ENERGY

Can the Indian Tiger make the leap Offshore?

4TH ASIA OFFSHORE WIND DAY – TAIPEI

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18 September 2018

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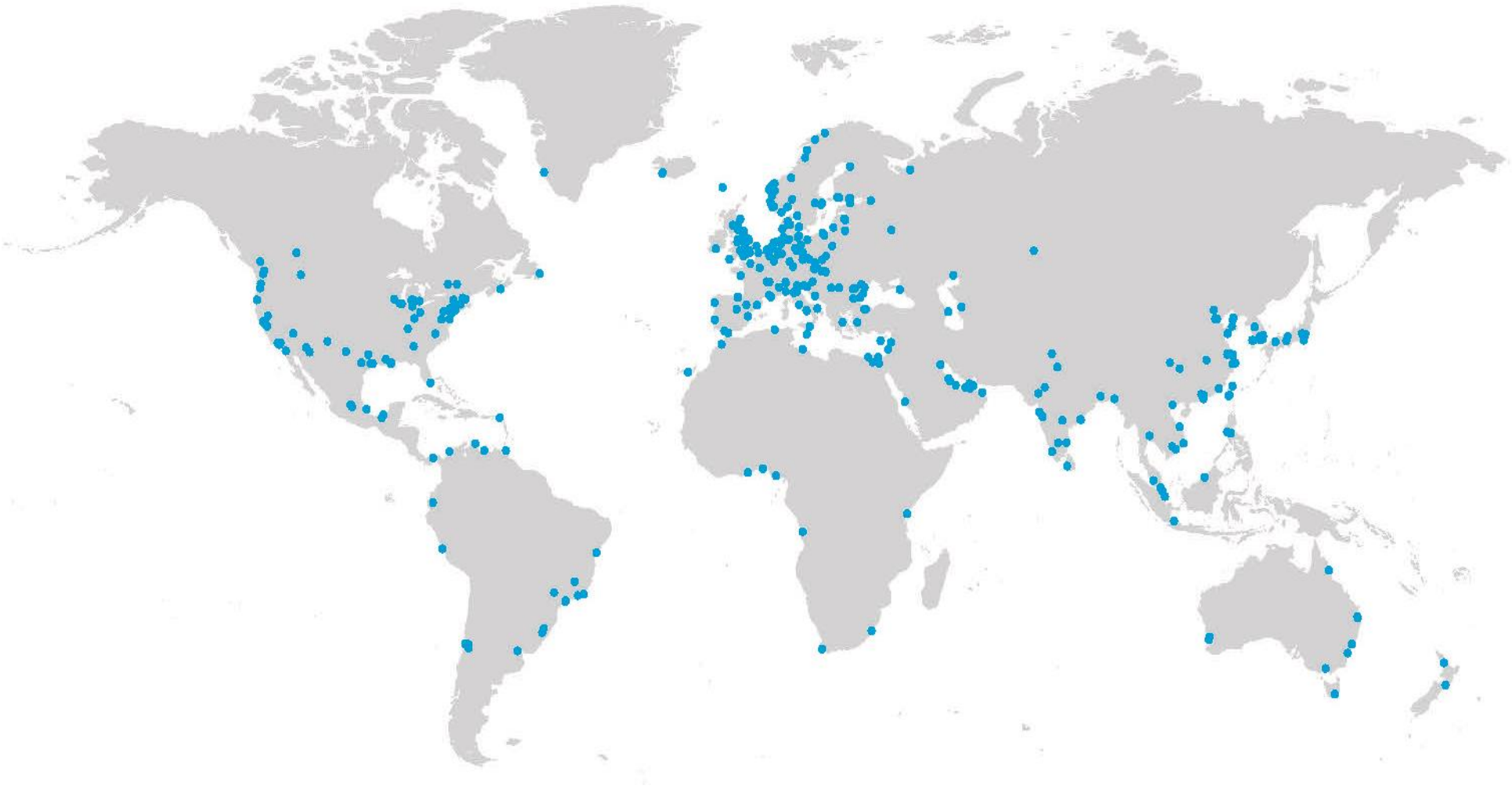
OUR PURPOSE:
TO SAFEGUARD LIFE, PROPERTY AND THE ENVIRONMENT
OUR VISION:
GLOBAL IMPACT FOR A SAFE AND SUSTAINABLE FUTURE

Global reach – local competence



150+
years

350
offices

100+
countries

12,500
employees

100,000+
customers

Global - Local:
Bringing experience to Asia – while maintaining international standards

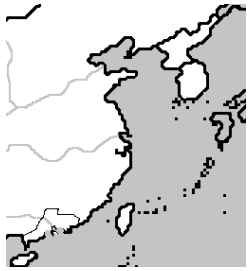
- APAC region has a diverse and wide ranging list of onshore & offshore wind challenges
- Some beyond those found in Europe, hence require:

  →Comprehensive local understanding

  →Location specific adaptive methods

European experience:
Over 30 years of experience and lessons learnt.
Extensive expert capacity in on- & Offshore
Wind widely recognised in industry

DNV·GL Europe



Local knowledge:
Key APAC differences
→Geotechnics, Extremes (typhoon, Earthcrages), GRID constraints, Policy

