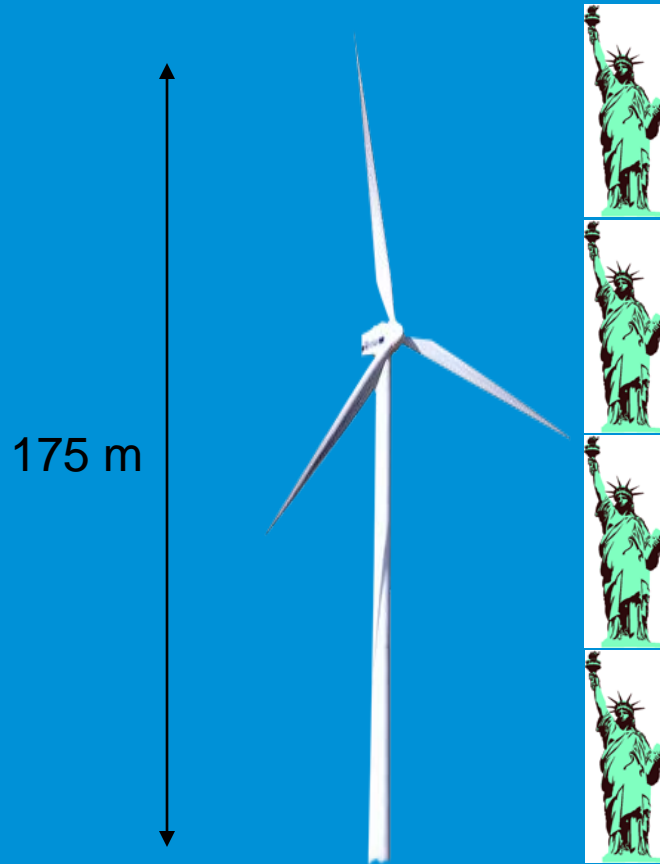


25 years ago, this was 3000 kW

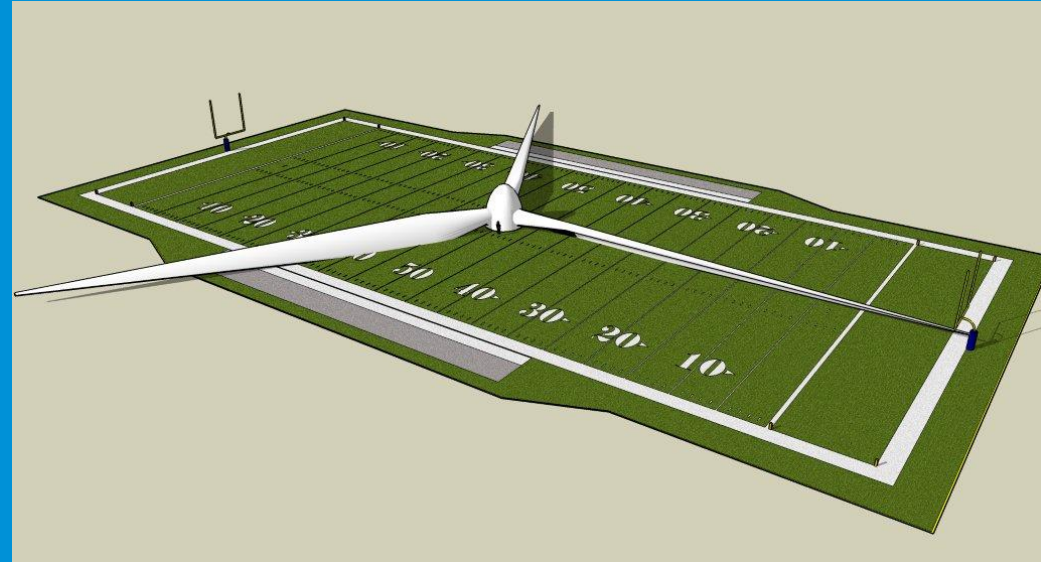


Today, 1 turbine is enough

One V112 = 3.8 Statues of Liberty...



...and its rotor alone won't fit in a football field



How big will be the recently announced V164?



164m

V-164 7MW – rotor diameter: 164m

Airbus A380 – wingspan: 80 m, length: 73m

London Eye – diameter : 135m.

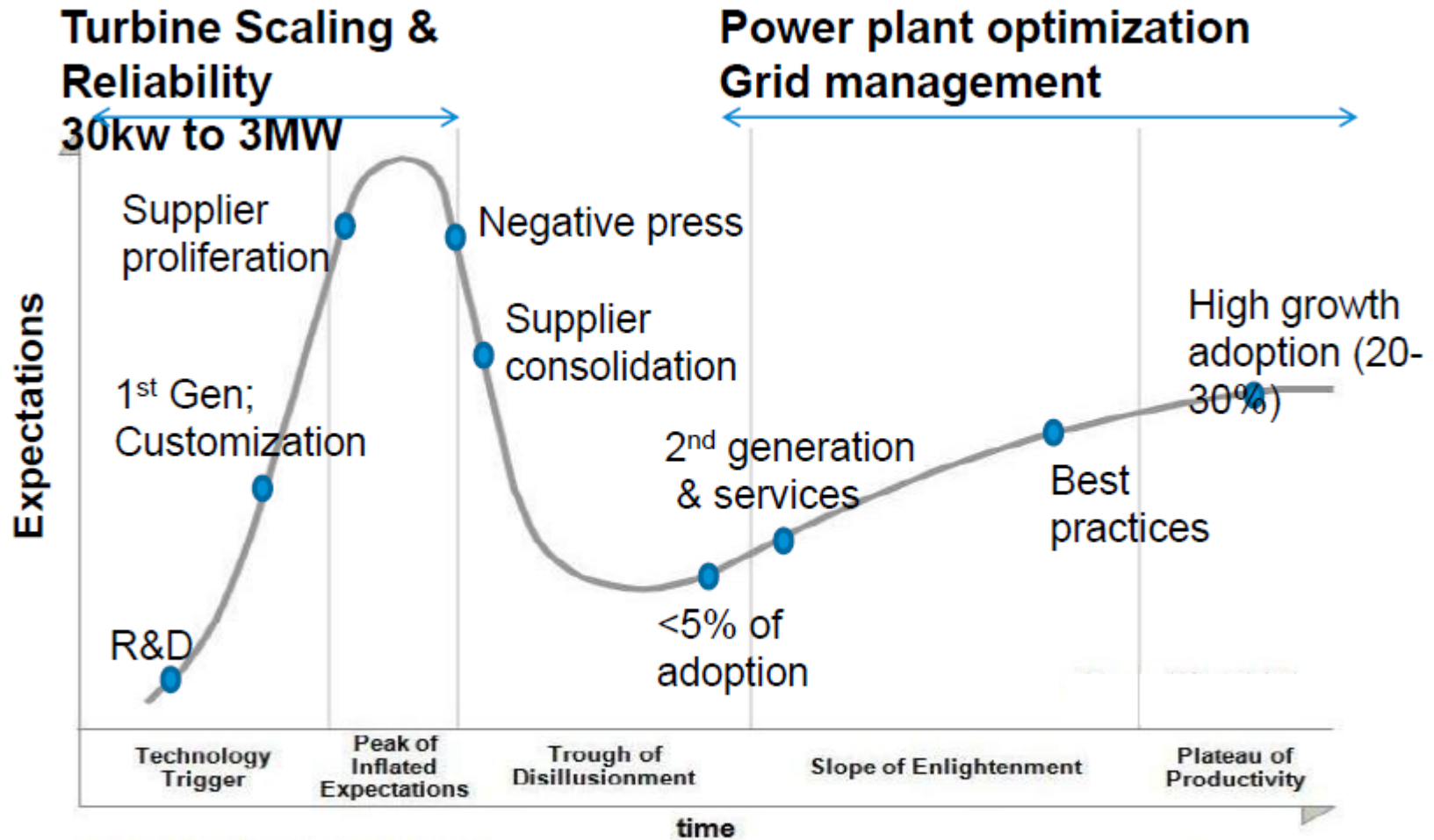
On the way up...

