FACTORS TO PROMOTE OFFSHORE WIND ENERGY SECTOR IN INDIA

By

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DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

(Swaminathan Mani)

THESIS COMPLETION CERTIFICATE

This is to certify that the thesis on **"Factors to promote offshore wind energy sector in India"** by **Swaminathan Mani** in Partial completion of the requirements for the award of the Degree of Doctor of Philosophy (Management) is an original work carried out by him under our joint supervision and guidance.

It is certified that the work has not been submitted anywhere else for the award of any other diploma or degree of this or any other University.

External Guide

(Dr Allabaksh Naikodi)

Internal Guide

(Dr Tarun Dhingra)

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Energy is a critical ingredient for the development and growth of any nation. Several studies have established a positive correlation between higher energy use and higher human development index. India that is experiencing accelerated growth is likely to consume energy more than ever before. However, these rapid enhancements in additional generation capacity need to come, in large proportions, from clean energy sources, as continued dependence on fossil fuel to power its economy will leave a devastated ecology apart from draining the foreign exchange reserves. Increased awareness and regulations around greenhouse gas emissions, environmental concerns and global warming will put additional pressure on India to move away from polluting fossil fuels.

India has access to substantial renewable energy sources whose potential can be tapped to bridge some of the deficit experienced in power generation and reduce the pressure on the need to commission fossil based power plants. India has begun well by having a dedicated ministry for renewable energy for policy formulation and for providing oversight. Several proactive initiatives from the ministry, research institutions, academia, private investments, thought leaders, financial institutions and project developers have resulted in India installing over 25,000 MW from clean energy sources in the overall power installed capacity of 202,000 MW as of April 2012 which has contributed to India becoming No 5 in the world in terms of installed wind energy capacity.

However, India has not tapped the potential it has in the offshore wind energy sector. India has over 7000 Kms of coastline, access to funds, technological knowhow, project management capabilities, economic need, captive market and ecological compulsions to adopt offshore wind energy in an accelerated manner.

Today, Europe is a world leader in adoption of offshore wind energy in their countries which was due to several investor friendly policies formulated by EU. India has similar experience of proactive policies driving the growth of onshore wind energy sector in the country.

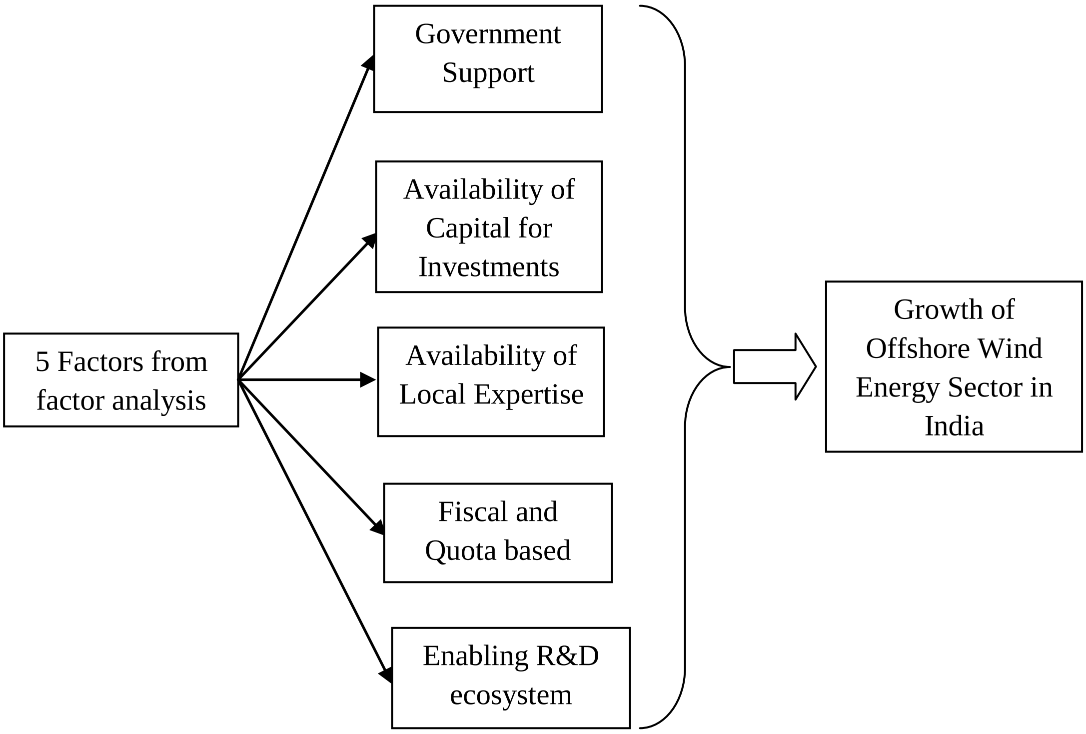
However, India is yet to formulate policies focussed on offshore wind energy that would encourage the growth of that sector in the country. India can consider and implement some of the best practices of select countries in Europe that have successfully harnessed offshore wind energy for electricity generation.

This thesis does an extensive literature survey of the offshore wind energy policies adopted by 4 countries (the UK, Germany, Netherlands and Denmark) with largest installation of offshore wind farms to understand the basic elements of policy formulation.

21 variables emerged, which formed the core building blocks of offshore wind energy policies in Europe. These 21 variables were subjected to factor analysis to logically group these variables and were empirically tested

The following research model is adopted in the study.

Research model



Objectives of the study

1. Feasibility analysis of the suitability and efficacy of offshore Wind farms for the Indian context (Dhanuskodi in Tamil Nadu as the chosen area) – Analysis of the technical, financial, Economic, Environment and Market of offshore wind energy in India

2. To develop and empirically test a model of constituents of effective offshore wind energy policy.

3. Critique of policies adopted by select European countries (notably UK, Denmark, Netherlands and Germany) to encourage the growth of the offshore wind energy sector in their respective countries.

4. To study the support of policies in the growth of onshore wind energy sector in India.

An elementary feasibility analysis (covering Market, Technical, Financial, Economic and Ecological feasibility studies) of setting up of offshore wind energy farms in India were conducted which points to the overall viability of these projects from investment purpose. Attractive IRR of 19.8%, positive NPV at 19% cost of capital and break-even tariff of Rs 6.68/unit of electricity were the financial highlights of the study. Preliminary studies undertaken by leading organisations in the world like RISO Denmark and Lawrence Berkeley labs, US indicates excellent potential for Indian offshore wind energy sector in India, that can be harnessed. Continuous demand-supply gap (generation deficit of 11% and peak load deficit of 13%) in power availability in India, coupled with good offshore wind energy potential that can be harnessed authenticated the availability of a captive market for offshore wind energy developers in India. Similarly, favourable technical, ecological and social cost benefit analysis pointed to the overall feasibility of offshore wind energy sector in India.

A conclusive research is carried out using deductive logic to empirically test the model using quantitative tools. A questionnaire was administered to 181 wind energy stakeholders using proportionate stratified sampling. The responses received were subjected to factor analysis and 5 factors emerged – *fiscal and quota based incentives, Government support, Availability of local expertise, Enabling R&D ecosystem* and *Availability of capital for investments*. These factors were treated as independent variables in the logistic regression model to predict the growth of offshore wind energy in India, which was the dependent variable. Prediction success of the model was overall 96.1%. Nagelkerke's pseudo R^2 of .891 indicated a strong relationship between prediction and grouping. The Wald criterion demonstrated that the factors *Government support*, *fiscal and quota based incentives* and *enabling R&D ecosystem* made a significant contribution to prediction.

This thesis also critiqued the offshore wind energy policies adopted by Denmark, Germany, Netherlands and the UK to encourage the growth the sector in their countries to identify best of breed policies that can be adopted by India. These countries adopted a combination of generation based incentives (Feed-in tariffs, fiscal measures, subsidies, quota obligation, green certificates) and capacity based incentives (Investment subsidies, tax credits), tailored to suit their local conditions, to encourage the growth of offshore in the state. The key inference from the critique of the policies were that the incentives needs to be focussed to a specific technology (offshore wind) and tailored for a local geography (covering consent procedures, tendering, award criteria, grid connectivity, tariffs, incentives and environmental clearances) to spur the growth of offshore wind energy in the respective countries. While some policies like single window clearances, grid connectivity may have uniformity in application, some others like feed-in tariff, tradable green certificates need to be customised to suit local conditions.

India has put together several policy and regulatory measures to promote wind energy in the country. The Electricity Act 2003 unbundled the power sector and encouraged private investments in the power sector. Renewable purchase obligation, National Electricity policy (encouraging private sector competition), National Tariff policy (preferential tariff for wind energy), Accelerated depreciation benefits, feed-in-tariff, tax subsidies, duty waivers, generation based incentives apart from state specific policies have enormously helped the growth of wind energy sector in India.

India needs to adopt demand side management measures, energy efficiency and leverage every avenue of generation sources to satiate the needs of a growing economy. Renewable energy sources need to play a larger role in the energy mix of the country. Offshore wind energy, given its promise, is an untapped avenue as yet. The conclusions of the study are: Overall offshore wind energy is feasible and can grow with dedicated policies, focussed to sector. With the right policy support from Government and enabling environment offshore wind energy can aid the growth of offshore wind energy in India.

Currently, there is limited amount of literature that is available on offshore wind energy sector in India. It is hoped that this thesis will bridge some the gaps of absence of literature in the area and add to the body of knowledge, which would benefit policy makers, researchers and wind energy stakeholders in the country.

LIST OF ABBREVIATIONS

AD	Accelerated Depreciation
BEE	Bureau of Energy Efficiency, India
BEP	Break-even point
BfN	Federal Agency for Nature Conservation, Germany
BMU	Federal Environment Ministry, Germany
BMW_i	Federal Ministry of Economics and Technology, Germany
BSH	Bundesamt für Seeschifffahrt und Hydrographie, Germany
BWE	Bundesverband Windenergie, Germany Wind Energy Association
BWEA	British Wind Energy Association now called Renewables UK
CCL	Climate Change levy
CDM	Clean Development Mechanism
CEA	Central Electricity Authority, India
CERC	Central Electricity Regulatory Commission
COWRIE	Collaborative Offshore Wind farm Research into the Environment
CWET	Centre for Wind Energy Technology
DEA	Danish Energy Authority, Denmark
DECC	Department for Energy & Climate Change, UK
DNR	Directie Noordzee van Rijkswaterstaat, Netherlands
DTU	Denmark Technological University
E&Y	Ernst & Young
EA	Electricity Act 2003, India
EEA	European Environmental Agency
EEG	Erneuerbare Energien Gesetz, Germany Renewable Energy Act
EEZ	Exclusive Economic Zone, Germany

EPC	Engineering, Procurement and Construction
ETF	Environmental Transformation Fund
EU	European Union
EWEA	European Wind Energy Association
EXIM Bank	Export-Import Bank
FDI	Foreign Direct Investment
FiT	Feed in tariff
GBI	Generation based Incentive
GDP	Gross Domestic Product
GHG	Greenhouse gases
GIS	Geographic Information System
GW	Giga Watt (= 1000 Mega Watt)
GWEC	Global Wind Energy Council
IEA	International Energy Agency
INCOIS	Indian National Centre for Ocean Information Services
INWEA	Indian Wind Energy Association
IPC	Infrastructure Planning Commission, UK
IPCC	Intergovernmental Panel on Climate Change
IREDA	Indian Renewable Energy Development Agency
IRR	Internal Rate of Return
IWPA	Indian Wind Power Association
IWTMA	Indian Wind Turbine Manufactures Association
JNNSM	Jawaharlal Nehru National Solar Mission, India
KfW	Kreditanstalt für Wiederaufbau, Germany – Banking Institution
KMO	Kaiser-Meyer-Olkin test

KW	Kilo Watt
Kwhr	Kilo- watt hour (1 unit of electricity)
MNRE	Ministry of New and Renewable Energy, India
MoEF	Ministry of Environment and Forest, India
MT	Million Tonnes
MW	Megawatt (= 1000 Kilo Watt)
NAPCC	National Action plan on Climate Change
NASA	National Aeronautics and Space Administration, US
NEEZ	Dutch Exclusive Economic Zone
NIMBY	Not in my back yard Syndrome
NPV	Net Present Value
NREL	National Renewable Energy Laboratory, USA
O&M	Operations and Maintenance
OfGen	Office of gas and electricity markets, UK
ONGC	Oil & Natural Gas Corporation of India
ORCU	Offshore Renewable Consents Unit
OWP	Offshore Wind Parks
PLF	Plant Load Factors
PPMV	Parts per million by volume
REC	Renewable Energy Certificates
REN 21	Renewable Energy Policy Network for the 21st Century
RES	Renewable Energy Sources
RISO	National Laboratory for Sustainable Energy, Denmark
ROC	Renewable Obligation Certificates
RPO	Renewable Purchase Obligation

RPS	Renewable Purchase Specification
RRF	Renewable Regulatory Fund
RSS	Remote Sensing Systems
SEA	Strategic Environmental Assessment
SEB	State Electricity Boards, India
SERC	State Electricity Regulatory Commission
SEZ	Special Economic Zones
SHP	Small Hydro Power
SPSS	Statistical Package for the Social Sciences (Software tool)
StAO	Coordination agency between Federal and State Governments
TCE	The Crown Estate, UK
TGC	Tradable Green Certificates
TSO	Transmission System Operator
TWhr	Terra-Watt hour (Billion units of power)
UBA	Federal Environment Agency, Germany
UNDP	United Nations Development Programme
VAT	Value added tax
WBR	Public works and water management act, Netherlands
WDV	Written-down value
WISE	World Institute of Sustainable Energy, Pune, India
WPD	Wind Power Density

LIST OF FIGURES

LIST OF TABLES

1 CHAPTER 1 - INTRODUCTION

1.1 Background

Indian Economy is growing at 8% for the past few years and is expected to continue this momentum into the foreseeable future. To sustain this growth, power sector needs to build additional generation capacity at an unprecedented pace (Planning commission of India, 2010). The total power generation capacity in India in April 2012 was 202 GW (CEA, 2012). Of this, 66% was fossil-fuel-fired power plants, 19 % hydroelectric power, 2 % nuclear power, and 12% renewable energy, as shown in Table-1.1. This trend of coal being the dominant fuel in the electricity mix is likely to continue in the business as usual scenario (Ministry of Power, 2011).

Table 1.1 - Total installed power generation capacity in India as of 30th April 2012

Fuel	**MW**	**%age**
Total Thermal	**133363.18**	**65.97**
Coal	113,782.38	56.29
Gas	18,381.05	9.09
Oil	1,199.75	0.59
Hydro	38,990.40	19.29
Nuclear	4,780.00	2.37
Renewable Energy Sources	**25017.88**	12.37
Total	**2,02,151.46**	**100.00**

Source: CEA, 2012

However, continued dependence on fossil fuels (especially Coal and Oil) to power the growth of electricity generation capacity, is hardly sustainable in the long run. The reasons are well known - environmental concerns, depleting fossil fuel resources, excessive dependency on oil imports - that it hardly merits repetition. If India failed to protect its environment, it would pose a huge economic and ecological challenge and hence for the overall development India needs to adopt renewable sources for power generation (Pode, 2010). Also India's coal resources are of low calorific value and hence of poor quality (NREL, 2010). India's oil and gas reserves are also in short supply while demand for oil has galloped unabated (NREL, 2010). Every year oil imports have increased substantially draining huge amount of foreign exchange ($ 125 Billion in 2011-12) reserves of the country (Ministry of Petroleum, 2011).