DNV·GL APAC

APAC project success

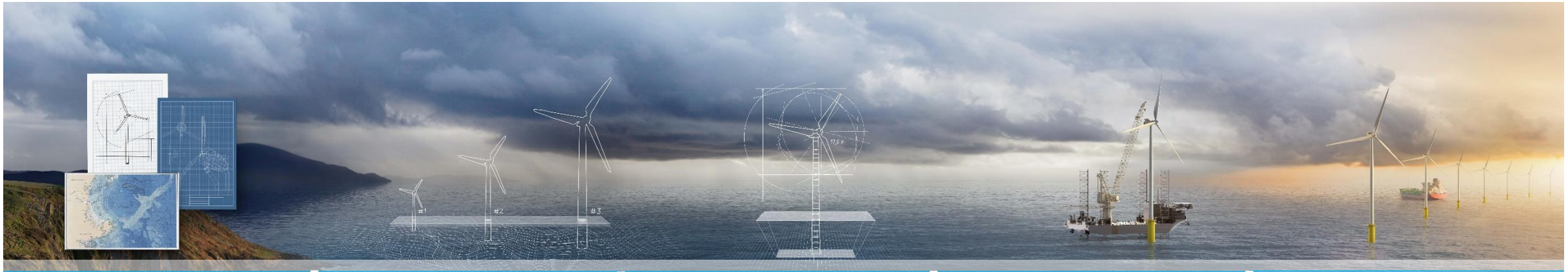
Accelerated learning-curves

→Location specific and adaptive methods

→Risk mitigation:
complex sites and conditions

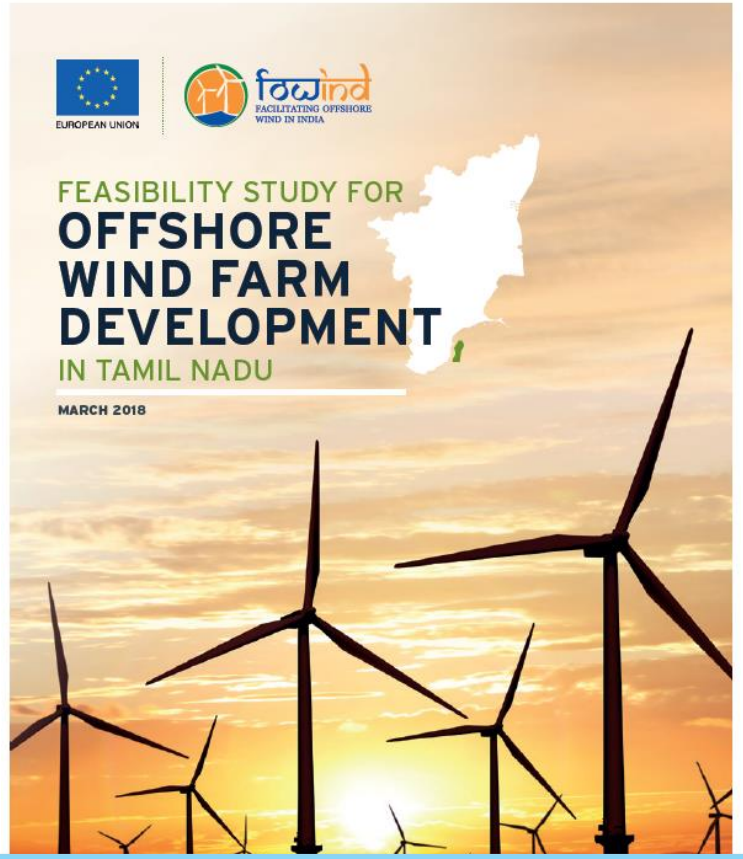
→Reduced project time-line

DNV GL – a “one-stop-shop” service provider for offshore wind projects can limit your project risk



FEASIBILITY	DEVELOPMENT	ENGINEERING	CONSTRUCTION	OPERATION
Site & concept selection	Project optimisation	Tender support	Construction monitoring	Operations & maintenance
Technology evaluation			Technical due diligence	
Wind mapping	Measurements	Energy assessment	Operational assessment	
Market intelligence	Cost modelling		Market forecasts	
Digitalisation, Software & training				
Project management		Marine warranty	Inspections	
Technology certification			Project certification	
Installation vessel classification			Operation & maintenance vessel classification	

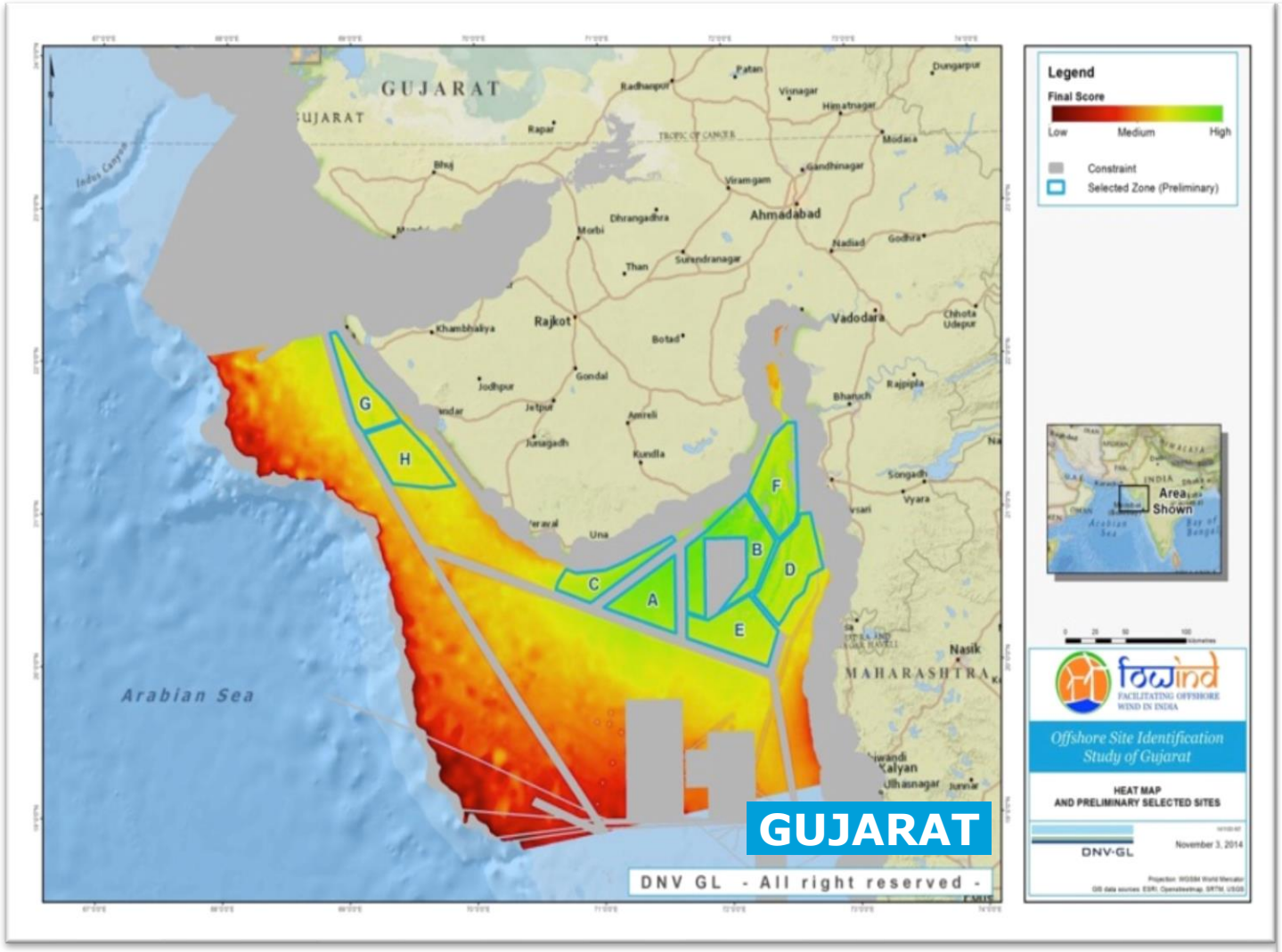
Gujarat and Tamil Nadu full feasibility studies