On the way *not* up...

participants becoming mature...

policy assistance shrinking...

The curve of maturity...



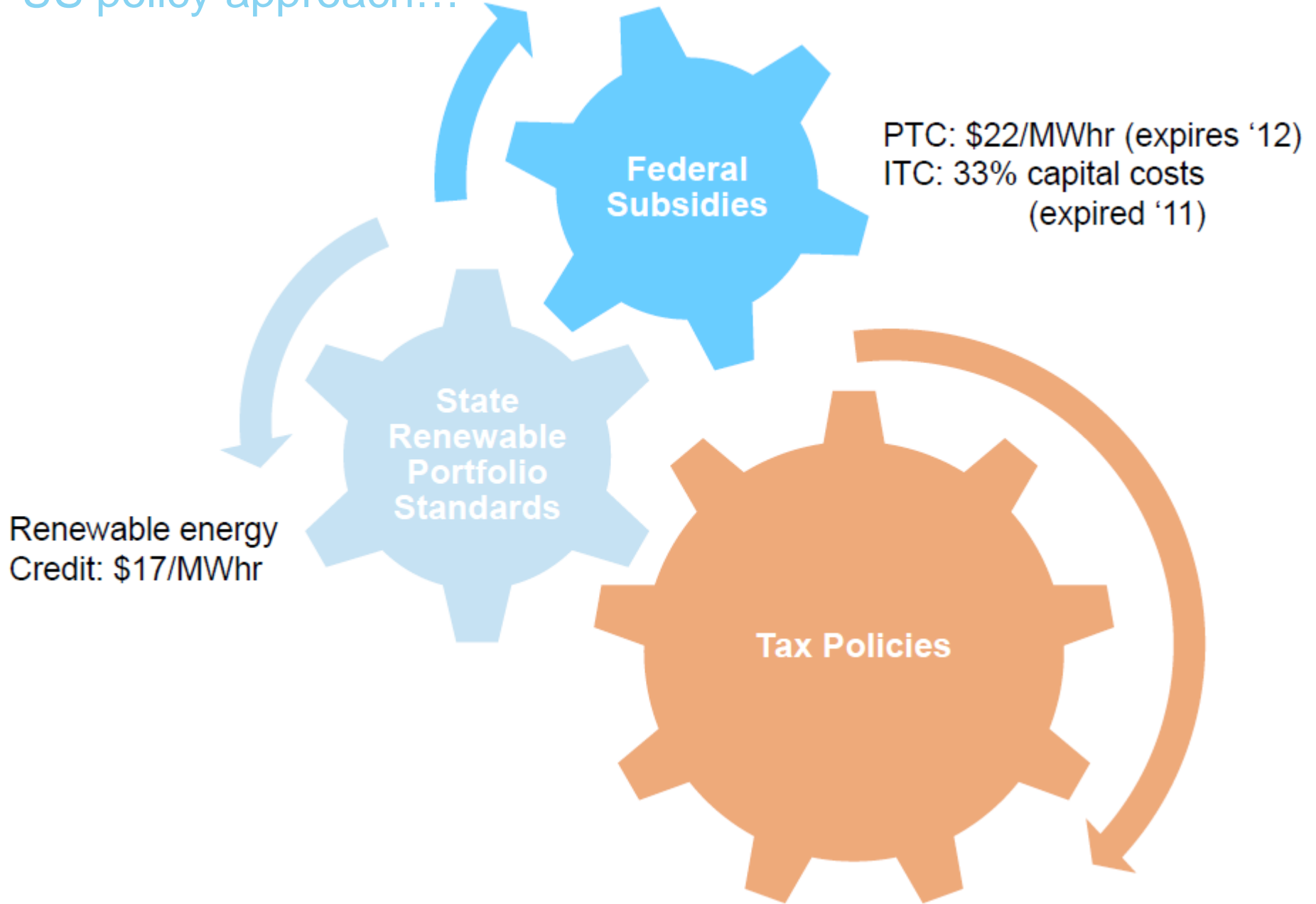
Source: Gartner's hype cycle



“Prostitution, horse racing, gambling and electricity are irresistible to politicians.”

