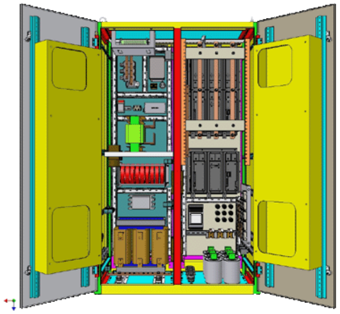
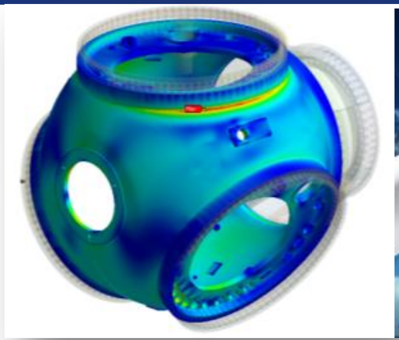
CONCEPTS FOR HIGH POWER WIND TURBINES

INTRODUCING HTS TECHNOLOGY

World Green Energy Forum 2010,
Gyeongju city, Korea, November 17 - 19, 2010




⇨ **Status of today's offshore technology**

⇨ Design concepts for high power wind turbines

⇨ HTS wind turbine

Why Go Offshore?

Benefits

- Higher wind speeds
- Less turbulence intensity
- Huge offshore wind resources
- Out of sight

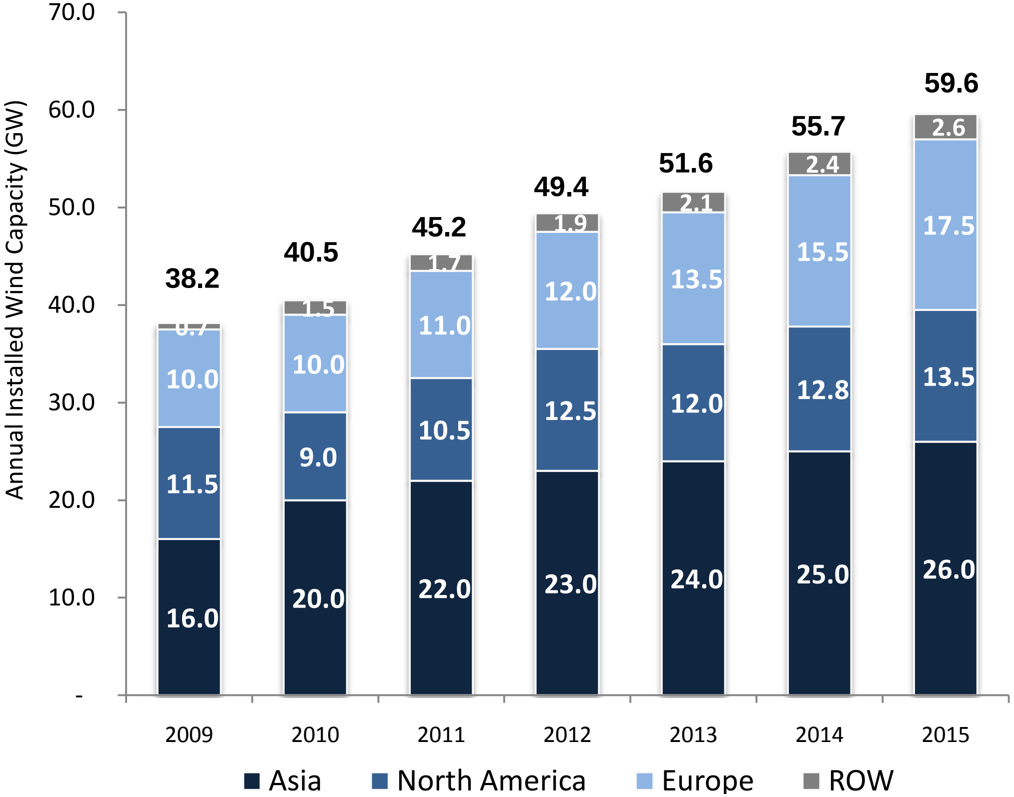
Challenges

- High project costs / investments
- Technology ready?
- All environmental impacts known?

Significant opportunities, but hurdles must be overcome

The Global Wind Power Market

Global Wind Added by Region



‘10-'15 CAGR	
Asia	5.4%
North America	8.4%
Europe	11.8%
ROW	11.5%
TOTAL	8.3%

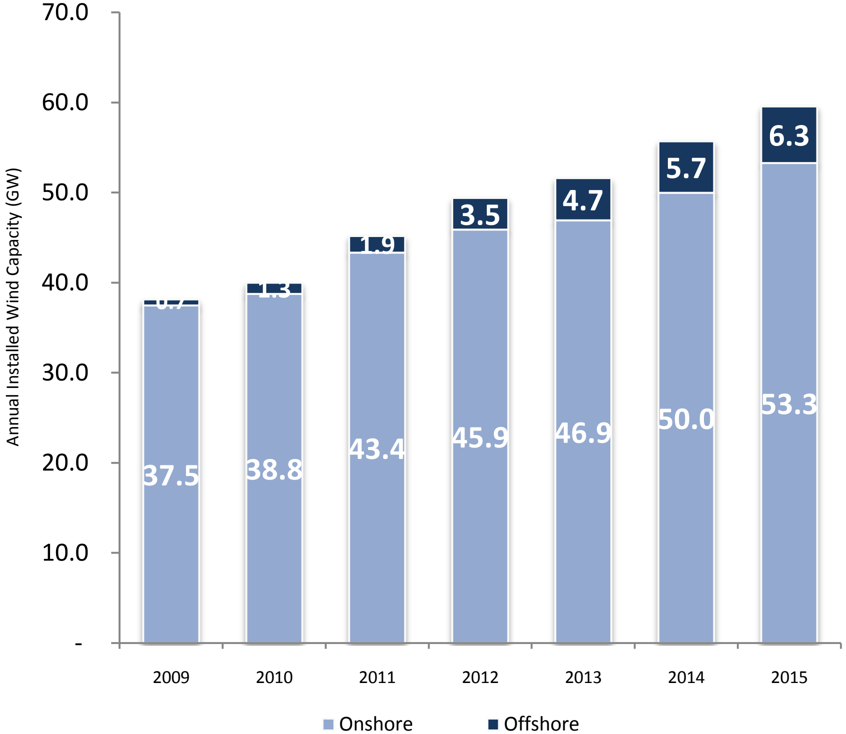
Source: EER, Make Consulting, Global Wind Energy Council, AMSC analysis

Market Overview

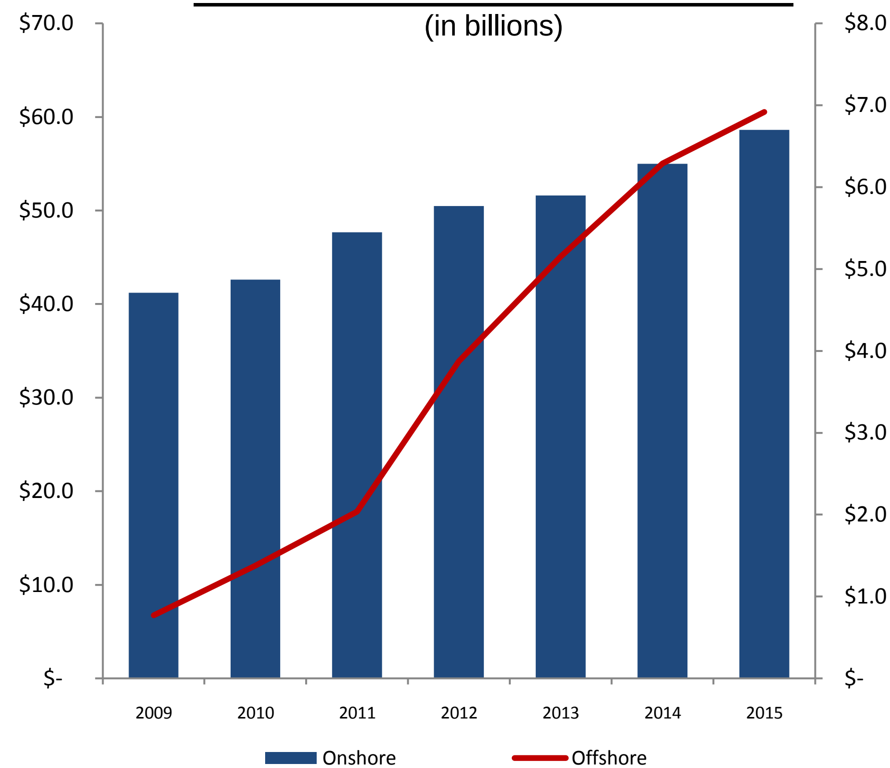
- Global installations nearly tripled from 2005 to 2009
- More challenging conditions in 2010, yet global installations still projected to increase
- Annual installations expected to increase more than 50% from 2009 to 2015
- ***Europe*** expected to be key contributor to growth through 2015, particularly in the offshore market
- Slow growth expected in ***North America*** due to lack of long-term policy, although recent BP crisis may alter the landscape
- Asia expected to lead the world in wind power adoption this decade
- **Long-term growth in all regions** expected as nations focus increasingly on clean technology to meet power demands, reduce carbon emissions and pollution, increase energy independence and create new jobs
- As wind technology matures, more focus will be placed on ***offshore development*** due to optimal wind patterns, transmission advantages and NIMBYism

Onshore vs Offshore

Onshore vs. Offshore Wind Capacity Added



Onshore vs. Offshore Wind Market Size



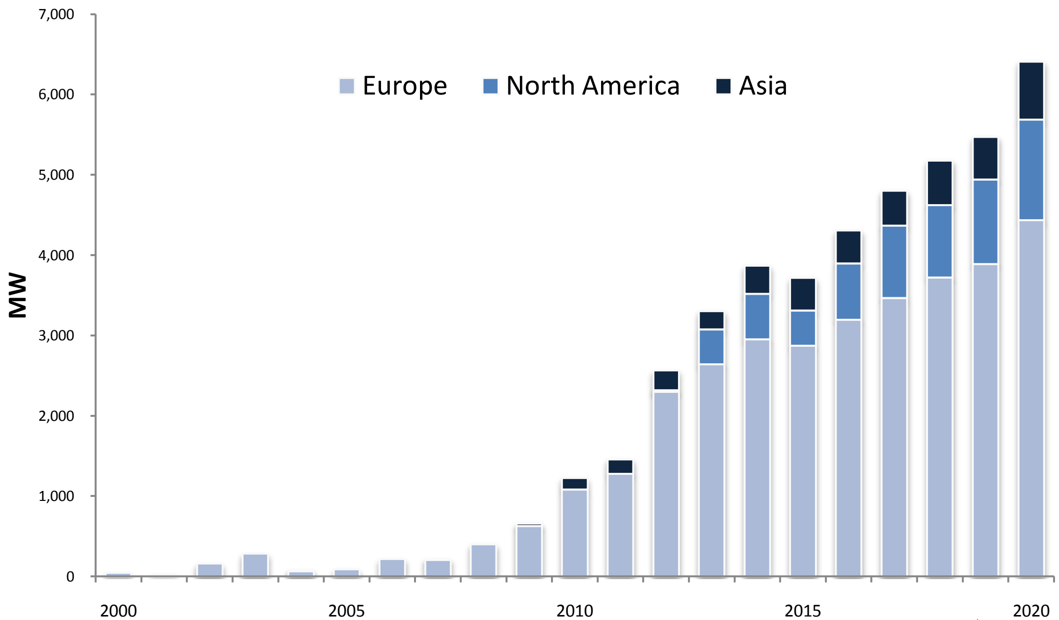
'10-'15 CAGR	
Offshore Wind	38.1%
Onshore Wind	6.6%
Global Wind Market	8.3%

- Currently, onshore wind dominates the market as installation costs and risks are generally lower than offshore
- Rapid growth for the offshore wind is expected as the technology develops and matures
- Offshore wind is expected to grow at a 38% CAGR through 2015 to become a $7 billion dollar industry

Source: EER, Make Consulting, Global Wind Energy Council, AMSC analysis

Offshore Wind Overview

Global Offshore Wind Megawatts Added by Region



Source: Emerging Energy Resources (Dec 2009)

Phase 1
1991 - 2007

Initial pilots

Avg project size <100MW

1MW – 3.6 MW turbines with gearboxes

Key players: Siemens & Vestas

Phase 2
2008-2013

Steady deployment

Avg project size is 100MW to 400MW

3.6MW- 5MW turbines, mix of gearbox and direct drive

Key players: Siemens, Vestas, BARD, Areva, Multibrid, Sinovel, HHI

Phase 3
2014-2020

Continued expansion

Avg project size is 400MW and larger

5MW- 10MW turbines with direct drive

Key players: TBD

Key Market Highlights

- As technology develops and continues to lower the cost of energy, we can expect a substantial increase in offshore wind investment
- Benefits of offshore include increased productivity.
  - Average onshore wind speeds = 7m/sec.
  - Average offshore wind speeds = 9-10m/sec.
- Developers have already saturated the most suitable onshore wind sites
- **Europe:** With solid long-term incentives in place, a 20% by 2020 renewable energy mandate and a saturated onshore market, major offshore development projects are getting underway
- **Asia Pacific:** Led by China’s and Korea’s offshore efforts, the region is now entering a rapid phase of growth
- **North America:** Cape Wind now appears to be moving forward and BP crisis may spark major new investments in the offshore wind market; DOE issued ROI for offshore wind demonstration projects last week

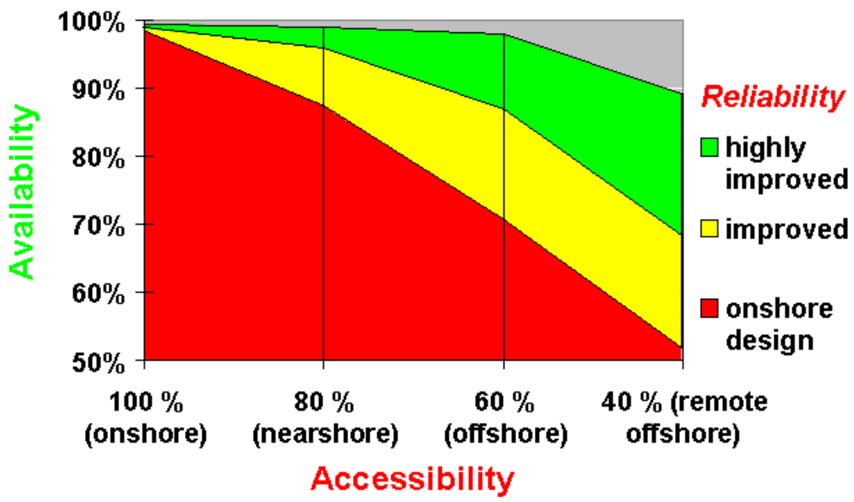
Current Offshore Technology

- Current off shore turbines driven by conventional technology

→Conventional wind turbines, big foundations, erection on sea…

- <u>On Shore</u> Cost Ratio between wind turbine and infrastructure: 70% / 30%
- <u>Off Shore</u> Cost Ratio between wind turbine and infrastructure: 30% / 70%