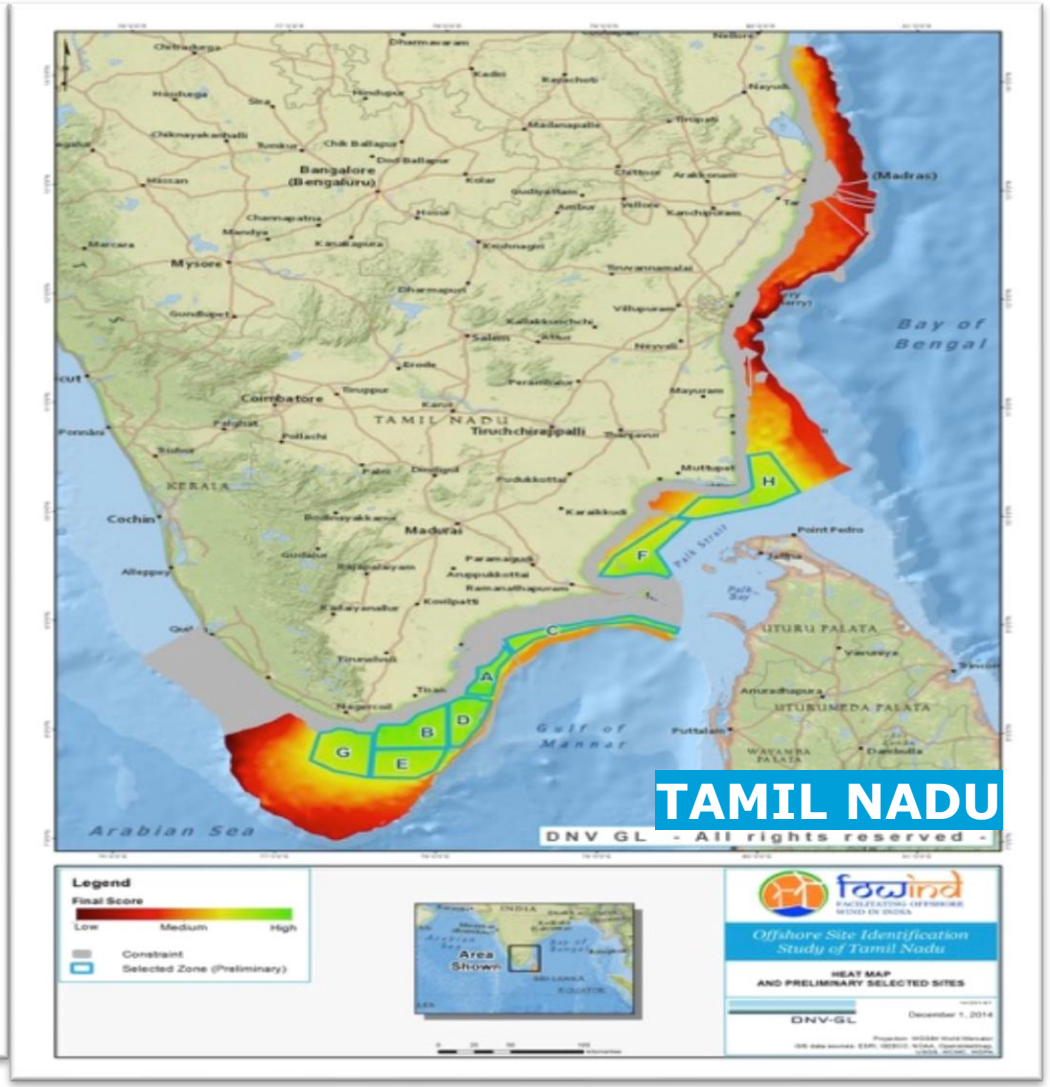


4-year project: Completed March 2018

The objective of these reports is to provide a concept design for a demonstration project of 150 to 500 MW in Gujarat's and Tamil Nadu's most promising offshore wind development areas, "zone A" identified in the 2015 Pre-feasibility studies.

Offshore heat map potential Gujarat & Tamil Nadu





Full feasibility study scope of work

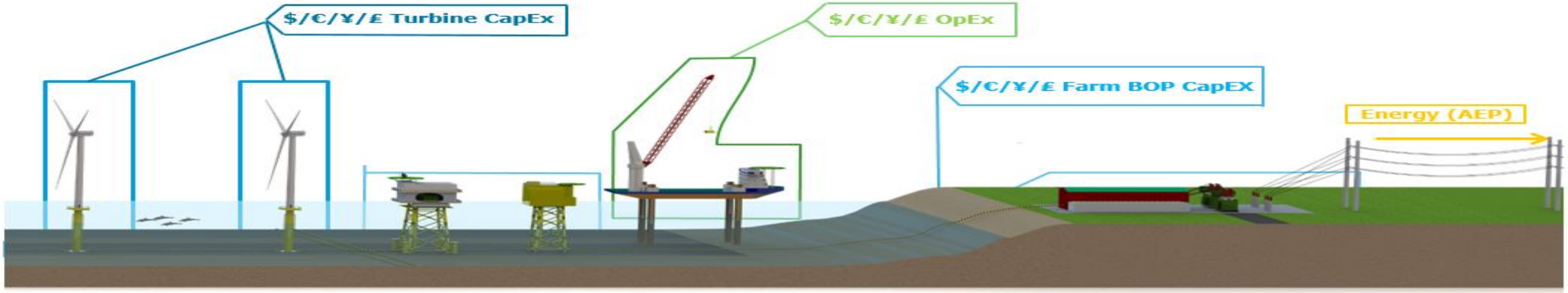
- Demonstration wind farm location
- Site data Study (metocean and geotechnical)
- Turbine selection study
- Windfarm layout
- Energy production
- Electrical concept design
- Preliminary foundation comparison
- Installation and logistics
- Operation and maintenance study
- Outline project costing (lcoe)
- Outline project risk register
- Environmental and social impact
- Key findings and recommendations

Offshore Wind Cost of Energy modelling tool – Turbine Architect

DNV GL's integrated cost of energy modelling tool, Turbine.Architect is at the core of this full feasibility study.