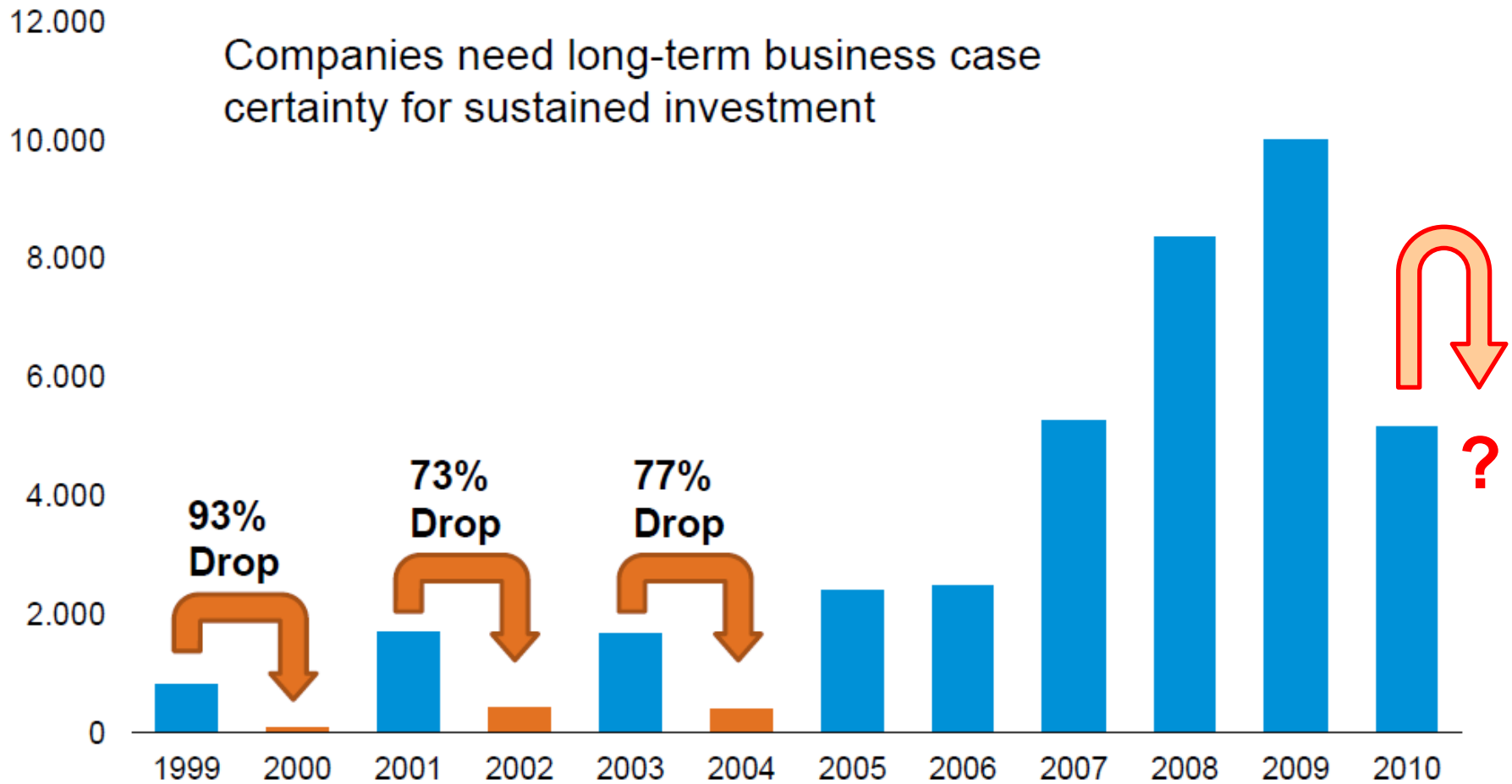
John Rowe, CEO of Chicago-based utility Exelon
Wall Street Journal, Oct. 22, 2011

US policy approach...



Effects to the business...

Annual Wind Installed [MW]