➔ Current off shore projects are very expensive



Off shore projects are at the moment very expensive

Doubly Fed Induction

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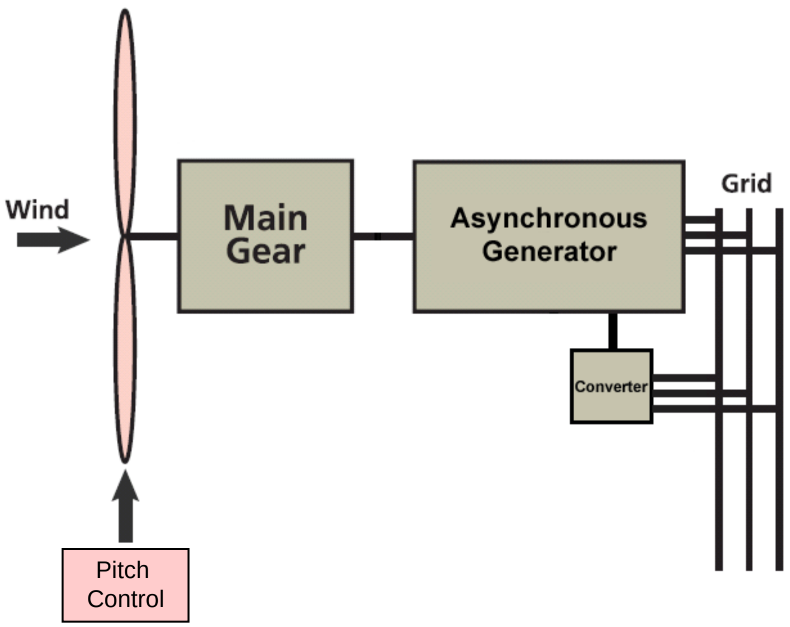
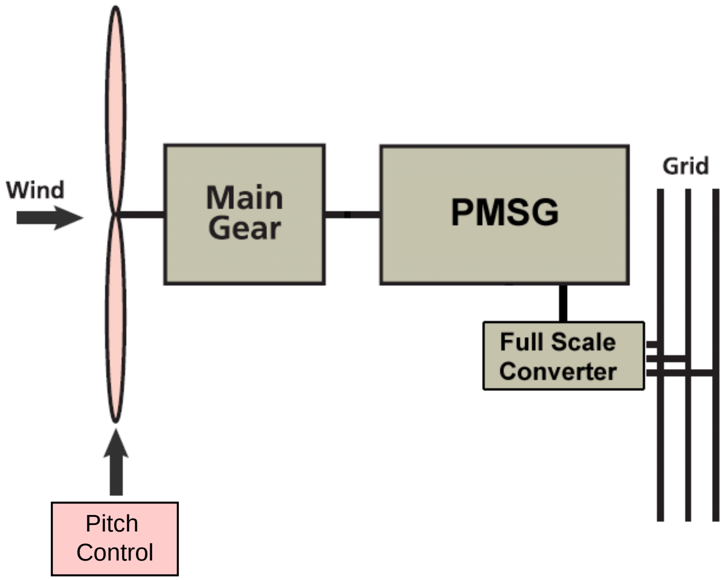
- Basis for AMSC's current growth in China
- \+ Most mature technology today
- \+ Excellent cost of energy
- \+ Excellent supply chain
- \- Power Quality restrictions, limited grid support
- \- Gearbox reliability
- \- Separate gearbox and generator for 50/60Hz
- \- GE patents in North America



Most common wind turbine generator world-wide

Full Conversion

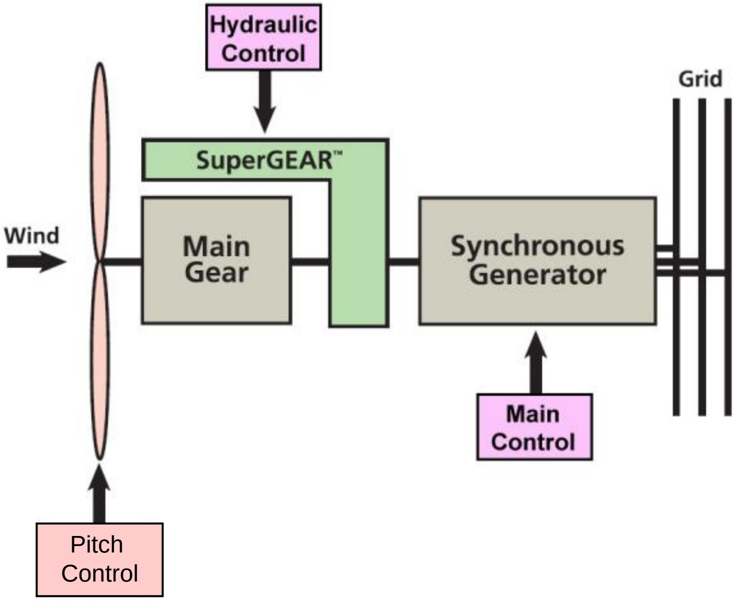
- Can be used with SCAG, PMSG or SG Generators
- + High reliability as gearbox fully isolated from grid
- + Same gearbox and generator for 50/60Hz
- + Superior power quality, optimum grid support
- + No patent limitations (in US from Feb. 2011)
- + Less maintenance (no slip ring)
- - Cost of Energy (large converter)
- - Higher losses



Newest designs using FC technology

SuperGEAR™ Drive Train

- Pursuing multi-megawatt licensees
- + Competitive cost of energy
- + Excellent power quality
- + High reliability – no converter, no transformer, gearbox isolated from grid
- + Direct medium voltage grid connection
- - New technology – associated risks
- - Gearbox supply chain
- - Maintenance (Hydraulic system)

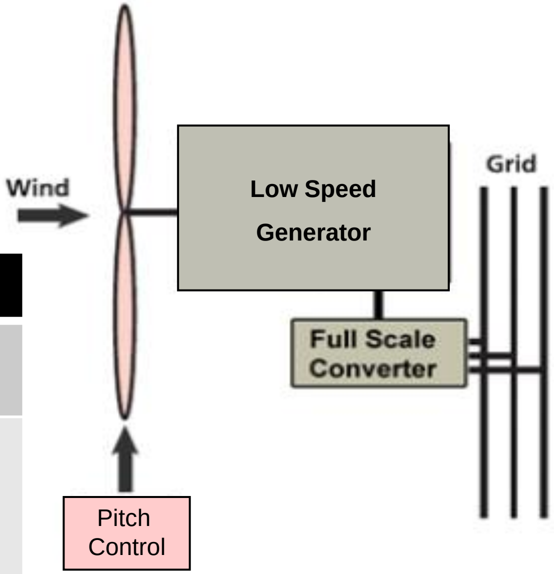


New, highly reliable drive train technology with direct grid connection for high power quality

Direct Drive

- Negates the need for a gearbox
- Drive train of choice for AMSC's SeaTitan wind turbine

	Conventional	New	HTS
Generator	Air cooled	PMSG, water cooled	SG, water cooled
Generator Diameter scaled for 10MW			4,5m
Power quality	++	++	++
Reasonable size	3-5MW	5-7MW	>10MW
Project costs	-	0	+
Site	Onshore	Onshore/ Offshore	Offshore
O&M	+	+	+
Nacelle weight	6MW = 550t		10MW = 500t



Offshore Competitive Environment – Technology Overview

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Established Players

	Model	Power	Gearbox	Generator	Rotor Diameter	Nacelle + Rotor Weight (tons)	Installed Capacity
Siemens	SWT 3.6-107	3.6 MW	3-stage	Asynchronous	107	235	270 MW
Vestas	V90	3.0 MW	3-stage	Asynchronous	90	111	290 MW
GE Energy	GE 3.6	3.6 MW	3-stage	Asynchronous	104	N/A	25 MW

New Entrants with Tested Prototypes

	Model	Power	Gearbox	Generator	Rotor Diameter	Nacelle + Rotor Weight (tons)	Installed Capacity
REpower	M5	5.0 MW	3-stage	Asynchronous	126	410	60 MW
Multibrid	M5000	5.0 MW	1-stage	Asynchronous	116	310	20 MW
Nordex	N90	2.5 MW	3-stage	Asynchronous	90	N/A	5 MW
BARD	VM	5.0 MW	3-stage	Asynchronous	122	375	5 MW
Sinovel	SL3000	3.0 MW	3-stage	Asynchronous	Varying	N/A	9 MW

Offshore Competitive Environment – Strategy Overview of Key Players

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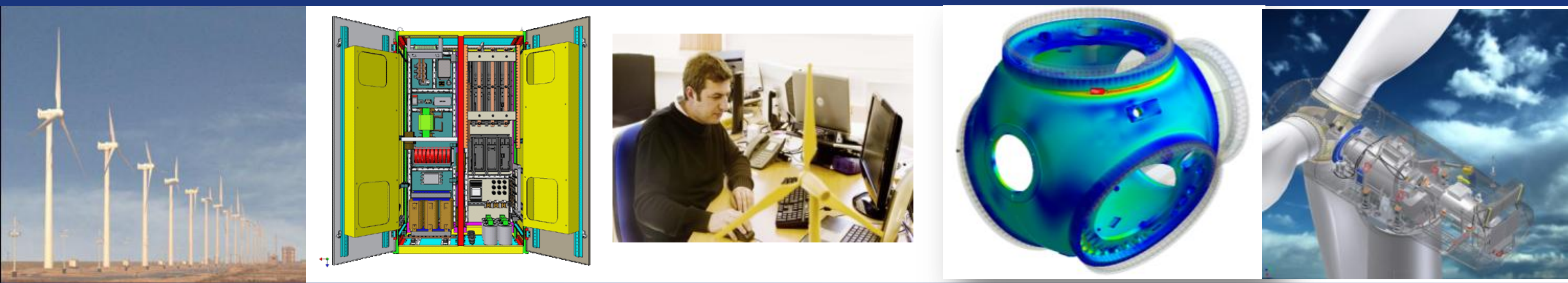
	Geographic Focus	Existing Order Book	Future Strategy
Siemens	▪ UK, Denmark, Germany	4 GW	▪ Currently positioned as the leading offshore wind turbine supplier ▪ Currently has largest bankable machine on the market ▪ Solidifying agreements for key UK and German projects is key to firm's position as it rolls out the 3.6MW direct drive turbine
Vestas	▪ Global, Europe	530MW	▪ Gained major lead as offshore leader but faced critical product quality issues with V90 product. Next 3 years thus crucial to establish a track record with key offshore offerings ▪ Has announced plans to focus on the Chinese and Great Lakes markets
GE Energy	▪ Global	N/A	▪ Recently reentered offshore market through ScanWind acquisition and in a position to strengthen turbine portfolio at higher capacities ▪ Focused on leveraging existing technologies around reliability rather than size
REpower	▪ Germany, Belgium, UK	2 GW	▪ Next three years will make a surge in installations with over 80 units planned for installation ▪ Proving O&M capabilities will be crucial to sustained growth
Multibrid	▪ US, Germany, Denmark	505 MW	▪ On the verge of establishing 5 MW turbine track record with five prototypes at Alpha Ventus ▪ Solid order book will test ability to scale up and deliver
Nordex	▪ Germany, Denmark	N/A	▪ Lack of focus on offshore specialization currenlty ▪ Future in offshore remains unclear until it can market a larger product or tie up a large order to re-establish the firm as a viable supplier
BARD	▪ Germany, Netherlands	400 MW	▪ Unique wind installation supply chain through network of partnerships and in-house production to avoid bottlenecks ▪ Current expansion of 5 MW offering to 6.5 MW suited for particularly harsh environments expands product portfolio exclusively for offshore
Sinovel	▪ China	900 MW	▪ Passed successful tests of 3 MW offshore offering but has plans to increase size over the next year ▪ Currently planning IPO to fund expansion into US and Europe



- ⇨ Status of today’s offshore technology
- ⇨ **Design concepts for high power wind turbines**
- ⇨ HTS wind turbine

Target Offshore Technology

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- Develop cost optimized, grid friendly and reliable off shore technology
- Reduce overall costs for off shore projects (turbine, foundation, erection, O&M)
- Increase Reliability significantly compared to main stream technology
- Target cost ratio between turbine and infrastructure of 45% / 55%
- Developed for production – optimized and proven design from beginning on

➔ Provide new and optimized off shore technology for lower investment costs and faster break even

➔ Key: develop light weight turbine design, new foundation concepts and assembly/erection techniques

Off shore projects are at the moment very expensive

Offshore Competitive Environment – Future Offshore Technologies Focus

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	Power	Gearbox	Generator	Rotor Diameter	Nacelle + Rotor Weight (tons)	Prototype Deployment
Siemens	3.6 MW	Direct Drive	Synchronous permanent magnet	107	235	2010
Vestas	6.0 MW	Direct Drive	Synchronous	130 - 140	N/A	N/A
GE Energy	4.0 MW	Direct Drive	Synchronous permanent magnet	110	250	2011
REpower	6.0 MW	3-stage	Doubly-fed asynchronous	126	450	2009
Multibred	5.0 MW	1-stage	Synchronous permanent magnet	116	310	2009
AMSC	10.0 MW	Direct Drive	HTS	164	500	2012
Clipper	10.0 MW	Direct Drive	Synchronous permanent magnet	144	N/A	2012
Sway/Enova	10.0 MW	Direct Drive	Synchronous permanent magnet	145	N/A	2012
BARD	6.5 MW	VS planary [?]	Synchronous	122	N/A	2010
Nordex	2.5 MW	3-stage	Doubly-fed asynchronous	90	N/A	2006
Sinovel	5.0 MW	Direct Drive	Synchronous permanent magnet			2010
Mingyang	3.0 MW					
Goldwind	5.0 MW					
XEMC-Darwind	5.0 MW	Direct Drive	Synchronous permanent magnet			2010
Doosan	3.0 MW	Direct Drive	Synchronous permanent magnet			2009
Hyosung	5.0 MW					
Hyundai	5.0 MW		Synchronous permanent magnet			2011
Samsung	5.0 MW					2011
Dongfang	5.0 MW		Synchronous permanent magnet			2011
STX	2.0 MW	Direct Drive	Synchronous permanent magnet			2010