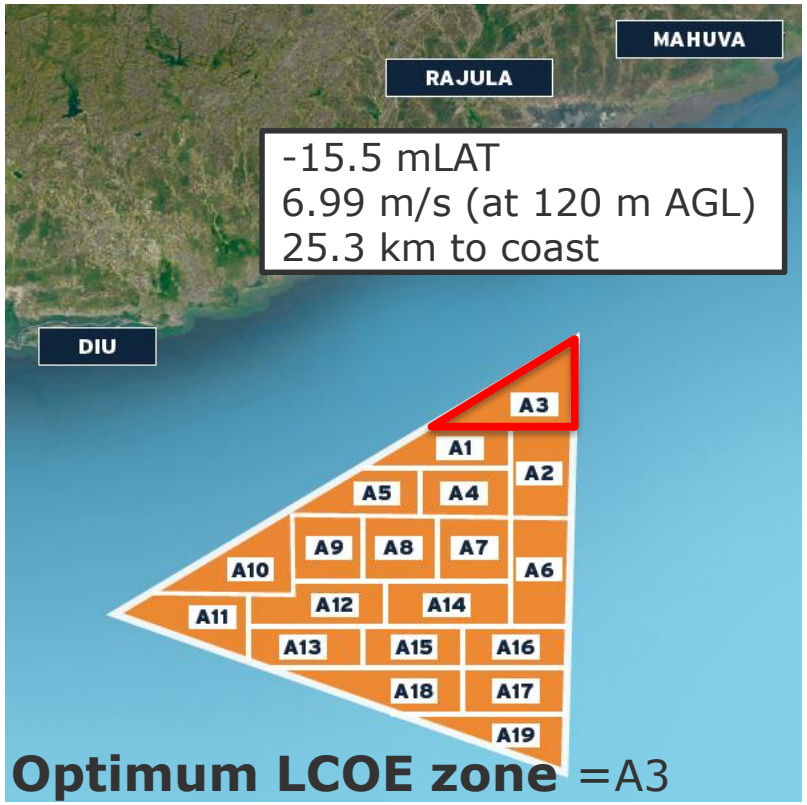
- Spatial analysis and selection of the demonstration wind farm location;
- Concept design of representative 4 MW, 6 MW and 10 MW offshore wind turbine platforms;
- Estimation of electrical system CapEx
- Preliminary foundation concepts and CapEx estimates, monopiles and jackets
- Estimation of construction CapEx
- Demo project Levelised Cost of Energy (LCOE) estimates for multiple configurations of MW capacity (150 and 504 MW) and wind turbines (4, 6 and 10 MW).

$$LCOE = \frac{\sum [(CAPEX_t + OPEX_t + D_t) * (1+r)^{-t}]}{\sum AEP * (1+r)^{-t}}$$



Demonstration wind farm location

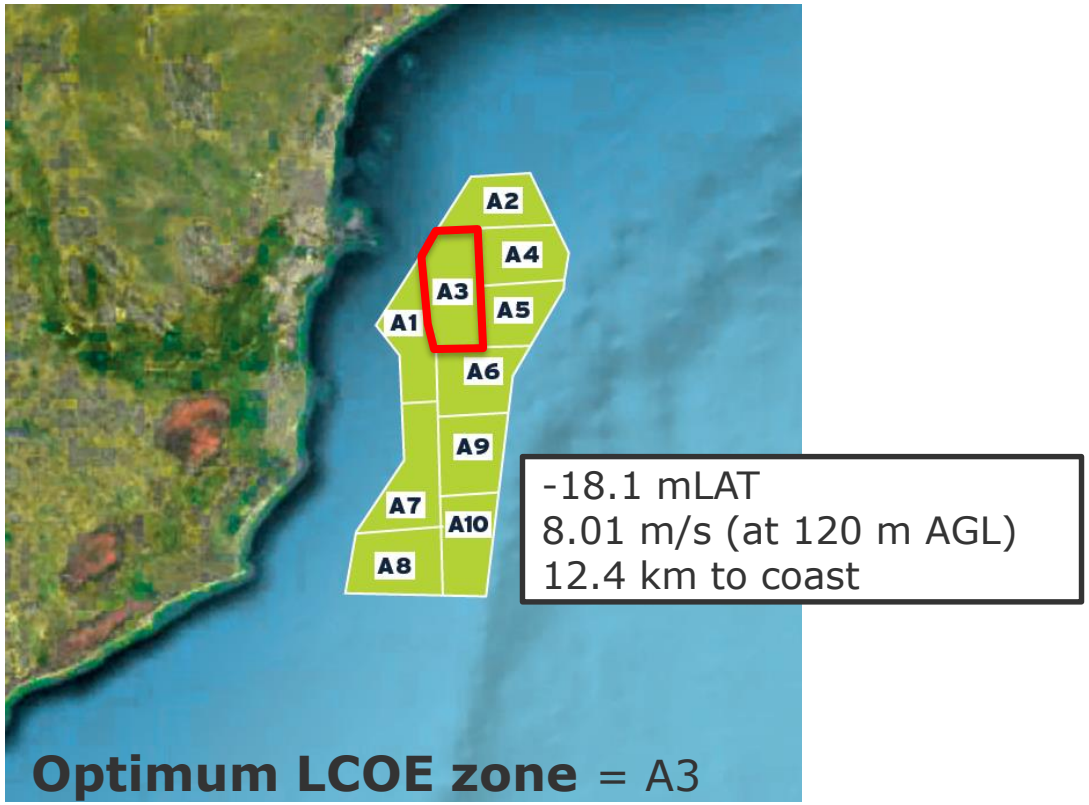
Gujarat – zone A, 19 sub-zones



Optimum LCOE zone =A3

lower CAPEX costs due to shallow water depth and shorter distance to shore. Despite A3 having the lowest annual mean wind speed.

Tamil Nadu – zone A, 10 sub-zones



Optimum LCOE zone = A3

relatively close to shore and having a shallow water depth. A3 does not possess all the most favourable values in these properties out of all the sub-zones, but has the best combination of favourable values.