Source: AWEA

Challenges with Wind

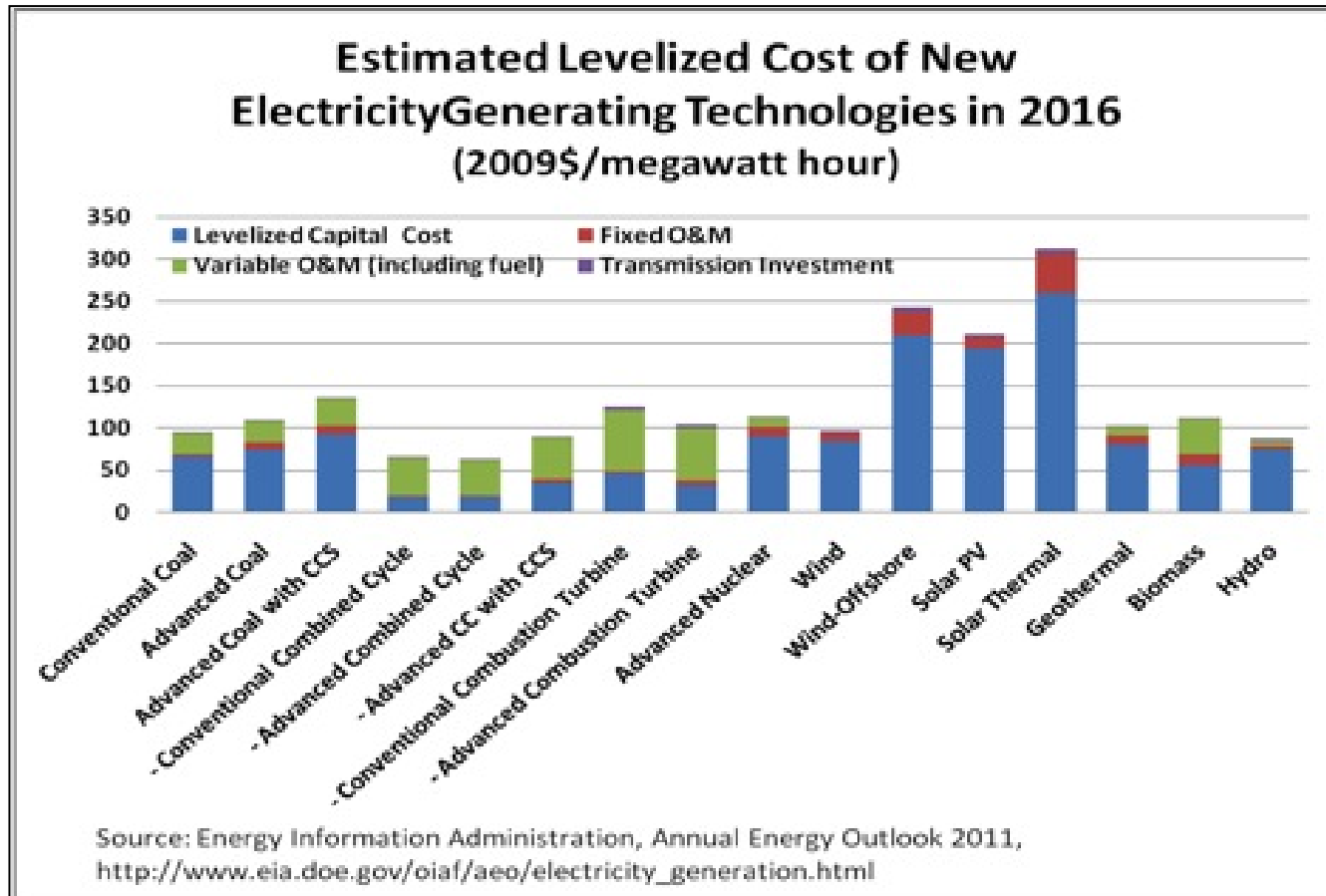
comparative LCOE

Opportunities with Wind

variability at grid interface

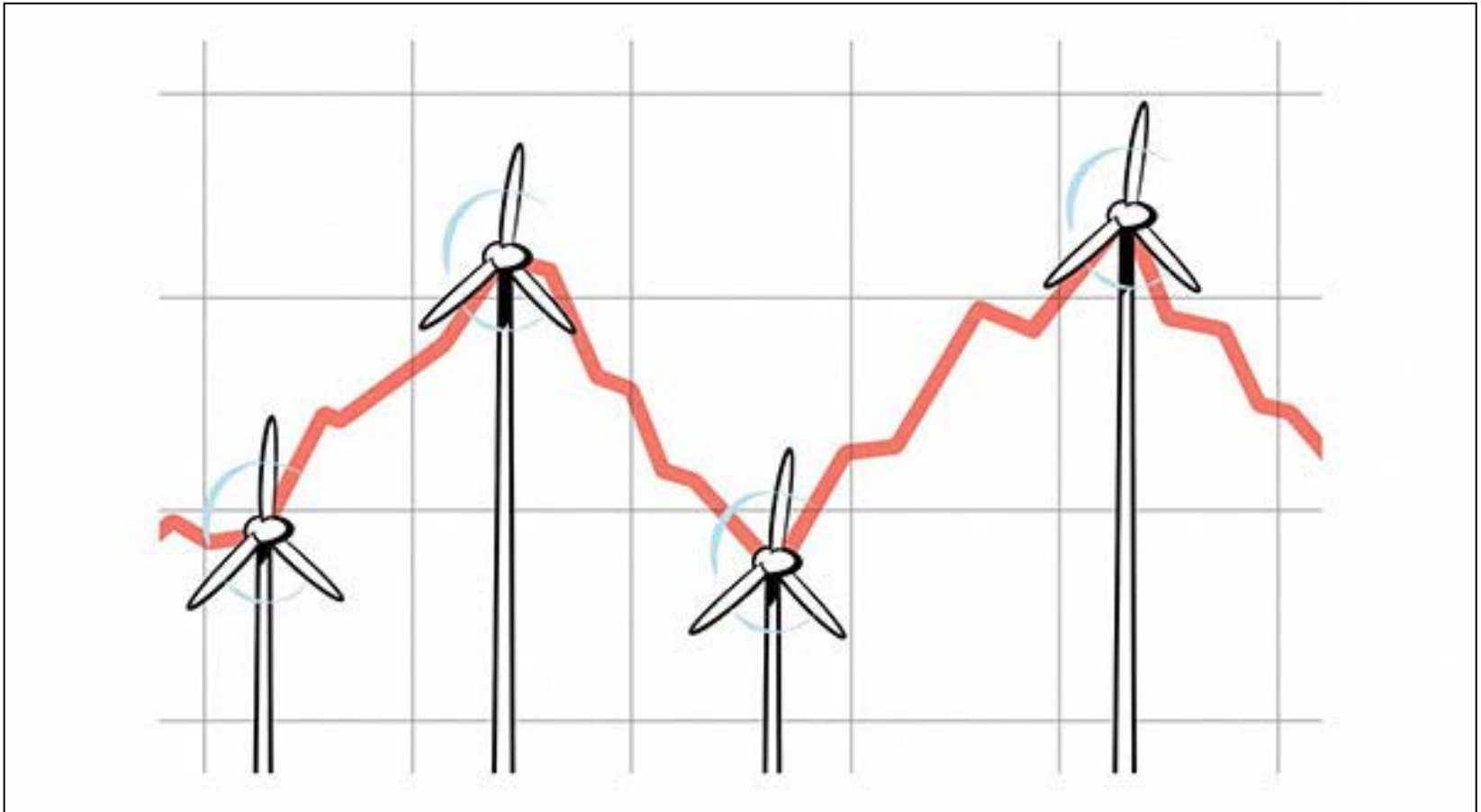
- Impediments for wide proliferation of wind assets are cost of wind generation (capital and maintenance), and risks associated with variability of wind (intermittency and unpredictability)

Challenge 1: Levelized Cost of Energy



- Wind industry participants have been focused on selling turbines in the PPA market
- Financial models are based on double digit EBIT through high contribution margins
- Elimination/reduction of PTC for renewable generation will limit contribution margins
- Way to profitability will be in making wind LCOE (w/o PTC) less than LCOE with gas
- Falling gas prices will further challenge competitive advantage w/ wind generation

Challenge 2: Variability at Grid Interface

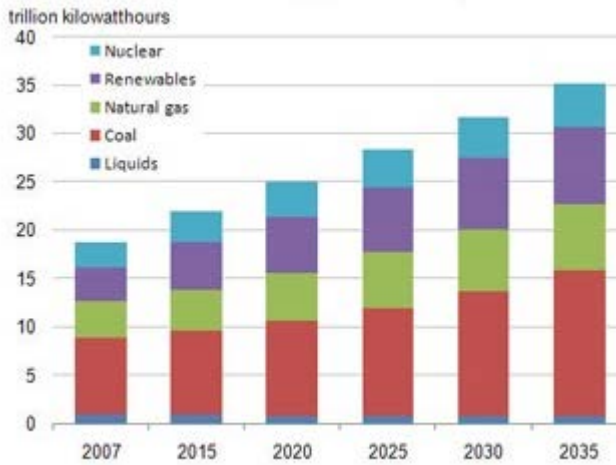


- Variability at grid interface is caused due to intermittency and unpredictability of wind
- Improved forecasting techniques quantify/limit the risks associated with variability
- Energy storage relieves short term variability, however increases system costs
- Low cost, high efficiency transmission (e.g. HVDC) further balances variability at grid