Offshore Wind Turbine Trends

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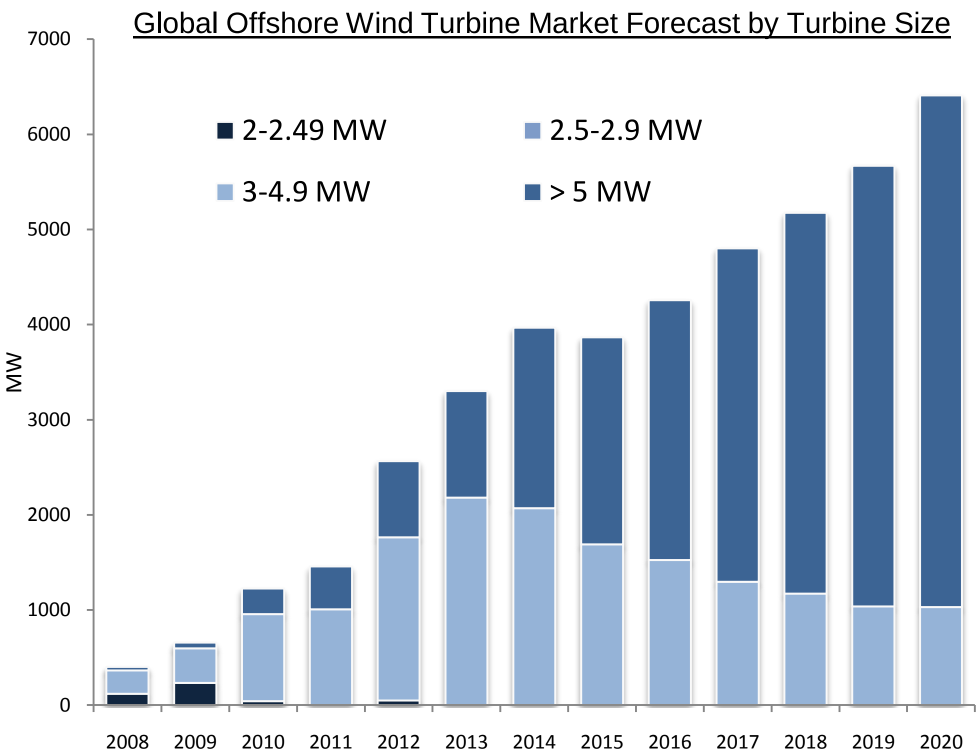


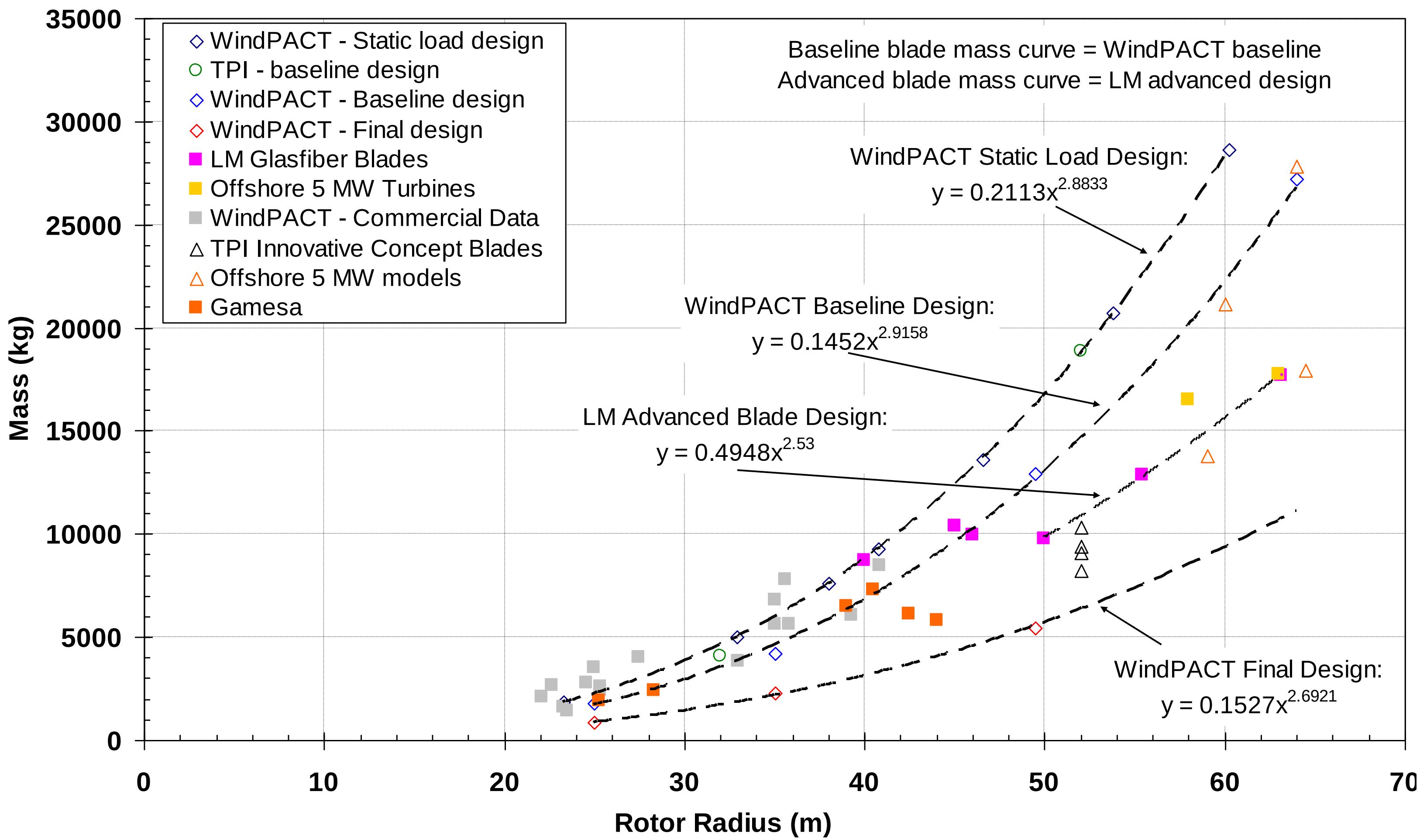
- 2-3 MW wind turbines expected to be dominant onshore platform through 2020
- 5-10 MW wind turbines expected to be dominant offshore platform through 2020

Source: EER, Make Consulting, Global Wind Energy Council, AMSC analysis

Key Market Highlights

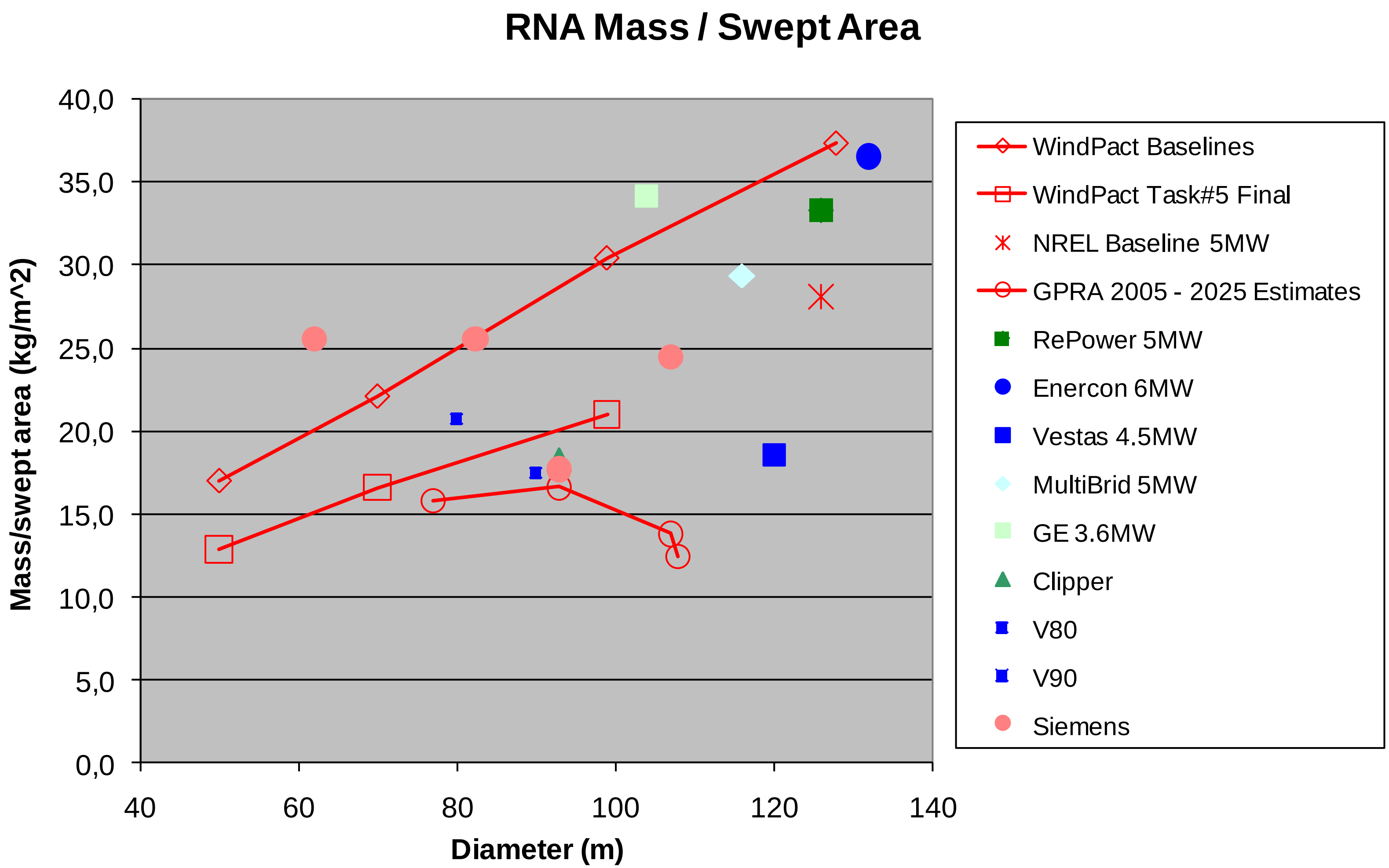
- **2.00 MW to 2.49 MW turbines** are supplied mainly by Siemens and Vestas. These offshore turbines are expected to die off in the near term due to the availability of larger reliable turbines
- **2.50 MW to 2.99 MW turbines** will serve as test bed for technology innovation in China, with modest impact
- **3.00 MW to 4.99 MW turbines** currently dominates the global offshore market and will be the dominant turbine used in China through 2020. In Korea, this platform should capture strong near-term order books, until 5 MW and larger technology is introduced post-2012.
- **5.0 MW+ turbines** expected to be main platform beginning mid-decade. Many manufacturers already working on 5 MW turbines with plans to deploy in 2011-2013 timeframe.

Technology Trends



Larger Rotor Diameter

Technology Trends



Scaling with or without Innovations

Technology Trends

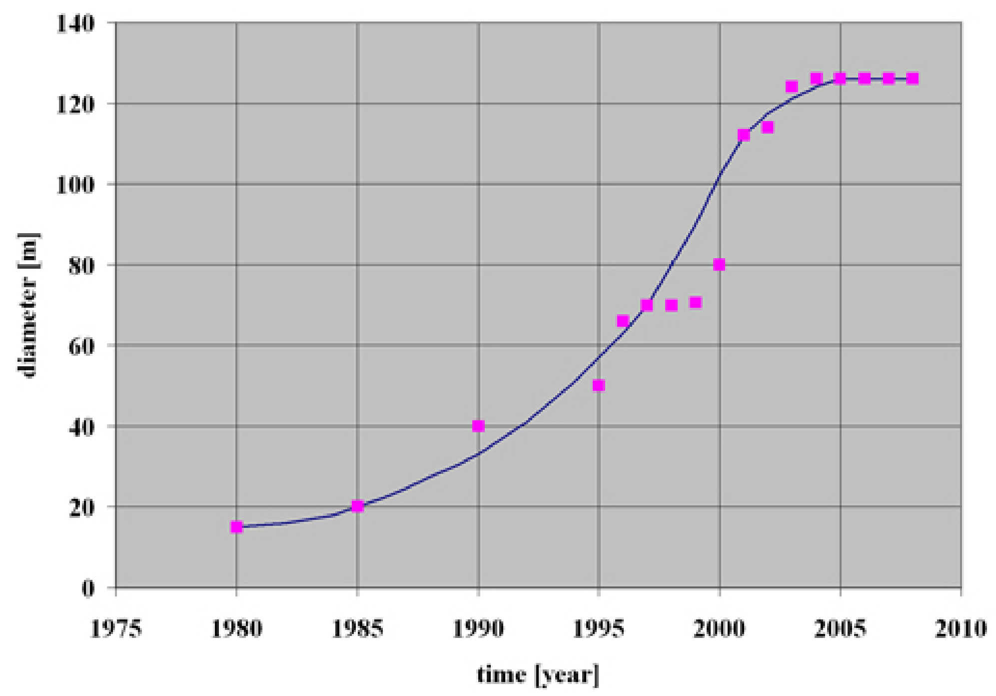
- The world's largest wind turbine is currently the Enercon E-126 (Figure 3.20) installed in Emden, Germany, in February 2008.

- The E-126 is a development from the E-112, which had been up-rated to 6 MW and may be up-rated to 7 MW.

- The physical size of the rotor is similar to the REpower 5 MW design.

- Thus there has been no significant increase in rotor size since 2004.

Figure 3.19: Turbine Diameter Growth with Time



Source: Garrad Hassan

Larger Rotor Diameter

Technology Trends

-There is no fundamental reason for tip speed to change with scale.

-Higher tip speed has the advantage that, for a given output power, the torque on the drive train is reduced and therefore the drive train mass and cost also decrease.

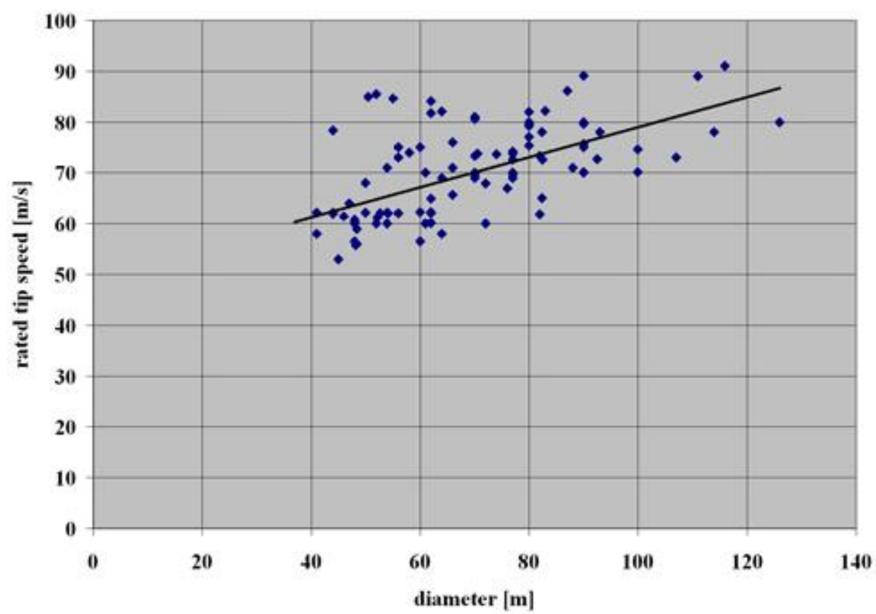
-Offshore, there is a clear potential benefit in higher tip speeds, and less constraint on acoustic emission levels.