Site conditions study

Gujarat

WIND RESOURCE:

- FOWIND's offshore LIDAR was commissioned on the 2nd of November 2017 and is collecting valuable on-site data

WAVE & CURRENTS:

- a preliminary metocean study for zone A in Gujarat provides wave, current and tidal data suitable for concept design. 50-year typhoon induced waves are estimated at 12.5m Hmax and tidal currents at 2.2 m/s

GEOTECHNICAL CONDITIONS:

- indicative lower/ upper bound soil profiles defined for zone A indicate extensive layers of weak clay persisting for 15 to 40m below seabed, before transitioning to competent sand. Upper clay layers exhibit limited strength both laterally and vertically

Tamil Nadu

WIND RESOURCE:

- currently there is no installed LIDAR in Tamil Nadu, NIWE have plans to commission a LIDAR in the Gulf of Mannar

WAVE and CURRENTS:

- a preliminary metocean study for zone A in Tamil Nadu provides wave, current and tidal data suitable for concept design. 50-year typhoon induced waves are estimated at 11.0m Hmax and tidal currents at 1.3 m/s

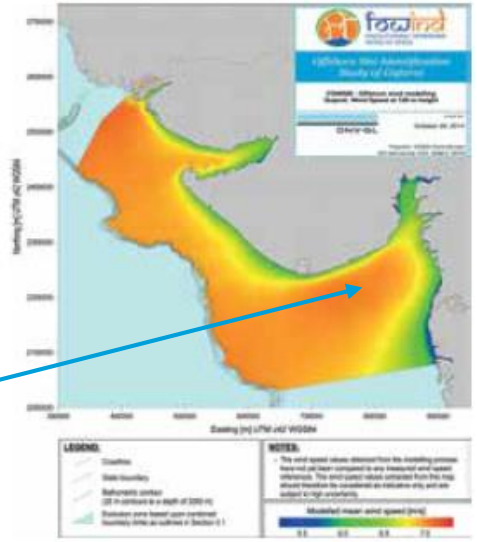
GEOTECHNICAL CONDITIONS:

- indicative lower/upper bound soil profiles defined for zone A indicate significant spatial variation in the southern Tamil Nadu offshore region; ranging from weak/loose sands/clays to strong cemented sand to depth. At the upper bound drivability would be a risk for piled foundations

Gujarat LiDAR initial data

Height (m)	Nov 17*			Dec 17*			Jan 18*			Feb 18*			Mar 18			Apr 18			May 18			June 18		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
40	5.68	0.40	12.30	6.11	0.54	11.29	4.84	0.31	11.64	5.71	0.38	14.15	6.12	0.57	12.31	6.48	0.28	14.47	8.36	0.35	16.51	9.33	0.73	16.29
60	5.99	0.51	12.45	6.52	0.56	12.73	4.96	0.30	11.72	6.05	0.20	14.56	6.48	0.40	13.53	6.65	0.24	14.88	8.50	0.37	16.89	9.53	0.84	16.54
70	6.12	0.48	12.47	6.69	0.40	13.84	5.14	0.19	12.49	6.18	0.19	14.80	6.65	0.40	15.14	6.73	0.23	15.11	8.57	0.39	17.04	9.61	0.90	16.65
80	6.24	0.68	12.74	6.81	0.68	13.09	5.12	0.38	12.36	6.27	0.25	15.00	6.79	0.48	14.26	6.80	0.28	15.26	8.62	0.41	17.19	9.68	1.00	16.72
87	6.31	0.69	12.83	6.89	0.73	13.37	5.17	0.32	12.65	6.31	0.24	15.16	6.87	0.45	14.27	6.84	0.27	15.38	8.65	0.41	17.32	9.72	1.07	16.75
100	6.44	0.69	13.01	7.04	0.80	13.85	5.26	0.24	13.09	6.36	0.35	15.40	6.97	0.32	14.53	6.87	0.29	15.61	8.68	0.42	17.53	9.79	1.28	16.78
107	6.50	0.69	13.18	7.12	0.82	14.09	5.31	0.27	13.28	6.39	0.26	15.54	7.04	0.26	14.89	6.90	0.32	15.74	8.71	0.43	17.63	9.83	1.35	16.83
120	6.61	0.69	13.46	7.25	0.82	14.50	5.39	0.31	13.52	6.47	0.20	15.77	7.19	0.28	15.75	6.98	0.37	15.99	8.78	0.46	17.71	9.93	1.39	17.05
140	6.77	0.69	13.90	7.43	0.81	15.08	5.50	0.44	13.67	6.51	0.37	16.08	7.28	0.49	16.84	7.02	0.38	16.41	8.83	0.54	18.04	10.03	1.34	17.36
160	6.91	0.69	14.31	7.59	0.80	15.70	5.60	0.27	13.93	6.55	0.36	16.60	7.35	0.35	17.07	7.07	0.32	16.76	8.88	0.52	18.53	10.16	1.00	17.69
180	7.04	0.69	14.67	7.74	0.80	16.31	5.68	0.23	14.58	6.59	0.39	17.31	7.38	0.40	16.42	7.11	0.39	17.09	8.91	0.53	19.99	10.29	0.96	18.09
200	7.15	0.69	15.01	7.88	0.79	16.89	5.74	0.27	15.22	6.57	0.37	18.22	7.36	0.50	16.08	7.12	0.43	17.11	8.85	0.54	18.98	10.38	0.90	18.31

Based on latest NIWE report



- On the 2nd of November 2017, the FOWIND Consortium successful commissioned India's first offshore LIDAR, off the coast of Gujarat
- Note that the typical annual trend of wind in the Gujarat region suggests stronger wind speeds in the summer period
- Avg. mean WS 7.3m/s @120m and 7.18m/s @100m
- Based on approximately 8 months of raw measured data (Nov 17 to Jun 18)
- Typically a full energy assessment would require data coverage above 95% with a minimum of 12 months data

Turbine Selection Study

- Predicted extreme typhoon wind conditions meant Class I or S wind turbines
- **Gujarat**: IEC Class I turbines could be sufficient with 3-second gusts of 61.8 m/s and 63.4 m/s for hub-heights of 100 mMSL and 120mMSL respectively.
- **Tamil Nadu**: IEC Class I turbines could be sufficient with 3-second gusts of 63.8 m/s and 65.4 m/s for hub-heights of 100 mMSL and 120mMSL respectively
- Offshore wind turbines with a significant operating track record are still few and far between - significant mergers and joint ventures between the big players
- Future "1x MW" turbine platforms with MW capacities exceeding 10 MW and with rotor diameters more than 200 m