Emissions and import bills will force India to adopt renewable sources in the future in an accelerated manner (Bhattacharya & Jana, 2009). However, Renewable Energy Sources (RES) forms a miniscule portion (25 GW, ~ 12%) of India's overall Energy consumption today (202 GW) (MNRE, 2012). The share of wind energy (17 GW) is 68% of the total renewable energy basket and is likely to remain so for the near future (MNRE, 2012). The importance of wind energy in comparison with other types of renewable technologies could be explained due to the combination of two factors: the availability of resources and the maturity of the technology in term of cost efficiency (Esteban et al., 2011). (Usha Rao & Kishore, 2008) found that there is a correlation between the diffusion parameters and the composite policy index. Hence is strong policy framework is a prerequisite for the growth of wind energy in India.

But the contribution from offshore wind farms is non-existent presently, as all the wind energy generated in India are only through onshore wind farms (MNRE, 2012). With increased pressure on availability of land for development purposes India has to quickly exploit its vast coastline (over 7000 Kms) for producing power from offshore wind farms. Several European countries, most notably, Denmark, Germany, Netherlands and the UK have proactively tapped the offshore wind energy potential to reduce their dependence on fossil fuels (EWEA, 2012).

One of the reasons for the impressive growth of Indian onshore wind energy is thanks to the proactive policies adopted by the Government of India (World Bank reports, 2010). As per (Goyal, 2010) Onshore wind power development in India grew over 27% when dedicated policies for renewable energy sources were announced. Schmid (2012) discusses about the policies that have been effective in the growth of renewable energy power in India. Similar views on policies helping to accelerate the growth of onshore wind energy in India have been made by several others (Pillai and Banerjee, 2009 and Srinivasan S, 2009). (Hossain et al, 2011) have argued that the wind energy potential in India is considerably higher than what was understood till now.

In the European Union (EU), which is the world leader in Wind energy, installed wind power capacity grew rapidly to 65,933MW in 2008 (EWEA, Wiser & Bolinger, 2010). Key drivers for the success of wind energy are various policy schemes that promote technology development and diffusion in countries such as Denmark, Germany and the UK (Lewis and Wiser, 2007;

Luthi & Prassler, 2011; Boyle, 2007; Dinica, 2006; Held et al., 2006; Toke, 2011; Haas et al., 2007; and Lund, 2008). Similarly, several researchers ((Esteban et al., 2011; Green and Vasilakos, 2011; Toke 2011; Prassler & Schaechtele, 2012) have concluded that offshore wind farms have immense potential for growth in Europe and articulated how policy support instruments determine the financial attractiveness of offshore wind farms in Europe.

(Boyle, 2007) mentions that uncertainty of policy environment was one of the deterrents to offshore wind development in the UK. Cost reductions and thereby greater adoption for offshore wind energy cannot materialize in the absence of any policy intervention (Kolev& Riess, 2007). These dedicated offshore wind energy policies have made Europe the world leader in offshore wind energy sector with close to 4000 MW of offshore wind energy installed and another 6000 MW is in advanced stage of completion in 2012 (EWEA, 2012). Initial studies conducted by RISO Denmark, CWET India and Lawrence Berkeley labs US, to ascertain the offshore wind energy potential for India shows promising results, however the exact commercial potential is in the process of being worked out. While, it is apparent from existing literature that offshore wind energy sources grew when there were enabling policy environment, there are no policies in India for harnessing its offshore wind energy potential as yet. Also, there has been no study carried out to develop and empirically test a model of constituents of effective policy.

This thesis will study the impact and success of policy initiatives adopted by European countries that helped them generate substantial proportion of electricity from offshore wind farms, identify a set of factors that form the core components of offshore wind energy policy intervention and recommend best of breed policies for India to adopt in this sector, which will result in proliferation of offshore wind farms.

1.2 Need for research

The projections of power requirement for the Indian economy growing at 8% and 9% per annum is given in the Table 1.2 below (Ministry of Power, 2005). Taking even a conservative growth of Indian economy at 8% per annum for the next 18 years; India needs an installed capacity of over 950,000 MW from the present 202,000 MW – a capacity addition of over 40,000 MW every year for the next 18 years or around 800 MW every week. Of course the capacity addition figures are much higher if one considers the economy growth rates of over 9% per annum. Today, for each 1% of economic growth, India needs around 0.75% of additional energy (Planning commission, 2011). The Planning Commission of India assessed that this value could fall to 0.67% between 2021 and 2031, however 0.67% is also substantial to source (Planning Commission, 2011).

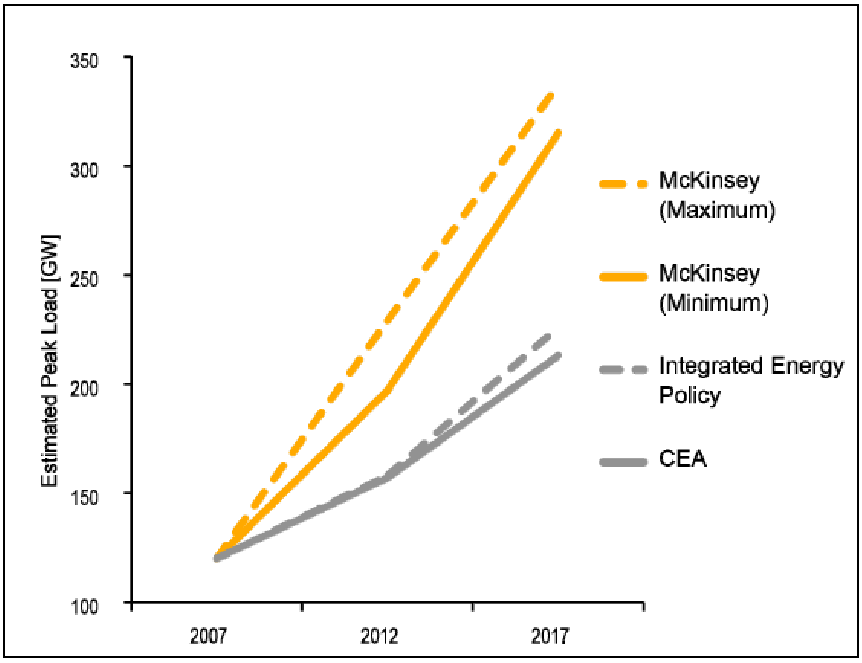
Table 1.2 - Projections for Electricity requirement in India

Year	**Billion kWh**		**Installed Capacity**	
	8%	**9%**	**8%**	**9%**
2006-07	700	700	140	140
2011-12	1029	1077	206	215
2016-17	1511	1657	303	331
2021-22	2221	2550	445	510
2026-27	3263	3923	655	785
2031-32	4793	6036	962	1207

Source: Ministry of Power, India 2005

The generation capacities needed to support economic growth given by the planning commission are conservative estimates if one goes by the report of Mckinsey and company (2009). McKinsey calculated that the peak demand will be around 350 GW by 2017 instead of 213 GW as estimated by the Central Electricity Authority (CEA) and 226 GW (assuming 8% annual GDP growth) as projected in the Integrated Energy Policy (Figure 1.1). Accordingly, by 2017, India would require a total installed capacity of 415–440 GW in order to service this demand. This means that over the next 5 years, the country would have to install twice as much capacity as it has been able to install over the last 65 years (202 GW). It is apparent that India has to encourage the growth of renewable in the country, more so offshore wind energy.

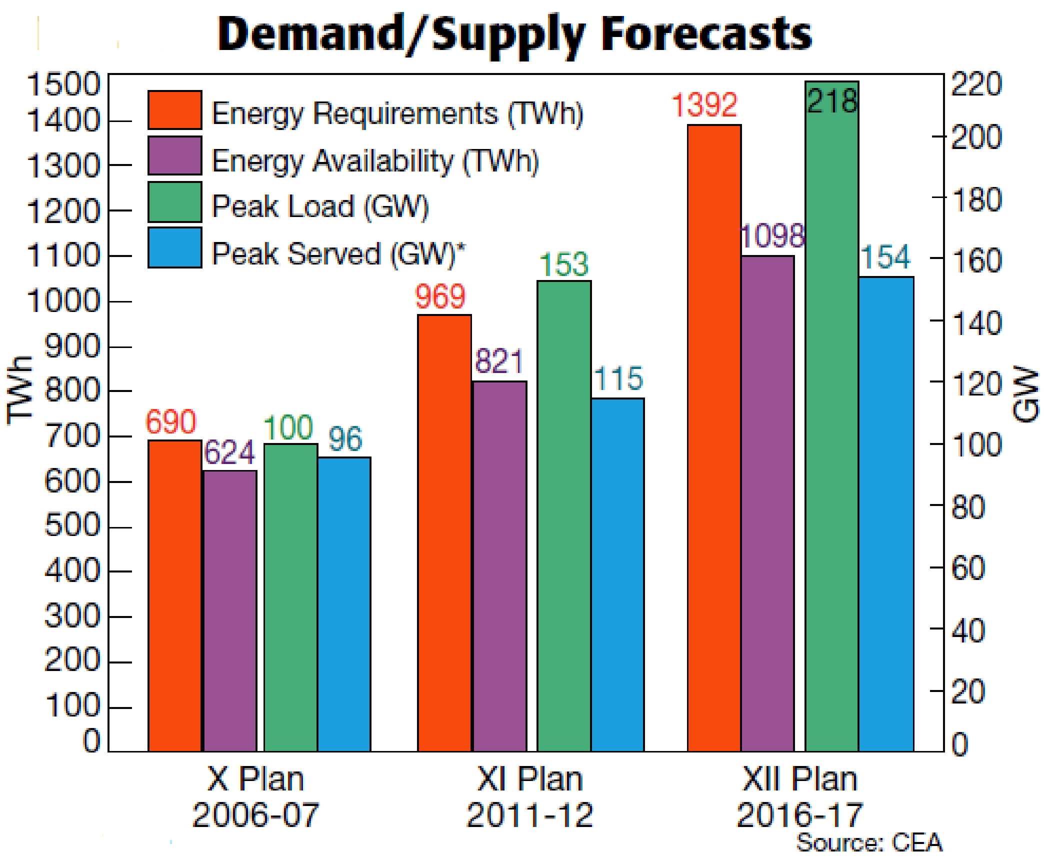
Figure 1.1 - Scenarios of peak load capacities for India



Source: Mckinsey Reports, 2009

The power-generating capacity in India, at present, is not enough to meet the demand either now or in the future (CEA, 2011) (Figure 1.2). In 2010–2011, India experienced a generation deficit of approximately 11% and a corresponding peak load deficit of 13%. India's frequent electricity shortages are estimated to have cost the Indian economy 6 -8% of gross domestic product (GDP) in the recent years. To power the economic growth currently being targeted, it is estimated that India will need to more increase its installed generating capacity to over 300 GW by 2017. The electricity undersupply in India is estimated to cost the economy as much as INR 34 to INR 112 for each missing kilowatt-hour (NREL, 2010). Thus, the total cost of the power deficit of 100 billion units in financial year 2010–2011 amounted to at least INR 5000 billion (NREL, 2010).

Figure 1.2 - Power demand and supply forecasts in India



Source: CEA, 2011

While the peak power deficit averaged 4 GW during 2006- 7, it worsened to 38 GW during 2011-12 and the gap in deficit is likely to grow to 64GW by 2016-17 as per CEA (Figure 4.8). With power deficit projected to increase further in the foreseeable future, and traditional fossil fuel based generations straining the exchequer, it is expected that India will need additional avenues of power generation to fulfil its energy needs. The government plans to provide universal access and to increase per capita consumption to 1,000 kWh by end of 2012 (IEA, 2009). About 100,000 villages have no access to electricity, and almost 400 million Indians (in 2009 as per IEA) are without electricity coverage. This number is likely to remain more or less the same as per projections of IEA in 2015 (Table 1.3).

Table 1.3 - Millions of people without access to electricity in 2009 and likely scenario in 2015 and 2030

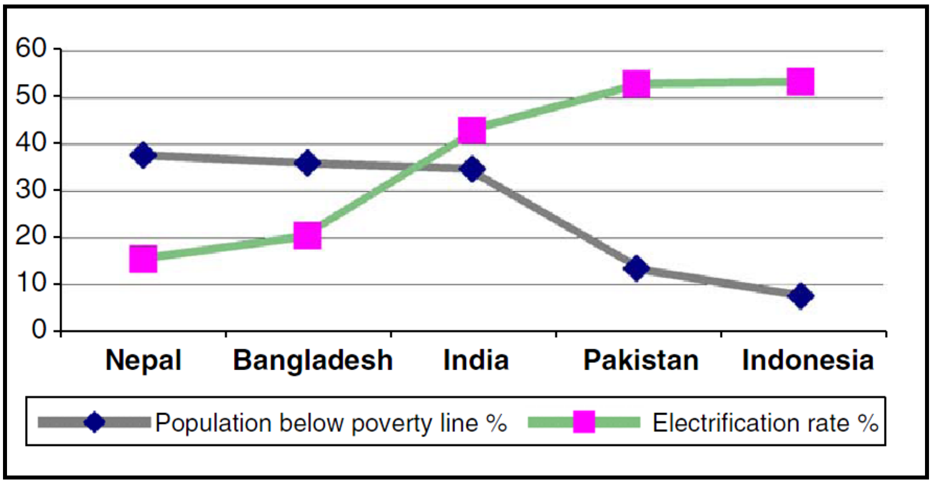
Region	2009			2015	2030	2009	2015	2030
	Rural	Urban	Total	Total	Total	%	%	%
Africa	466	121	587	636	654	42	45	57
Sub-Saharan Africa	465	120	585	635	652	31	35	50
Developing Asia	716	82	799	725	545	78	81	88
China	8	0	8	5	0	99	100	100
India	380	23	404	389	293	66	70	80
Other Asia	328	59	387	331	252	65	72	82
Latin America	27	4	31	25	10	93	95	98
Developing Country*	1,229	210	1,438	1,404	1213	73	75	81
World**	**1,232**	**210**	**1,441**	**1,406**	**1213**	**79**	**81**	**85**

Notes: *Includes Middle East countries, **includes OECD and transition economies.

Source: IEA (2010), IPCC (2011)

India's per capita consumption (~ 750 kWh) is one of the lowest in the world. There is a critical link between energy and economic activity and low levels of energy consumption has a negative bearing on the quality of life of the people and also on other drivers of livelihood including water, agriculture, and health (Srivastava & Rehman, 2005). The relationship between energy and development is corroborated by the fact that the population living below the poverty line in developing countries reduces as we move from a low level of electrification to higher levels. (Srivastava & Rehman, 2005 – Figure 1.3).

