Offshore Wind -
High Cost is the Key Barrier to Break

Suzlon Energy Ltd.

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VP Offshore Projects Development , Suzlon Energy Ltd.
On 25th April 2013

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Group companies

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	SUZLON WIND	REpower Systems
	Wind turbine manufacturer and turnkey solution provider	Wind turbine manufacturer (Subsidiary of Suzlon)
Geographical Presence	India, USA, China, Australia, Europe, Latin America, South Africa	China, Europe (mainly Germany), Canada, USA
Market Share	7.6% (5th largest globally)	
Current Mfg. Capacity (MW)	~3,600	~1,700
Product Portfolio	Low to Medium capacity WTGs (600kW – 2.25 MW) - onshore	Medium to High capacity WTGs (2.0 MW – 6.15 MW incl. offshore)

Integrated Business Model

Infrastructure
Access roads, power evacuation, grid interconnection and power lines

Equipment Supply
Onshore and Offshore WTG & Component design, development and manufacturing

Services
EPC, project execution, installation, commissioning and O&M

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Offshore - Preamble

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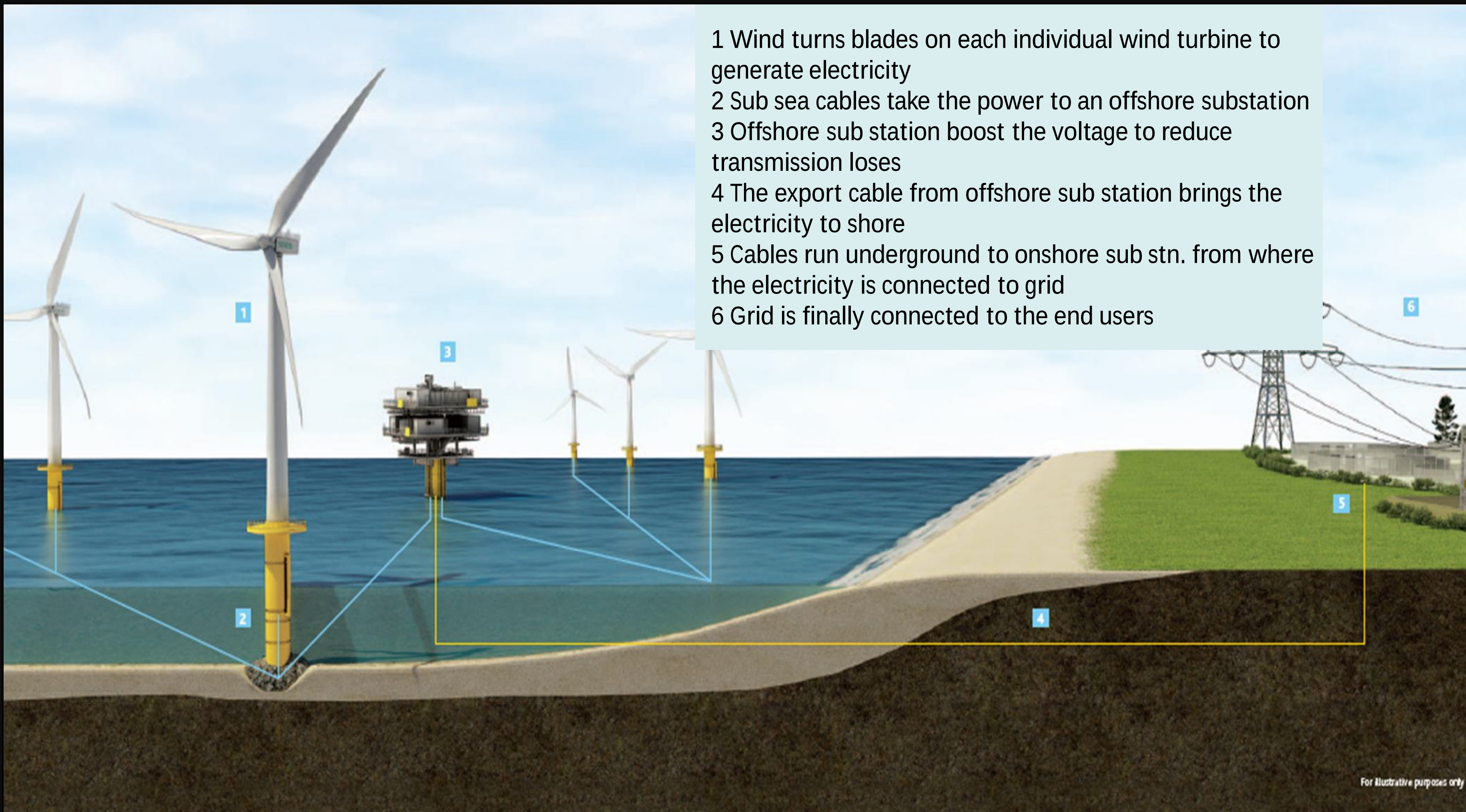

OFFSHORE WIND FARMS WORK IN THE SAME WAY AS THEIR ONSHORE COUNTERPARTS, BUT HIGHER /STRONGER WINDS MEANS THEY GENERATE MORE ENERGY . HOWEVER , IT IS MORE EXPENSIVE TO BUILD AND RUN OFFSHORE WIND FARM DUE TO HARSH AND UNPREDICTABLE MARINE ENVIRONMENT . EACH OFFSHORE WIND FARM PRESENTS UNIQUE CHALLENGE DUE TO ITS LOCATION AND SEA BED CONDITIONS BEING COMPLETY DIFFERENT .

Current Offshore Market Outlook

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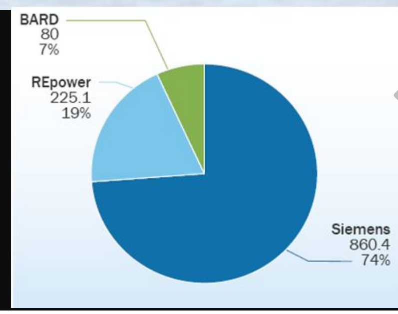
Continent	Country	No. of Farms	No. of Turbines	Capacity Operational *
Europe	United Kingdom	26	750	2515.7
	Denmark	15	403	864.5
	Netherlands	4	128	246.8
	Germany	8	56	220.3
	Belgium	3	73	268.8
	Sweden	5	75	163.7
	Finland	2	9	26.3
	Ireland	1	7	25.2
	Norway	1	1	2.3
	Portugal	1	1	2
Asia	China	3	92	251.3
Total		**69**	**1595**	**4586.9**

* Data as on 30 June 2012 for Europe and Nov 2012 for China

Sources : EWEA & Wikipedia

14 offshore projects currently under construction of capacity totaling 3.3 GW
Prep. Work in progress on 7 other projects with a cumulative capacity of 1,174 MW.
2013 installations expected 1,400 MW
2014 installations around 1,900 MW.



Offshore Turbines Grid Connected in 2012

Offshore Wind Farm Cost

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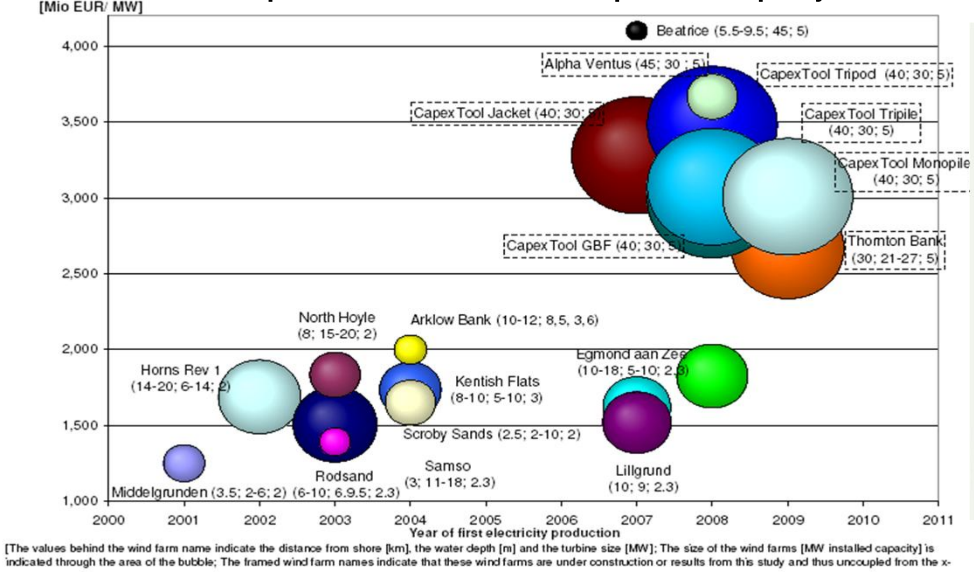
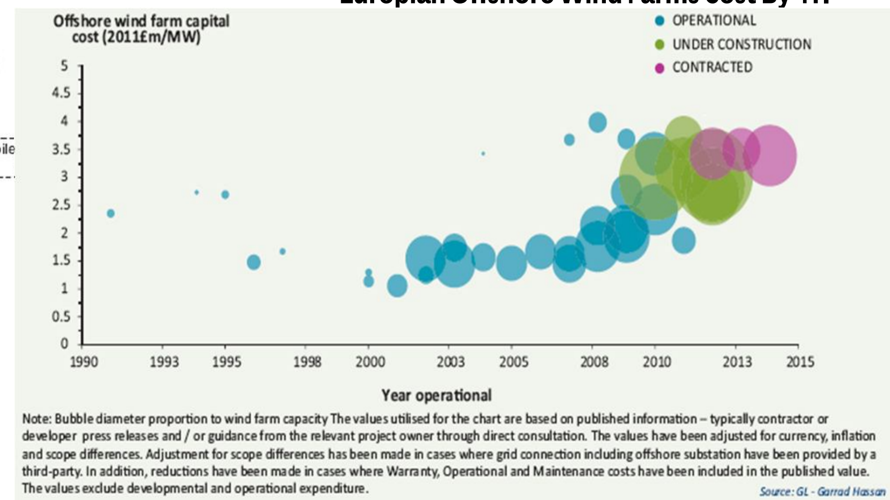
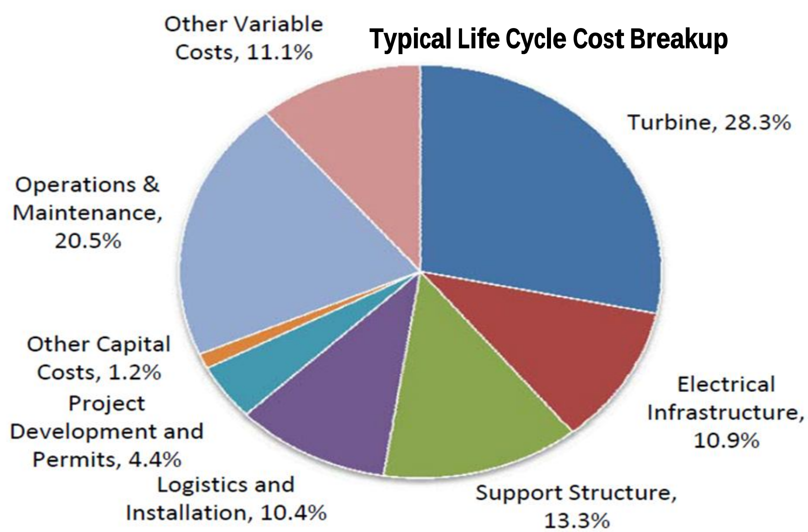
Capital cost w. r. to Distance/Depth/OWT Capacity



Europian Offshore Wind Farms Cost By Yr.