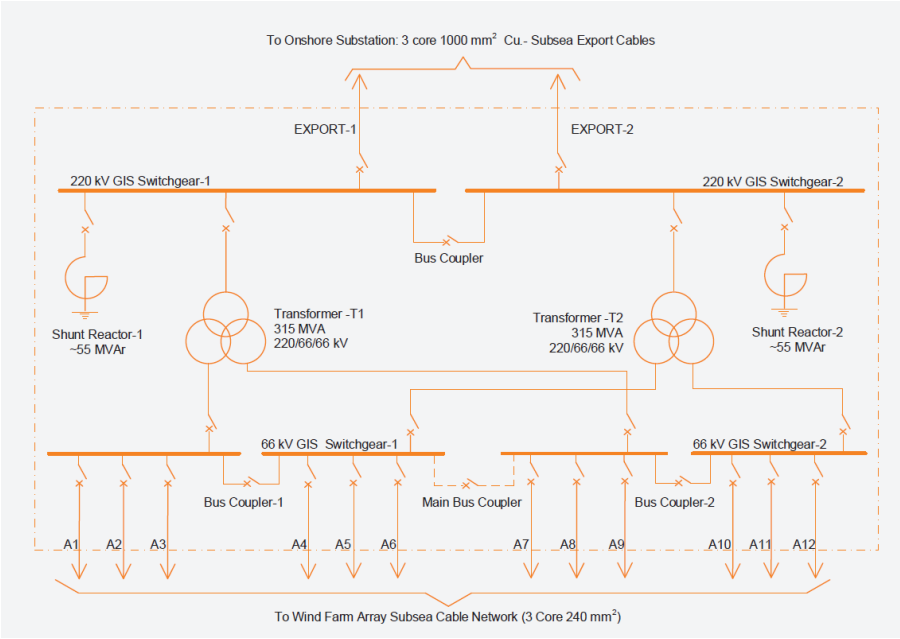
Wind Turbine Classes

WTG classes	I	II	III	IV	S
Reference wind speed, U_{ref}	50	42.5	37.5	30	Values specified by the manufacturer
Annual avg. wind speed U_{avg} = 0.2 x U_{ref}	10	8.5	7.5	6.0	
50 year return gust speed, Ue50 = 1.4 x U_{ref}	70	59.5	52.5	42	
Turbulence classes	A	B			
I_{15} characteristic turbulence intensity at 15m/s	18%	16%			

Electrical study

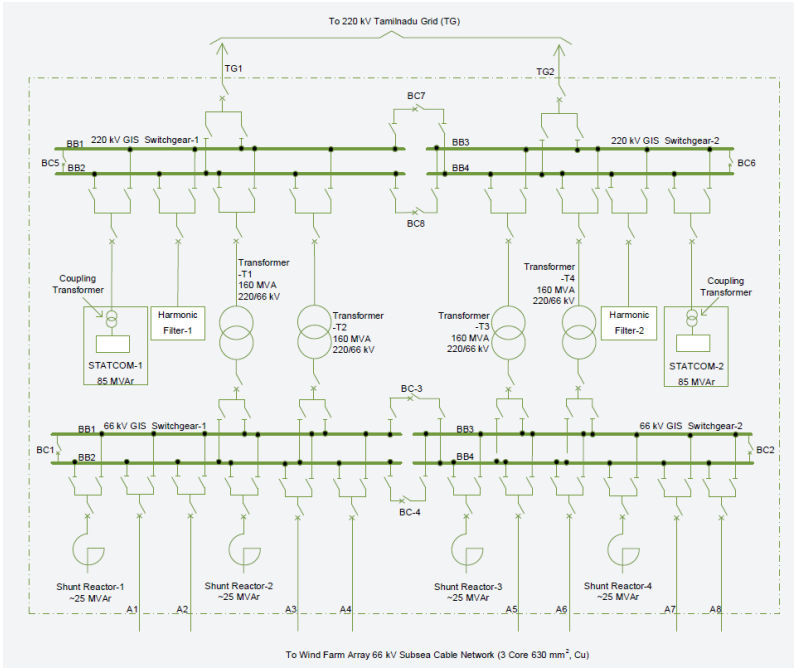
Gujarat

- Distance from shore invokes the requirement of having an offshore substation which facilitates the transmission of 150 to 500 MW from the offshore windfarm to the shore at high voltage.
- 66 kV array cables are assumed for 6 MW and 10 MW turbines and 33 kV assumed for 4 MW turbines



Tamil Nadu

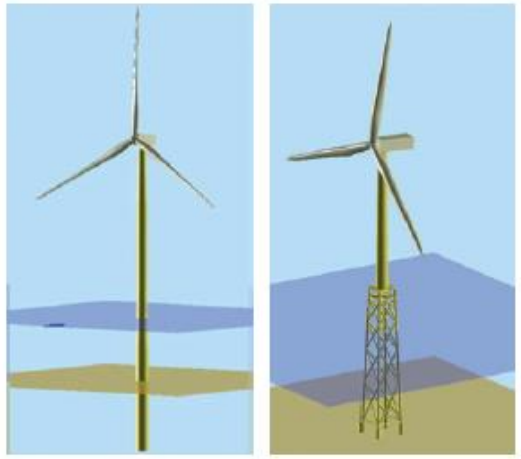
- Close proximity to shore is assumed to facilitate a direct HVAC connection of the offshore wind farm to the onshore substation.
- 66 kV collection system voltage level is assumed for all turbine MW capacities;



Foundation study

Gujarat

- Either monopile and jacket foundations will be likely options to take forward to the next stage of investigation.
- If actual in-situ conditions align with the estimated upper bound soil profile parameters, monopiles could be favourable given the shallow water depths.
- Lower bound conditions very challenging for monopiles.