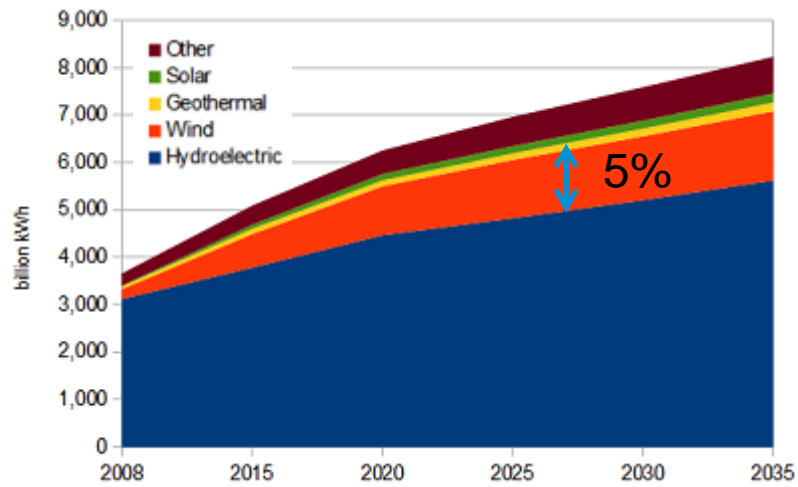
Challenges with Wind

Opportunities with Wind

reaching 20% proliferation



Source: EIA



Challenges

competitive LCOE

5%

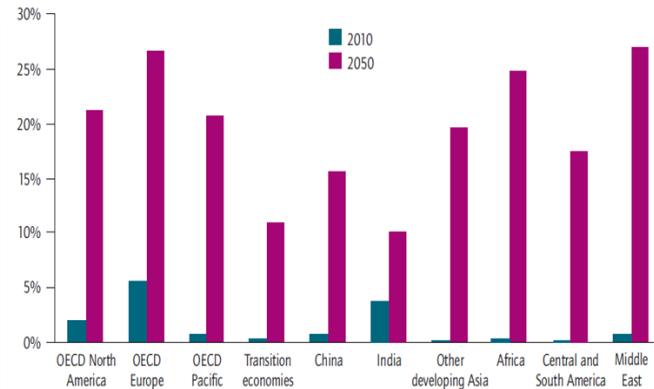
Opportunities

variability at grid interface

power transmission barriers

smart grid integration

15%



Source: IEA, 2010.

Besides cost of wind generation that will gain 5% market, impediments for wider (20%) proliferation of wind assets are variability of wind (unpredictability and intermittency), barriers for transmission (transportability), and compliance with smart grid infrastructure

PCS in Wind

components of a turbine

PCS in turbine

PCS in storage interface

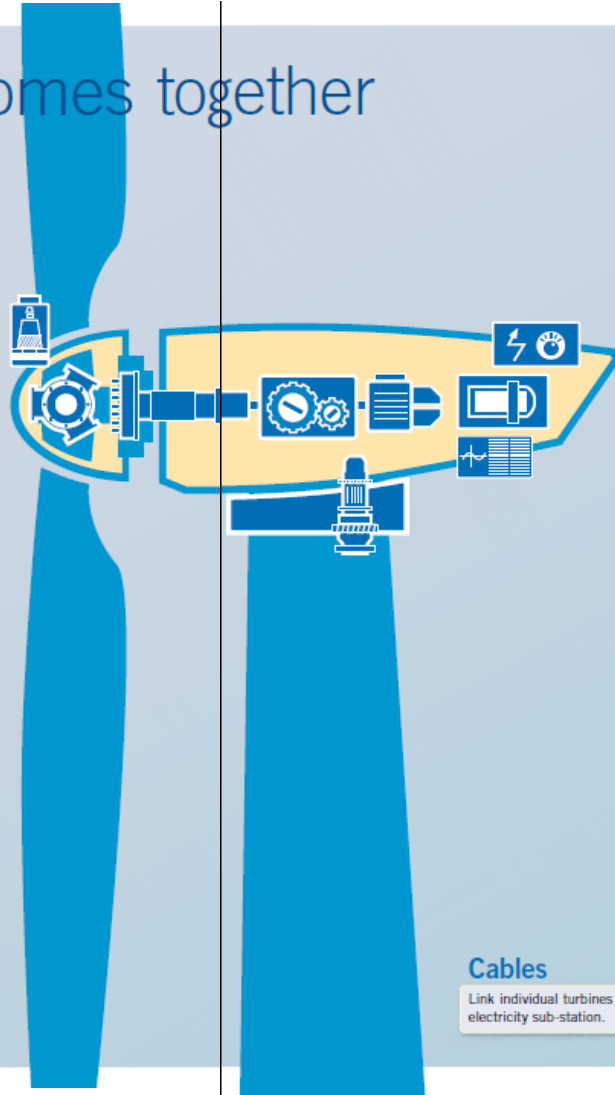
PCS in energy collection

PCS in power transmission

Components of a turbine...

How a wind turbine comes together

A typical wind turbine will contain up to 8,000 different components. This guide shows the main parts and their contribution in percentage terms to the overall cost. Figures are based on a REpower MM92 turbine with 45.3 metre length blades and a 100 metre tower.



Tower 26.3%
Range in height from 40 metres up to more than 100 m. Usually manufactured in sections from rolled steel; a lattice structure or concrete are cheaper options.

Rotor blades 22.2%
Varying in length up to more than 60 metres, blades are manufactured in specially designed moulds from composite materials, usually a combination of glass fibre and epoxy resin. Options include polyester instead of epoxy and the addition of carbon fibre to add strength and stiffness.

Rotor hub 1.37%
Made from cast iron, the hub holds the blades in position as they turn.

Rotor bearings 1.22%
Some of the many different bearings in a turbine, these have to withstand the varying forces and loads generated by the wind.

Main shaft 1.91%
Transfers the rotational force of the rotor to the gearbox.

Main frame 2.80%
Made from steel, must be strong enough to support the entire turbine drive train, but not too heavy.

Gearbox 12.91%
Gears increase the low rotational speed of the rotor shaft in several stages to the high speed needed to drive the generator

Generator 3.44%
Converts mechanical energy into electrical energy. Both synchronous and asynchronous generators are used.

Yaw system 1.25%
Mechanism that rotates the nacelle to face the changing wind direction.

Pitch system 2.66%
Adjusts the angle of the blades to make best use of the prevailing wind.

Power converter 5.01%
Converts direct current from the generator into alternating current to be exported to the grid network.

Transformer 3.59%
Converts the electricity from the turbine to higher voltage required by the grid.

Brake system 1.32%
Disc brakes bring the turbine to a halt when required.

Nacelle housing 1.35%
Lightweight glass fibre box covers the turbine's drive train.