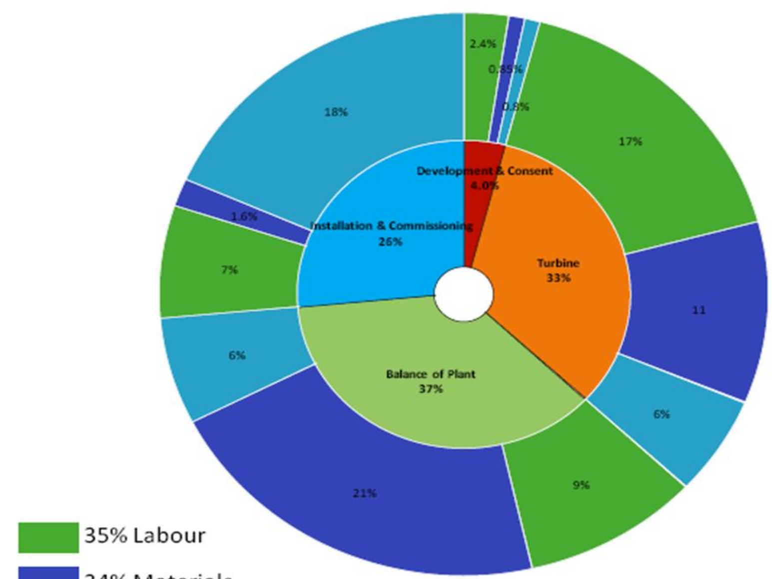


Typical Life Cycle Cost Breakup



Ref : http://www.nrel.gov/docs/fy10osti/45889.pdf

Cost of Capital Breakup - 2015



Source : UK Renewable Advisory Board Report By BVG Associates

Offshore Cost Component Breakup

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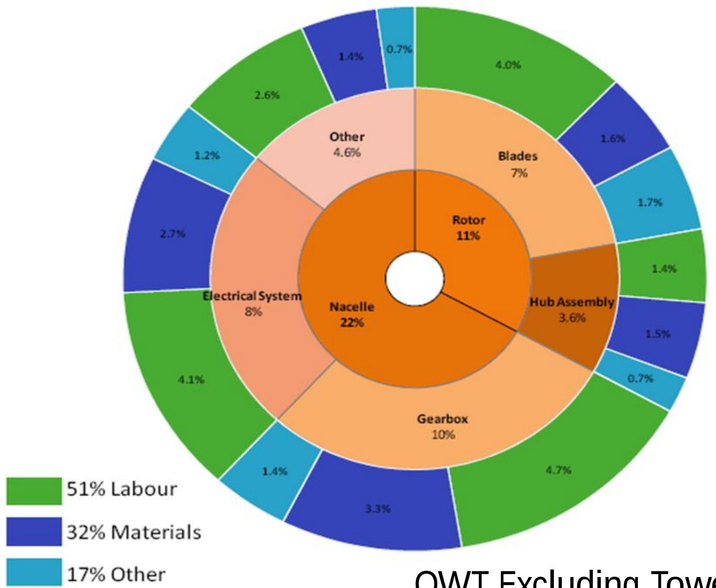
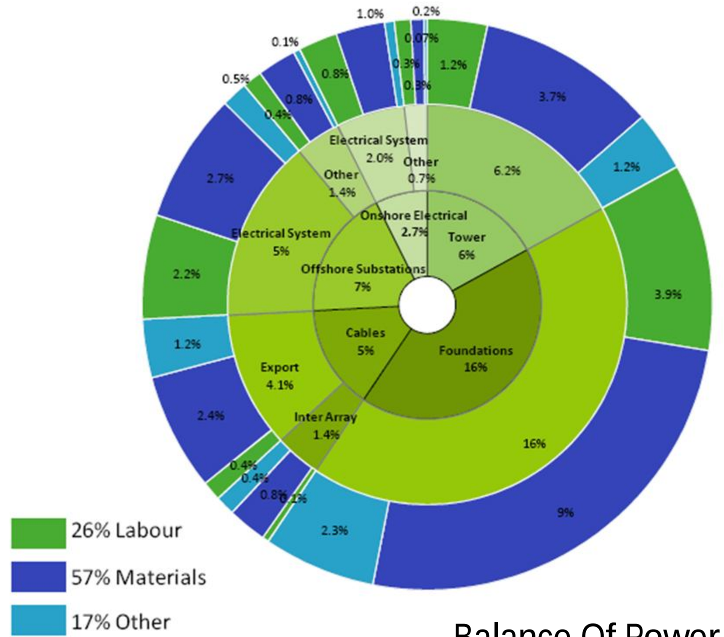
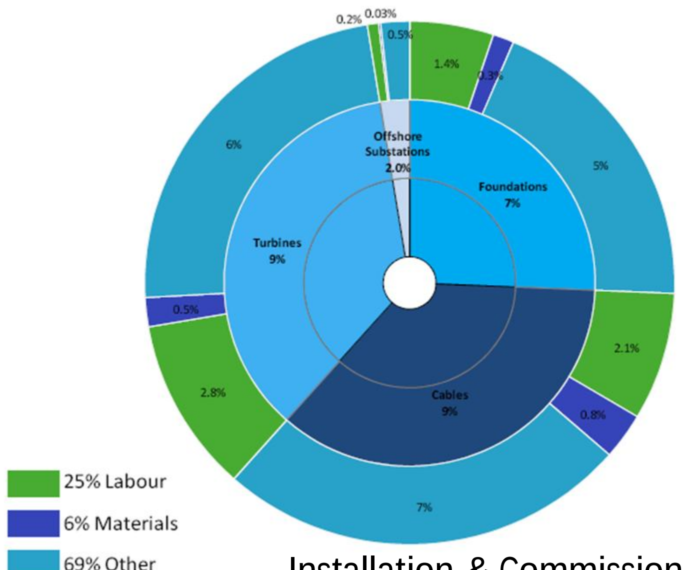


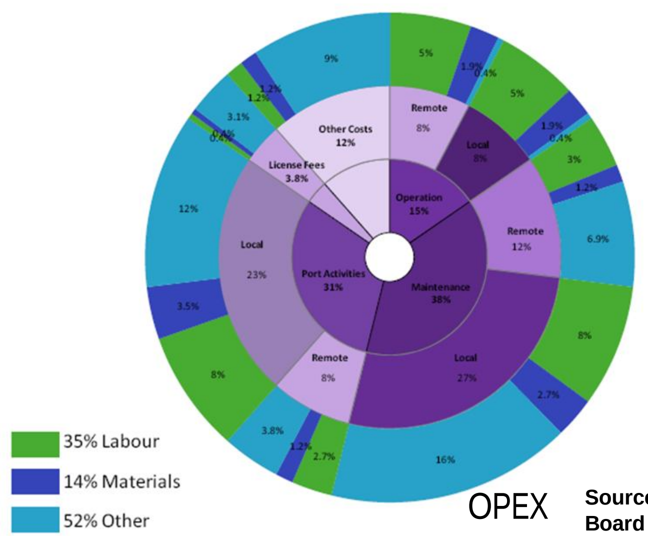
OWT Excluding Tower



Balance Of Power



Installation & Commissioning



OPEX

Source : UK Renewable Advisory Board Report By BVG Associates

Offshore Wind Cost of Energy

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Further to higher capital costs, offshore wind energy currently has a higher cost of energy than comparable technologies.

This cost of energy can be broadly calculated as the sum of all up-front annualized capital equipment costs and operations and maintenance costs over the life of the project, divided by the total energy output of the project.

Offshore Wind Cost of Energy Calculations

The general formula for calculating the cost of offshore wind energy can be represented as:

$$COE = \frac{(DRF \times ICC) + O\&M + LRC + Fees}{AEP}$$

COE = cost of energy
DRF = discount rate factor
ICC = installed capital costs
O&M = operations & maintenance costs
LRC = levelized replacement costs
AEP = annual energy production
Fees = annual insurance, warrantees, etc.

$$DRF = \frac{d}{1 - 1/(1+d)^N} \times \frac{(1 - T \times PVDEP)}{1 - T}$$

d = discount rate
N = analysis period
T = marginal income tax rate
PVDEP = present value of depreciation

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DOE of USA

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DOE of USA has planned for reducing the cost of offshore wind energy from $0.27 per kWh in 2010 to $0.07 per kWh in 2030 by increasing system efficiency and decreasing capital costs through the development of larger systems, innovative components and fully integrated system designs.

They claim, it would result in installed capital cost will decline by 39% from $4,259/kW to $2,600/kW, average turbine rating will increase from 3.6 MW to 10.0 MW, and turbine capacity factor will improve from 39% to 45%.

They intend to focus to expand access to the most promising wind resource areas. More than half of the estimated life-cycle cost of an offshore wind turbine farm is determined by following which shall be addressed:

- Foundation
- Electrical infrastructure,
- Installation and logistics,
- Operations and maintenance costs.

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Potential Path to Reduce Cost of Offshore Wind Energy in Class 6 Wind

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Component	2010	2020	2030	2010 - Land
Installed Capital Cost ($/kW)	$ 4,259	$ 2,900	$ 2,600	$ 2,120
Discount Rate Factor (DRF)[6]	20%	14%	8%	12%
Turbine Rating (MW)	3.6	8.0	10.0	1.5
Rotor Diameter (m)	107	156	175	77
Annual Energy Production / Turbine (MWh)	12,276	31,040	39,381	4684
Capacity Factor	39%	44%	45%	36%
Array Losses	10%	7%	7%	15%
Availability	95%	97%	97%	98%
Rotor Coefficient of Power	0.45	0.49	0.49	.47
Drivetrain Efficiency	0.9	0.95	0.95	0.9
Rated Windspeed (m/s)	12.03	12.03	12.03	10.97
Average Wind Speed at Hub Heights (m/s)	8.8	9.09	9.17	7.75
Wind Shear	0.1	0.1	0.1	.143
Hub Height (m)	80	110	120	80
Cost of Energy ($/kWh)	**0.27**	**0.10**	**0.07**	**0.09**
Cost of Energy ($/kWh) at constant 7% DR	**0.12**	**0.08**	**0.07**	**0.08**

Courtesy NREL-USA

Rs 15.00-

Rs 5.50

Rs 3.85

Rs 5.00

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Reduction in Cost of Energy – European Drive

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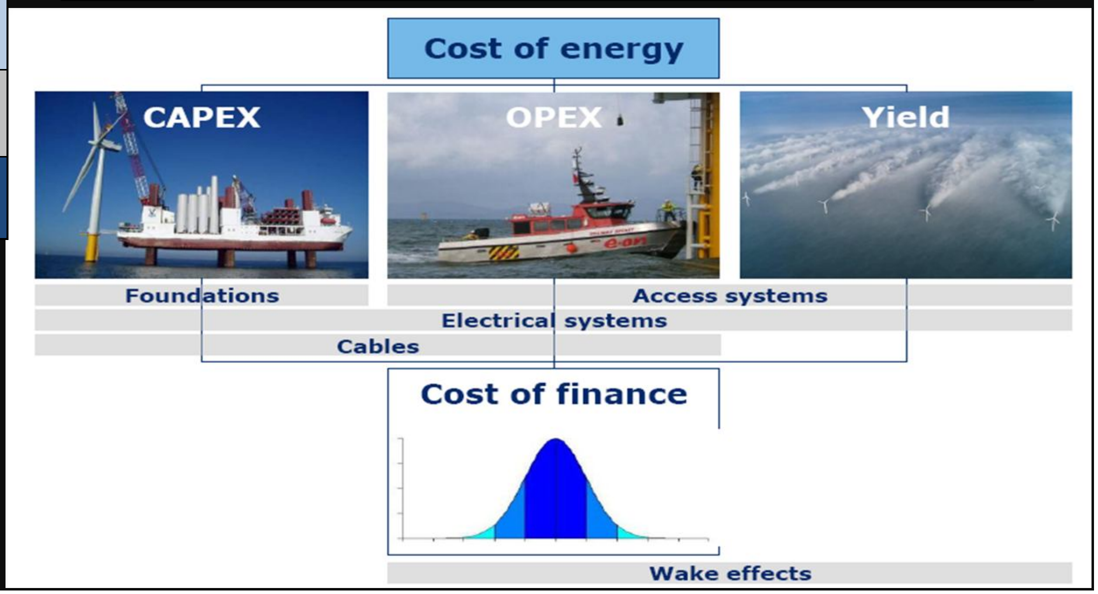
Offshore Wind Accelerator - Research, Development and Demonstration Project to reduce cost of offshore CAPEX by 10% by 2014 @ Budget GBP40Million with 9 developers & Carbon Trust

DONG Energy	E.ON
MAINSTREAM RENEWABLE POWER	RWE
SSE Renewables	SCOTTISHPOWER RENEWABLES
Statoil	Statkraft
VATTENFALL	Carbon Trust Carbon Trust.pptx
60% (30GW of licensed capacity in UK waters)	



DECC UK Grant for Cost Reduction

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Offshore wind innovation has been given a boost by the Department of Energy and Climate Change (DECC) UK. Innovation is key to improving efficiency and has the potential to drive down costs of offshore wind by 25 % by 2020 and 60 % by 2050.