Tamil Nadu

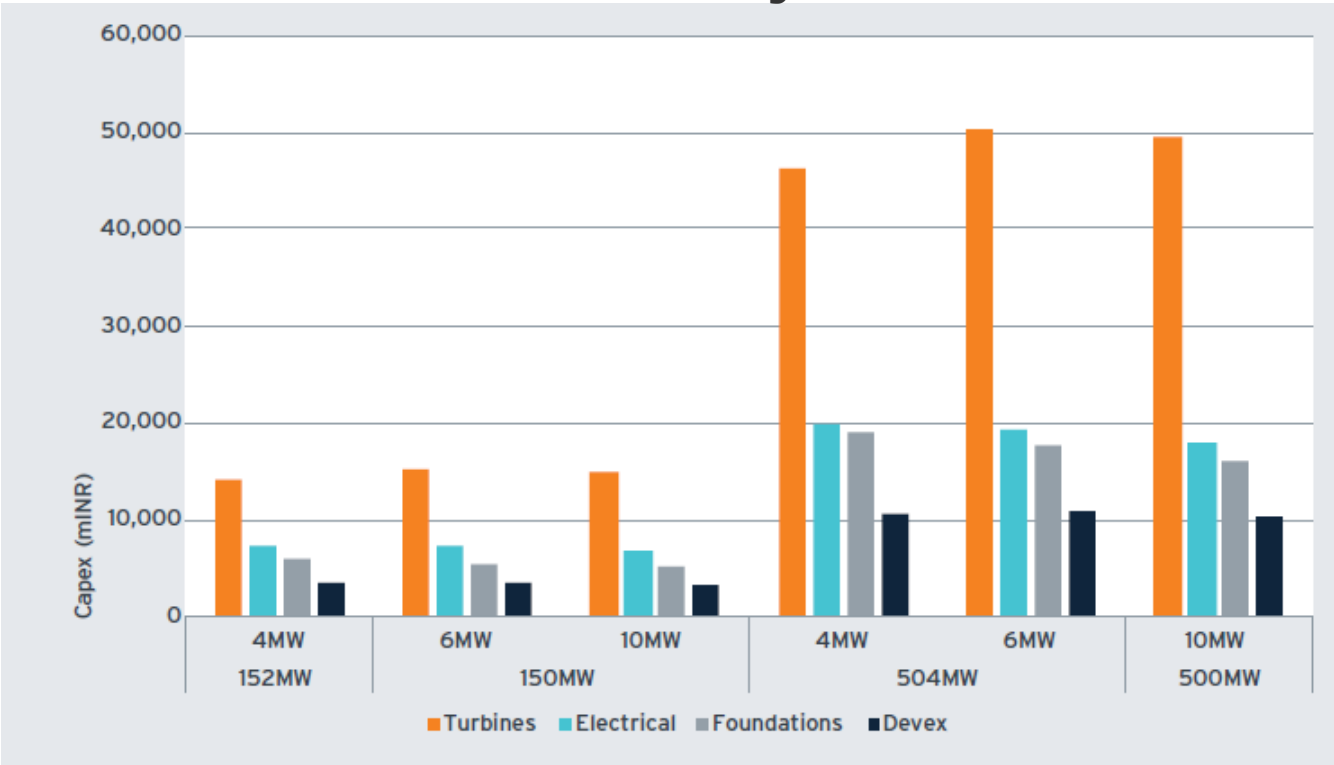
- Either monopile or jacket foundations will be likely options to take forward to the next stage of investigation.
- Gravity-based Structure (GBS) foundations could be financially favourable but will be very site specific and dependent on the presence of highly competent soils.
- In terms of cost monopiles are more economical compared with jackets, however pile drivability is a risk.

Cost of Energy Estimates

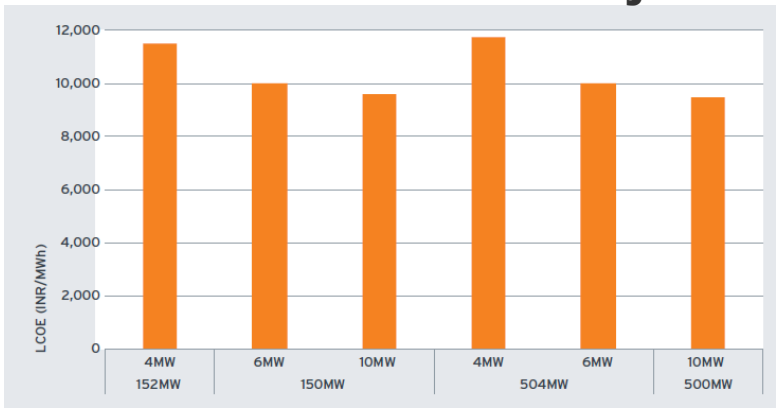
Gujarat & Tamil Nadu

Wind resource and the financial discount rate are the most significant factor affecting offshore wind Cost of Energy (COE). Increasing the capacity of the wind turbines from 4MW to 10MW results in a cost of energy reduction.