-With increasing tip speed, blade solidity decreases and blades will tend to become more flexible.

-This can be beneficial for system loads but problematic for maintaining the preferred upwind attitude, with adequate tower clearance of the blade tips in extreme loading conditions.

-very large offshore turbines will not adopt design tip speeds much below 80 m/s.

Figure 3.21: Tip Speed Trend



Source: Garrad Hassan

Tip Speed Trends

Technology Trends

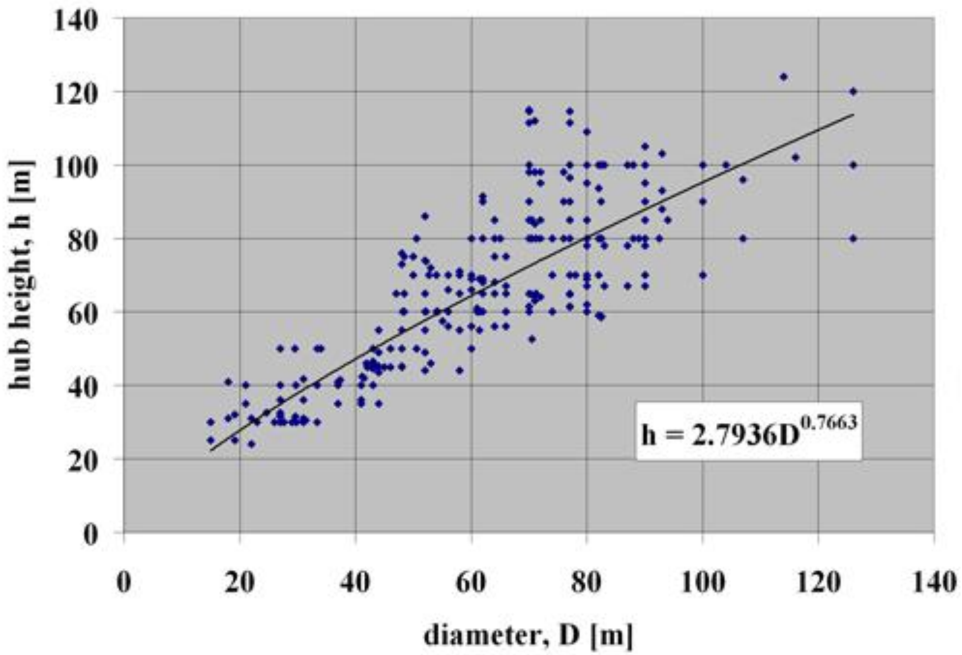
Onshore

– Clear average trend of hub height, increasing linearly in proportion to diameter

Offshore

– reduced wind shear
– the economic penalties of increased foundation loads and tower cost will typically outweigh any small energy gains from a much increased hub height

Figure 3.24: Hub Height Trends



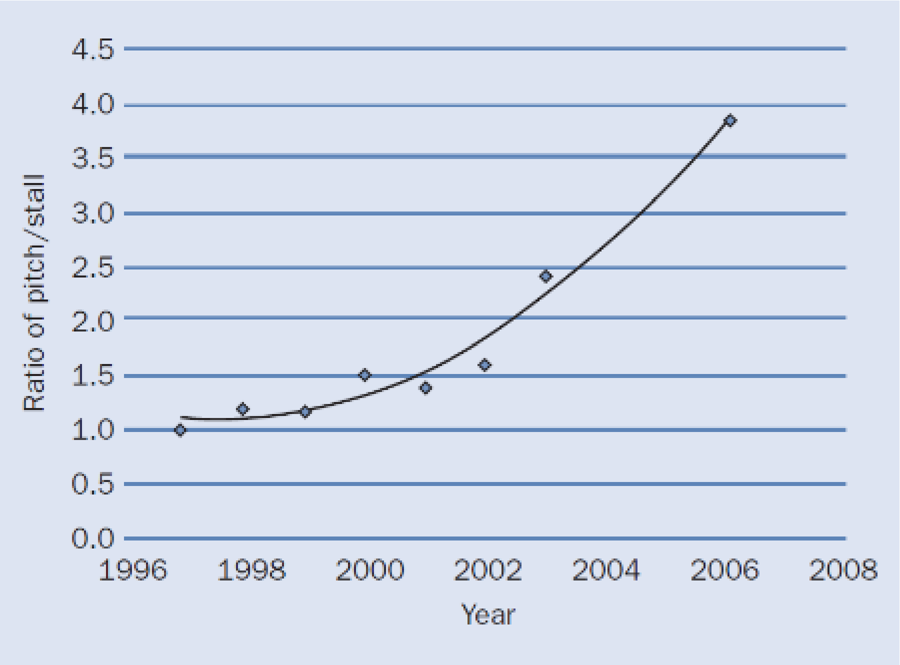
Source: Garrad Hassan

Hub Height

Technology Trends

- In mid-1990s, stall regulation was predominated, Pitch regulation is now the favored option

- The prevalence of pitch regulation is due to a combination of factors.
  - Overall costs are quite similar
  - Pitch regulation offers potentially better output power quality
  - Pitch regulation with independent operation of each pitch actuator allows the rotor to be regarded as two independent braking systems for certification purposes.
  - Individual pitch can reduce the loads at the turbine



Source: Garrad Hassan

Stall - Pitch – Individual Pitch

Technology Trends

Lightning has been more problematic offshore than expected.

Wind turbine blades need better methods of lightning protection

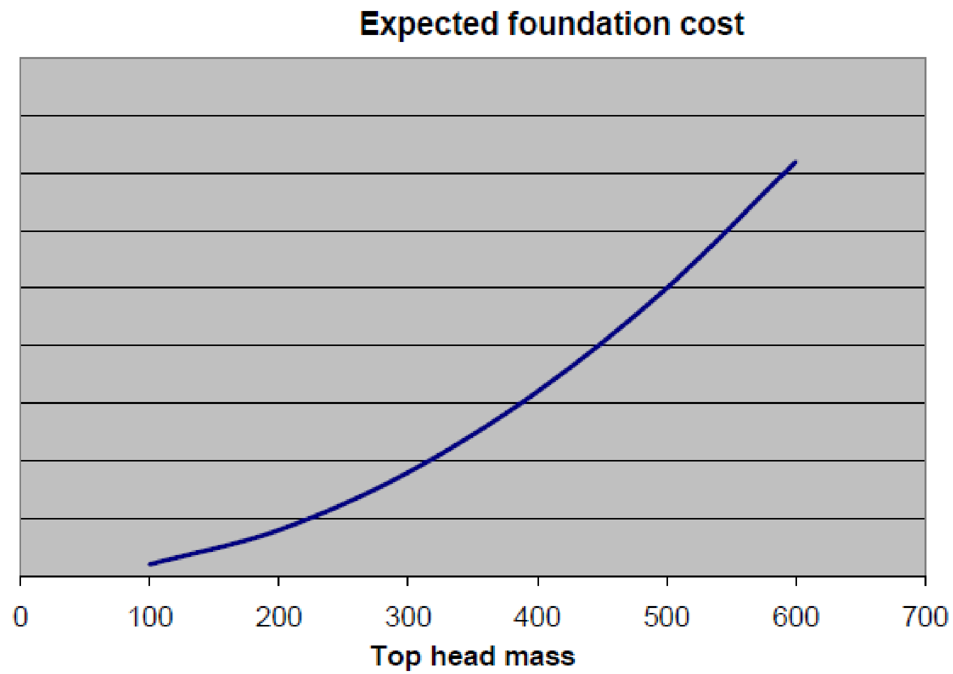
Lightning Risk

Technology Trends

The tower top mass is an important influence on foundation design.

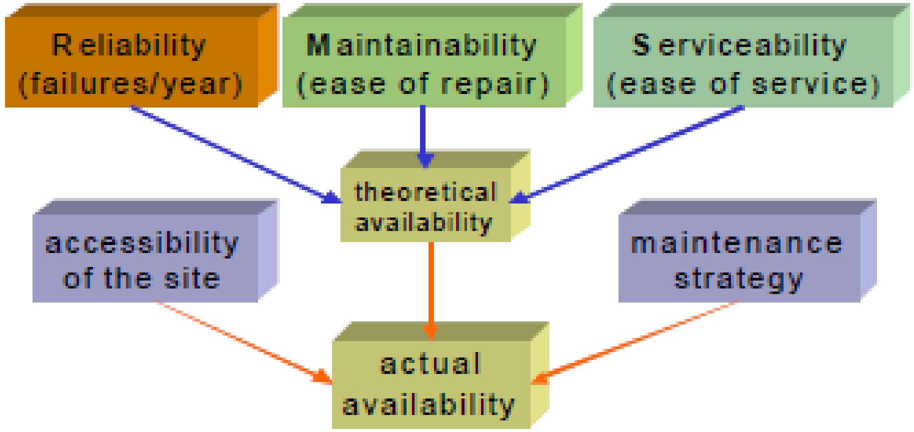
In order to achieve an acceptable natural frequency, greater tower top mass may require higher foundation stiffness, which could significantly affect the foundation cost

Increased demand for foundation stiffness increases the costs



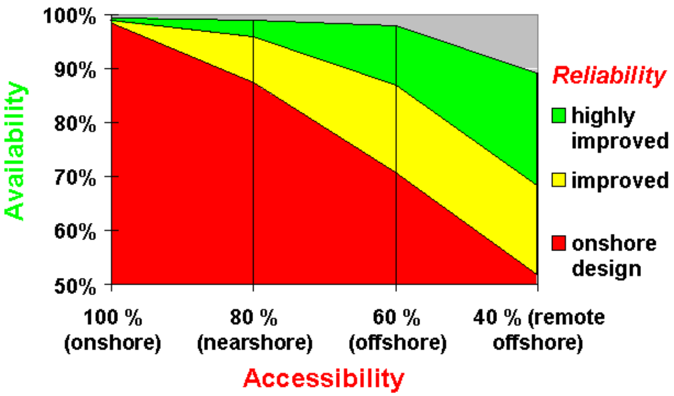
Tower Top Weight impact heavily the Foundation Costs

Availability Issues



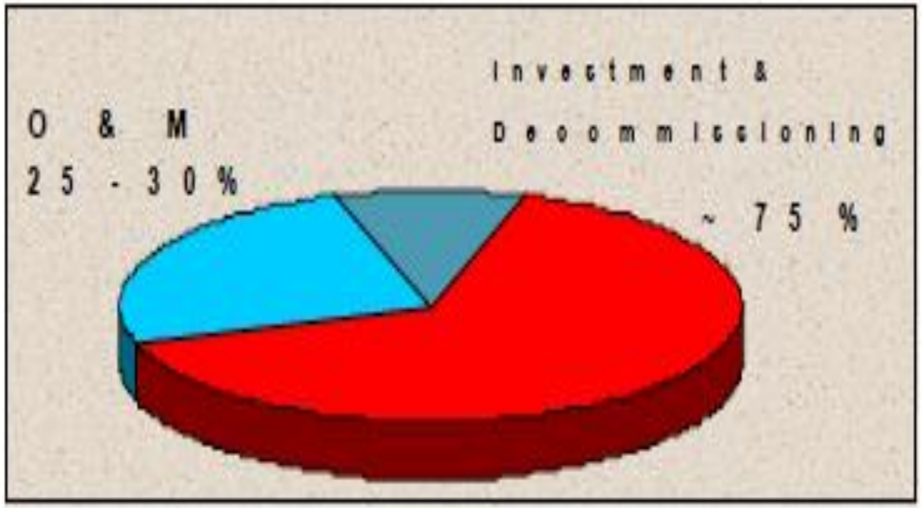
Availability drops down dramatically even with proven onshore technology

Special offshore solutions are required (CMS, redundancy, …)



O&M Issues

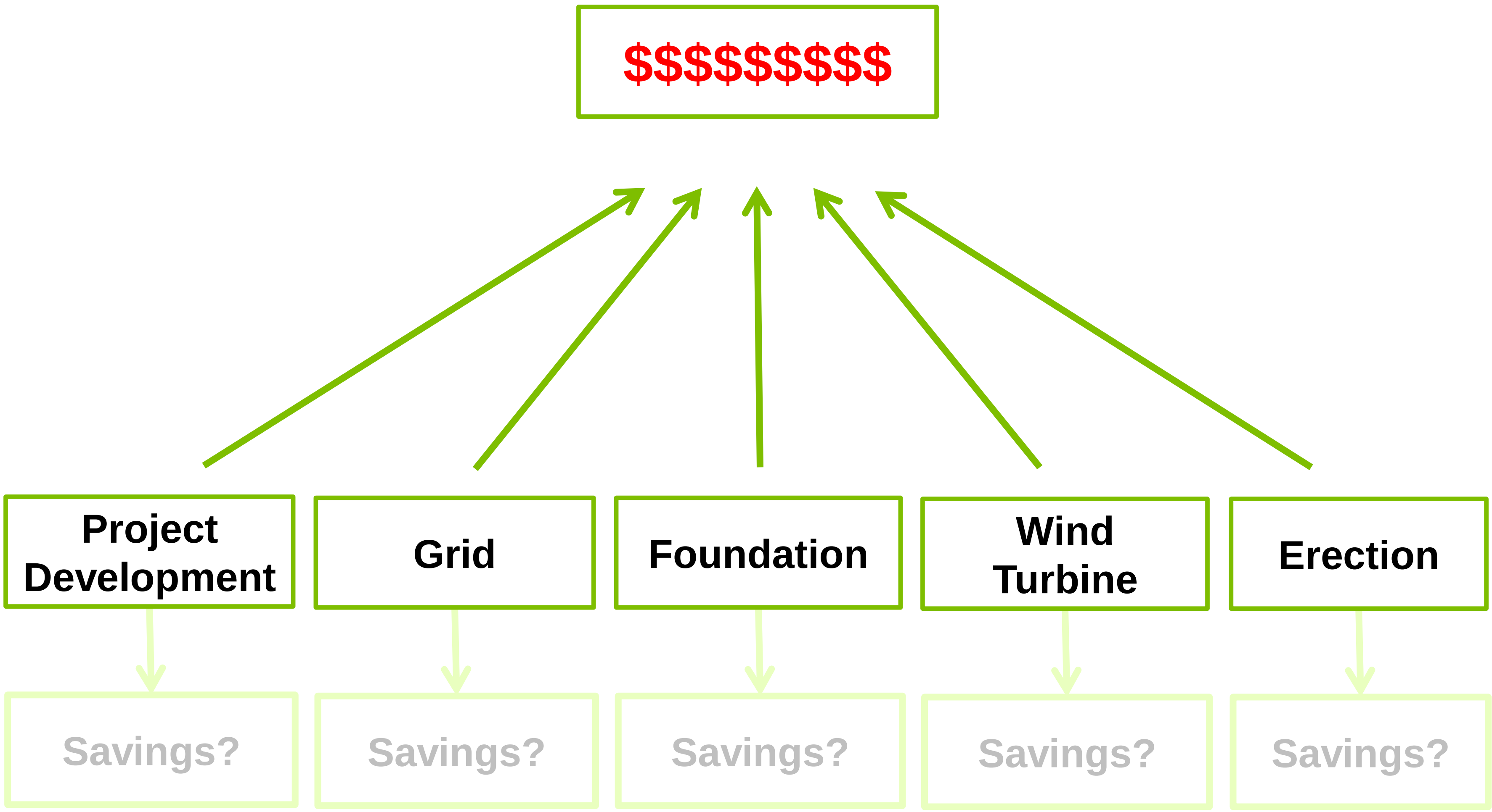
- Further adaption are required due to harsh maritime environment
- Improved methods for access
- Reduced maintenance time
- Simplified and modular design
- Use of high reliable components
- Improved corrosion protection
- Effective remote control and condition monitoring systems
- Appropriate maintenance strategies



O&M Costs can be up to 30% of the project costs

Off Shore Cost Driver

Where are off shore projects costs coming from?