The DECC grant will give the companies the boost they need to take their innovative designs to the next level, helping cut costs in offshore wind generation.

The DECC grant has been awarded for project ideas @ GBP 4 Million each viz.

- Create an integrated offshore high voltage network management system (OHVMS) for wind farms
- Develop and build innovative HVAC cables
- Develop the design and serial manufacturing process for innovative WindFloat floating foundations for wind turbines

10MW for depths beyond 50m , Principle Power is deploying the WindFloat technology worldwide - pursuing projects in Portugal, Oregon and Maine.

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Cost of Offshore –Pathway Study

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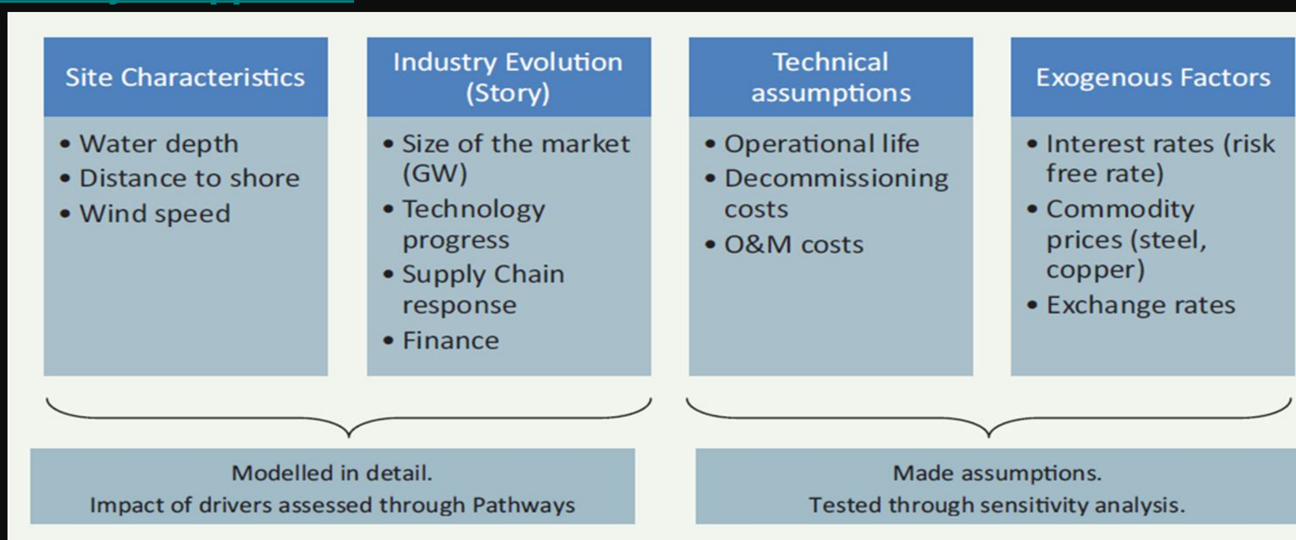
The cost of offshore in UK have increased since early 2000. This has been attributed to supply chain bottle necks, also to move to deeper water sites. Recent wind farm projects have indicated that cost has stabilized around GBP 140/MWh for projects FID in 2011.

Financial Investment Decided

UK Government and industry have worked together to shape up the offshore wind industry and investment in new technologies and facilities. The future cost is considered critical in deciding the future size in UK. Participation with 120 related companies has resulted that reducing the cost of offshore wind to 100GBP/MWh by 2020 is achievable (Pathway Study)

Cost Driver Analysis Approach



Source : Offshore wind cost reduction pathways study

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Offshore Wind Cost Reduction Pathway Study

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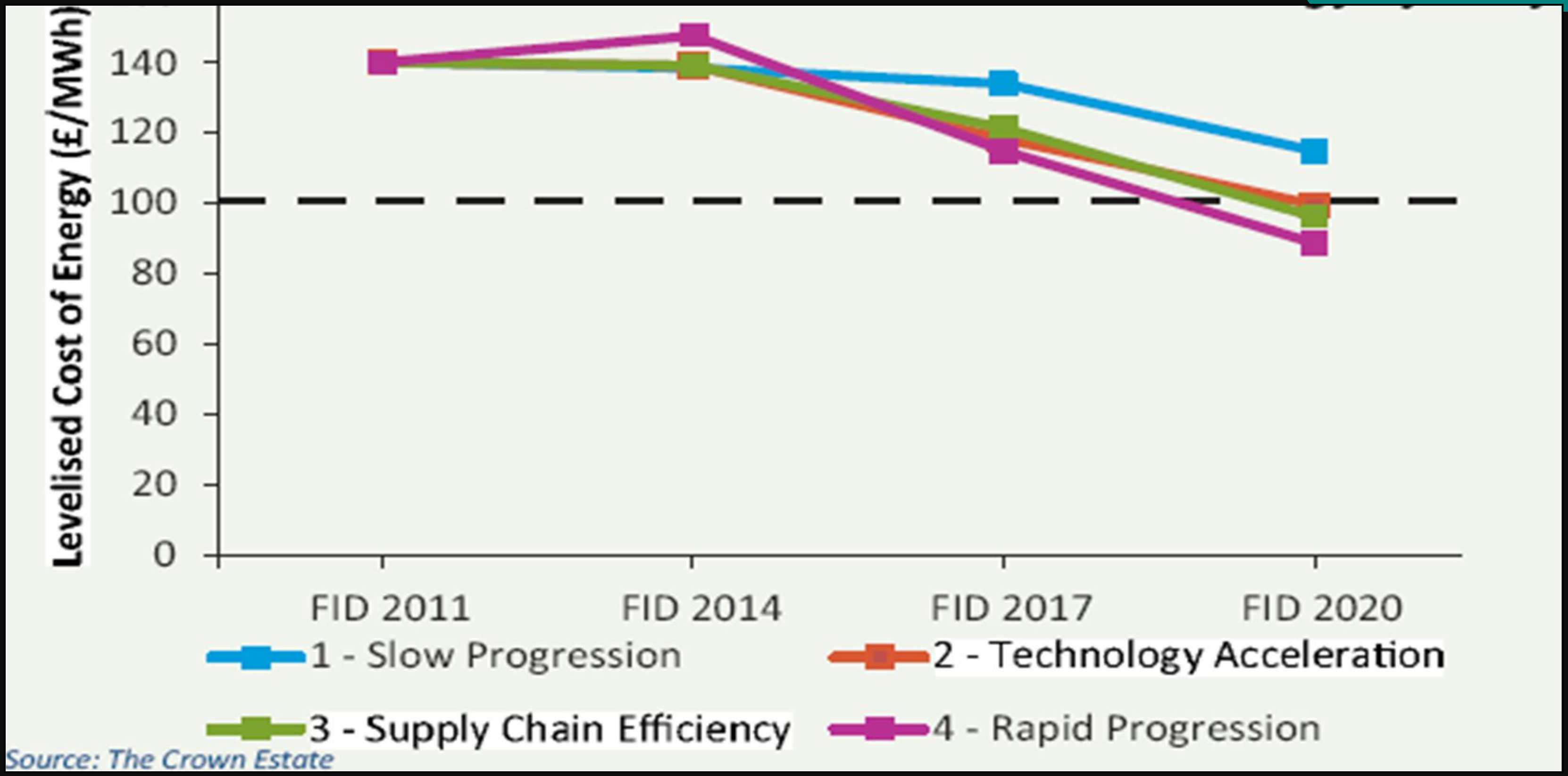

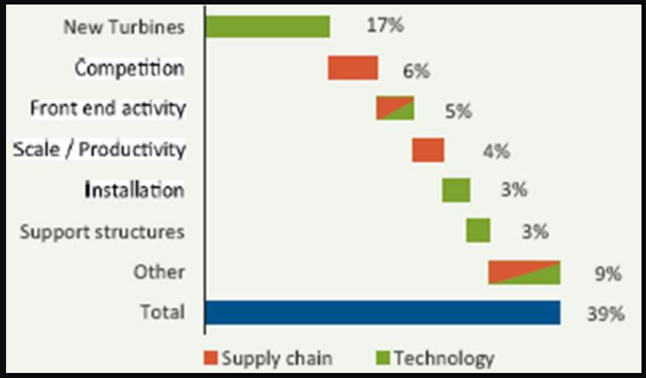

Cost Reduction Opportunity by Technology & Supply Chain as % Reduction in LCOE[Industrial Story.pptx]

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Sensitivity Modeling Results

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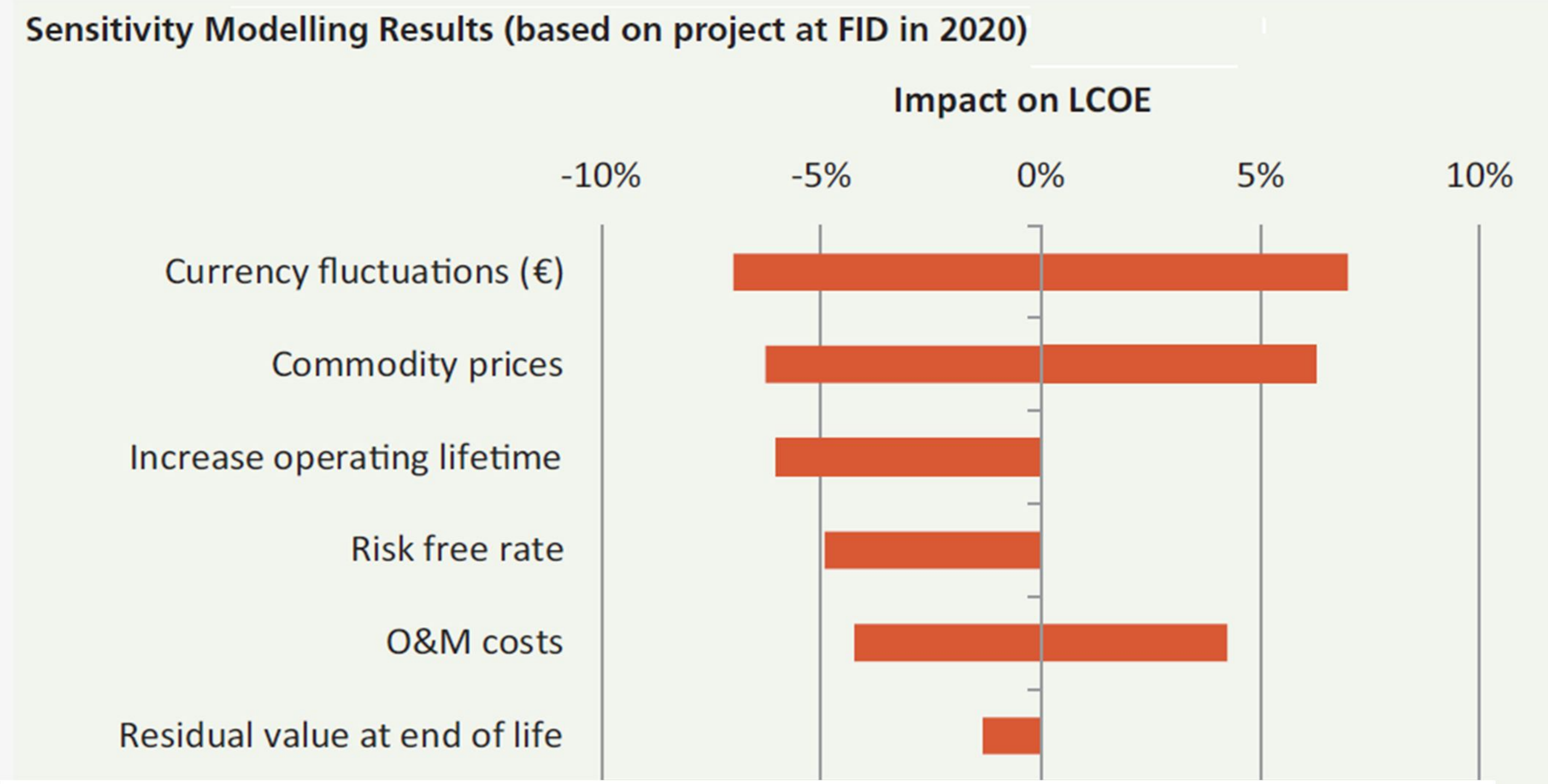