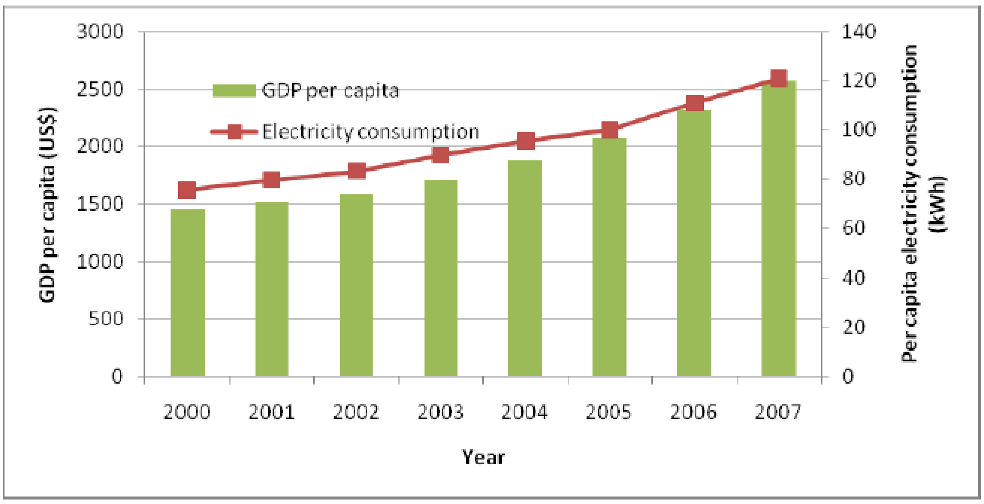
Figure 1.3 – Electrification and reduction of poverty in select countries



Source: Srivastava & Rehman, 2005

Also, it is well established that there is a high correlation between energy consumption and economic growth. Between 2000 and 2007 India's economy grew nearly 77 percent and this was matched by a 60 percent increase in electricity consumption (World Bank, 2010) (Figure 1.4)

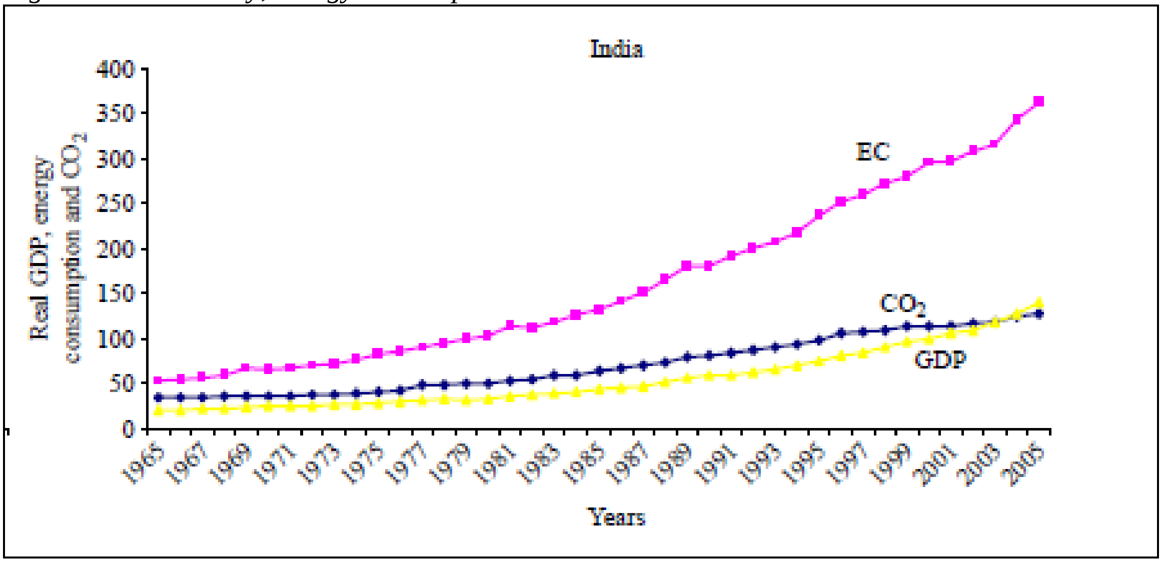
Figure 1.4 - Economic growth and electricity consumption in India



Source: World Bank report, 2010

However, the downside to all these spectacular growth is that the Co_2 emissions, as a consequence of energy consumption of predominantly fossil fuel based energy generation, grow along with the economy as shown in the figure 1.5 below (Rafiq & Salim (2009). In fact energy consumption grows at a much faster rate compared to the GDP growth. All these puts phenomenal strain on the resources needed to generate electricity.

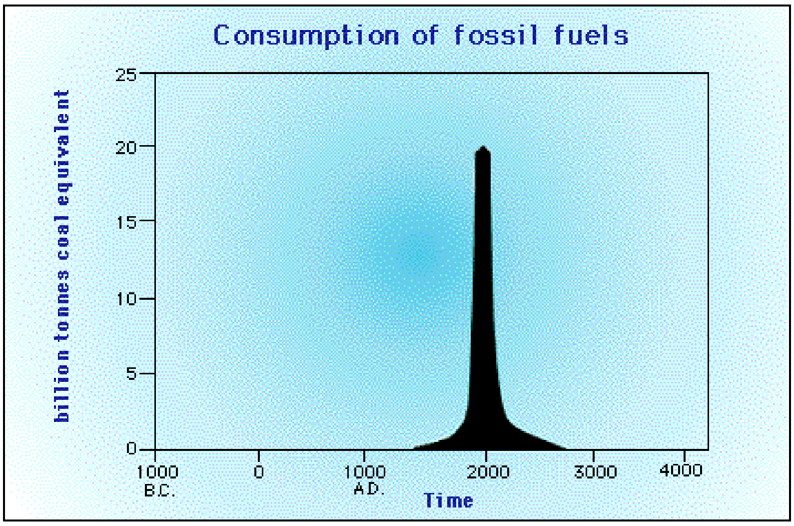
Figure 1.5 - Economy, energy consumption and carbon emission in India



Source: Rafiq & Salim (2009). GDP, EC and CO2 represent real output, energy consumption in million tonnes oil equivalent and carbon emission in hundred million tonnes, respectively

There is a danger of the world running out of fossil fuels not in too distant future. Coal and other fossil fuels which have taken millions of years to form are likely to deplete soon. In the last two hundred years 60% of available resources have been consumed (BEE, 2003). The remaining 40% of these reserves are continually diminishing at a faster pace with increasing consumption (BEE, 2003) (Figure 1.6).

Figure 1.6 – Fossil fuels reserves in the world



Source: Bureau of Energy Efficiency, India, 2003

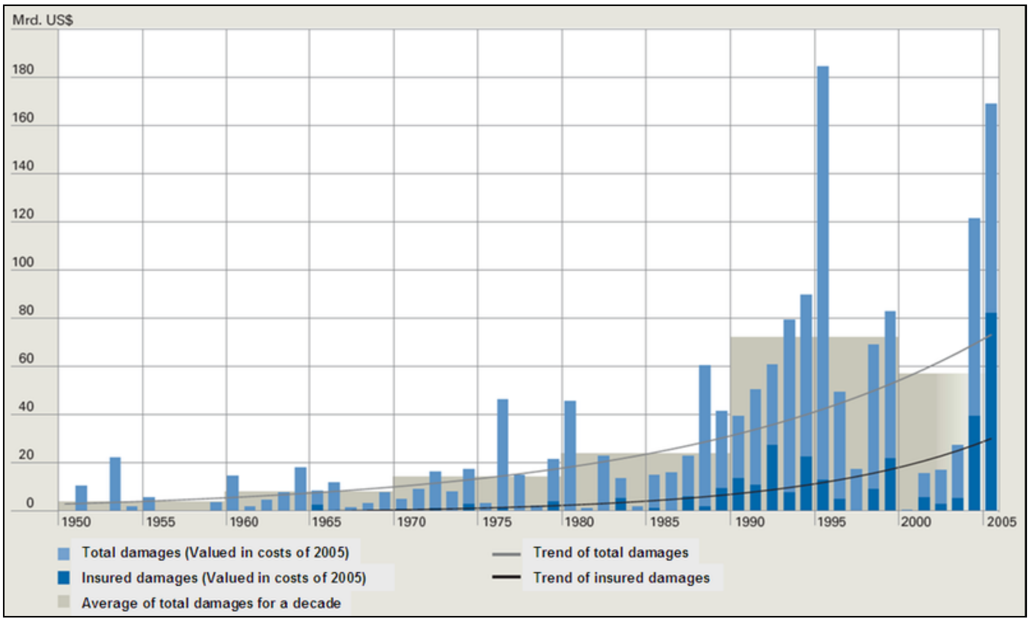
India has to leverage every avenue of clean energy sources available in the country to add to the electricity generation mix. Today, wind energy has over 65% share of the renewable basket. However, entire wind energy is generated from onshore wind farms since offshore wind farms are non-existent at the moment in India. Given the pressure on land availability, the stupendous growth witnessed by onshore wind energy farms in India, over the last 2 decades, needs to be carried forward by offshore wind farms. India is blessed with 7000 Kilometres of coast line with steady wind speeds for offshore to take off in a big way. Also, most of the large wind turbine manufacturer in the world has presence in India, capital available, some of the best EPC contractors and developers are doing business in the country and economical, skilled labour accessible – India seems to have all the necessary ingredients for success of offshore wind farms. However, what's missing is a comprehensive policy to harness offshore wind energy. This thesis studies the success of policy initiatives adopted by select European countries that helped them grow their offshore wind energy sector and also identifies the core components that form the building blocks of policy intervention needed for India to proliferate offshore wind farms in the country.

1.3 Consequences of wanton use of fossil fuels

According to the Planning Commission, coal-based thermal power plants are likely to contribute about 300 GW in 2030, up from about 113 GW in 2011(Planning commission, 2011). With the large number of coal-based thermal power plants are likely to be commissioned; coal consumption in the power sector was 610 MT of 380-500 MT by 2011-12 and 1.3 Billion tonnes by 2021-22 (Chikkatur & Sagar, 2009). Meeting the growing energy demand based on the current pattern of energy supply will become increasingly difficult in view of the needs to keep Greenhouse gases (GHG) emissions and crude oil import bill low. Thus the importance of renewable energy in the case of India is likely to grow monotonically in the future (Bhattacharya & Jana, 2009).

There have been several studies (IPCC, 2012, REN 21, 2012, WISE, 2010) that have documented the havoc created by unbridled use of fossil fuels by the world community, increasing concentration of Co2 in the atmosphere and the ill-effects of global warming. For instance, in the US during a 9 year period (1996 to 2005), economic damages caused by natural disasters (Climate changes mainly due to use of fossil fuels) amounted to $ 575 Billion (Munich RE, 2009). That’s more than $ 60 Billion per year (Figure 1.7). Even though estimates are not available for India, and the magnitude of damage may be much less than that of the US, but still the potential for damage due to fossil fuel on the economy is real and daunting. Sooner India moves into a renewable led energy generation economy; the better it would be for the overall development (Pode, 2010).

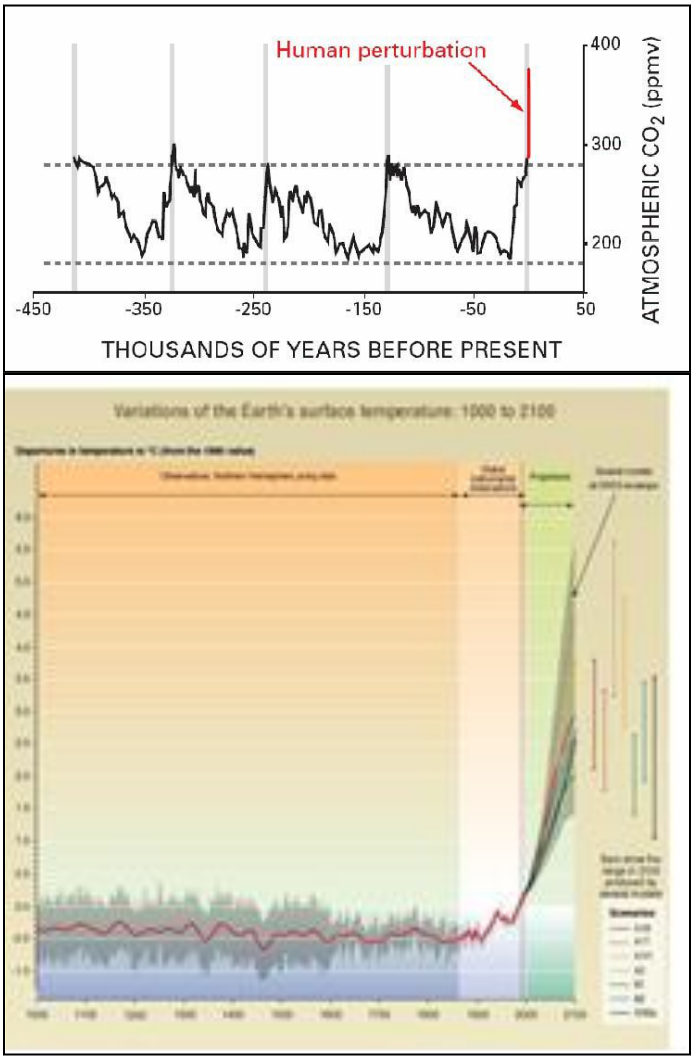
Figure 1.7 - Economic damages due to natural disasters in the US, for 10 years



Source: Munich RE Group, 2009

Wanton use of fossil fuels has contributed to temperature increases that are significantly higher than at any time during the last 1000 years (World climate program, 2008) (figure – 1.8*)*. Already the human activities have increased the Co2 concentrations in the atmosphere to alarming levels (Table -1.4). Ice cores indicate that in the past 420,000 years, the concentration of CO2 in the atmosphere has ranged from 180 to 280 parts per million by volume (ppmv). The current CO2 atmospheric concentration is ~375 ppmv; this dramatic increase is primarily the result of human combustion of fossil fuels (World climate program, 2008).

Figure 1.8 - Co_2 concentration and temperature increase



Source: World climate program, 2008

Table 1.4 - CO_2 emissions by fuel source

	Carbon Dioxide Emissions (t/GWh)
Coal	964
Oil	726
Gas	484
Nuclear	8
Wind	7
Photovoltaic	5
Large Hydro	4

Source: Breeze P, 2008

There are several documents(IPCC, 2012, REN 21, 2012, WISE, 2010) that highlight havoc created by continued use of fossil fuels including air pollution, acid rains, severe storms, flooding, food shortages due to reduced rainfalls, dwindling freshwater supply, loss of biodiversity, health problems and many more. Renewable energy can be an important part of India's plan not only to add new capacity but also to increase energy security by diversifying supply, reduce import dependence, mitigate fuel price volatility and address environmental concerns. Accelerating the use of renewable energy is also essential if India has to meet its commitments of reducing emissions by 20—25% of the 2005 levels (NAPCC, 2008) to reduce its carbon intensity. Every 1 GW of renewable energy capacity added reduces CO_2 emissions by more than 3 million tons a year. Renewable energy can provide secure electricity supply to foster domestic industrial development, attract new investments, and hence serve as an important employment growth engine, generating additional income.

1.4 Business Problem

The challenges faced by the electricity power generation sector in India can be summarised as below

1. Install and commission additional capacities of power generation to support economic growth
2. Leverage every avenue of power generation sources (renewable and conventional) to add additional power generation capacity

3. Reduce the dependency on imported fossil fuels (Coal and Oil) as they continue to drain the country of its precious foreign exchange reserves apart from the challenges caused due to their price volatility and energy security concerns.
4. Reduce greenhouse gas emissions caused due to burning of fossil fuel as environmental and ecological concerns continue to mount.
5. Encourage renewable energy sources of power generation as they are indigenous, abundant, clean and inexpensive in the long run.