Off Shore Cost Driver

Where are off shore projects costs coming from?

$$$$$$$$$

Project Development

Grid

Foundation

Wind Turbine

Erection

Savings?

Savings?

Savings?

Savings?

Savings?

Costs: Project Development

<u>No Potential:</u>

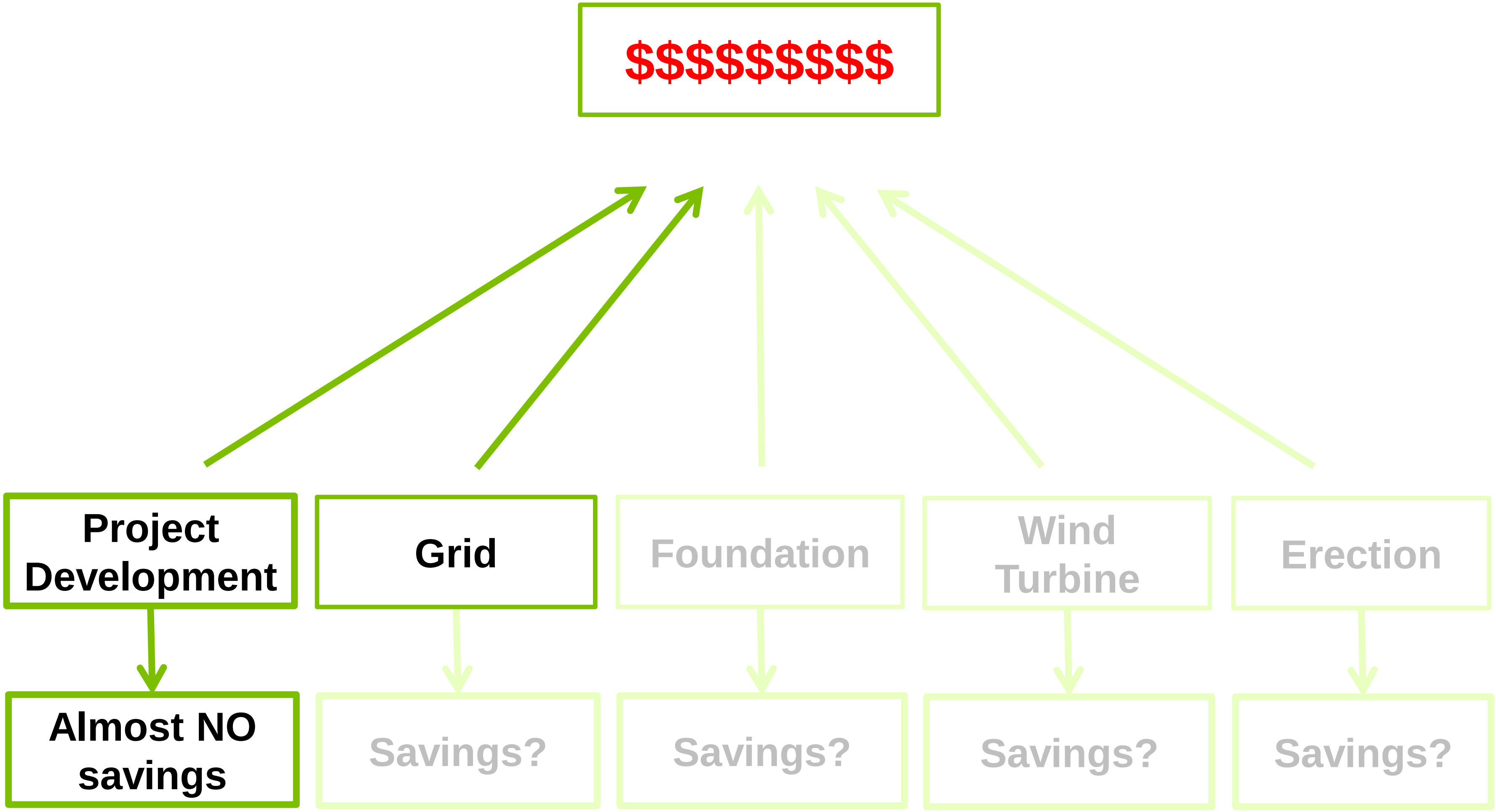
- Wind Resource Assessment
- Permissions (might be a bit easier as floating concepts have less environmental impact)
- Power Purchase Agreements
- Wind Turbine Selection
- Wind Farm Micrositing
- Grid Connection
- Overall Construction Planning and Implementation (might reduce costs slightly by optimized pre-manufacturing technology and assembly techniques

➔ New off shore technology has no effect on the total costs for project development

Different technology does not lead to cost reductions

Off Shore Cost Driver

Where are off shore projects costs coming from?



Costs: Grid

<u>No Potential</u>:

- Initial planning costs

<u>Minor Potential:</u>

- reduce cable installation costs by implementing HVDC
- reduce power losses over long distance
- reduce running costs by grid code compliance, power control, stability and black start capability
- add value by supporting grid with intelligent wind park controller
- add value by providing high power quality through optimized wind turbine technology

AC

DC

➔ Reduce costs and increase efficiency

Grid costs are mostly but not totally independent to turbine technology

Off Shore Cost Driver

Where are off shore projects costs coming from?

$$$$$$$$$$

Project Development	Grid	Foundation	Wind Turbine	Erection
NO savings	MINOR savings	Savings?	Savings?	Savings?

Costs: Foundation

Huge Potential:

• reduce costs with light weight turbine design

→ each reduced ton on the turbine has positive effects on the total weight of tower and foundation and weight is equal to costs

• reduce costs by reducing loads

→ loads have a direct effect on the dimensioning of components. Low loads mean lighter components, mean smaller foundation

• reduce costs by implementing floating concepts

→ Floating foundations are smaller, easier to implement and enablers for deep water off-shore projects

Costs: Foundation

Huge Potential:

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• reduce costs by implementing floating concepts

→ Floating foundations are smaller, easier to implement and enablers for deep water off-shore projects

• reduce costs by on-shore/near-shore assembly and dragging to actual site

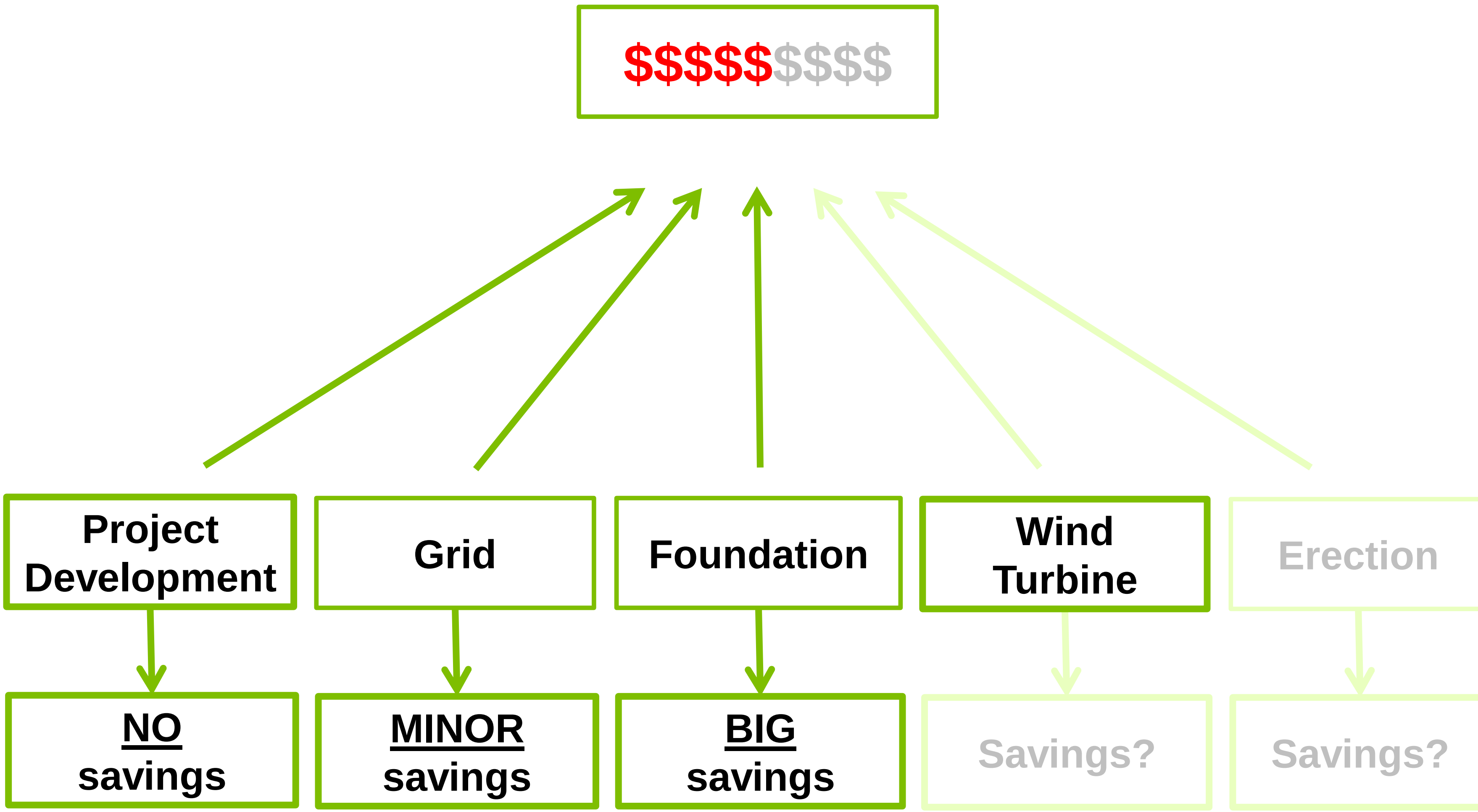
→ no preconstruction of foundation at site, no weather effects, no big floating cranes required

➔ Significant cost reduction on heavy steel parts and on-site construction

Grid costs are mostly but not totally independent to turbine technology

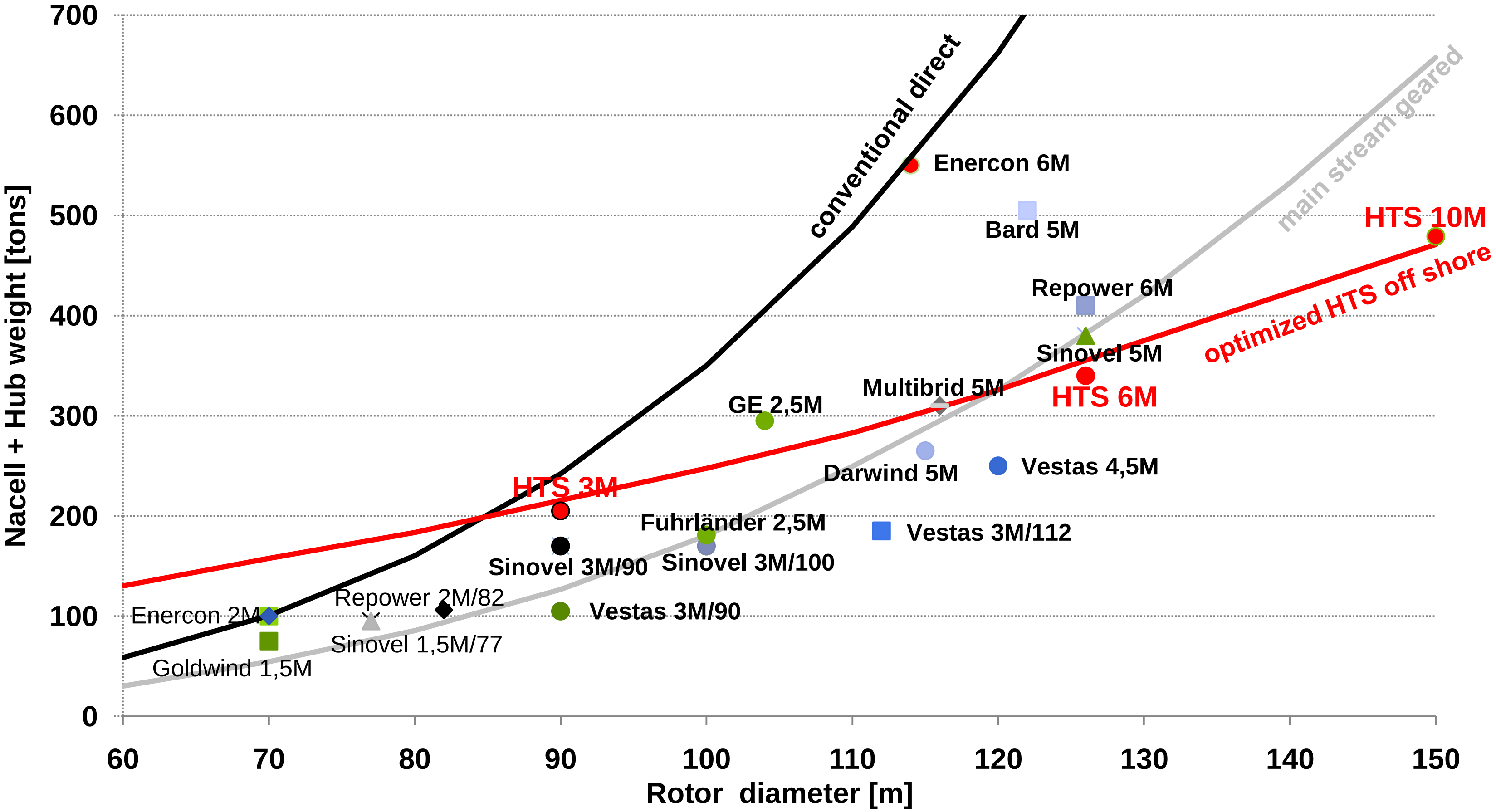
Off Shore Cost Driver

Where are off shore projects costs coming from?