[41] O&M costs and Decommissioning costs are calculated for each data point (ie site, story, turbine, year combination); whereas the operational lifetime, commodity prices, exchange rates and interest rates are fixed across all datapoints. See Appendix 2 for more details of our assumptions.

[42] Analysis based on a wind farm at FID in 2020 using 6MW turbines, on site B, in the Supply Chain Efficiency story

[43] It should be noted that the impact of each of these sensitivities changes over time. For example, since the turbine increases as a proportion of CAPEX and LCOE between FID 2011 and FID 2020, the impact of the steel price sensitivity also increases over time. The results presented related to a typical project at FID in 2020.

Source : Offshore wind cost reduction pathways study

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Offshore Requirement

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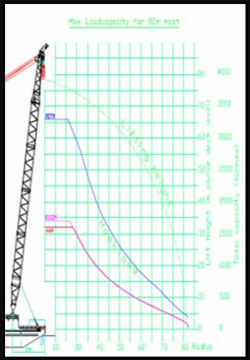

Installation Specific

- Multi Task Capability
- High Speed (~14knots)
- Higher Installation rate
- Pay load - 10 to 12 Installation in single voyage
  - Jackable weight & system capability
  - ~7000 to 8000t
- Crane - Optimum Position
  - Crane Capacity (~ 800 to 1200t)
  - Crane Curve /out reach/hook height (~ 115m)
- Accommodation (80 to100 men)
- Propulsion ; Transit speed & DP 2 capabilities (4xAzimuth thrusters +Tunnel thruster)
- Power : In accordance with above, critical DP with jacking (~ 12,000 to 14,000KW)
- Vessel to be in accordance with Class Regulations

Site Specific (TIV)

- Range of Water Depth – 50 to 70m
- Deck Strength (min. 10t/m2)
- Length of leg (~130m)
- Distance to coast – max 100 km
- Relevant Harbor in proximity - ~250nm
- Environment Conditions– Wave Ht. Transit; Stand on Bottom Off ; Operational & Survival
  - Current Velocity (Typical range 0.9 to 1.2 m/sec, Max. 1.8m/sec)
- Soil Condition – Pre loading capacity / Leg penetration / Spud cans
- Operational Availability – (250 to 290 days a year /aimed 75%)

Large number of new generation installation vessels are needed featuring innovative technologies, capable of operating in deeper waters (up to 75 m) and in harsher sea conditions

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Advance TIVs

(Clockwise)

Swire Blue Ocean

MML Vessel

SWATH –WTS Husiman

RWE Innogy Vessel

MPI MV Adventure

Beluga Hochtief

Cost Of Operation & Maintenance

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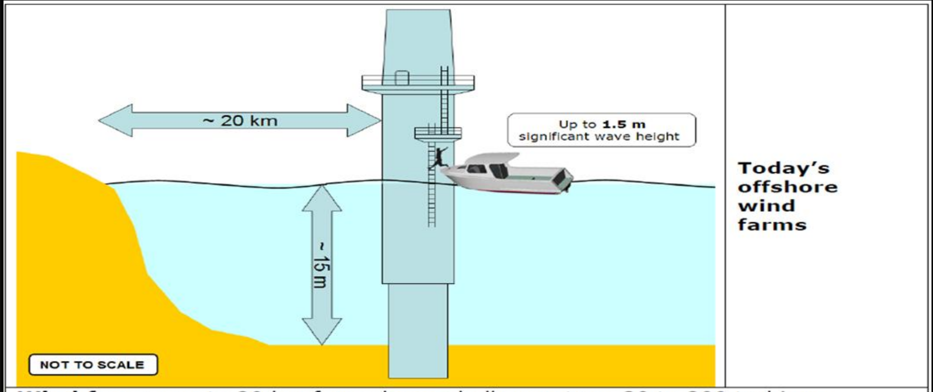
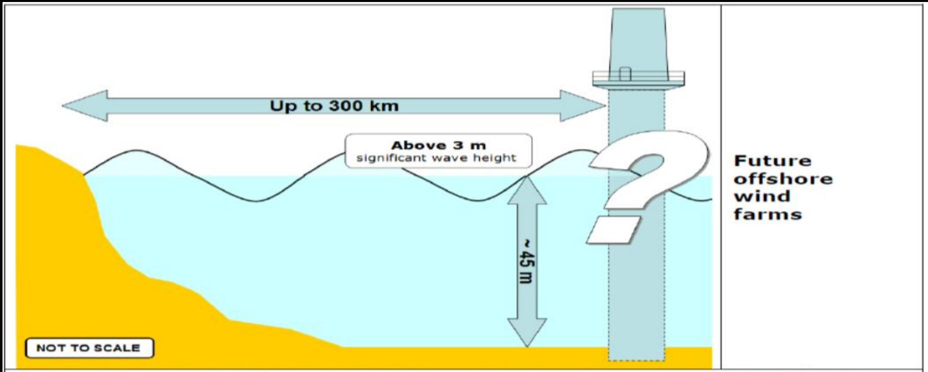
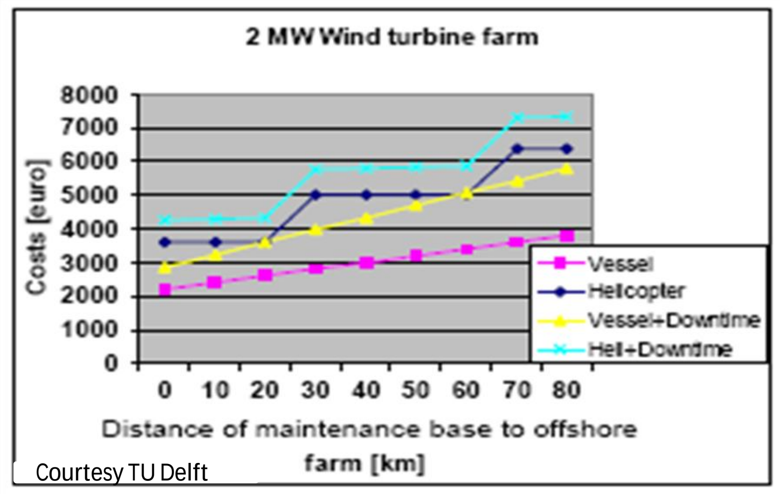
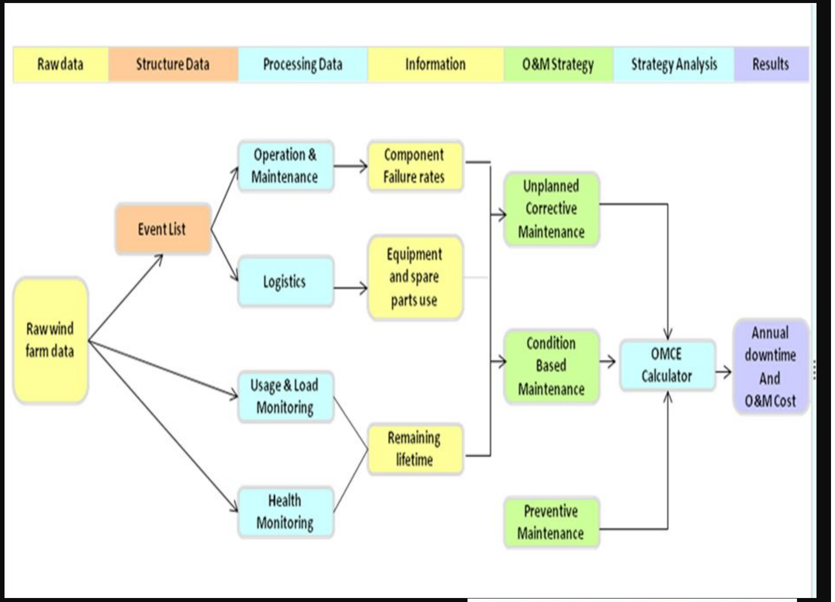


Wind farms: up to 20 km from shore, shallow waters, 30 to 200 turbines.
Metocean conditions: up to 1.5 m significant wave height.
Foundations: Predominantly monopiles.
Access: from shore via work boats and personnel stepping across onto ladders.



Wind farms: up to 300 km from shore, deeper waters, 200 to 2,500 turbines.
Metocean conditions: above 3 m significant wave height.
Foundations: Monopiles, jackets, gravity bases and piled tripods.
Access: from in-field bases or mother-ships via daughter-craft equipped with new safer transfer systems.