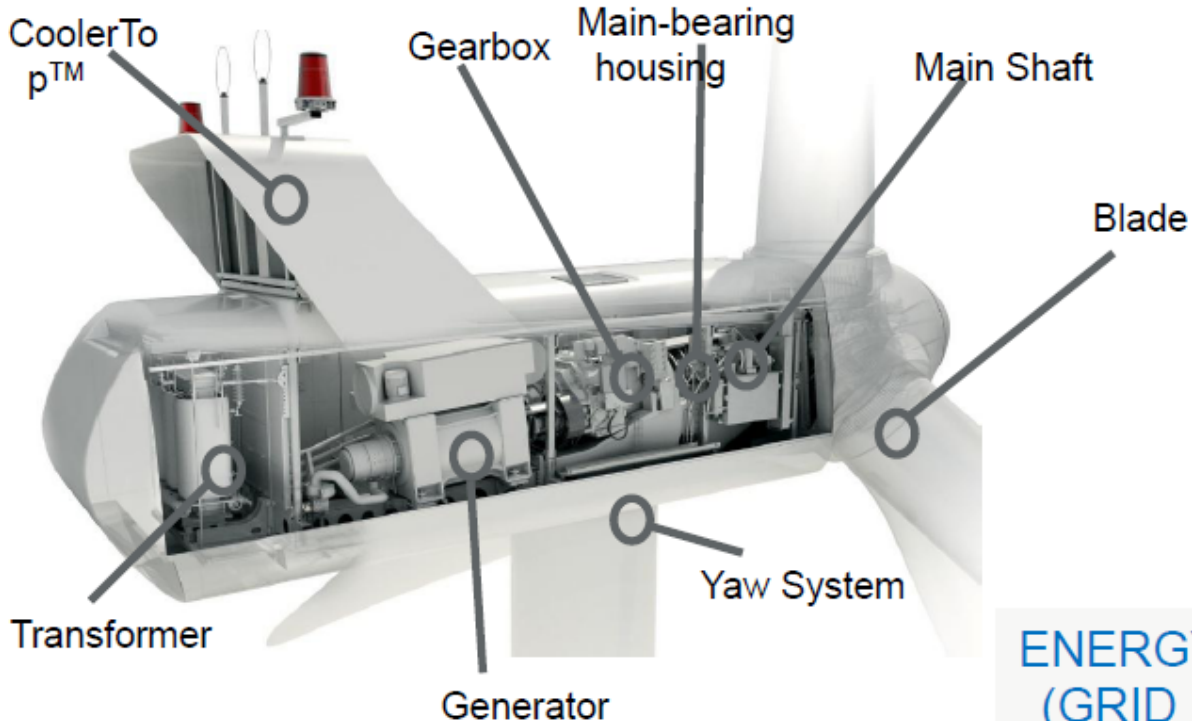
Cables 0.96%
Link individual turbines in a wind farm to an electricity sub-station.

Screws 1.04%
Hold the main components in place, must be designed for extreme loads.

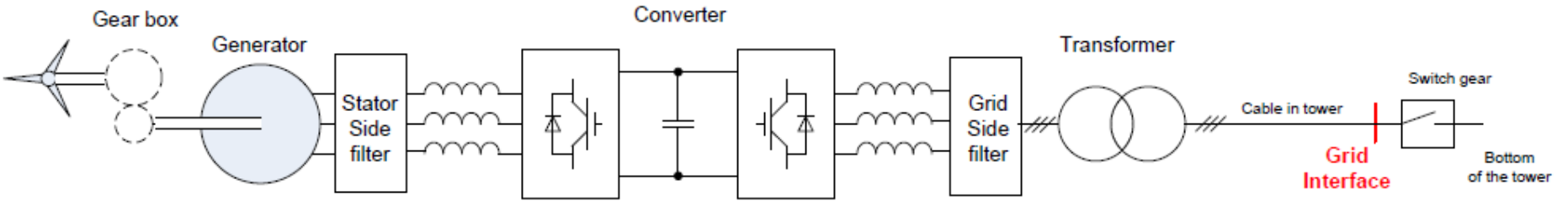
Components of a turbine...

ENERGY CONVERSION (DRIVE TRAIN)

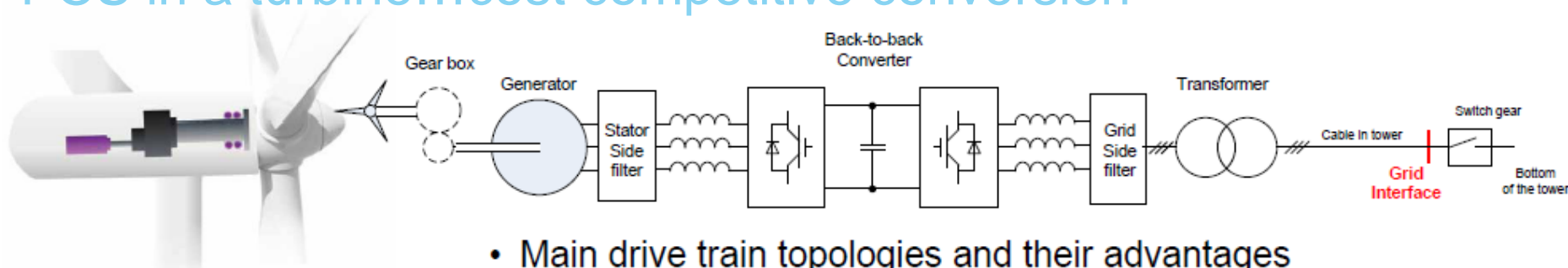
ENERGY CAPTURE (ROTORS)



ENERGY DISTRIBUTION (GRID MANAGEMENT)



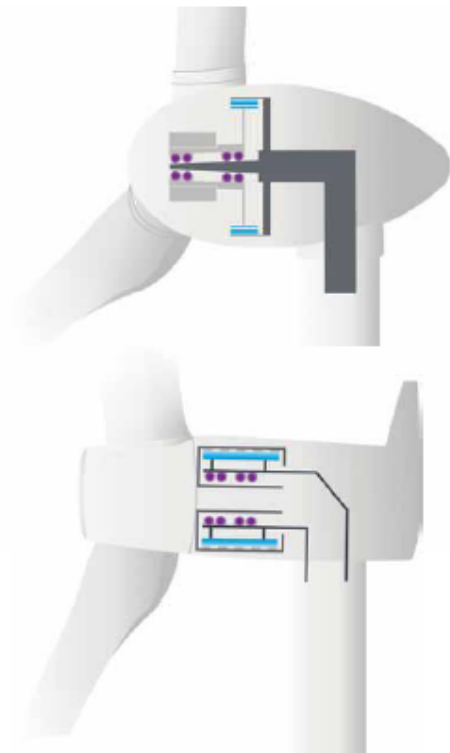
PCS in a turbine...cost competitive conversion