Costs: Wind Turbine

Between light weight, geared Vestas and heavy, direct drive Enercon models, HTS technology will make direct drive wind turbines competitive at 6MW and the leading technology at 10MW and above.



Costs: Wind Turbine

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Huge Potential:

- reduce costs with light weight turbine design

→ optimize drive train with compact and light weight design; keep in the nacelle only what is absolutely necessary

- reduce costs by reducing loads and increase reliability

→ reduce loads via implementation of new blade technology, individual pitch control, down wind technology and new control settings

- reduce costs by implementing new tower concepts

→ optimize towers by new concepts AND lower loads and nacelle weight

- reduce costs by assembling the wind turbine at the project harbor

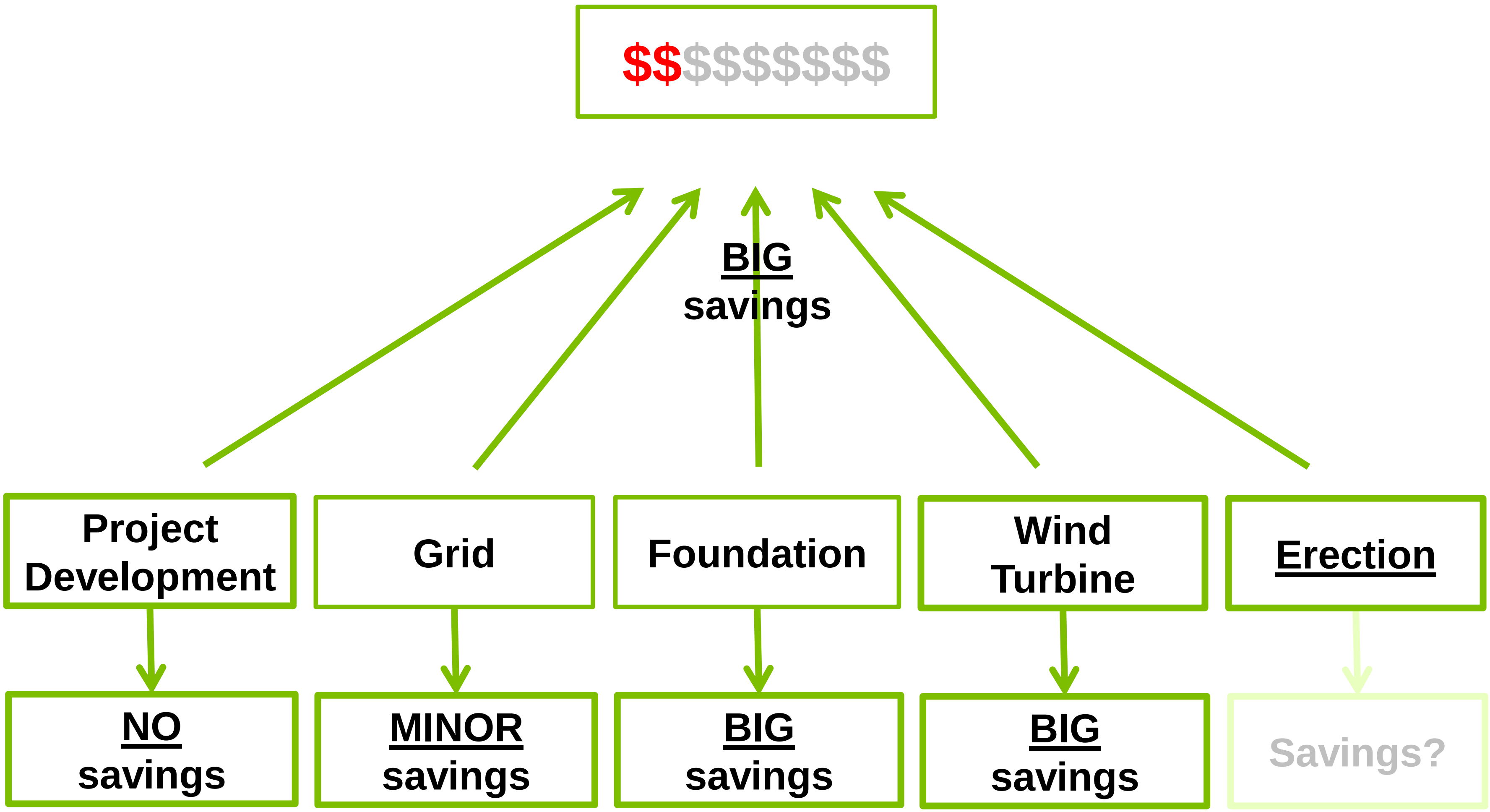
→ preassembled components and simple nacelle design enables harbor assembly option

➔ Significant cost reduction on heavy steel parts and on-site assembly

By reducing overall weight and loads, total projects costs go down significantly

Off Shore Cost Driver

Where are off shore projects costs coming from?



Costs: Erection

Huge Potential:

• reduce costs by using on shore erection crane and improved harbor logistics

→ no need for floating cranes; no impact by bad weather; reduced transportation costs

• reduce costs by commissioning the turbine on shore

→ more efficient commissioning process as commissioning team works on shore; easier access to spare parts; no weather impact

• reduce costs by dragging wind turbine to harbor in case of component problem

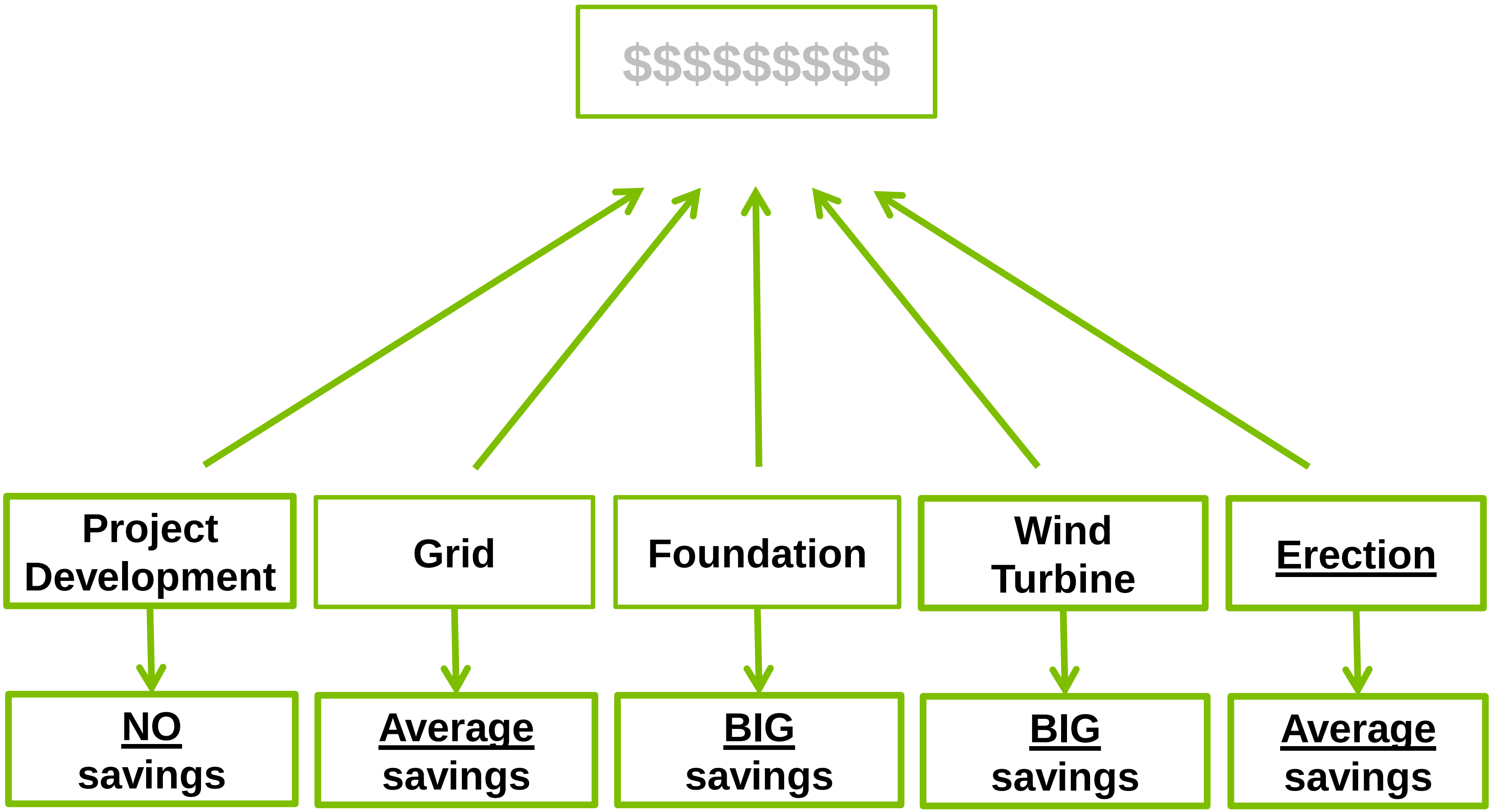
→ maintain and repair turbine at harbor; no waiting time for floating crane; no big turbine maintenance crane; minimum turbine downtime

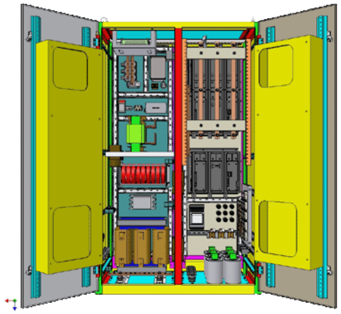
➔ Significant cost reduction by efficient and flexible erection, commissioning and maintenance

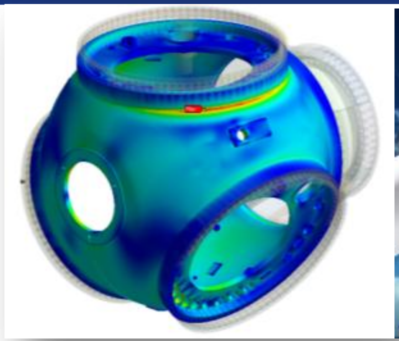
Faster erection/commissioning and minimized turbine downtime

Off Shore Cost Driver

Where are off shore projects costs gone to?