The costs of O&M figures show a spread of values, with the majority in the range £10/MWh to £20/MWh .

http://www.renewableenergyworld.com/rea/news/article/2013/04/cost-modeling-for-offshore-o-m?page=2

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Typical Port Infrastructure

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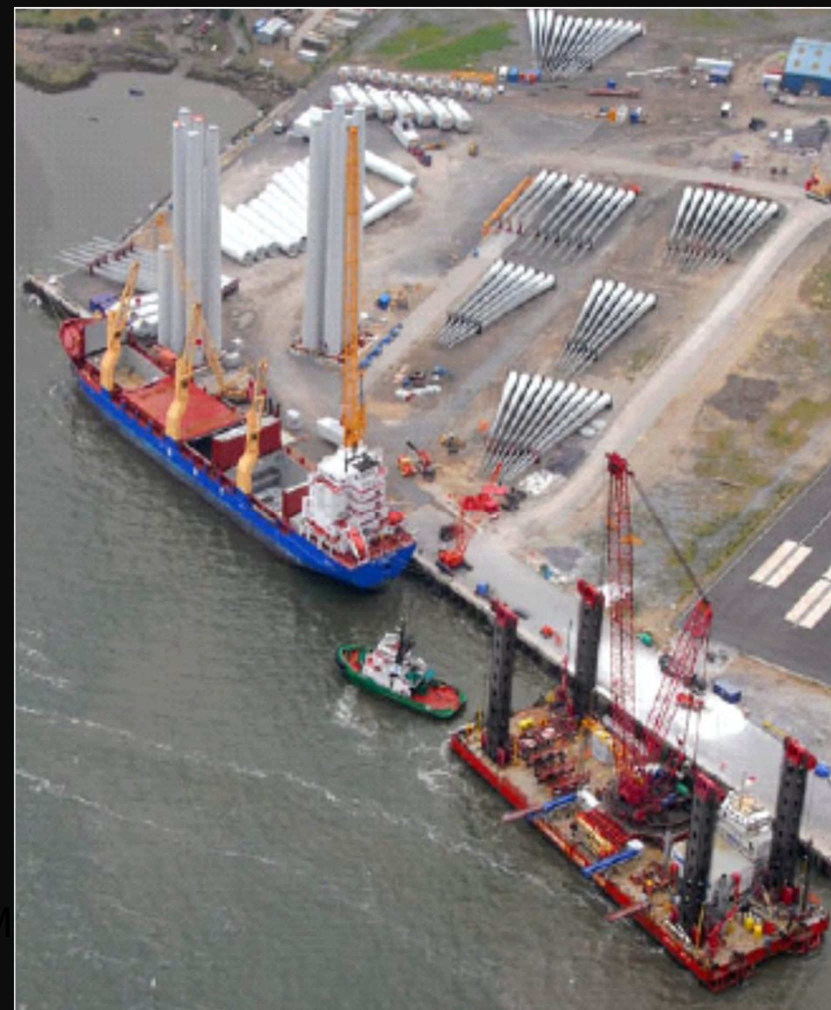
- Area for storage : 6 to 25 ha (60.000m2 to 25.000m2)
- Dedicated road between storage and quay side
- Quay length: approximate 150 m - 250 m
- Quay bearing capacity : 3 to 6 Ton/m2
- Seabed with sufficient bearing capacity near the pier
- Draft : minimum 6 m
- Ware house facilities 1000-1500 m2
- Access for smaller vessels (pontoon bridge, Barge etc.)
- Access 365-24/7
- Access for heavy /oversize trucks
- Helicopter transfer
- Longer estimated period of use for construction + O&M



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Offshore Foundations

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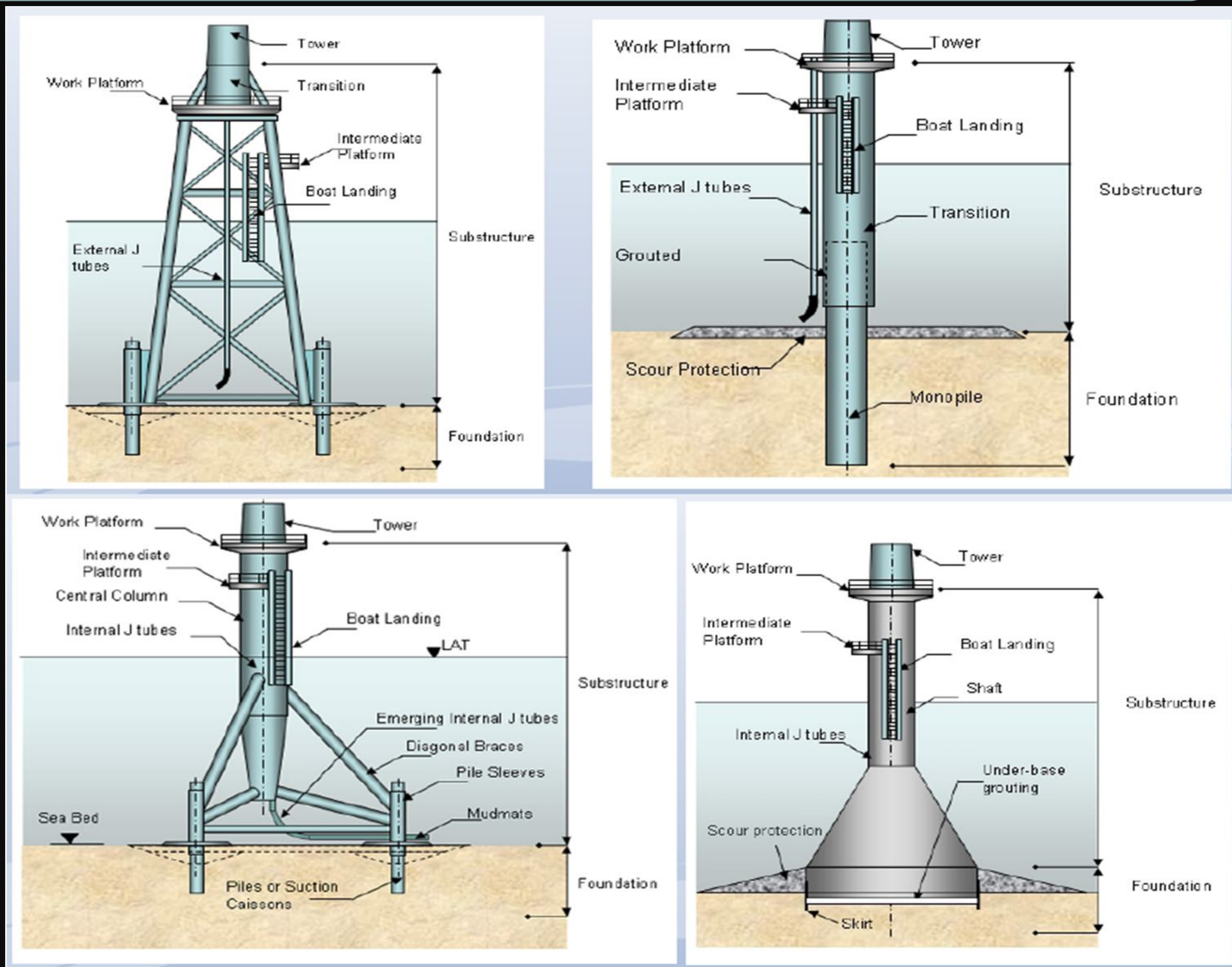
73% of substructures are monopiles,13% jackets, 6%, tripods,
5% tripiles & 3% gravity based foundations.
There are also two full scale grid connected floating turbines, and two down-scaled prototypes.



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Foundation Technologies Comparison

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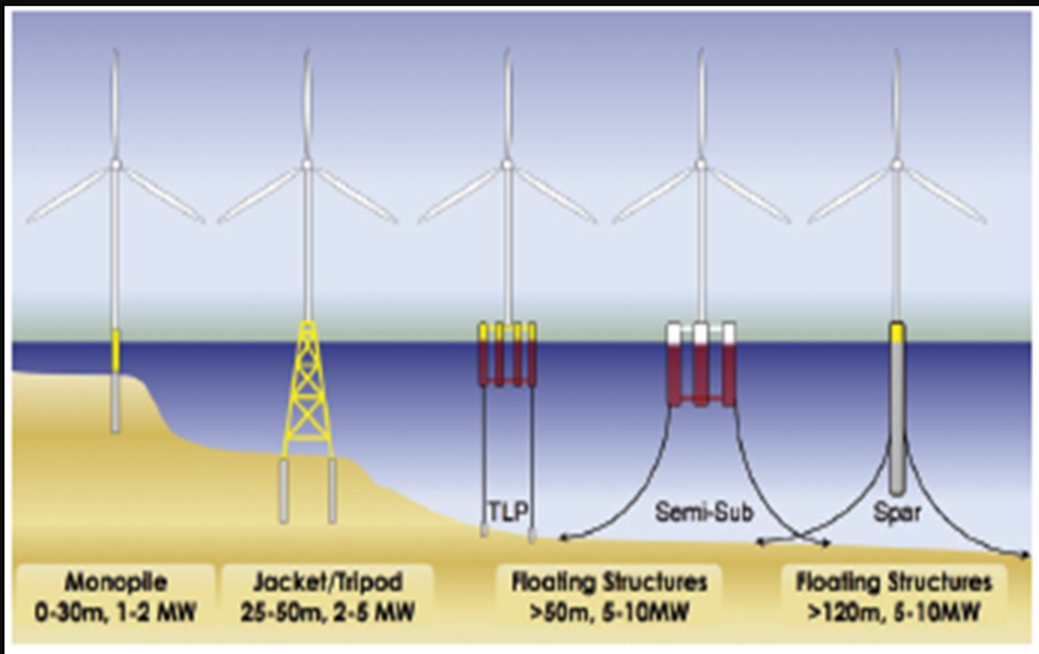
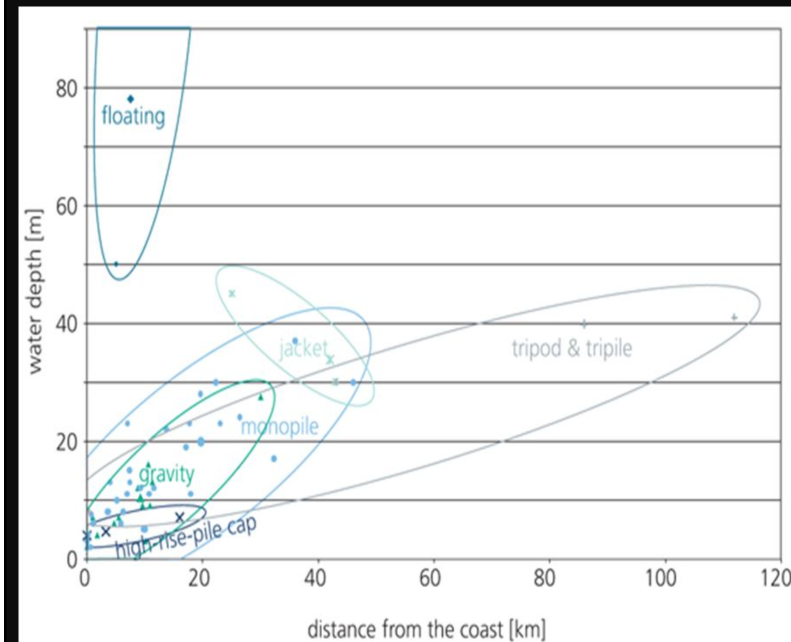
Cost & Functionally Effective Foundations





http://windmonitor.iwes.fraunhofer.de/windwebdad/www_reisi_page_new.show_page?page_nr=426&lang=en

Siting	Monopile	Jacket	Tripod	Tripile	Gravity base	Suction bucket	Floating
Varying soil conditions	0.08	0.1	0.09	0.09	0.03	0.02	0.09
Poor soil conditions	0.06	0.08	0.07	0.07	0.03	0.03	0.08
Sloping sea	0.05	0.08	0.08	0.08	0.02	0.03	0.1
Ice	0.06	0.04	0.04	0.04	0.08	0.06	0.06
Total	0.063	0.075	0.07	0.07	0.04	0.035	0.083

Courtesy : Wind Energy Update

Floating Offshore Turbine

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Hywind floating wind :

<u>Wind turbine</u>

- Capacity: SWT- 2.3 MW, built by Siemens
- Weight of turbine: 138 tonnes
- Turbine height: 65 metres
- Rotor diameter: 82.4 metres

<u>Floatation element and offshore installation</u>

- Built by Technip
- Consists of a steel floater filled with ballast
- Floatation element's draught below sea surface: 100 metres
- Diameter of floatation element: 8.3 metres

<u>Total weight: 5300 tonnes.</u>

<u>Diameter at sea surface: 6 metres.</u>

<u>No. of anchor moorings: 3</u>

StatoilHydro and Siemens have jointly developed a special control system to control the movement of the floating structure

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Future Developments -Offshore