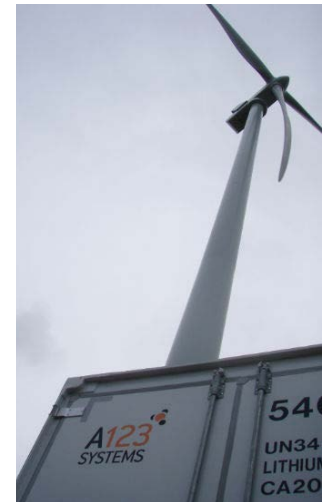
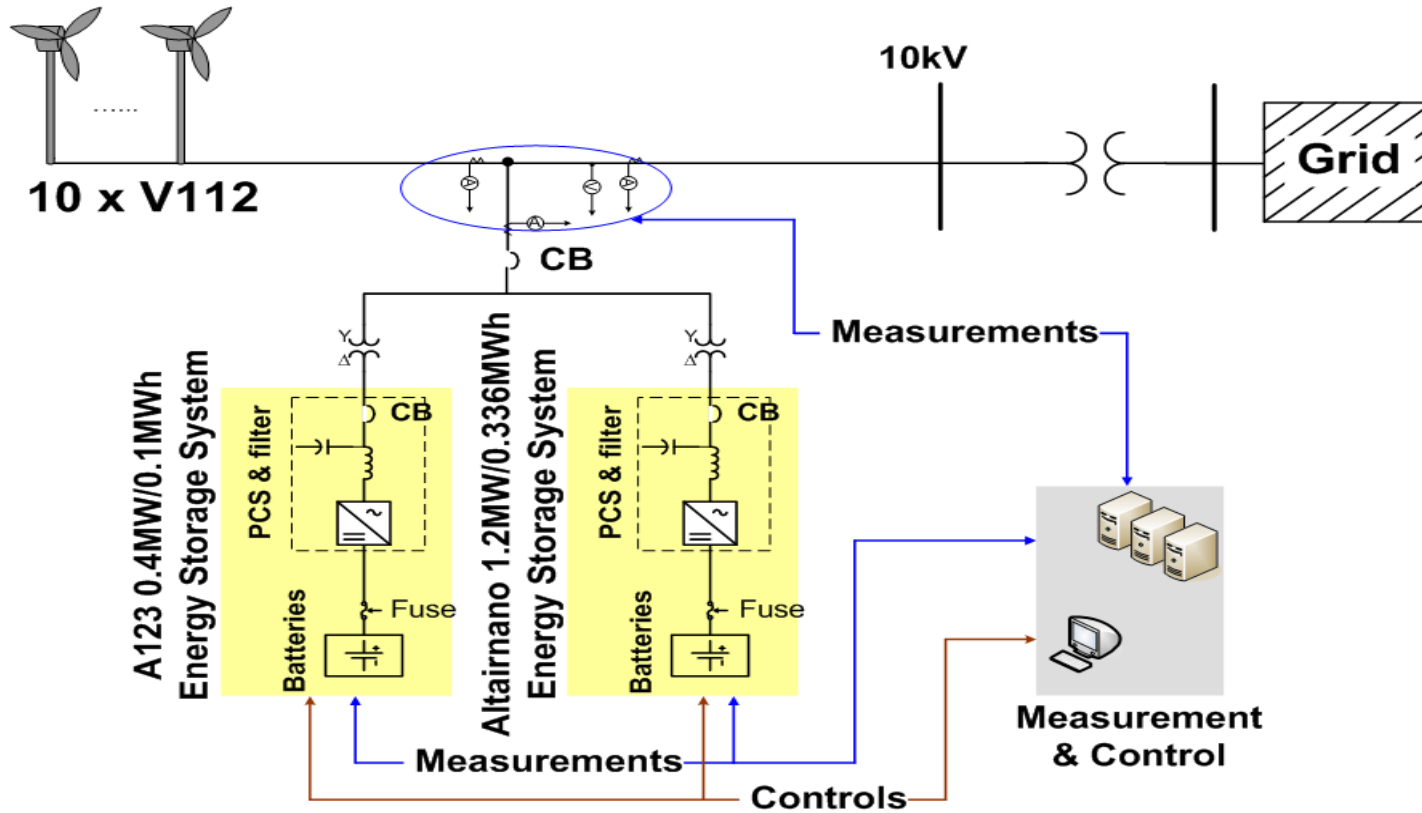
- Main drive train topologies and their advantages

Geared	Gearless
Lower cost Lower weight Proven technology	High reliability (yet to be proven)

- The technology adoption will be influenced by
 - Cost
 - Reliability in very long term operation >20 years
 - Scalability > 10MW
- On-going R&D on power conversion topics
 - Crossover from low voltage to medium voltage to HVDC
 - Do not use power electronics all together? E.g. hydraulic transmissions with synchronous generators coupled to the grid.