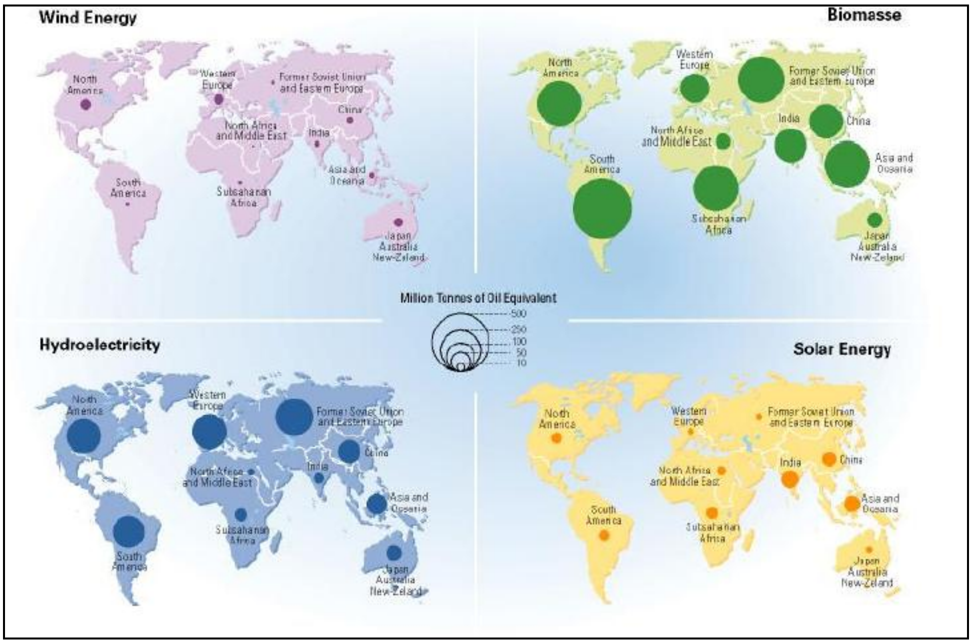
All these five challenges are inter-related as fossil fuels are in short-supply and hence needs to be imported which drains the foreign exchange reserve ($125 Billion in 2010-11) apart from polluting the environment, which makes it appropriate to encourage renewable energy sources in the country.

The business problem can hence be stated as how can India leverage additional sources of power generation to support its economic growth, that are non-fossil fuel based, that are non-polluting and are indigenously available thus saving precious foreign exchange .

1.5 Renewable Energy Scenario in India

India is blessed with generous sustainable resources to make a shift to renewable energy (Figure 1.9); abundant solar resources available for 300 days in a year, plentiful small hydro potential in the Himalayan states, long coast line of over 7000 Kms for tapping the offshore wind energy, several zones with wind speeds of over 7m/sec for onshore wind energy installations, a predominantly agrarian economy to act as a perennial supply chain for bio fuels (Figure 1.10). Consequently, India has made an impressive start in the renewable journey (MNRE, 2010).

Figure 1.9 -Renewable energy potential in India

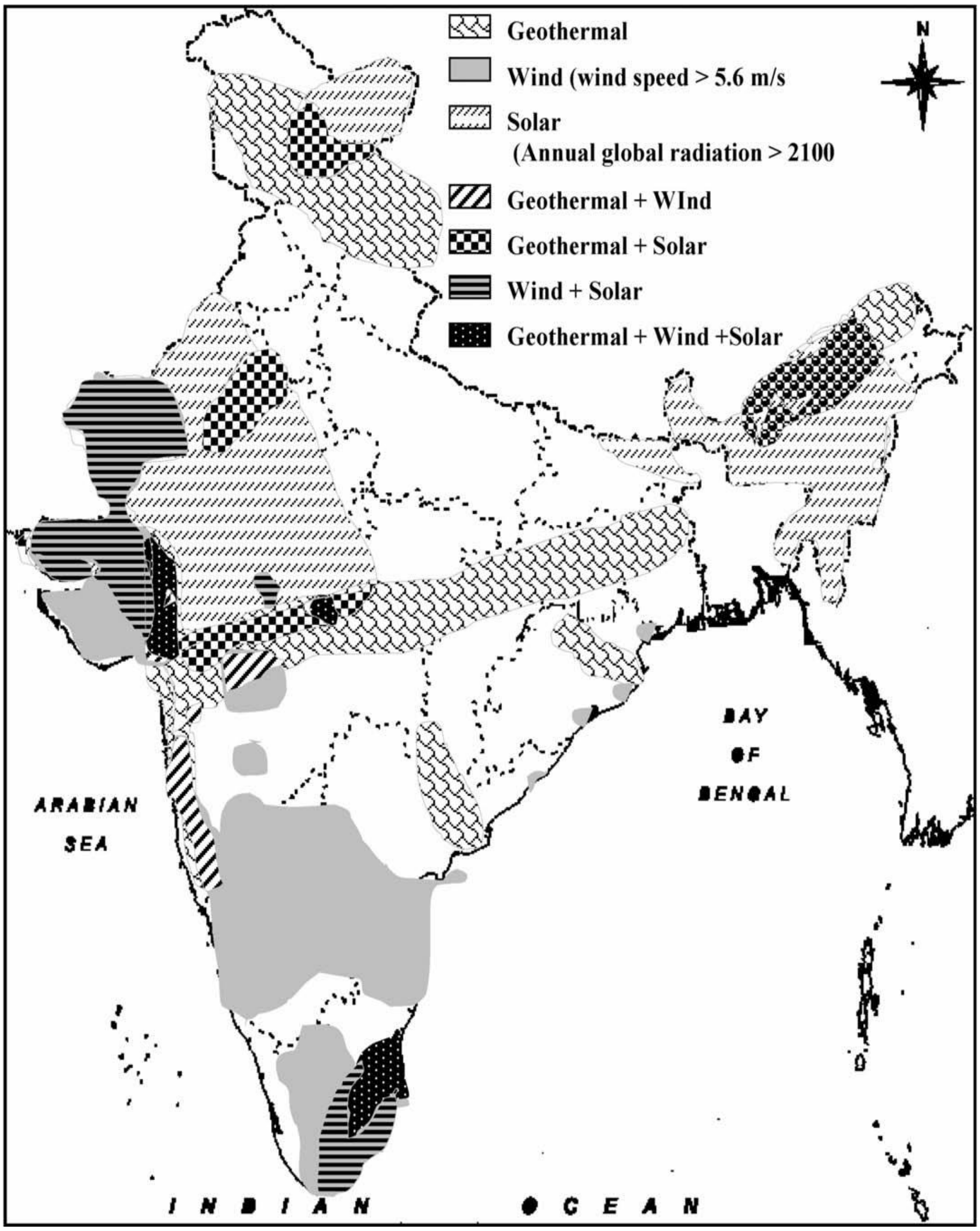


Source: GENI, 2010

<u>Wind Energy</u>: Wind energy technology is the most mature for energy generation among all renewable sources in India and contributes over 65% of the renewable installed capacity in the country. The Southern states of Tamil Nadu, Karnataka, Andhra Pradesh and Western states of Gujarat, Rajasthan and Maharashtra have huge wind energy potential(MNRE, 2010). Centre for Wind Energy Technology (CWET) has re-assessed the overall wind energy potential of the country as 102 GW (CWET, 2011). Around 17 GW of this potential has been tapped (Table 1.5 & 1.6). However the actual potential

could be much larger as per reports by Lawrence Berkeley labs (2012), Hossain et al (2012).

Figure 1.10 - Renewable resource map of India



Source: Pillai and Banerjee, 2009

<u>*Solar Energy*:</u> Deserts of Rajasthan and Gujarat offers solar energy potential. India, 7^{th} largest country in the world by area, is located near the equator and

hence subjected to a large amount of solar radiation throughout the year. The average solar radiation received by most parts of India range from about 4 to 7 kilowatt hours per meter square per day, with about 250-300 sunny days in a year(MNRE, 2010). The Government plans to tap 20,000 MW of grid connected solar energy by 2022 as part of the Jawaharlal Nehru National Solar Mission (JNNSM, 2008) program. Currently, around 980 MW of solar installation is already present in India (MNRE, 2011).

Table 1.5 - Achievement and Potential of Renewable Power in India (in MW)

	Achieved		**In Process**	**Anticipated**	**Targets**	**Estimated Potential**
Five – Year Plan	Cumulative Installed Capacity by the end of 9th Plan	10th Plan – additions during the plan period	Anticipated in the 11th plan (additions during the plan)	By the end of the 11th plan (Cumulative installed capacity)	By the end of the 13th plan (cumulative installed capacity)	Medium Term
Years	Through 2002	2002-2007	2007-12	Through 2012	Through 2022	10 Years
Wind	1667	5415	10,500	17,582	40,000	102,000
Small Hydro	1438	520	1400	3358	6500	15,000
Biomass	368	750	2100	3218	7500	23,700
Solar	2	1	1000	1003	20,000	20-30 MW/Sq. Km
Total	**3,475**	**6,686**	**15,000**	**25,161**	**74,000**	**~ 150,000**

Source: MNRE, Government of India & Planning Commission reports, 2009

Small Hydro Projects: Hydro projects up to 25 MW of installed capacity have been categorized as Small Hydro Power (SHP) projects and comes under the administrative purview of the Ministry of New and Renewable Energy (MNRE, 2010). MNRE had estimated the potential of SHP as 15,000 MW of which around 3400 MW has been tapped, (2011). Hydro projects have long gestation period compared to solar and wind energy projects due to delays in getting regulatory clearances and inhospitable terrains.

Biomass and Cogeneration: Biomass is the energy source for majority of the population that are living in rural areas. About 32% of the total primary energy users are still using biomass and more than70% of the country's population depends upon it for its energy needs (Pillai & Banerjee, 2009). The Biomass technologies being promoted by the MNRE are bagasse-based cogeneration in sugar mills, biomass power generation, and biomass gasification for thermal and electrical applications. The potential of power generation from surplus biomass was assessed as 18,000 MW (MNRE, 2010). Apart from biomass, separate potential from bagasse cogeneration was assessed as 5000 MW (MNRE, 2010). Biomass has immense potential as India is a predominantly agrarian economy.

Waste-to-Energy: Urban liquid and solid waste is used for development of waste-to-energy in India which estimated the potential of around 462 MW by 2017 from urban liquid waste and 4566 MW by 2017 from solid waste (MNRE, 2010). Apart from these bodies, industries too generate a lot of waste which has a potential of around 2000 MW by 2017. Currently around 90 MW of installed capacity exist for power generation from waste (MNRE, 2009).

Geothermal Energy: Around 350 geothermal potential regions have been identified by Geological Survey of India (GSI, 2009) which can generate 10,600 MW of power (GSI, 2009). Of this, 20% of the sites are distributed in the states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand. Exact potential and commercial viability of this energy source needs to be studied further.

These official estimates are conservative to say the least. The actual potential of say wind energy (onshore) in India as per several studies (Hossain et al., Xi Lu et al., Berkeley labs**)** are much more than these official estimates of 102 GW. More details of this are presented in chapter 4 of this document. Nevertheless, the official estimate of 150 GW of renewable energy potential is substantial enough to be tapped.

1.5.1 Installed capacity of renewable energy sources

India has over 25,000 MW of installed renewable power generating capacity as of April 2012. Installed wind capacity has the largest share at over 17,000 MW, followed by small hydro at 3400MW. The remainder is dominated by bioenergy, with solar contributing 979 MW. Aggressive plans to scale up wind, solar, bio-mass power and small hydro projects are planned, which will net new investments of over US $ 50 Billion in the clean energy sector in the next few years (MNRE, 2011).

Table 1.6 - Achievement of Renewable energy sources (in MW) in India, April 2012

Renewable Energy Systems	**Target for 2012-13**	**Achievement during April 2012**	**Cumulative achievement up to 30.04.2012**
Wind Power	2500	36.65	17389.31
Small Hydro Power	350	5.75	3401.06
Biomass Power	455	16.00	1166.10
Bagasse Cogeneration		7.5	1992.73
Waste to Power -Urban	20	-	89.68
-Industrial		-	-
Solar Power (SPV)	800	37.72	979
Total	**4125**	**103.62**	**25017.88**

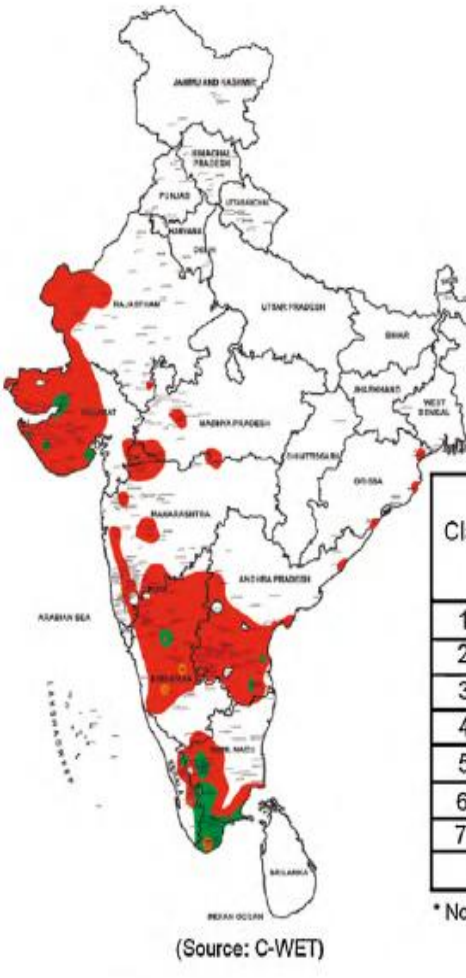
Source – MNRE, 2012

1.5.2 Wind Energy in India

The development of wind power in India began in the late 1980s and has progressed steadily in the last few years (World Bank, 2010). The short gestation periods for installing wind turbines, and the increasing reliability and performance of wind energy machines have made wind power a favoured choice for capacity addition in India. Currently, India has the fifth largest installed wind power capacity in the world (WISE, 2011). The official wind energy potential at 50 m hub height was 48,000 MW (Figure 1.11) and at 80 m hub height is given as 102,000 MW (CWET, 2011). Excellent wind energy potential is observed in the southern and western parts of the country (Figure 1.12 & 1.13). The actual wind energy potential in India is expected to be much more than what is regarded till now and has been discussed in detail in chapter-4 of thesis. The potential of wind energy at various Plant Load Factors

(PLF) is given in Figure 1.14. It can be observed that at 25% PLF the potential is 2500 GW (Hossain, 2011). To put that in perspective, the power generation in India from all the sources is 202 GW. Wind power accounts for 2/3rd of installed renewable capacity in the country and a leader by a long margin as compared to other renewable sources. Wind energy grew substantially on the back of supportive policies of Government of India (World Bank, 2010). All these capacities are from onshore. Offshore wind sector does not exist at present in India.