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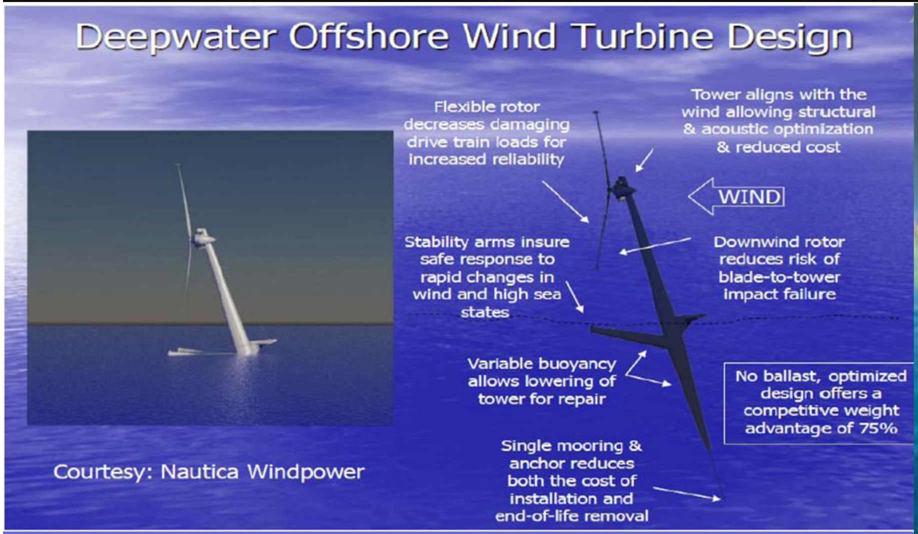
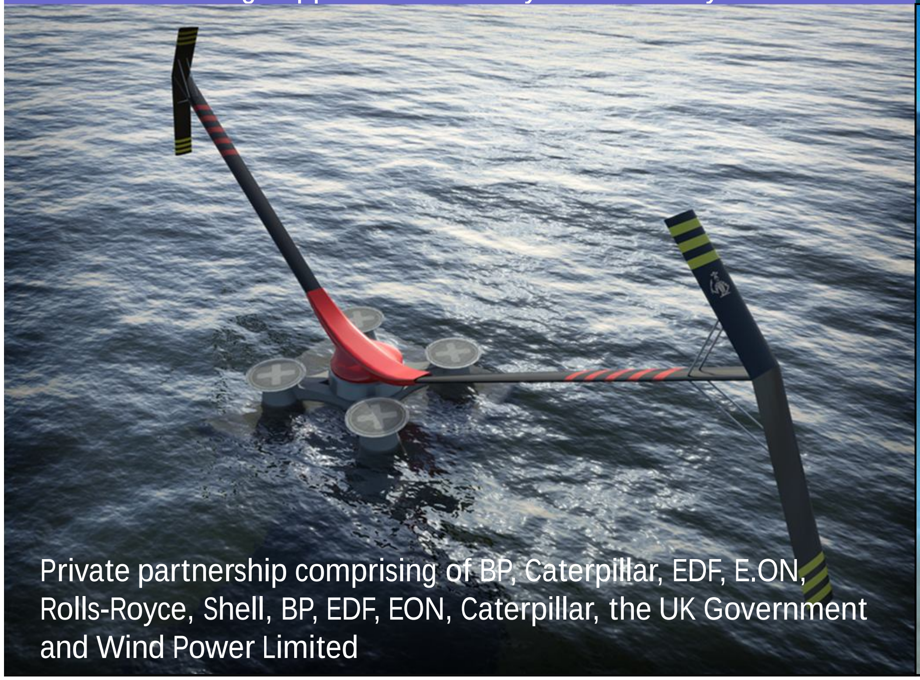
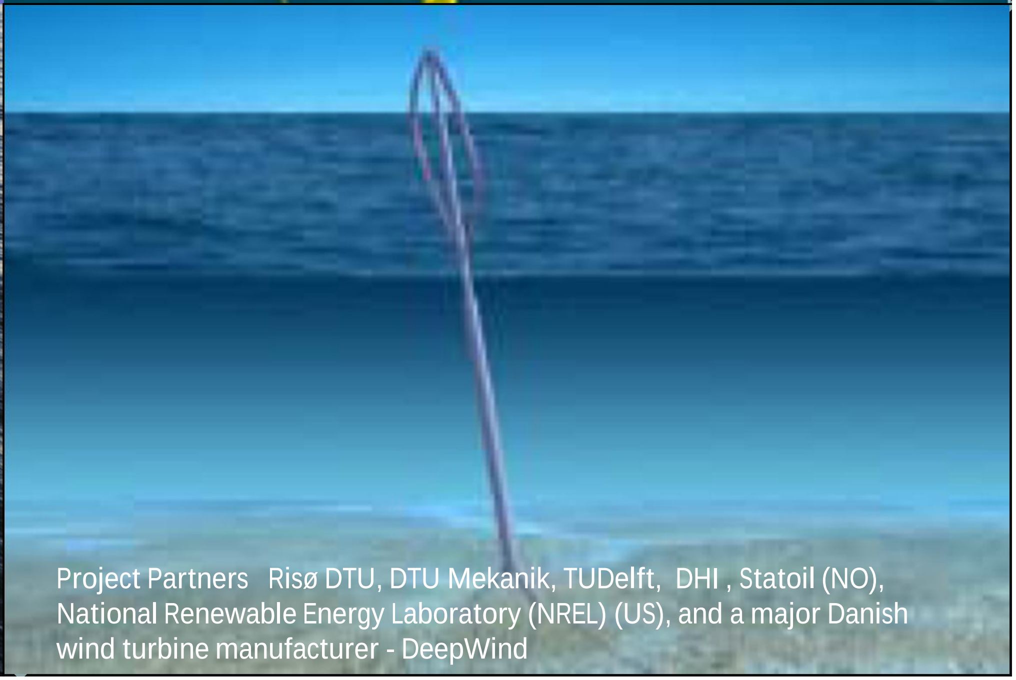


Partners including Clipper of UK & Sway AS of Norway

Sway AS of Norway -10MW OWT



Private partnership comprising of BP, Caterpillar, EDF, E.ON, Rolls-Royce, Shell, BP, EDF, EON, Caterpillar, the UK Government and Wind Power Limited



Project Partners Risø DTU, DTU Mekanik, TUDelft, DHI , Statoil (NO), National Renewable Energy Laboratory (NREL) (US), and a major Danish wind turbine manufacturer - DeepWind

Hybrid Solution

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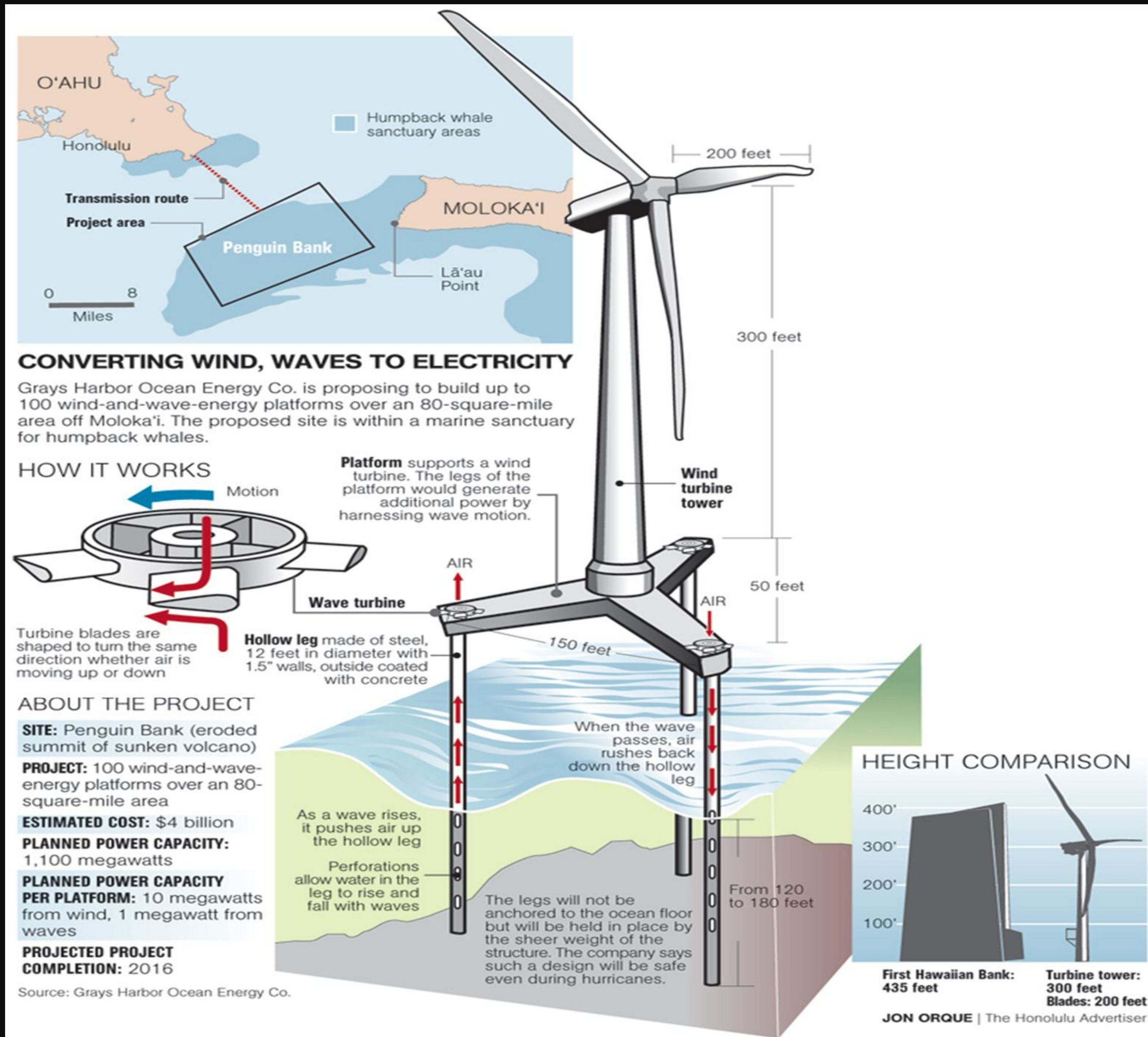

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Increase in Offshore Installation Cost

As a Function of Distance to the Coast

		Distance to coast (km)							
		0–10	10–20	20–30	30–40	40–50	50–100	100–200	> 200
Cost (EUR/kW)	Turbine	772	772	772	772	772	772	772	772
	Foundation	352	352	352	352	352	352	352	352
	Installation	465	476	488	500	511	607	816	964
	Grid connection	133	159	185	211	236	314	507	702
	Others	79	81	82	84	85	87	88	89
	Total cost (EUR/kW)	1 800	1 839	1 878	1 918	1 956	2 131	2 534	2 878
	Scale factor	1	1.022	1.043	1.065	1.086	1.183	1.408	1.598

As a Function of Water Depth

		Water depth (m)			
		10–20	20–30	30–40	40–50
Cost (EUR/kW)	Turbine	772	772	772	772
	Foundation	352	466	625	900
	Installation	465	465	605	605
	Grid connection	133	133	133	133
	Others	79	85	92	105
	Total cost (EUR/kw)	1 800	1 920	2 227	2 514
	Scale factor	1.000	1.067	1.237	1.396

As a Function of Water Depth Distance to Coast

		Distance to coast (km)							
		0–10	10–20	20–30	30–40	40–50	50–100	100–200	> 200
Depth (m)	10–20	1	1.022	1.043	1.065	1.086	1.183	1.408	1.598
	20–30	1.067	1.090	1.113	1.136	1.159	1.262	1.501	1.705
	30–40	1.237	1.264	1.290	1.317	1.344	1.464	1.741	1.977
	40–50	1.396	1.427	1.457	1.487	1.517	1.653	1.966	2.232