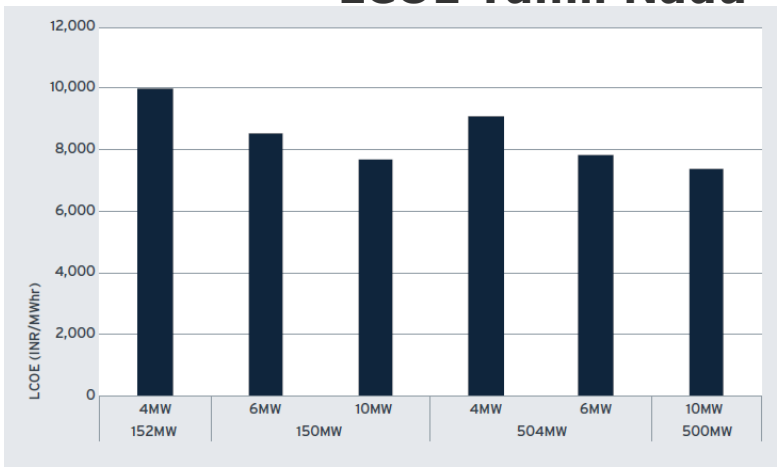
CAPEX Gujarat



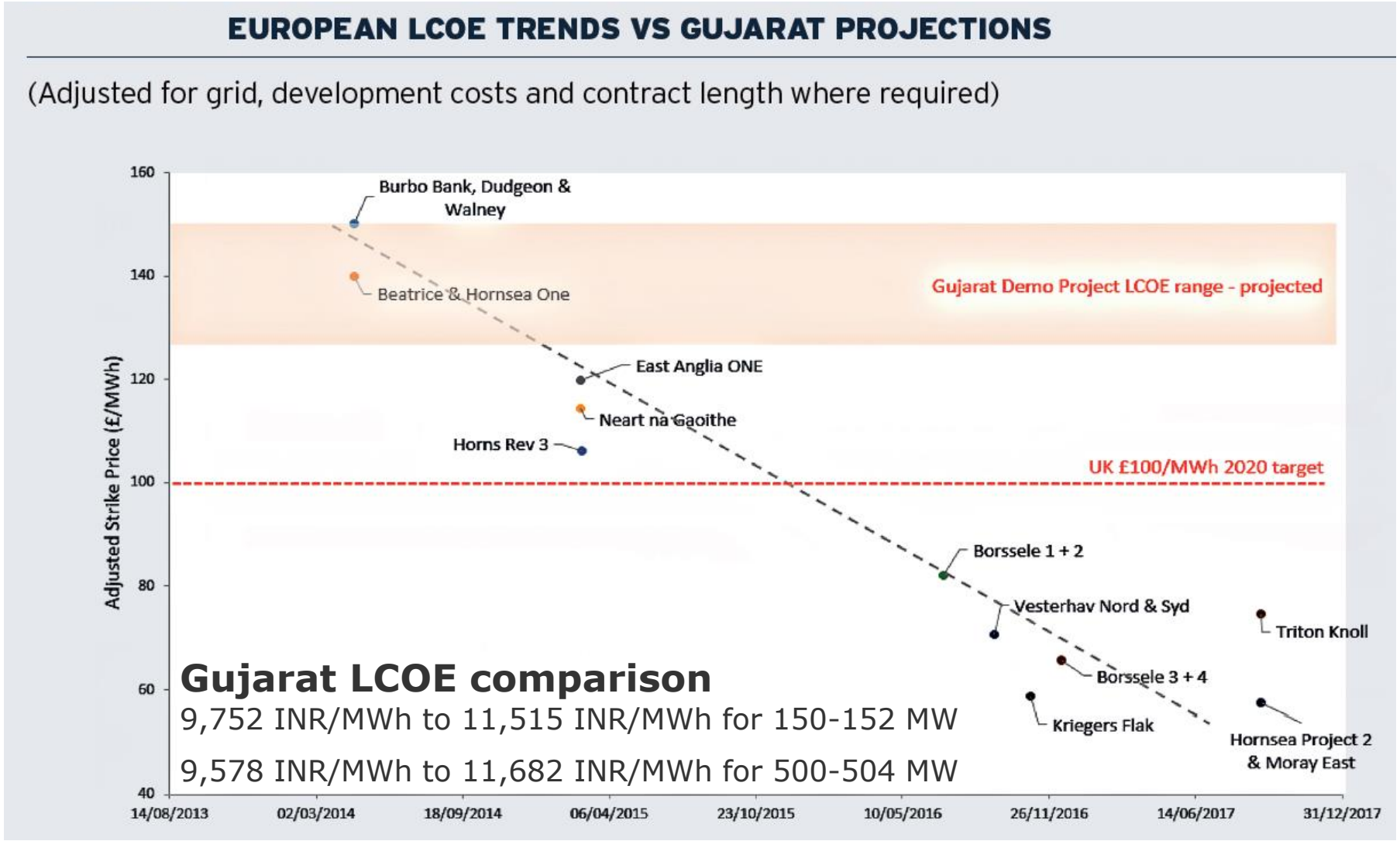
LCOE Gujarat



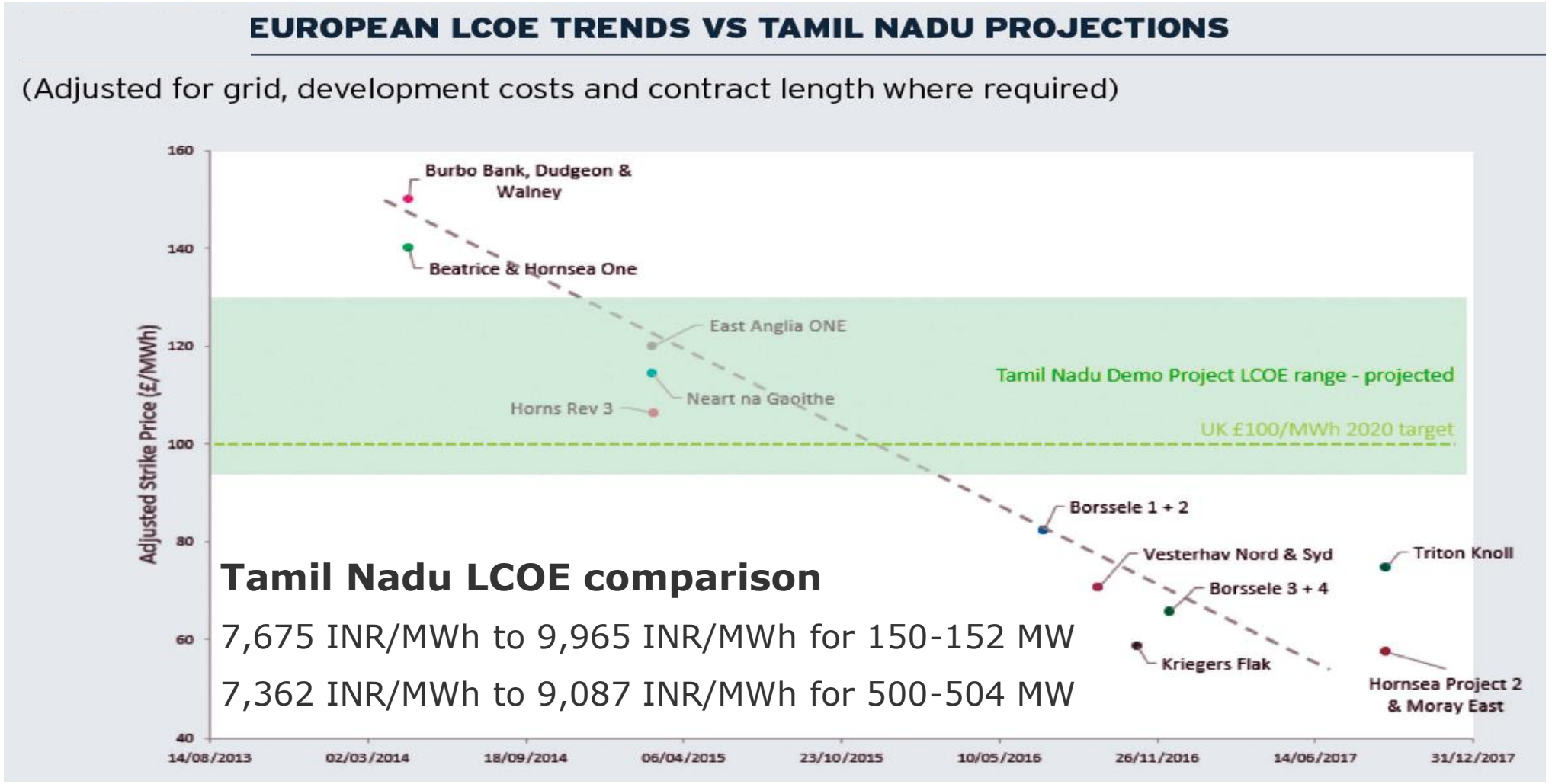
LCOE Tamil Nadu



Cost of Energy Estimates



Cost of Energy Estimates



Concluding statements

- **Offshore Wind in India is commercially viable, subject to:**
  - Supportive policy and financial incentives
  - Localization of the supply chain
  - Improvements in offshore wind speed measurements (e.g. from the Gujarat LiDAR)
  - Risk management, supported by lessons learnt in overseas markets

- **FOWIND feasibility studies have provided outline wind farm concepts for 150 to 500 MW demonstration projects in Gujarat and Tamil Nadu**

Providing companies and government institutions with a starting point for future detailed offshore Front End Engineering Design (FEED) studies and assistance with identifying key risks

KEY RISKS

- **Wind Resource**: high uncertainty of the wind resource assessment (noted FOWIND LIDAR now installed and collecting valuable data in Gujarat);
- **Geotechnical Conditions**: there is only limited information on the seabed geology of the Gujarat and Tamil Nadu regions available;
- **Grid Connection**: grid availability.

LET'S TALK

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