Figure 1.11 - Wind power density map of India (Watt/M^2)



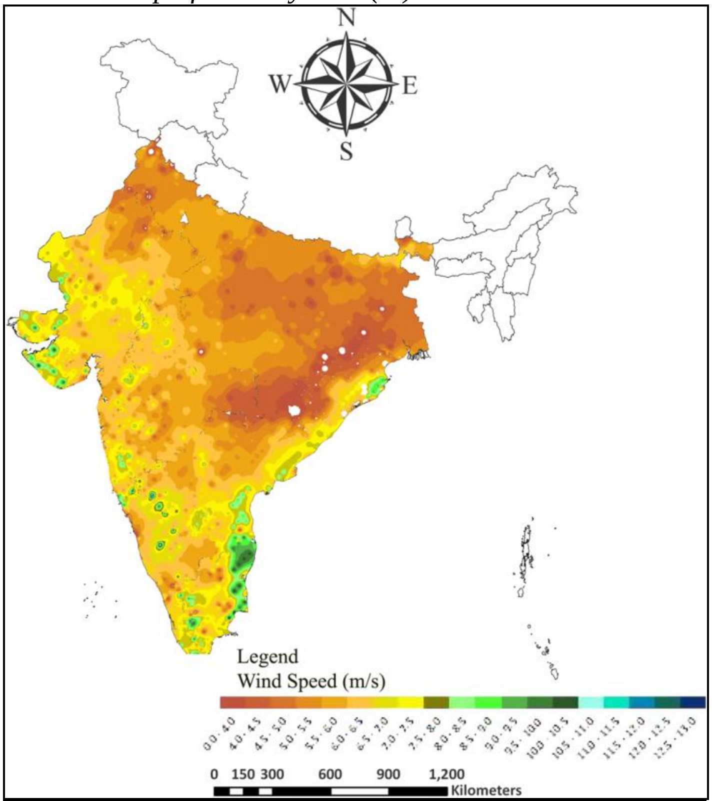
Standard Wind Class definition

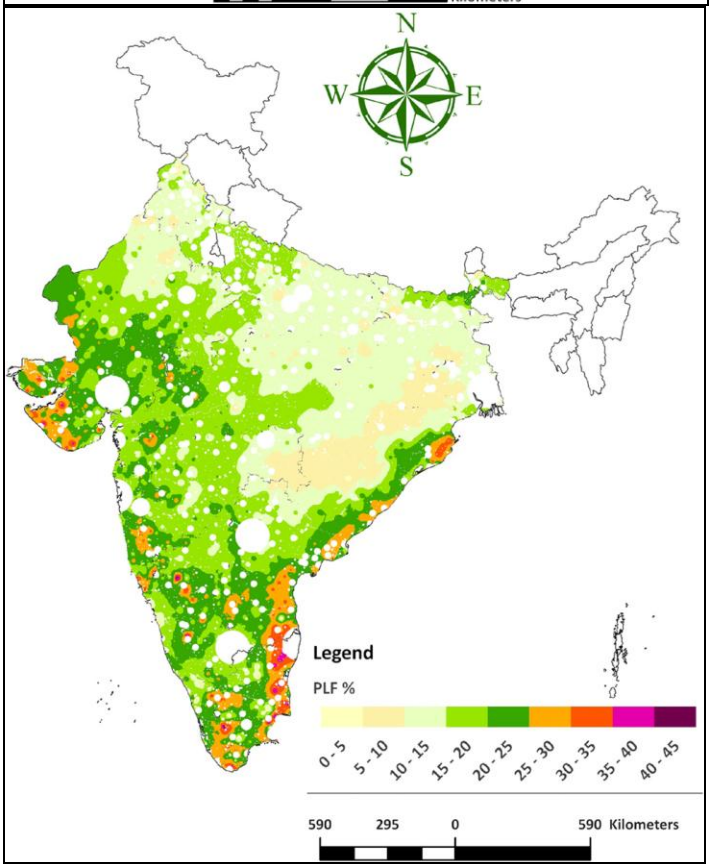
Class	50 m Height		Installable MW*	Wind Power Density (W/sq.m)
	Wind Speed (m/s)	Wind Power (W/sq.m)		
1	<5.6	<200		
2	5.6 - 6.5	200 - 300	43106	red
3	6.4 -7.0	300 - 400	4680	green
4	7.0 - 7.5	400 - 500	397	orange
5	7.5 - 8.0	500 - 600	16	light blue
6	8.0 - 8.8	600 - 800	-	purple
7	8.8 - 11.9	800 - 2000	-	blue
		Total	48199	

* Note: 1. Installble power on the assumption that 1% of land becomes available for wind farming.
2. An area requirement of 12 hectares/MW assumed.

Source – CWET, MNRE, India, 2008

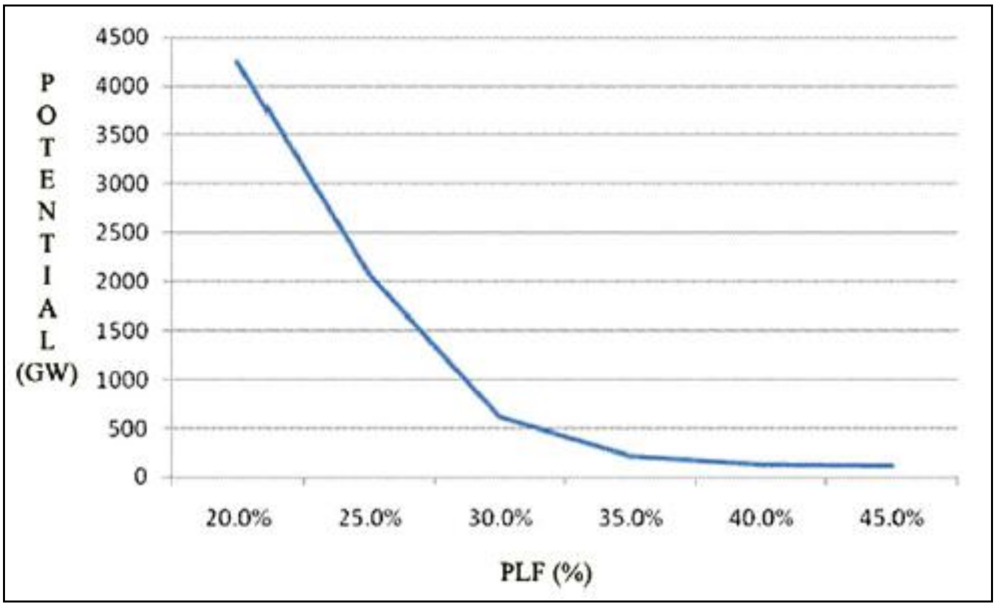
Figure 1.12 and 1.13 - Wind speed map of India at 80 m and Wind Power Potential map of India by PLF (%)





Source: Hossain et al., 2012

Figure 1.14 - Wind energy project potential for India (at PLF levels)



Source: Hossain et al., 2012

Assessment on a GIS platform from TERI University shows that the onshore wind energy potential in India is around 4250 GW (Hossain et al, 2012) at 20% PLF. Field level studies needs to be carried out to corroborate the suitability of a particular site. But the growth of wind energy cannot depend just on onshore wind farms for the following reasons;

- Limited availability of contiguous parcels of land
- Unpredictable nature of wind sources on land
- Potential land litigations
- Competing uses for land from other infrastructure projects

Offshore wind farms have to be promoted to compensate for the likely challenges, as mentioned above, that would be faced by onshore wind farms. The world is aggressively (EWEA, 2012) moving towards tapping offshore wind energy sector to mitigate some of the challenges faced from onshore wind farms (EWEA, 2012). India's long coast-line offers a large potential;

proper assessment and development of this potential would offer challenges and new opportunities to India’s wind energy industry (Bhattacharya & Jana, 2009). Initial studies conducted suggest that the offshore wind energy potential for India could be between 250 GW and 500 GW, which is quite large (Lawrence Berkeley labs, 2012). Even though India has all the necessary ingredients for offshore wind farms it needs to formulate a comprehensive policy to encourage offshore wind energy sector. The rest of thesis addresses this point in greater detail.

1.6 Outline of the study

It is apparent that India needs to encourage growth of offshore wind energy sector to mitigate the risks associated with fossil fuels and enhance the share of renewable sources in the electricity mix. However, a comprehensive policy is needed to start and sustain the adoption of offshore wind farms, as observed in several countries in the world (the literature review section covers this in detail). What constitutes the basic elements of offshore wind energy policy, at a fundamental level, needs to be known to draw up the entire architecture of this intervention.

The main objectives of the study are to conduct a elementary level feasibility analysis (covering market, financial, technical, economic and ecological feasibilities) of setting up offshore wind parks in the Dhanuskodi areas of India, study the support of policies in the growth of onshore wind energy sector in India, critique the policies adopted by select European countries (UK, Denmark, Netherlands and Germany) to encourage the growth of the offshore wind energy sector in their respective countries apart from developing and empirically testing a model of constituents of effective offshore wind energy policy for India.

This thesis does an exhaustive literature survey of successful adoption of offshore wind energy sector by select countries in Europe, to identify the basic building blocks (variables) that are needed to encourage growth of offshore wind energy in those countries. Research model and hypotheses are formulated keeping an eye on the objectives of the study. 21 such variables were identified; Statements are formulated and measured by 7-point likert scale & itemised rating scale. A pilot study was conducted and reliability of the instrument was calculated using Cronbach Alpha which was further validated. The responses attained by field survey are analysed with the help of SPSS 16.0 version and proposed framework is validated. The data collected were subjected to factor analysis to discover the underlying structure and Hypothesis testing is carried out by multivariate analytical technique like logistic regression to empirically test the framework to predict the probability of growth of offshore wind energy sector in India. The results are presented in chapter 4 of this document.

1.7 Significance of the study

India needs to leverage every avenue of power generation, embrace demand side management programmes and adopt energy efficiency measures to make available additional units of electricity to power its economy and cater to the growing aspirations of its people. While, almost all indigenously available source of power generation has been tapped, offshore wind energy has continued to remain an uncharted territory. With domestic production of coal and oil in short supply and imports of these fossil fuels burdening the exchequer, India has to quickly exploit the offshore wind generation opportunity it has, to get additional electricity into the grid. Currently, there is limited amount of literature available on what could be the offshore wind energy potential in India, the feasibility of setting up of offshore wind farms and the policies that need to be adopted by India to support the growth of offshore wind energy in the country. This thesis will attempt to bridge that gap and will try to add to the existing body of knowledge of literature, which may be useful to policy makers, energy planners and researchers to unlock the potential of offshore wind energy sector in India.

1.8 Organization of the Report

The study consists of **seven chapters**. The first chapter is the **introduction** to the topic including the energy needs of India to sustain its current economic growth, the contribution of renewable energy in the electricity mix, renewable energy scenario in the country and the importance of policies to augment the growth of renewable energy in the country. This chapter also mentions that India needs to tap into offshore wind energy.

The second chapter is **review of literatures**, which studies the global renewable energy scenario, wind energy development in the world, present status of onshore and offshore wind energy sector in Europe, brief on Indian wind energy sector and policies to encourage the growth of renewable energy in India. This chapter also highlights the gap in availability of literature in the area of offshore wind energy policy for India. Thus identified variables are presented in this section.

The third chapter explains the **research design**, the rationale of the study followed by the statement of the research problem, objectives of the study, research questions, scope of the study, research model and hypotheses, the research methodology, sampling process, Instrument design, questionnaire format, scale formation, Instrument reliability, Instrument validity, pilot testing, data collection and operating definitions of variables found through literature survey and analytical tools used for analysis of primary data.

The fourth chapter deals with the **feasibility study** (Market, Technical, Financial, Social-cost benefit and Ecological feasibilities) of setting up offshore wind energy farms in India. The study done confirms the viability of offshore wind energy projects in the country.

The fifth chapter explains the **model design and analysis**. The factor analysis reduces the 21 variables, identified through literature survey and administered as a questionnaire to 181 respondents, into 5 factors and then the logistic regression gives the log odds of growth of offshore wind energy in India. The formulated research model is empirically validated and consequent results are reported.

The Sixth chapter is the **critique of offshore wind energy policies** adopted by select European countries (Germany, UK, Denmark and Netherlands). It identifies a set of offshore wind energy policies from Europe that can be adopted by India and identify a set of offshore wind energy policies that need to be uniquely tailored by India. This chapter also studies the support of policies in the growth of onshore wind energy sector in India.

Finally the seventh chapter gives the **conclusions and recommendations**. Bibliography is given at the end as reference.

1.9 Concluding Remarks

India is one of the fastest growing economies in the world and an emerging superpower. Increase in power generation capacity to support this growth in economy is essential. However, continued reliance on fossil fuels to add additional generation capacity will prove unviable from the ecology and economic point of view. India has to tap into its abundant renewable energy potential to build new generation capacity. Presently, Wind energy constitutes 2/3rd of installed capacity of renewable energy in India. But India has not attempted to tap the potential of generating power from offshore wind farms. Given several challenges faced by onshore wind farms in terms of limited availability of contiguous parcels of land and other factors, the phenomenal growth hitherto witnessed by wind energy technology in India needs to be carried forward by offshore wind farms. India has all the necessary ingredients for offshore wind farms. However, what’s missing is formulation of comprehensive policy to harness offshore wind energy. Extensive literature survey was conducted to identify the basic elements or fundamental building blocks that need to be addressed to accelerate the growth of offshore wind energy in the country. Since European countries, the UK, Germany and Denmark, are the leaders in harnessing offshore wind energy, literature survey was focussed to understand the success mantras of these countries in promoting offshore wind energy sector and whether these learning can be leveraged by India to encourage offshore wind energy in the country. Currently there is a dearth of literature on offshore wind energy sector in India. This thesis also is an attempt to fill the gap owing to nascence of literature on factors that may drive the growth of offshore wind energy for India, by identifying a set of variables that form the core components of offshore wind policy to develop & empirically test a model for it. It is hoped that this thesis may add to the existing body of knowledge as literature on the offshore wind energy sector in India is in nascent stage. In next chapter literature review on above said line is presented

2 Chapter 2 - REVIEW OF LITERATURE

2.1 Introduction

In this chapter the learning from the earlier research work carried by scholars, industry associations, policy makers and thought leaders in the renewable energy area have been described to capture the essence of the body of knowledge that exist in this field. Once the current literature is studied to develop an overall understanding of the scenario as it transpires today, it becomes imperative to build on the foundation of existing body of knowledge by identifying the research gap that exist. The research gap becomes the starting point of this research work.

The objectives of the literature review are

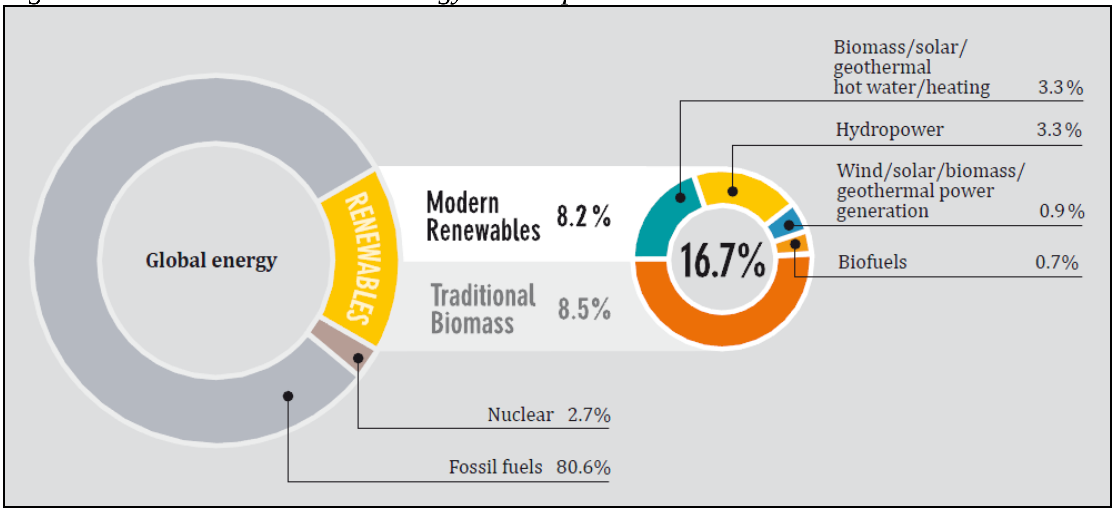
1. To study the overall renewable energy scenario in the world
2. To study the global wind energy scenario and highlight the supportive policies (demand side and supply side policies that encompass both the generation based and capacity based interventions) that have helped the growth of wind energy in the world
3. To discuss about the overall wind energy scenario in Europe and explore the literature that analyses the contribution of supportive policies in the growth of wind energy in Europe
4. To review the status and growth of offshore wind energy in Europe and find out the supportive policies which contributed towards growth of it.

5. To review the existing renewable energy policies in India and find out the policies which supported its growth.
6. To study the existing wind energy scenario in India.
7. To briefly discuss about the offshore wind energy feasibility in India
8. To identify the list of variables that forms the core building blocks of a comprehensive offshore wind energy policy in a country.
9. To identify the research gap in the existing body of knowledge.