Source: EEA,

Installation Cost Reduction By Large Number Installations

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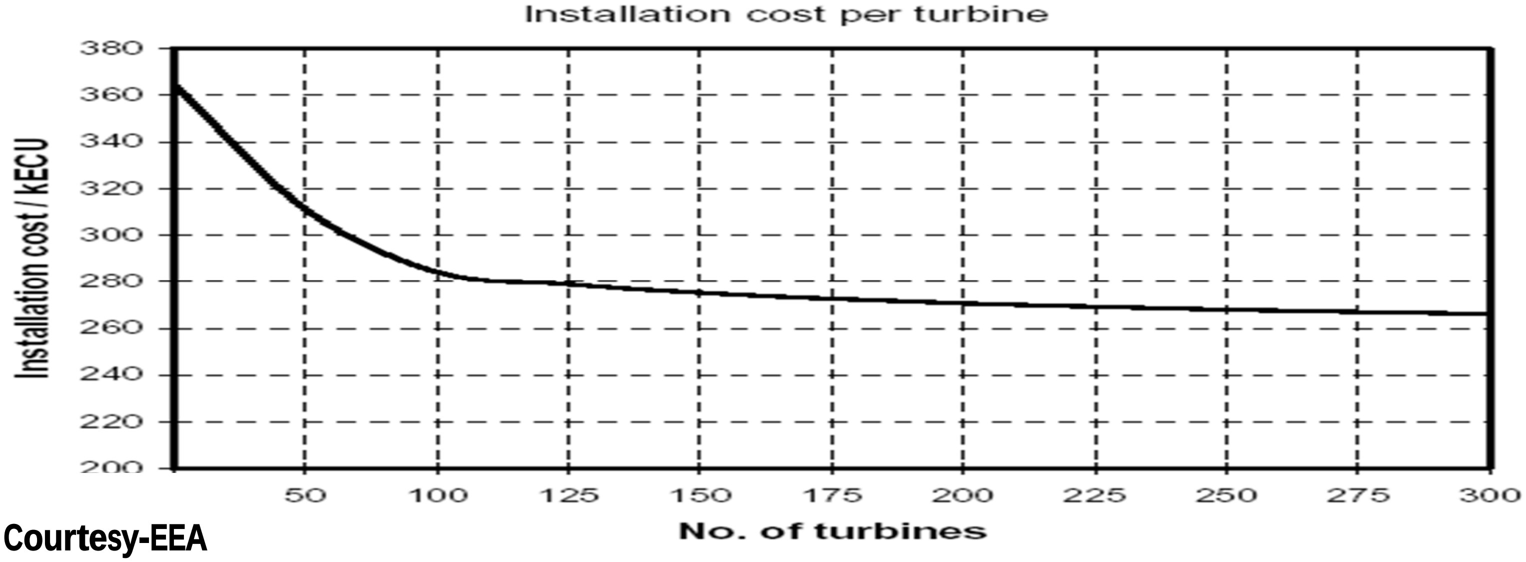
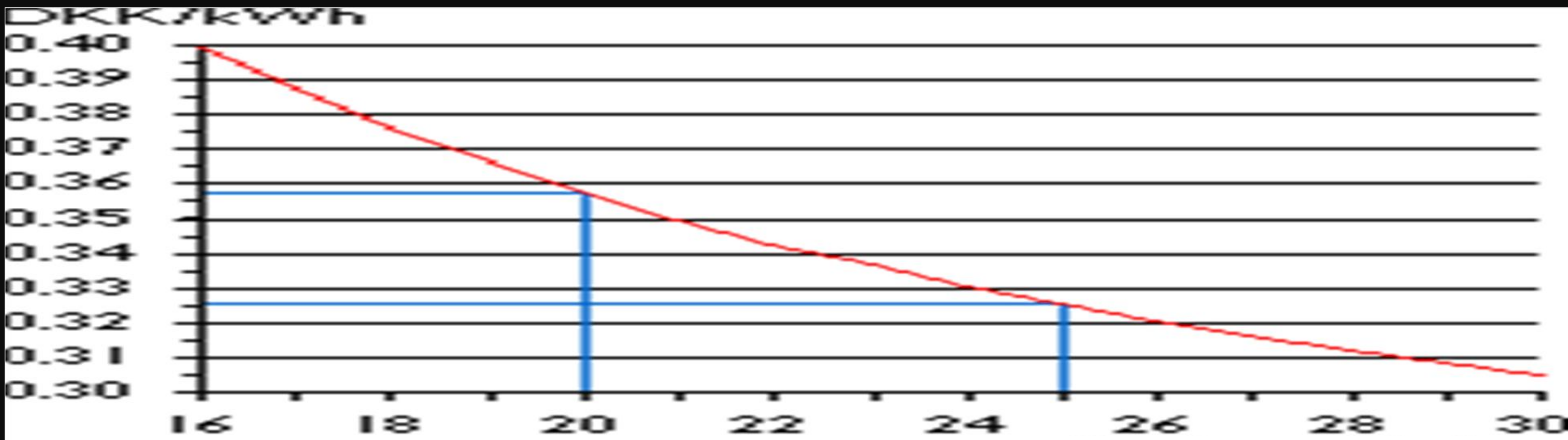


Courtesy-EEA

Reduced Cost - Longer Life Cycle

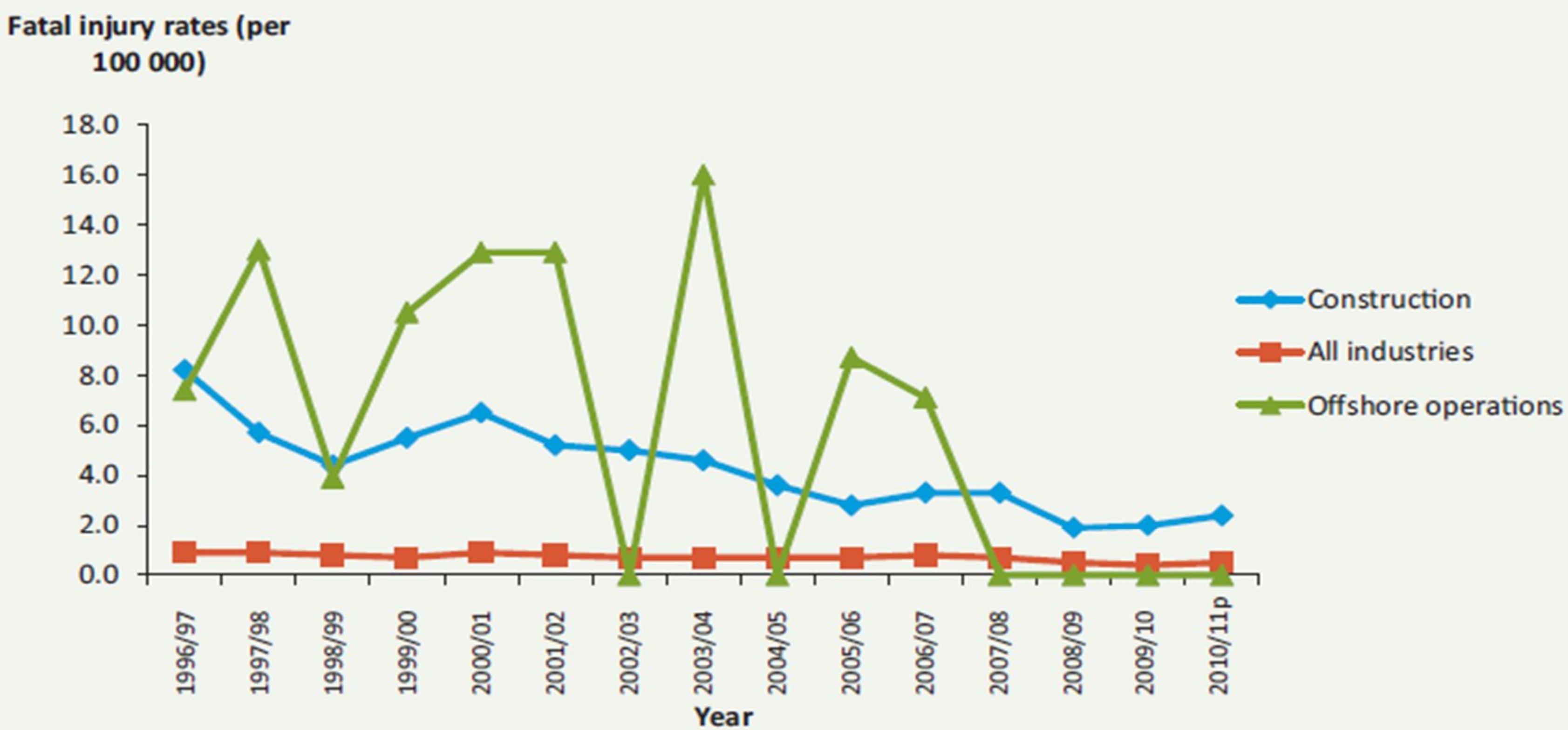


Courtesy -www.windpower.org

Safety Performance of Offshore Operations

Suzlon Energy Ltd.

Safety performance of offshore operations compared with construction and all industries, 1996/7 to 2010/11



Note: Offshore operations include both oil and gas and offshore wind, but exclude air transport activities and cover all workers. Construction and all industries cover employees only.

Source: Health and Safety Executive

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Low Cost Offshore Wind Measurement

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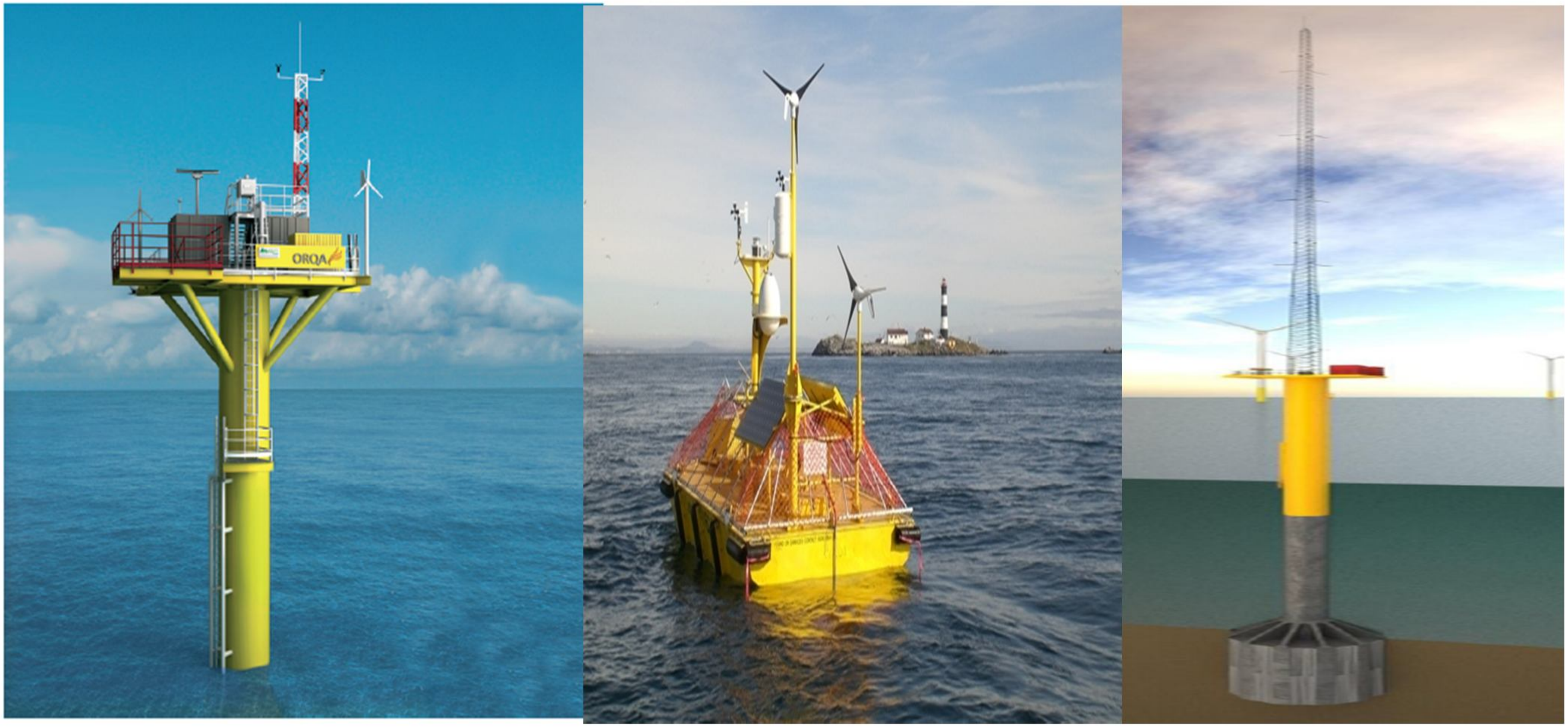