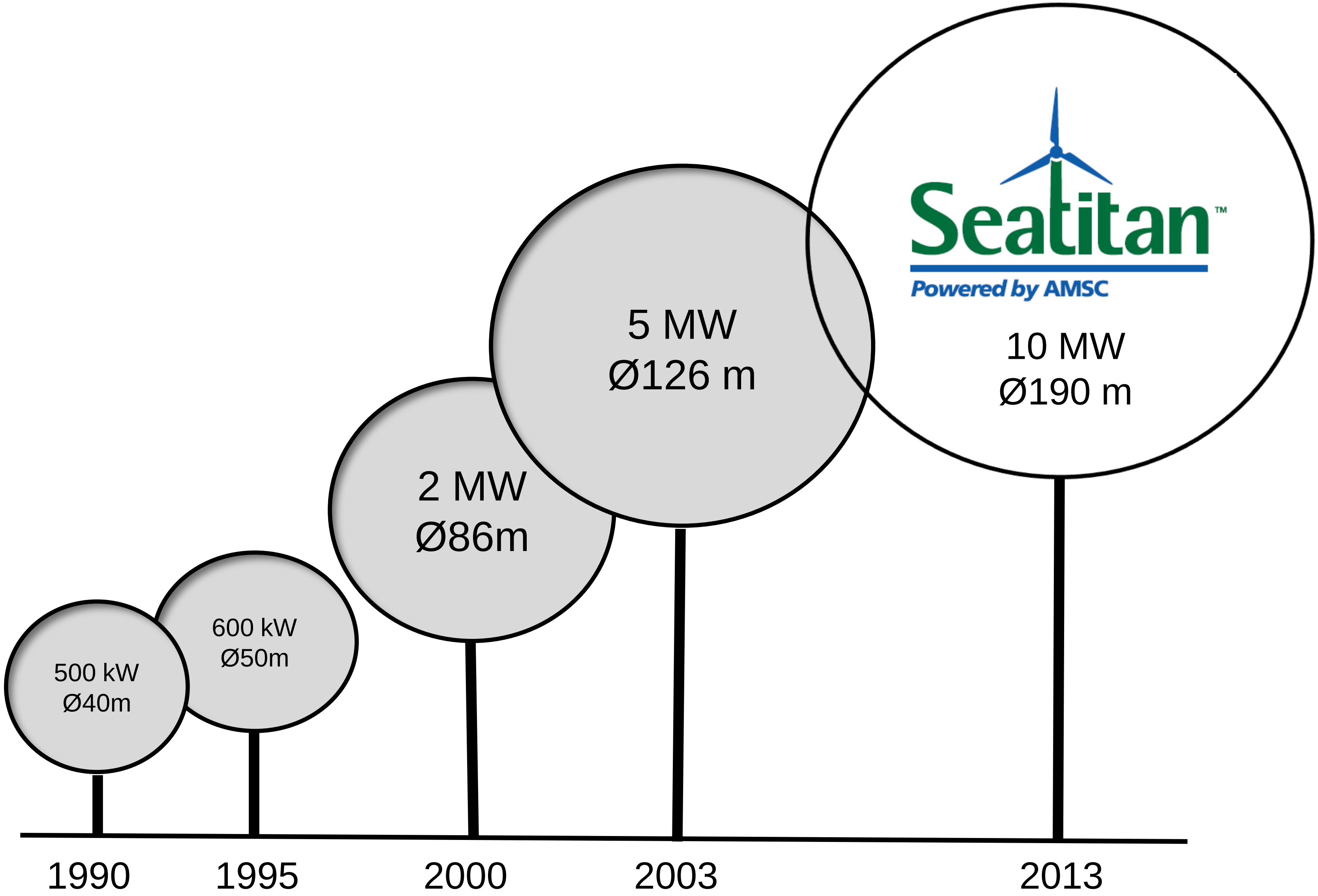


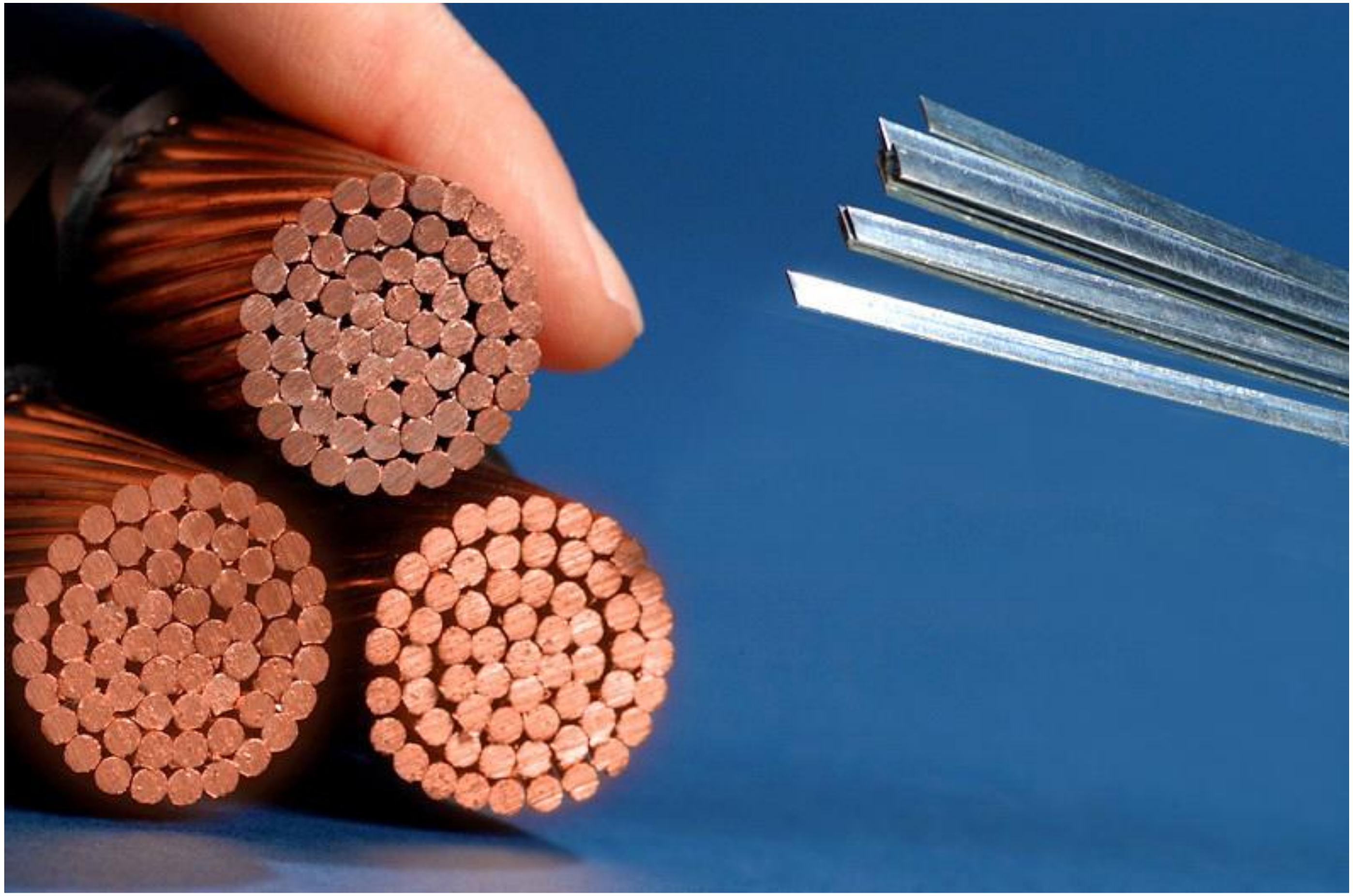



- ⇨ Status of today’s offshore technology
- ⇨ Design concepts for high power wind turbines
- ⇨ **HTS wind turbine**

SeaTitan Wind Turbines Will Leapfrog Today's Wind Turbine Platforms



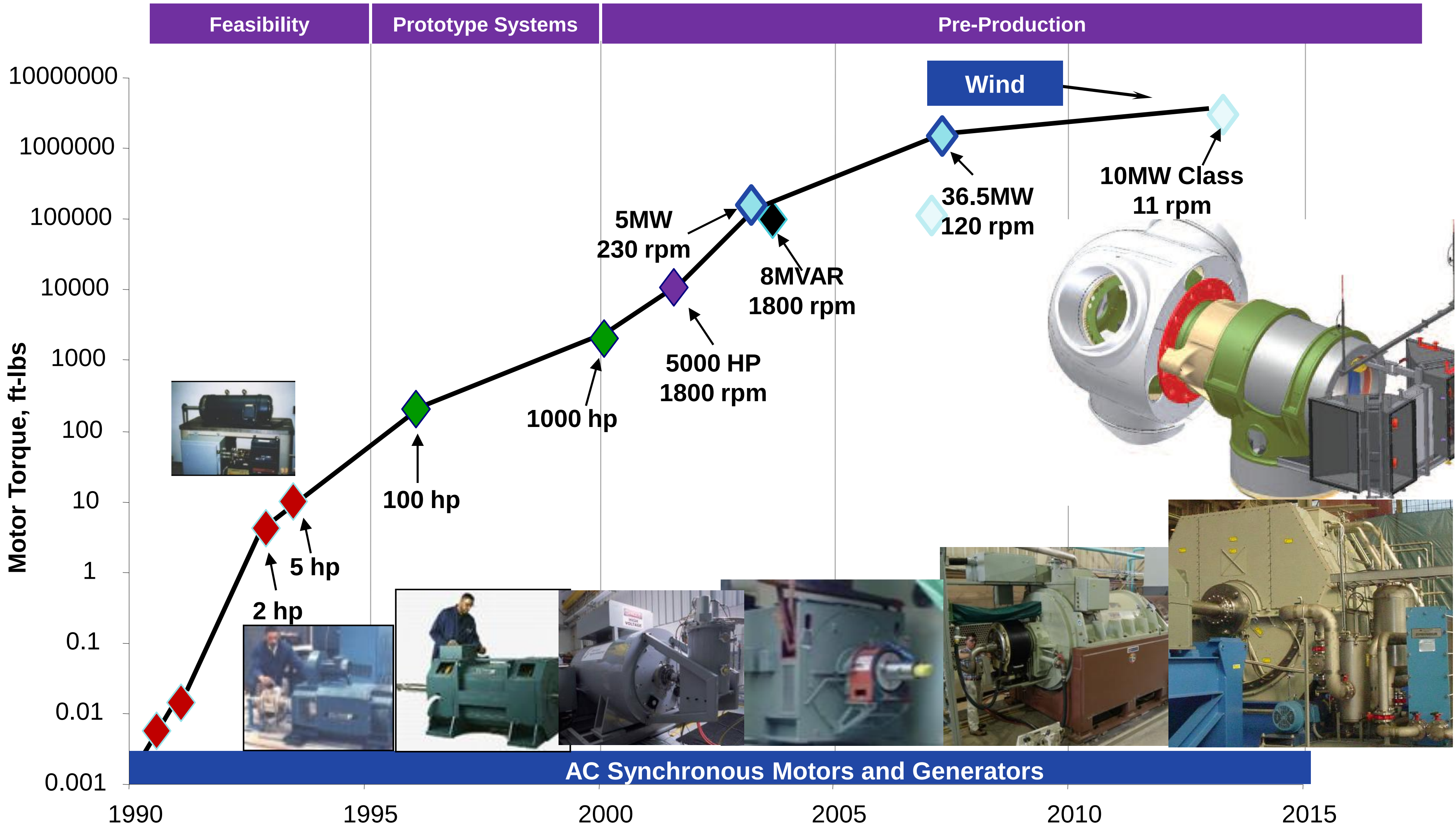
Key to the SeaTitan's Success: Superconductor Wire



Power density advantage drives system adoption and opens markets for HTS

Electric Machine History

12 Machine Classes Developed and Proven

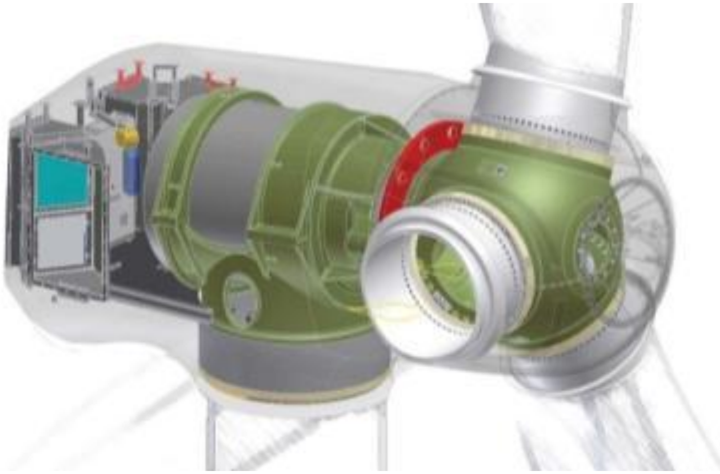


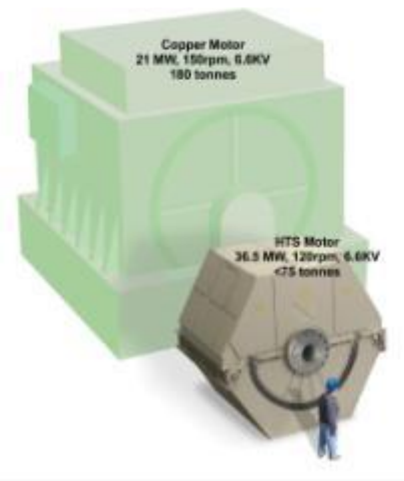
12 Machine Classes Developed and proven; Over Over 18 years of HTS machine experience

Titan Superconducting Generator

AMSC Superconducting Machine Experience Applied to Wind Turbines

Powered by AMSC


Generator Mounted In Mainframe



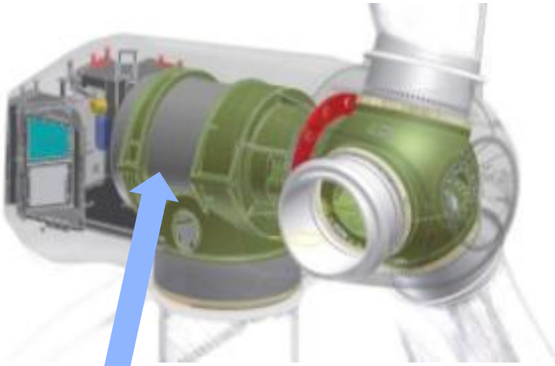
Propulsion Motor Comparison

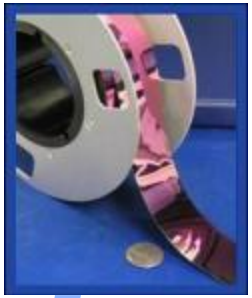
- **Less than half the size**
- **Less than a third the weight**
- **High efficiency**
- **Controllable field**
- **Integrated cooling system**

Designs validated in full load motor testing

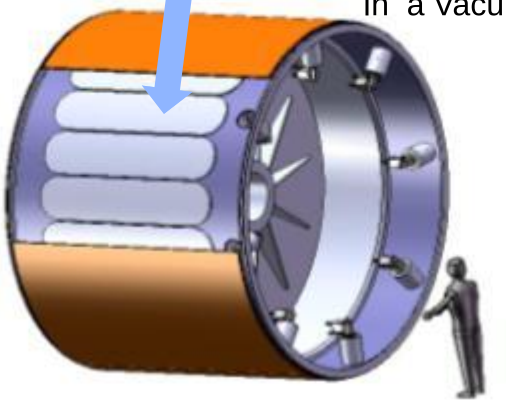
Titan Superconducting Generator

Superconducting Rotor

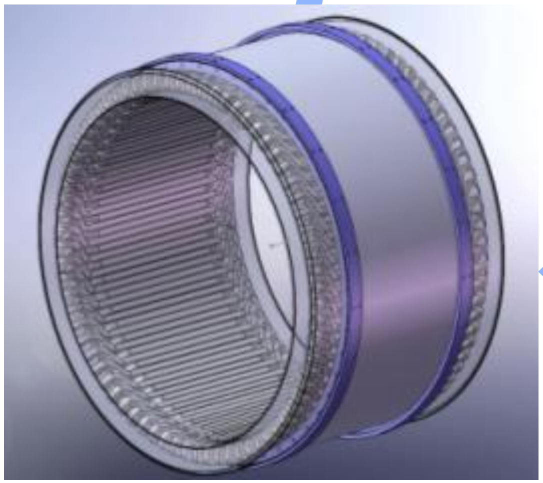




Wide 2nd Generation
High Temperature
Superconductor



24 Superconducting Coils
In a Vacuum Insulated rotor



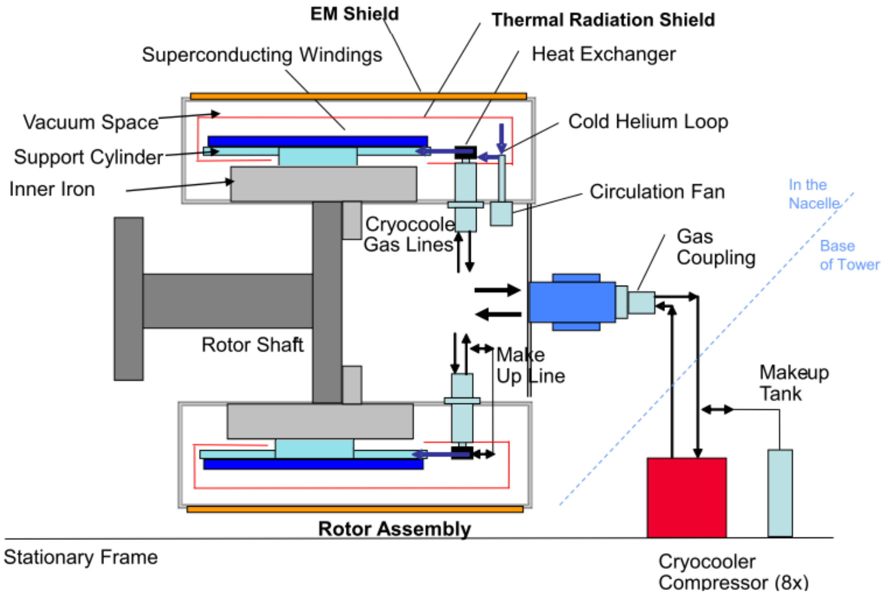
Copper Stator With Back Iron
4.5 m OD

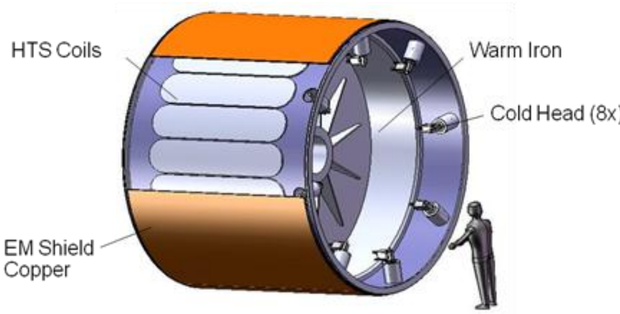
Superconducting Rotor

HTS Generator Design

Cooling of HTS coils

- The HTS needs a operation temperature of about 30-40K
- Cooling is done by expansion of compressed Helium
- Compressors can be somewhere
- A coupling between non rotational part and rotational part (rotor) is needed