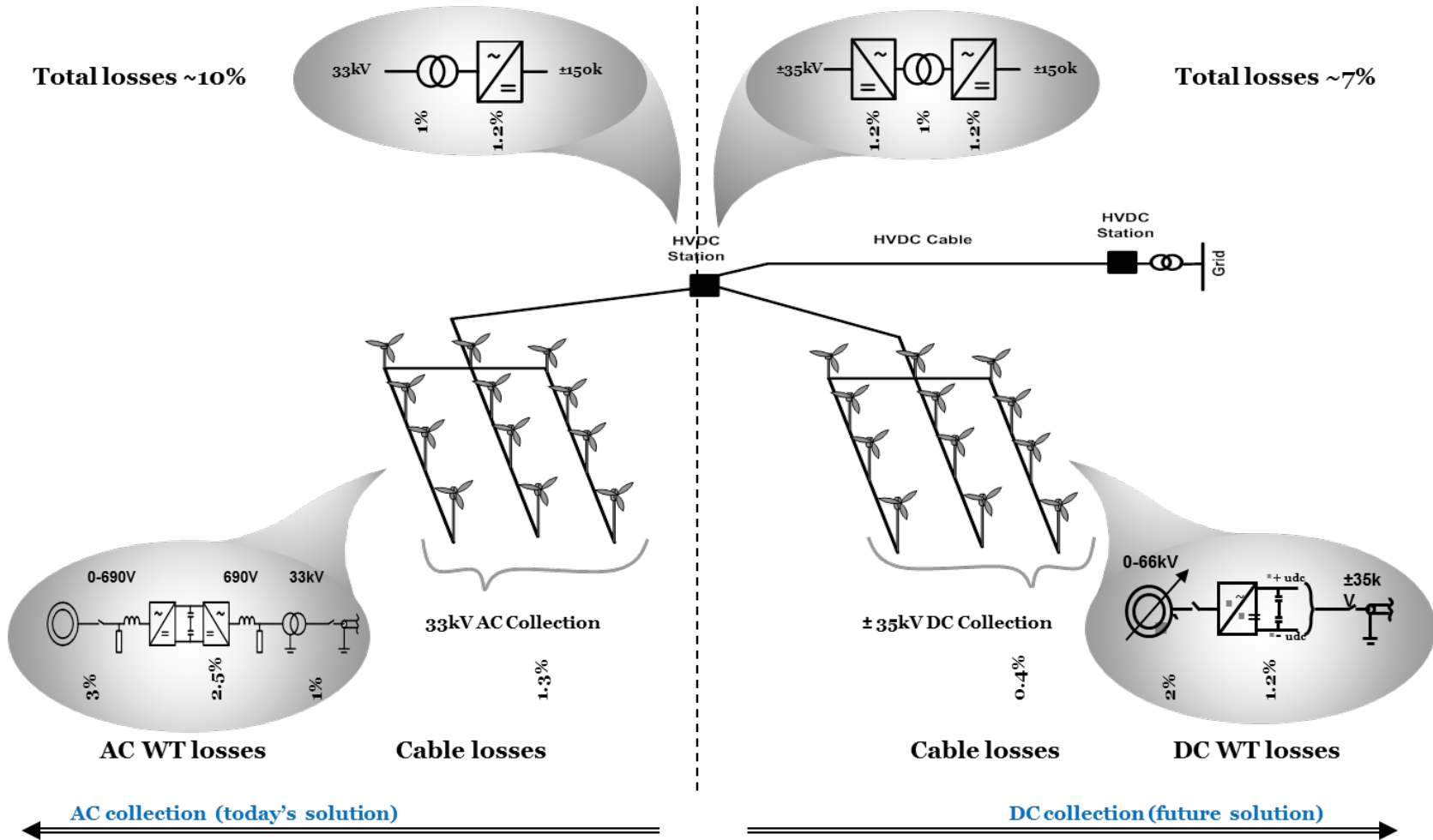


PCS in energy storage interface...cost effective invariability



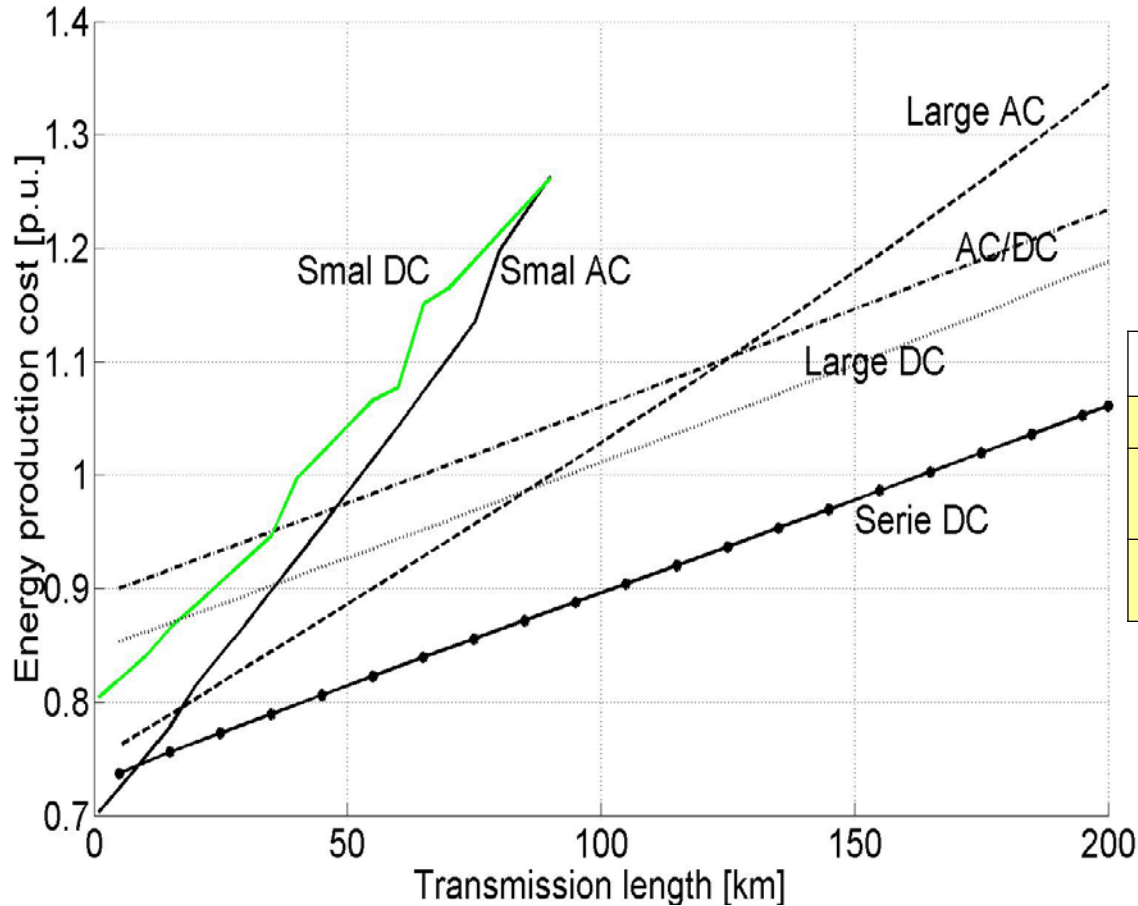
- 1.6MW energy storage combined with 30MW wind power plant
- Offers energy buffer for wind to participate in ancillary services market
- Challenge is in making the system attractive from RoI perspective

PCS in energy collection...maximize efficiency



DC turbines combined with DC collection has a potential to offer up to 30% improvement in reducing energy losses. This improvement is obtained through reduction of turbine-side and station-side converters. However, the challenge is in realizing such high power DC/DC converters

PCS in power transmission...maximize power plant AEP



<i>Vestas Offshore Options</i>	
<i>Current (HVAC)</i>	<i>Future (HVDC)</i>
High Losses	Low Losses Reactive power not required
High Costs	Low Costs One less cable + converter

HVDC is appearing to be the technology of choice to transport power from wind power plants over long distances (e.g. from deep water offshore to onshore). However, significant challenges are in protection and control of such DC architectures.