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Identified Offshore Challenges 1

- Large turbines
- Large project sizes
- Lower O&M cost
- Holistic design of the tower with the foundation
- Improvements in blade aerodynamics
- Continuously variable transmission drive trains
- Multi-variable optimization of array layouts
- Buoyant concrete gravity base foundations
- Introduction of DC power take-off (incl impact of DC array cables)
- Improvements in jacket manufacturing
- Introduction of direct-drive superconducting drive trains
- Introduction of float out and sink installation of turbine and support
- Increase in turbine power rating

Identified Offshore Challenges 2

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- Integrated offshore grid system
  - o Higher standardization – e.g. platform design
  - o Technology improvements
  - o Improved risk management process
- Advance materials and coatings against protection from sea environment
- LIDAR, SODAR and remote wind sensing for wind measurements
- Condition based monitoring and predictive maintenance
- Optimization of design for offshore
- Weather window forecasting
- Improved access vessel
- Advance Installation vessels of foundations, turbines & substations
- Ease to remove sub structure while decommissioning

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Offshore Wind Farms Area - Europe Vis a Vis India

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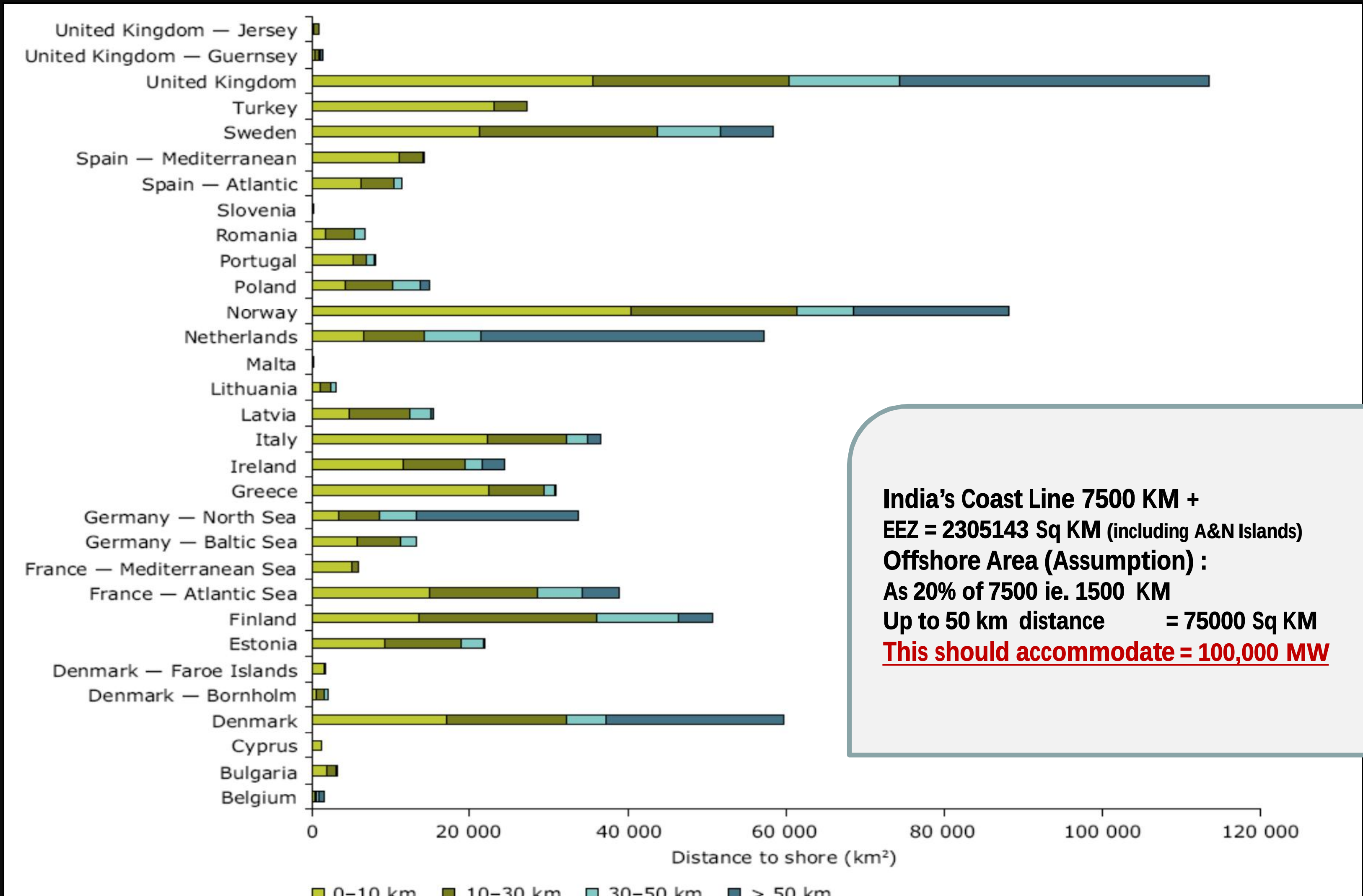

Source: EEA, 2008.

India's Coast Line 7500 KM +
EEZ = 2305143 Sq KM (including A&N Islands)
Offshore Area (Assumption) :
As 20% of 7500 ie. 1500 KM
Up to 50 km distance = 75000 Sq KM
This should accommodate = 100,000 MW

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Offshore Way Ahead in India

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Enhance green /wind energy potential of the country by formulating plans & policy to introduce offshore component .

Ensure timely regulatory and permitting approvals that too will help reduce financing costs.

Focused effort to integrate the resources and expertise of the country to propel the India to the leading edge of offshore wind technology.

Initially the focus area be on risk reduction to facilitate the initial deployment of offshore wind projects in the Indian waters.

Over the long term, adopt developing new technologies that lower the cost of energy, promote/sustain growth of domestic industry leveraging cheaper labor, cheaper steel fabrication and extending existing Oil & Gas offshore EPC to wind industry there by make offshore wind cost-competitive without compromising high standards of HSE.

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Thank You

Suzlon wind farm in Paracuru, Brazil

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Industry Stories

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High Innovatio

Finance &
Supply Chai

Incremental
Improvement

3. 'Supply Chain Efficiency' • 36GW in Europe by 2020 (17GW in UK) • Incremental technology evolution (e.g. steady progress to 5-7MW turbines) • Greater compensation, investment, project collaboration and better risk management • Deeper financial markets, lower risk/lower cost of capital	**4. 'Rapid Growth'** • 43GW in Europe by 2020 (23GW in UK) • High levels of technology evolution across all wind farm elements (e.g. turbines progress rapidly to 5-7MW+) • Greater competition, investment, project collaboration and better risk management • Challenging volume of finance required
1. 'Slow Progression' • 31GW in Europe by 2020 (12GW in UK) • Incremental technology evolution, progress limited by market size • Limited competition/economies of scale • Modest developments in financing solutions, reduced in risk / cost of capital	**2. 'Technology Acceleration'** • 36GW in Europe by 2020 (17GW in UK) • High levels of technology evolution across all wind farm elements (e.g. turbines progress rapidly to 5-7MW+) • Fragmented supply chain with some improvement in collaboration • Limited improvement in cost of capital due to ongoing changes in technology

Incremental
Improvement

Technology

High Innovation

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Offshore Project Life Cycle

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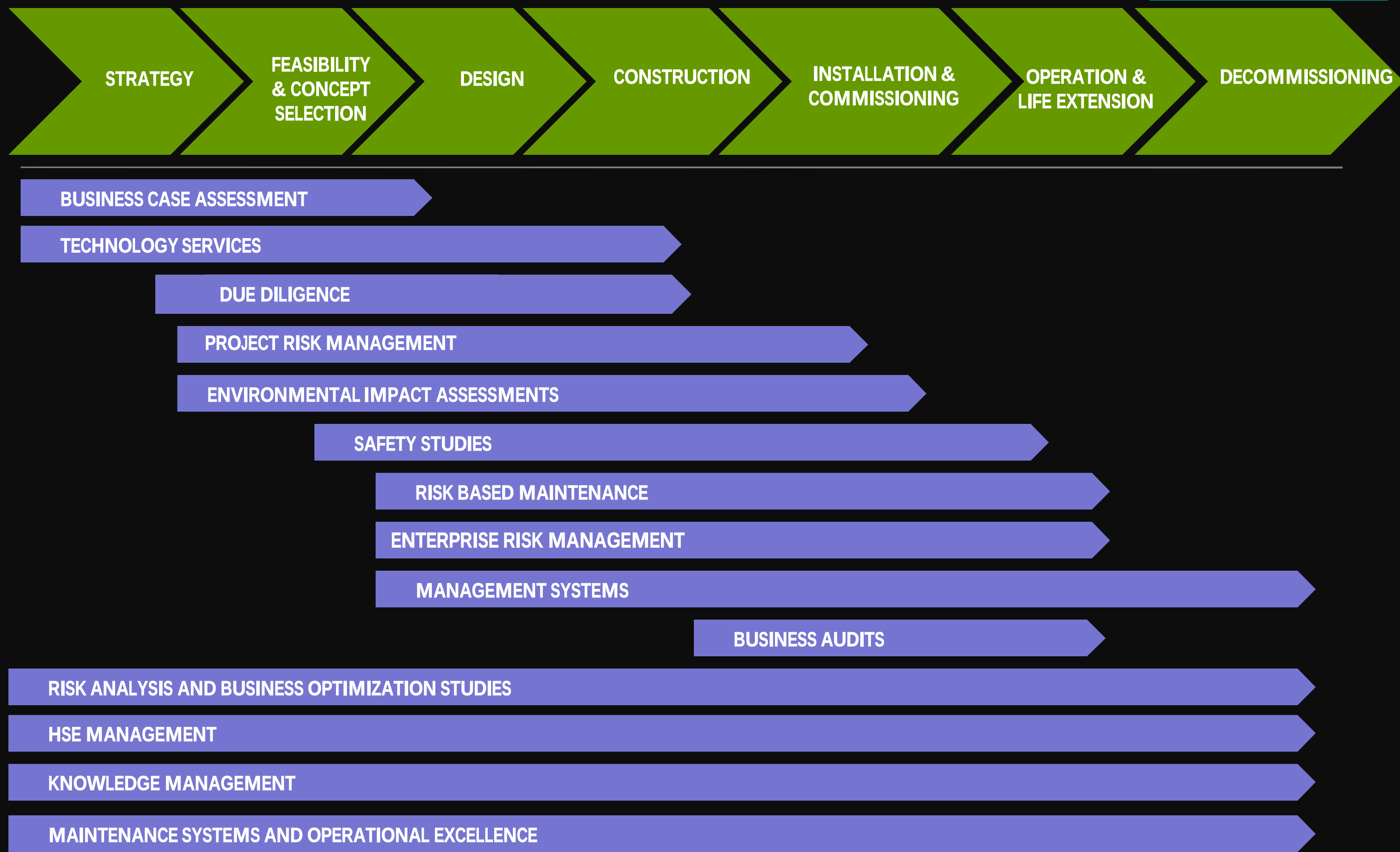

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