2.2 Global Renewable Energy Status

The contribution of renewable energy sources in the total energy consumption in the world is around 16% in 2010 REN 21 (2012) (figure 2.1). In 2011, renewable energy accounted for almost half of the 208 GW of electricity generation capacity added globally in the power sector REN 21 (2012). Out of these, Wind energy accounted for close to 40% and solar PV accounted for 30% of new capacity added. Hydroelectric power's contribution to the capacity was nearly 25% REN 21 (2012).

Figure 2.1 – Global Renewable Energy consumption in 2010.



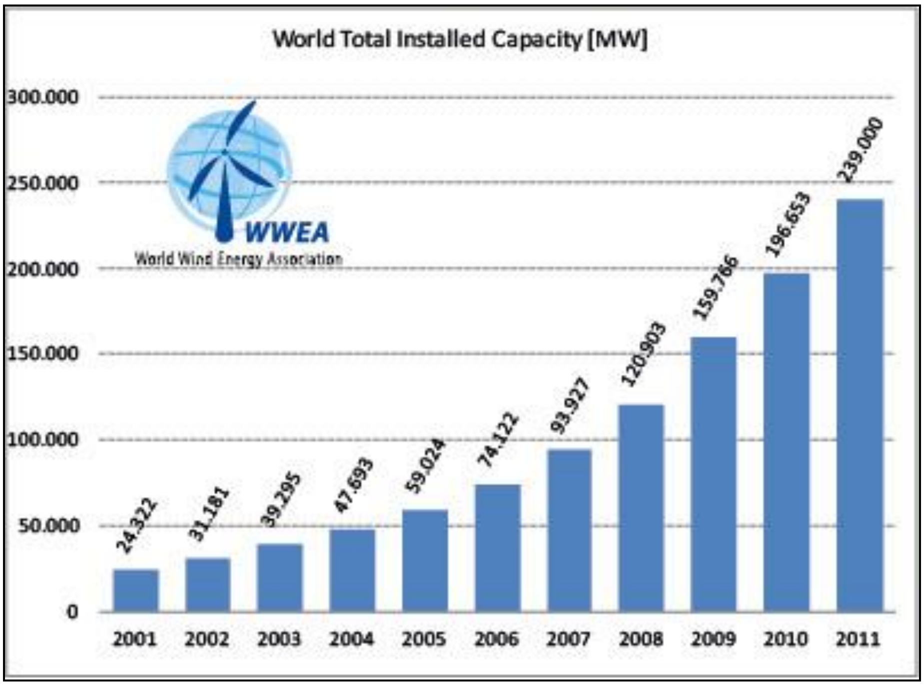
Source: Renewables 2012

In 2011, the total installed renewable energy capacity in the world was over 1360 GW a growth of 8% over 2010. In 2011 the renewable energy constituted over 25% of total global power-generating capacity and supplied over 20% of global electricity (Renewables, 2012). If hydroelectric power is not considered as part of the above capacity, then cumulative installed capacity of renewable energy sources in the world exceeded 390 GW, an increase of 24% in capacity additions over 2010 (REN 21, 2012). Hydroelectric power and geothermal energy sources are witnessing a growth of around 3% per year, globally. Seven countries have a share of 70% of the total installed capacity of renewable energy sources among them in the world. They are China, US, Germany, Spain, Italy, India, and Japan (Renewables, 2012). Close to 120 countries in the world, out of which more than 50% are developing nations had renewable energy targets in place in Jan 2012 a modest increase of 11 countries from 2010 (Renewables, 2012). Enabling policies and having focussed targets for renewable energy generation are the twin driving force to grow the market for renewable energy in the world (REN 21, 2012). Renewable energy requires both economic support and public support on both local regional level and also at national level to succeed. (Wüstenhagen et al., 2008; & Hohler et al., 2009) mention that in 2008, global power generation investment in renewable power technologies exceeded investment in fossil-fuel technologies for the first time thereby indicating the potential this sector holds for the world.

2.3 Wind Energy Scenario in the world

Wind energy has become one of the mainstream power generation sources for the electricity industry in the world. Figure 2.2 indicates that from a cumulative capacity of 14 GW at the end of 1999, global installed capacity increased to reach almost 240 GW by 2011 (~ 250 GW in April 2012) (World Wind Energy Association, 2012). The majority of the capacity has been installed onshore, with offshore installations primarily in Europe and totalling a cumulative 4 GW (GWEC, 2012). Today China is the market leader in Wind energy followed by the US, Germany, Spain and India making the top 5 countries to harness wind power. Europe continues to lead the offshore wind energy generation with UK leading the pack with over 2 GW of offshore wind energy installation followed by Denmark, Germany and Netherlands.

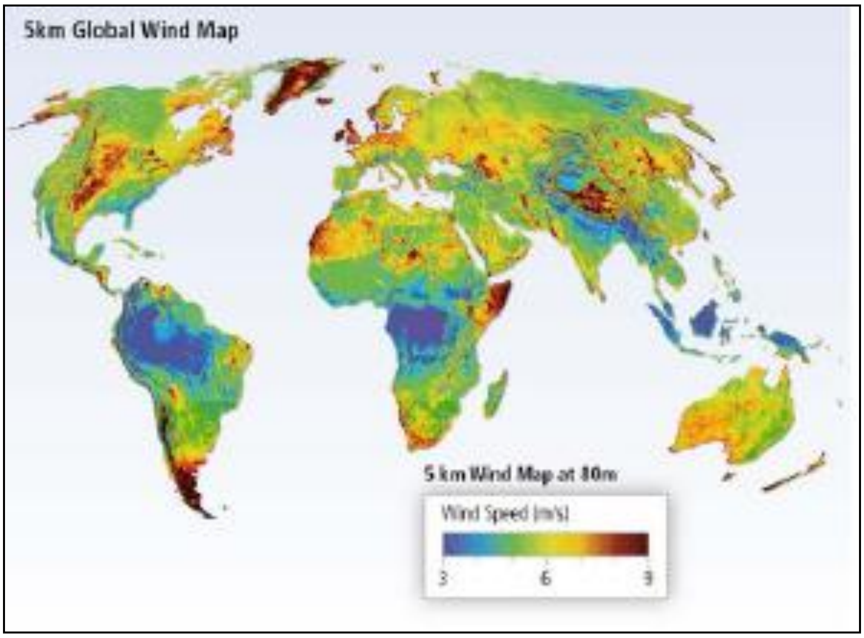
Figure 2.2– Global Wind energy scenario in 2011 (MW)



Source: World wind energy association, 2011

The technical potential for onshore wind energy in the world is 50,000 TWh/yr (Billion units per year) (IPCC, 2011). There are several other estimates of the global technical potential for wind energy that ranges from 19,000 TWh/yr (onshore only) to 125,000 TWh/yr (on- and near-shore). The figure 2.3 below shows steady wind speeds in Europe, North America and several parts of Asia. Estimates of the technical potential for offshore wind energy range from 4,000 to 37,000 TWh/yr (IPCC, 2011) considering only areas closer to the coast. Of course the potential for offshore wind energy is much greater if areas that are truly 'offshore' (ranging from 5 Kms to 50 Kms) are also considered.

Figure 2.3 - World wind resource map



Source: IPCC – SRREN, 2011

However, irrespective of the exact figure, it is quite apparent that wind energy (both onshore and offshore) has phenomenal potential to be tapped for growing the renewable energy basket for countries around the world (Lawrence Berkeley, 2012). Energy policy hence plays a vital role to mitigate the impacts of global warming and crisis of energy availability. It is noticed that energy policy could help increasing wind power generation as well as stimulating the energy industry (Lund, 2011). It may be stated that without specific energy policy, a country would not be able to solve the acute problems like reducing greenhouse gases (GHGs) emission, scarcity of energy, etc.

Several studies (Onut et al., 2008; Komor and Bazilian, 2005 & Beccali et al., 2003) have pointed out that specific renewable energy policy goals lead to the growth of specific renewable energy sources and renewable energy technologies. As per Luthi & Prassler (2011) the cost of wind has reached grid parity in those areas that have strong wind speeds - despite that, the growth of wind energy continues to be driven due to proactive policies adopted by the state. The policies drawn for wind energy need to address both the financial aspects and the risk mitigation aspects to see positive outcomes – the risks stemming from the regulatory environment (legal security, administrative process and grid access) and the ability to finance projects, as developers judge the attractiveness of the investment proposition both through financial and perceived risk lens (Luthi & Prassler, 2011).

(Menanteau et al., 2003) have shown that several renewable energy sources have benefitted due to policy support in developed countries for the last 2 decades. However, Wind energy has had the biggest impact of these proactive policies and has reached grid parity with conventional energy sources.

(Saidur, et al., 2010) discuss the existing renewable energy policies for few selected countries that have been successful. They have found that FIT (Feed in tariff), RPS (Renewable purchase specifications), incentives, pricing law and quota system are the most useful energy policies practiced by many countries around the world, which has helped these countries to significantly accelerate the generation of wind energy (Table 2.1). Menz & Vachon (2006) have argued that prices of energy from conventional sources do not factor in the externalities they are accountable for and hence do not reflect the true costs of their use, there by alluding to the fact that comparing the levelised cost of fossil fuels and that of renewable energy may be specious at best.

As per Wang (2006) renewable energy needs policy support and market cultivation in the initial stages as several barriers thwart adequate investments into renewable energy from occurring. Saidur et al. (2010) mentions that almost all countries that utilize wind energy for power generation have policies specific to wind energy. The existence of wind energy policies managed to increase wind power generation significantly in these countries.

(Huber et al., 2004) discuss about the importance of careful design of renewable energy strategies that are crucial to support its growth. Their major conclusions are that policy measures have been a major driver to grow wind energy in the world. Policies are needed for the promotion of newly installed plants rather than already existing plant and it is crucial for a successful strategy. Moreover, they argue that so far well-designed FITs were more effective and cost-efficient than other promotion schemes.

Table 2.1 - Top 10 Countries in wind energy, 2011

COUNTRY	Total End-2010	Added 2011	Total End-2011
		(GW)	
China[1]	30/44.7	15/17.6	45/62.4
United States	40.3	6.8	46.9
Germany	27.2	2.0	29.1
Spain	20.6	1.1	21.7
India	13.1	3.0	16.1
France	6.0	0.8	6.8
Italy	5.8	1.0	6.7
United Kingdom	5.2	1.3	6.5
Canada	4.0	1.3	5.3
Portugal	3.7	0.4	4.1
World Total	**198**	**40**	**238**

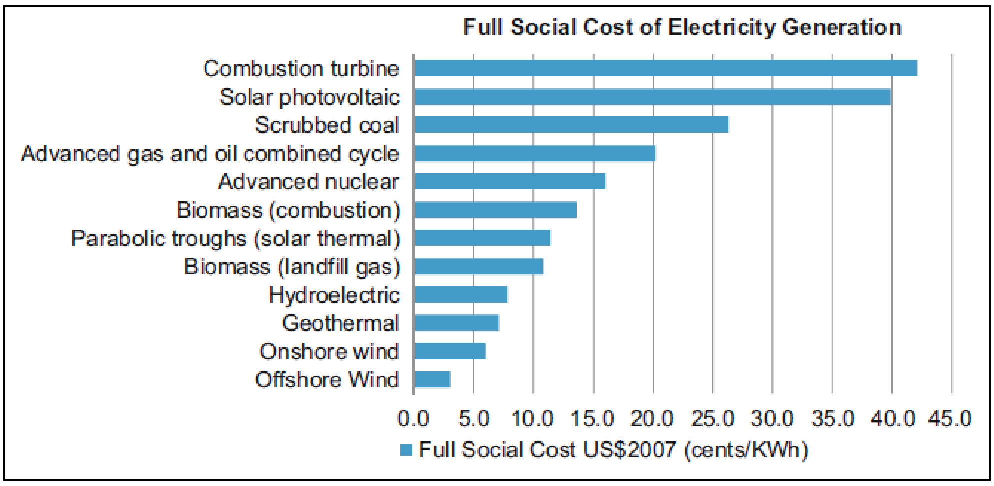
Source – Renewable, 2012

1. In China, the lower figure indicates operation capacity and the higher figure indicates installed capacity.

As per Sovacool (2008), energy policy makers are increasingly appreciative of the fact that wind energy becomes an economically attractive option to generate power, if the environmental and social costs, usually called as externalities, associated with the various conventional technologies are factored into and have been fully internalized (Figure 2.4).

Moreover, the carbon foot print of wind energy is amongst the lowest of all renewable energy technologies not to mention comparisons with fossil fuels.

Figure 2.4 – Cost of electricity with externalities

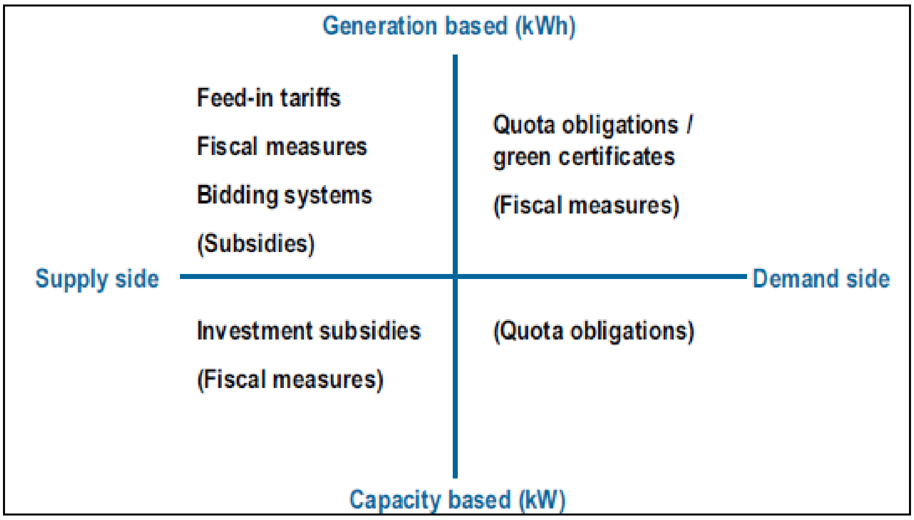


Source: Sovacool, 2008

Policies for promoting wind energy in the world

Policy instruments to encourage wind (renewable) energy growth are targeted either on the demand side or on the supply side – that is they focus either on the production of electricity or on installed capacity. (Vries et al., 2003) identified basic policy measures that are generally adopted by countries around the world (figure 2.5)

Figure 2.5 – Typical Policy measures to promote wind energy



Source: Vries, 2003

Renewable energy sources can be promoted in a country by adopting fiscal measures which include waiver of taxes, tax break for construction or through indirect tax incentives and ranges from accelerated depreciation – 80% of capital cost can be claimed as depreciation during the first year (MNRE, 2009), lower VAT rates, to tax exemption on income generated. Feed in tariffs are announced by the state for the quantum of electricity fed into the grid by the renewable energy generator and are substitutes for the market price of electricity. The rates are decided for a longer duration to give the generator confidence of cash flows in the future (Haas, 2007). Quota obligations or Renewable purchase obligation (RPO) is a mechanism which mandates the supplier to source a minimum quantum of power, as determined by the regulator in the country and communicated in advance, from the renewable energy generator. This is complemented by the concept of Green certificates that can be bought by the supplier in lieu of purchasing clean power. These certificates are traded in power exchange and give a premium for the renewable energy producers (Luthi & Prassler, 2011).