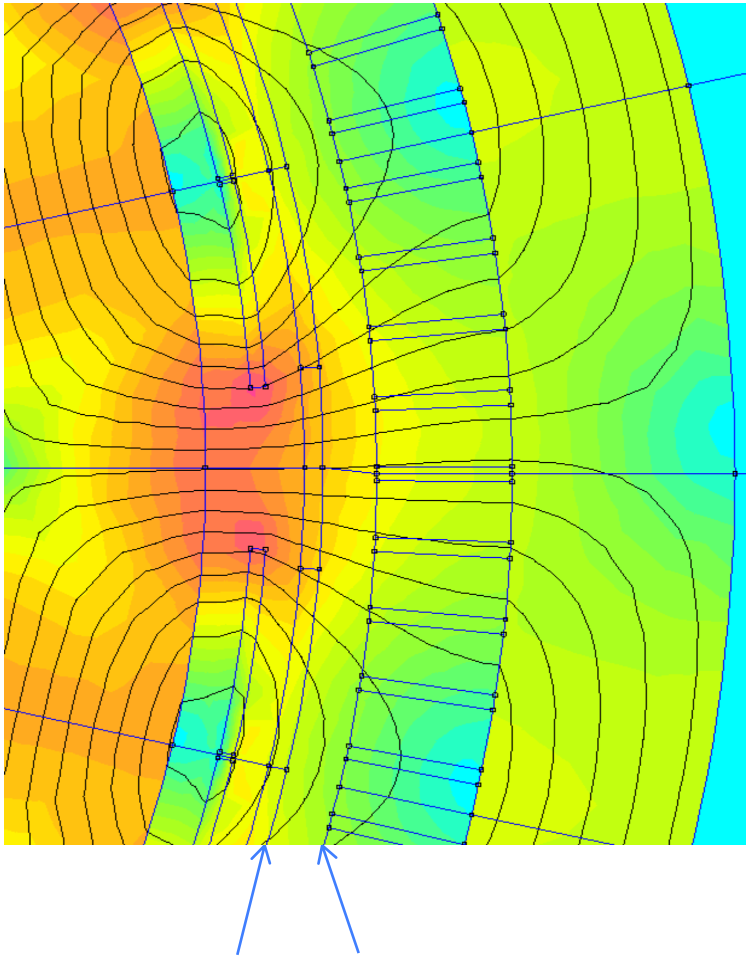




HTS Generator Design

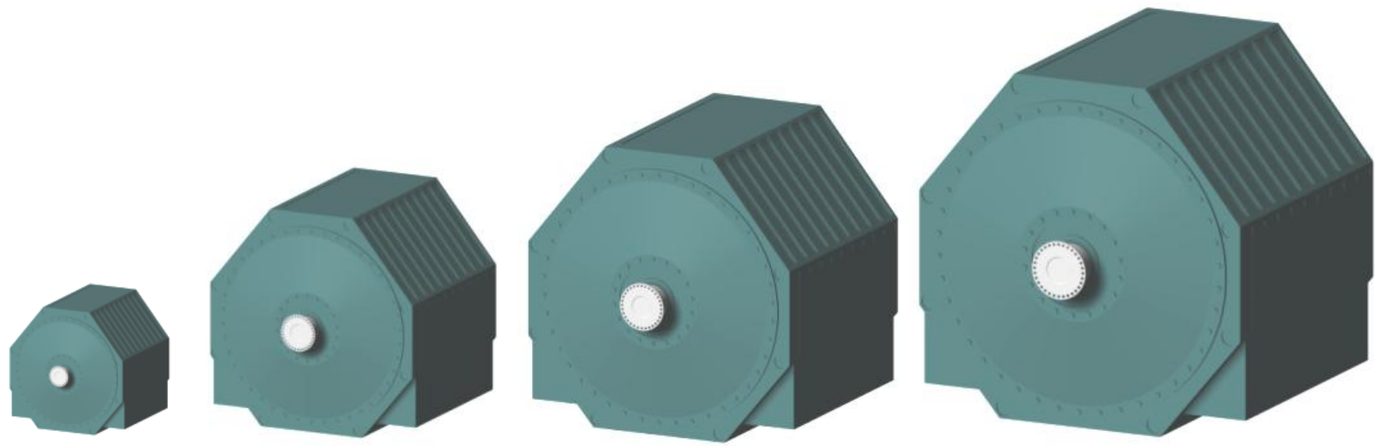
Air Gap Design

- The advanced HTS Generator has a large air gap (app. 2cm)
- HTS windings can generate high ampere-turns and flux density without iron pole faces
- The EM air gap is significantly larger than the mechanical gap
- Forces due to misalignments are small. 3MW WTG Example: 10 mm vertical deflection yield 370 kN, but the force vector is toward deflection



Power Density Advantage of HTS Applied to Direct Drive Wind Turbine Generators

Powered by AMSC



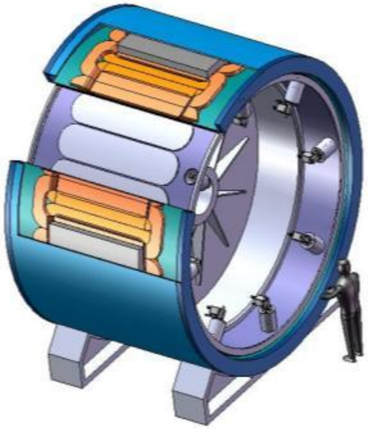
Permanent Magnet DD				
Approx. diameter Approx. weight	3.5 meters 50 tons	6 meters 90 tons	8 meters 175 tons	>10 meters >320 tons

HTS DD				
Approx. diameter Approx. weight	2.5 meters 50 tons	3 meters 65 tons	3.5 meters 110 tons	4.5 meters 150 tons

10 MW-Class HTS Wind Turbine

- Based on HTS motor and generator technology from AMSC
- Focus is on utilizing superconductor technologies for wind turbine generators that can lower nacelle weight, thus reducing total cost of energy
- AMSC Windtec now designing the SeaTitan wind turbine as part of prototype phase

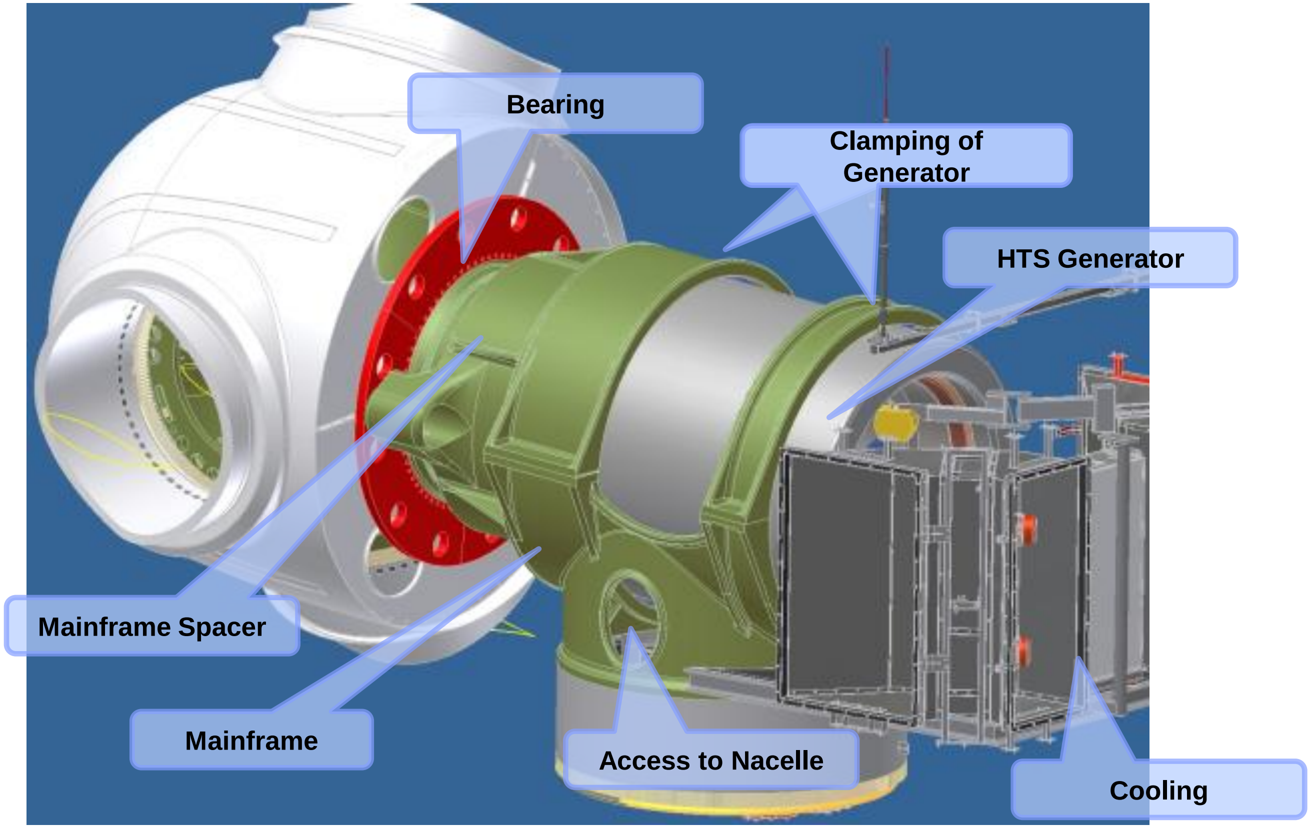
Seatitan™
Powered by AMSC



Primary focus is for the huge offshore market expected to emerge around 2015

HTS Wind Turbine

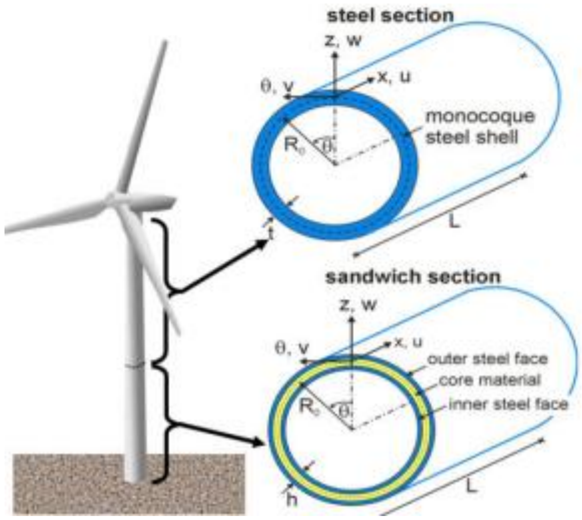
- Direct Drive, synchronous, medium voltage superconductor generator will enable a extremely <u>compact</u>, <u>light weight</u> and <u>reliable</u> wind turbine nacelle design
- No oil, high speed moving parts and power electronics in the nacelle anymore



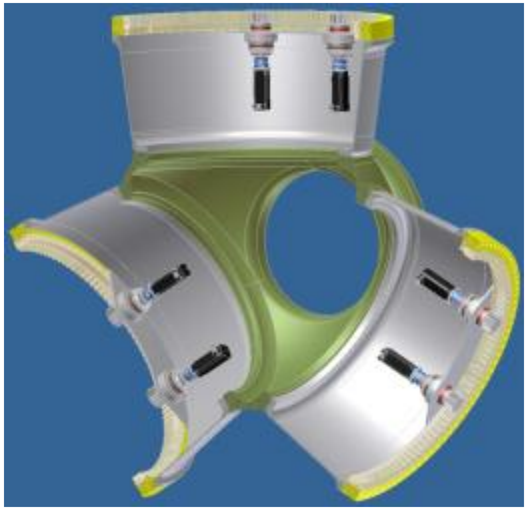
HTS Wind Turbine

Many special optimized components reducing total turbine weight, manufacturing complexity, improved assembly processes, reduced transportation and erection costs as well as increased reliability and reduced component replacement time

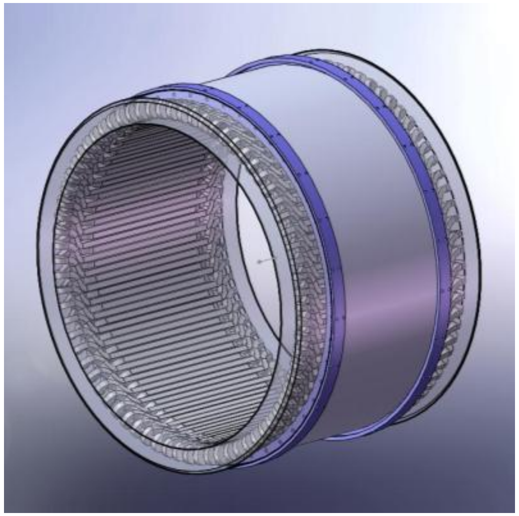
Optimized Tower



Optimized Hub



HTS Generator



Optimized Yaw

SeaTitan Wind Turbine

Powered by AMSC

- Reduced costs with light weight turbine design
  - → Optimized drive train with compact and light weight design; nacelle contains only what is absolutely necessary
  - → Reduced costs by reducing loads and increase reliability
- Reduced loads via implementation of new blade technology, individual pitch control, and new control settings

Operation & Maintenance Advantages SeaTitan™

- Simplified drive train
  - Just two rotating bearings
  - No gearbox
- Modular design approach
  - Smaller parts to manufacture → higher precision
  - Smaller crane required for exchange of components
- Most components placed in tower bottom
  (converter, cryogenic cooling compressors ,control cabinet, switch gears,…)
  - Easier access
  - Faster exchange
- Redundancy for essential components
  - ≥ 2 pitch drives
  - Cold heads (+1)
  - Modular power converter system
  - Modular cryogenic cooling system

SeaTitan™ Differences Versus Conventional Designs

Powered by AMSC

Description	Gearbox Drive Train	HTS Direct Drive
Shaft deflection caused by rotor loads	Compensated within gearbox – can cause damage of teeth	Compensated by generator air gap – no damage
Noise caused by vibrations	Noise decoupling required	Vibrations not present
Power level	Up to 6MW tested	Up to 20MW or even higher

- Direct drive → low speed → reduced load cycles over lifetime → lower fatigue loads
- Reduced tower head mass compared to other solutions such as geared, gearless or hybrid turbines
- Generator above tower. This gives improved main frame design and better load transfer from hub to tower
- Operation & Maintenance HTS: lower service costs due to:
  - Modular designed components
  - No gearbox exchange necessary
  - Large ships and big cranes not required for service & component replacement
  - Time-saving service missions

Thank you!

Andreas Thieme
Director Business Development and Sales

Lakeside B08
9020 Klagenfurt
Austria

Ph: +43 (0) 463 444604-430
Fx: +43 (0) 463 444604-444
Email: andreas.thieme@amsc-windtec.com
http: //www.amsc-windtec.com