The regulators may also establish sourcing of clean power ‘technology bands’ in order to protect clean energy sources from competition by less expensive options (Vries, 2003). Although the fuel for wind farms is free, have no storage costs or transportation costs, unlike fossil fuels, it takes substantial initial investments (up to 80% of the project lifetime costs goes into plant construction and grid connection) to establish wind farms (Blanco, 2009). Hence investment subsidies encourage the growth of wind farms by reducing the initial outlay needed to establish the project. Bidding procedures are used to select a successful bidder(s), using pre-defined criteria, among several competing potential investors to award rights to a site to establish renewable energy project or for investment support/or production support. Usually, this is combined with other policy instruments like quota obligation to promote a risky renewable energy investment like say offshore wind energy. Bidding helps to discover the most cost effective solution to a renewable energy project (Vries, 2003).

The survey of literature thus far is summarised in table 2.2 below.

Table 2.2 - Summary of literature review of Renewable energy and wind energy in the world categorized under different themes

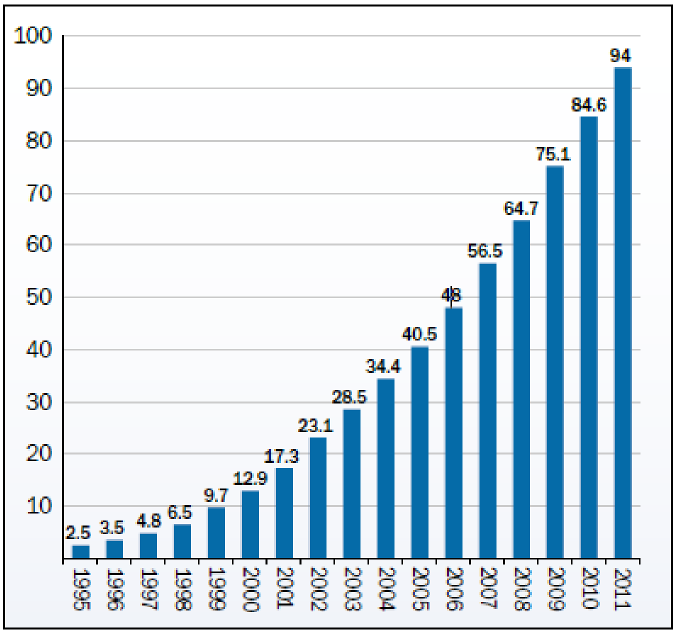
S.No	Themes	Select Author(s)	Context	Inferences
1	Renewable Energy scenario in the world	REN 21 (2012)	World	Close to 400 GW of renewable energy installed in the world (excluding large hydro), about 50% of them are wind energy with top 7 countries accounting for 70% of these installed capacity. Renewable being adopted in 120 out of the 194 countries in the world.
2	Renewable Energy growth in the world	REN 21 (2012), Wüstenhagen et al., 2007), Hohler et al., 2009)	World	Having a dedicated target for renewable energy backed by supportive policies have enabled renewable to grow 25% in 2011 over the previous year.
3	Wind energy scenario in the world	GWEC (2012), IPCC, 2011), REN 21 (2012), Lawrence Berkeley (2012).	World	Wind energy capacity installed in the world in 2011 is about 240 GW with offshore wind energy

				contributing 4 GW of this total. The total technical potential of wind energy ranges between 19,000 TWhr to 125,000 TWhr in a year.
4	Role of policies in aiding the growth of wind energy in the world	Lund 2011), Luthi & Prassler2011), Menanteau et al.2003), Saidur, et al., 2010), Wang 2006), Huber et al. 2004), Vries et al. 2003), MNRE, 2009)	World	Identifies several supply side (like Feed-in-tariff, subsidies, fiscal measures) and demand side (like quota obligation and green certificates) policies that have helped the growth of wind energy sector (also renewable in general) in the world
5	Wind energy has achieved grid parity	Sovacool 2008), Menz& Vachon2006), Luthi & Prassler 2011)	World	Wind energy has reached grid parity (similar to the cost of fossil fuel generation sources) and bettered it if the costs of externalities are also included.

2.4 Wind Energy (Onshore and Offshore) in Europe

The total installed power capacity for the EU has increased by 35,000 MW to become almost 900,000 MW, with wind power increasing its share of installed capacity to 10.5% (~ 94,000 MW as shown in figure 2.6 and figure 2.7), and renewable capacity increasing its share to 31% (EWEA, 2012). The wind farms installed is likely to produce 204 TWh of electricity, representing over 6% of the EU's gross electricity consumption (EWEA, 2012). In the EU, in 2011, Germany was the market leader in wind energy installing almost 2,100 MW of new wind power generation capacity (EWEA, 2012).

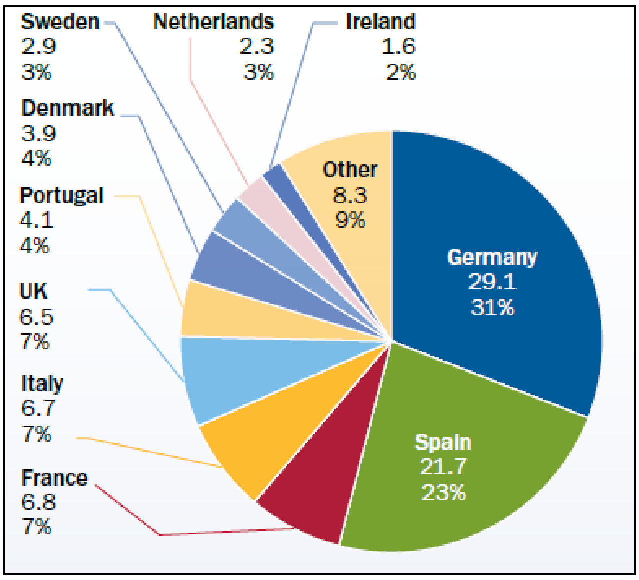
Figure 2.6 - Total wind capacity in EU (in GW) in 2011



Source – EWEA, 2012

Spain was third with around 1,050 MW of wind power installations followed by Italy (950 MW), France (830 MW), Sweden (763 MW) and by Romania (520 MW) (EWEA, 2012). Germany has the credit of having the largest cumulative wind energy generation capacity installation in the EU followed by Spain, Italy, France and the UK (Figure 2.7) till 2011. As per (EWEA, 2012) Denmark has the highest penetration of wind power generation of electricity (almost 26%), then Spain (~ 16%), Portugal (15.6%), Ireland (12%) and Germany (~11%). European leadership of the wind industry is a result of successful European policy frameworks for renewable, centered on renewable energy targets. There are two key factors that are responsible for the success of wind energy in the world compared to other types of renewable energy technologies – abundant availability of resources and the maturity of wind turbine and ancillary technologies (Esteban et al., 2011).

Figure 2.7- Individual countries share of wind capacity in EU in 2011 (total 93.7 GW)



Source: EWEA, 2012

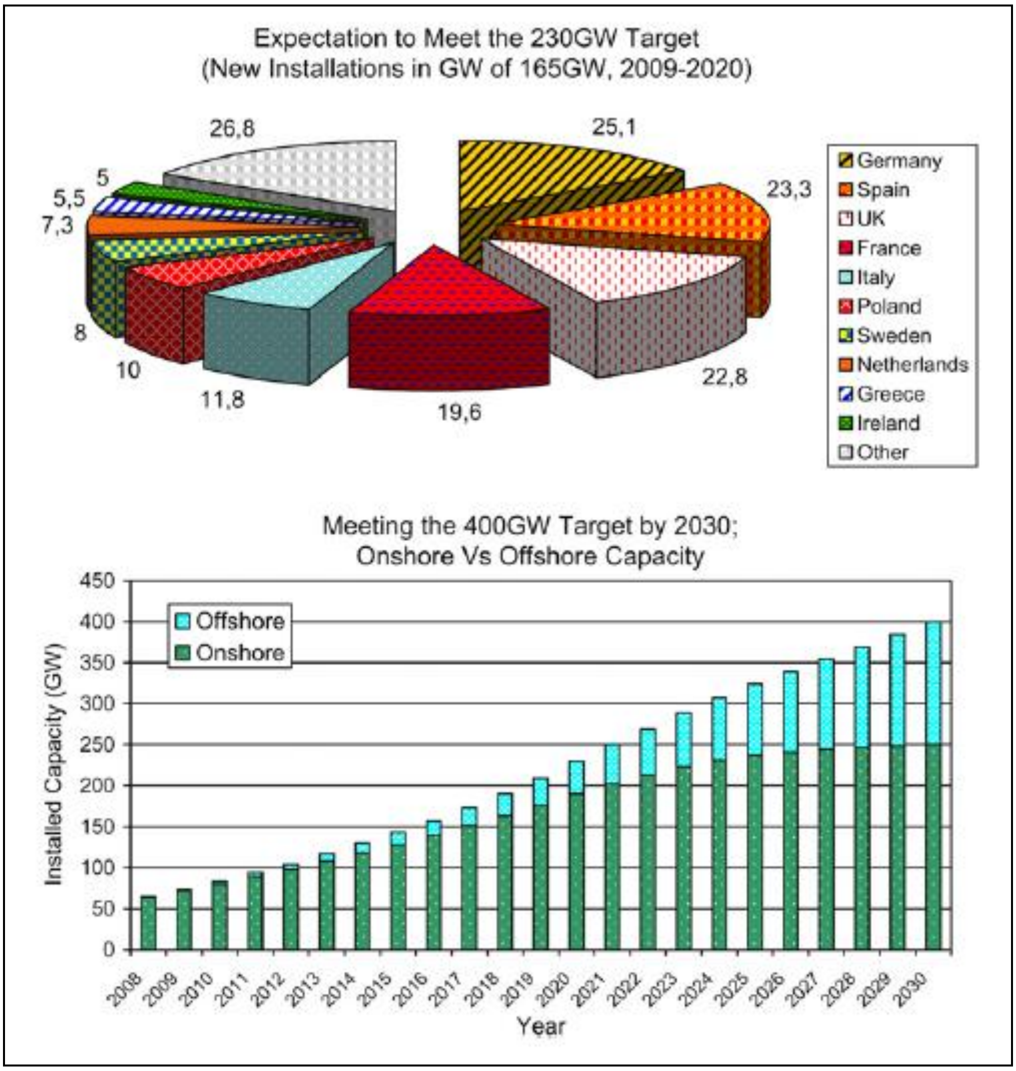
As per (Buen, 2007; Lewis & Wiser 2007 & Munksgaard & Morthorst, 2008) key drivers for the success of wind energy in Europe are various policy schemes that promote technology development and diffusion in countries such as Denmark, Germany and the UK. EWEA (2011) believes that having a binding target for renewable energy and effective implementation of existing directives on renewable energy technology is the most effective way to maintain and increase Europe's leadership in wind energy.

Alishahi et al. (2012) have shown that the investment strategies of wind energy generation are greatly impacted by adoption of different methods of structuring the incentives. (Lewis & Wiser, 2007) has clearly proven that stability of policies for a long term as one of the most successful policy instruments for promotion of large-scale wind energy markets necessary for investors to set up manufacturing base locally. However, several policies may be effective, if implemented carefully and in conjunction, including a quota mechanisms, auctions and concessions (Lewis & Wiser, 2007).

(Van der Linden et al., 2005) discuss the success of renewable energy obligation support mechanisms in Europe and the U.S. They conclude that Green certificates are excellent mechanisms in theory and are also effective but it is too soon to call it a winner in terms of accelerating the growth of wind energy in a country. More proof points are needed to arrive at the conclusion that Green Certificates are delivering what they are promising. (Dinica, 2006) examines the diffusion of renewable energy technologies taking into account the role of investors. According to her secure investment climate that guarantees adequate return on investments combined with low risks is vital for a considerable growth of renewable energy sources, especially wind energy.

As per (Marques & Fuinhas, 2011) Europe's directive on renewable energy targets to be accomplished for the EU by 2030 is a good example of adopting the path of continuity and definition of objectives for the medium and long term. Researches by (Haas et al., 2007; Held et al., 2006; Toke, 2011; Huber et al., 2004 & Ragwitz et al.,2006) recognised that separate policies focussed on creating additional capacities are needed to add new capacities and not to mix promotional mechanisms for existing and new capacities. Also, they highlighted that for energy policy to be effective, the potential investors need to be convinced of the credibility of the system to enforce these policies. One important criterion to build credibility is to have policies for longer term, as frequent changes in the policy will destroy investor confidence and no investments may happen. According to long-term plans 400 GW (250 GW onshore and 150 GW offshore) (Figure 2.8) of wind power in the EU is likely to be installed by the year 2030. (Kaldellis et al, 2011)

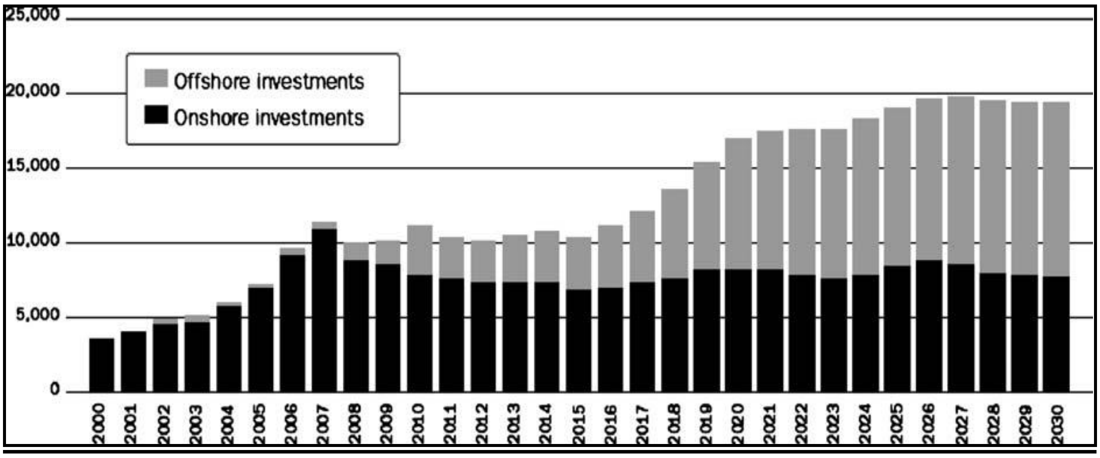
Figure 2.8 –Wind energy targets for the EU in GW



Source: Kaldellis JK et al, 2011

As per EWEA, by 2020, the annual market for wind power generation would have increased to € 17 billion annually with approximately 50% of the investments going to offshore wind energy sector. By 2030, annual wind energy investments in EU will increase to almost € 20 billion with 60% of investments going to offshore wind energy sector (EWEA, 2009). The expected annual wind power investments from 2000 to 2030 in the EU are shown in figure 2.9 (EWEA, 2009). The investments are expected to hover around € 10 billion/year up to 2015, and subsequently are likely to witness a steady increase for offshore wind sector (EWEA, 2009). Wind energy investments in EU in 2011 were €12.6 billion, which was similar to the figure in 2010. Out of these €12.6 billion, onshore wind energy attracted about €10billion, while the rest went to offshore wind sector (EWEA, 2012).

Figure 2.9 – Likely investments in Wind energy in EU between 2000 and 2030 (€ Mil)



Source – EWEA, 2009

(Lund, 2011) claims that by 2050 the share of wind power in the electricity mix would increase to 25% and solar to 15% thanks to sufficient encouragement from policy instruments. On the flip side, absence of adequate policy support to renewable energy sources (mainly Solar & Wind) decelerate investments in these sources thereby reducing their combined share in the energy mix to as low as 11% (Lund, 2011). The paper mentions that high penetration of wind energy technologies means a full buy-in into these technologies, in other words a preferential position in the upcoming investments due to a very encouraging long-term policy framework.

(Lemming, 2003) explores the risk-rewards associated with the tradable green certificates (TGC) market and concludes that the higher risks associated with TGC-systems, due to the vagaries of the market dynamics, vis-a-vis the Feed-in-tariff (FiT) system result in higher return expectation by investors. Similarly, (Mitchell et al., 2006) compare the risks vs. policy effectiveness of the UK RPO system with the German FIT system and conclude that perception of low risks by investors implies high policy effectiveness and that the latter provides higher security for investors than the UK RPO system.

(Toke, 2007) evaluates the effectiveness of the UK's Renewable purchase Obligation (RPO) system. He concludes that UK RPO has several problems and do not deliver as good as a Feed-in tariff system. According to (Sperling et al., 2010) Denmark managed to grow their wind energy sector due policy support, entrepreneurial spirit of the locals and the economic stake the locals had in the wind farm projects in their locality. Meyer (2007), Hvelplund (2001)) is a supporter of the effectiveness of the feed-in tariffs system and mention that they have accelerated spectacular growth in the installed capacity of wind turbines. (Haas et al., 2007; Reiche & Bechberger, 2004; Ackermann et al., 2001; Lauber, 2004) disagree with the above view of FIT system being the primary driver for capacity increase of wind installations. They argue that the policy mix must act in conjunction with technological developments, based on the local context and tailored to the local conditions which determine the growth of wind energy capacity.

Johnstone et al., (2010) and Frondel et al., (2010) studied the impact of public policies on renewable energy sources and the effect of these policies remained inconclusive. Johnstone et al. concluded that the impact of the policies on the growth of a particular renewable source depended on the type of renewable energy source. As per (Rooijen & Wees, 2006) Netherlands witnessed slowdown of renewable energy installation due to the uncertainty that crept into the policy continuation. Similarly, for Sweden, (Wang, 2006) conclude that lack of continuity in the energy policy and the uncertainty were the main reasons for the slowdown of renewable installations. (Buen, 2005) distinguished the role of policy interventions in the growth of wind energy in Denmark and concludes that supportive policy accelerated the diffusion of wind energy and innovations in Denmark while incoherent policy formulation has stymied the wind energy sector in Norway – thereby establishing a direct link between policy measures and growth of Wind Industry in Nordic.

(Butler & Neuhoff, 2004) opine that electricity supplied using the FIT system of incentives results in lower rates for the public compared to the Tradable green certificates system as these are market driven. (Held et al., 2006, Ragwitz et al., 2007) also study the effectiveness of policies to stimulate the growth of renewable energy in EU. They conclude that the policy instruments that are effective in promoting renewable sources are also the cost effective ones. They also reinforce other researchers in the highlighting that investors have lower expectation on the return of their investments from a project when their perception of risk in a particular investment is low, which leads to lower cost of electricity to the society. As per (Hass et al., 2007) the main reasons for growth of wind power in Denmark in the 1990s were supportive policy environment and a robust legal framework. Now on the contrary, stalling of growth of onshore wind capacity in Denmark is also due to policy changes which rely on the market dynamics to drive the growth of wind energy thereby causing uncertainties. (Hass et al., 2007) also mention that the return on investments for developers of wind energy in Denmark has drastically come down due to changes in recent policy announcements whereas other countries in Europe have adopted lucrative polices which resulted in remarkable wind farm installations as investments chase enabling environment– establishing a direct connection between policy support and growth of the wind energy sector.

(Lund, 2008) highlights that renewable energy industry as a whole has grown on the back of supportive policies and have found several cases where companies that did extremely well in global market were incubated at home market and became leaders thanks to these proactive policies. (Haas et al., 2007) conclude that promotion schemes that are grounded in stable framework offering continuity and clarity for all stakeholders tend to be successful in its ability to attract investments in renewable sector and produce better results. Similar views were put forward by (Meyer, 2007) who analyses the major lessons learned from wind energy policy in the EU. The author concludes that lack of a supportive and enabling policy environment was the main reason for the different development patterns of wind energy in these countries. Also, lack of adequate remuneration for the investments caused the slowdown of investments in wind energy deployment in Denmark.

The summary of literature review undertaken for wind energy in Europe is summarised under various themes in Table 2.3 below.

Table 2.3 - Summary of literature review of wind energy in Europe categorized under different themes

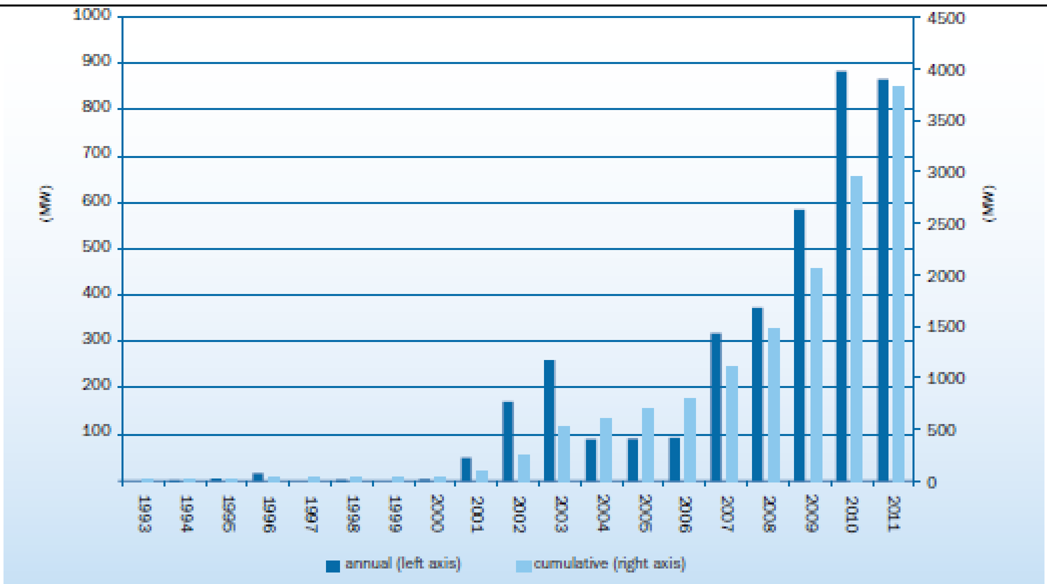
S.No	Themes	Select Author(s)	Context	Inferences
1	Wind energy status in Europe	EWEA (2009-12), REN 21, (2012), Haas et al (2007), Wiser & Bolinger (2010), Lund (2011), Moller (2011), GWEC (2011), (Toke, 2007), Luthi & Prasseler (2011), Meyer (2007), Dinica (2006),	Europe	Wind energy has reached 94,000 MW installed capacity contributing 6% of energy consumption in Europe with Germany the leader followed by the UK. Denmark has the highest wind penetration as proportion the electricity mix. History and growth of wind energy in Europe
2	Specific policy that aided growth of wind energy in Europe	Alishahi (2012), EWEA (2011), Lewis & Wiser (2007), Van der Linden (2005), Dinica (2006), Munksgaard & Morthorst (2008), Buen, (2007), Hvelplund (2001) & Meyer (2007)	Europe	How FIT, binding targets, structuring of incentives, green certificates, secure investment climate, helped growth of wind energy in Europe. was also key to grow wind energy
3	Comparisons among the various components of the wind policies	Lemming, (2003), Mitchell et al., (2006), Toke, (2007), Butler and Neuhoff (2004)	Europe	Compares the tradable certificates and feed-in tariff incentive system to promote wind energy reaches different conclusions. One set of literature concludes that FIT is better as it gives more stability and another set concludes that tradable green certificates are better as they give a higher price realisation.
4	Critique of the components of	(Ackermann et al., 2001); (Haas et al., 2007);	Europe	Conclude that FIT on a stand-alone basis is not responsible

	the wind energy policies	(Lauber, 2004); (Reiche & Bechberger, 2004), (Johnstone et al., 2010) and (Frondel et al., (2010)		for the spectacular growth of wind energy in Europe but policy tailored for local conditions aided growth. Also the growth depends on the type of renewable energy and not just on the policy alone.
5	Stability of policies for long term helped growth of wind energy	(Marques & Fuinhas, 2011), Lewis & Wiser (2007), (Huber et al., 2004); (Held et al., 2006); (Ragwitz et al., 2006); (Haas et al., 2007); (Toke, 2011), (Lund, 2011), Wang (2010), (Buen, 2005)	Europe	Adoption of a wind energy specific targets and continuing to support the sector with supportive policies for long term helped accelerate growth
6	Slow adoption of offshore wind in some European countries due to lack of cogent/consistent policies	Boyle (2007), Buen (2005), Meyer (2007), Van Rooijen & Van Wees (2006), Wang (2010), (Buen, 2005), Haas (2007)	Europe	How inconsistent or lack of cogent policies can slow or reverse the growth of wind energy sector in a country.

2.5 Wind Energy in Europe (Offshore)

A total of over 1350 offshore wind turbines, generating over 3800 MW of power, are installed in Europe, which is spread across over 50 wind farms in 10 countries (EWEA, 2012). The offshore wind farms in Europe will produce around 14 TWh of electricity, which is less than 0.5% of the EU’s total consumption (Figure 2.10).

Figure 2.10 - Offshore wind energy installation (in MW) in Europe in 2011 (Total and Annual)



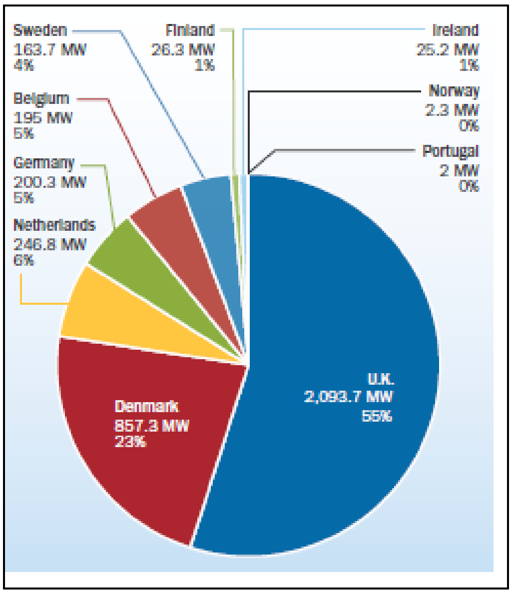
Country	UK	DK	NL	DE	BE	SE	FI	IE	NO	PT	Total
No. of farms	18	13	4	6	2	5	2	1	1	1	53
No. of turbines	636	401	128	52	61	75	9	7	1	1	1,371
Capacity installed (MW)	2,093.7	857.3	246.8	200.3	195	163.7	26.3	25.2	2.3	2	3,812.6

Source: EWEA, 2012

The UK is the largest market for offshore wind energy in Europe, and also in the world, with over 2,000 MW installed, which is more than 50% of the installed offshore wind capacity in Europe (EWEA, 2012). Denmark comes next with 857 MW (23%), then the Netherlands (247 MW), Germany (200 MW), Belgium (195 MW), Sweden (164 MW), Finland (26 MW) and Ireland 25 MW. Norway and Portugal have (2.3 MW and 2 MW respectively) (Figure 2.10 & 2.11). (EWEA, 2012)

The UK and Denmark are the leading producers of offshore wind power in Europe (Moller, 2011). The estimated technical potential in 2020 may be between 25,000 and 30,000TWh, which is seven times the European electricity demand at that time (Moller, 2011).

Figure 2.11 – Break – up of Offshore wind energy in 2011 (in MW) in Europe

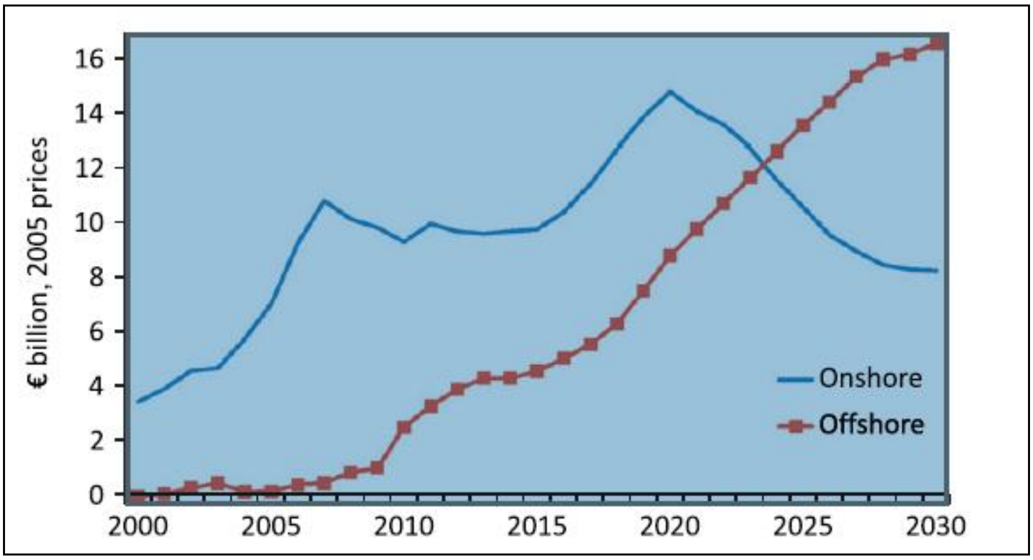


Source: EWEA, 2012

(Pr¨assler & Schaechtele, 2012) have shown how policy support instruments determine the financial attractiveness of offshore wind farms in several European countries. Several factors such as permit procedures, grid connectivity, environmental clearances and availability of wind resources, combine to influence the perception of risks by investors in offshore wind park projects which in turn influences the quantum of investments in the sector. (Bergek and Jacobsson, 2003) identified a four-strand approach to German policy towards the wind sector which they consider to be the reason for the success of wind energy sector in Germany. Foxon et al. (2005) have articulated the need for a multi-faceted policy that responds to the unique needs of the different stages of evolution of the renewable technology life cycle such as ‘pre-commercial’, ‘supported commercial’ and ‘commercial’ stages. (Wolsink, 2000) has concluded that major wind power producing countries in the Europe enjoy high degree of public support for wind power which probably leads to higher deployment of wind power thereby feeding into the other positively. (Warren et al., 2005; Aitken, 2010) found that while people are generally supportive of wind power as an abstract concept due to its contribution in reducing carbon foot print etc. but are against commissioning of wind farms in their area – a variation of the NIMBY) (Not in my back yard) syndrome - but the opponents of wind power are well-informed and are not wrong as usually presumed by the enthusiasts of wind energy.

(Krohn et. Al., 2009; Warren et al., 2005) have concluded that once wind farms are completed and are operational, the support found for wind farms in the local communities tend to increase which is a significant observation for policy makers and project developers to overcome initial resistance. (Boyle, 2007) mentions that initially the offshore wind energy industry in the UK had challenges mainly due to the uncertain policy environment which has been now addressed and is the main reason for UK to become the world leader in offshore wind energy sector. (Markard & Petersen, 2009) have concluded that though onshore and offshore wind parks use same core technology in the design of turbines, at least as of now, the similarities end there; as there are some significant differences in their operations with offshore wind parks facing many unique difficulties and challenges. (Green & Vasilakos, 2011) compared the policy support that exists for offshore wind energy among a few European countries. (Esteban et al., 2011) gave a detailed comparison between the advantages and disadvantages of onshore and offshore wind farms and concluded that offshore wind farms have immense potential for growth. Proactive policies, immense offshore wind energy potential, challenges with onshore wind site have ensured that offshore wind energy in Europe is likely to grow faster than its onshore counterparts (figure – 2.12).

Figure 2.12 - Anticipated investments in the wind sector in Europe (Onshore and Offshore)



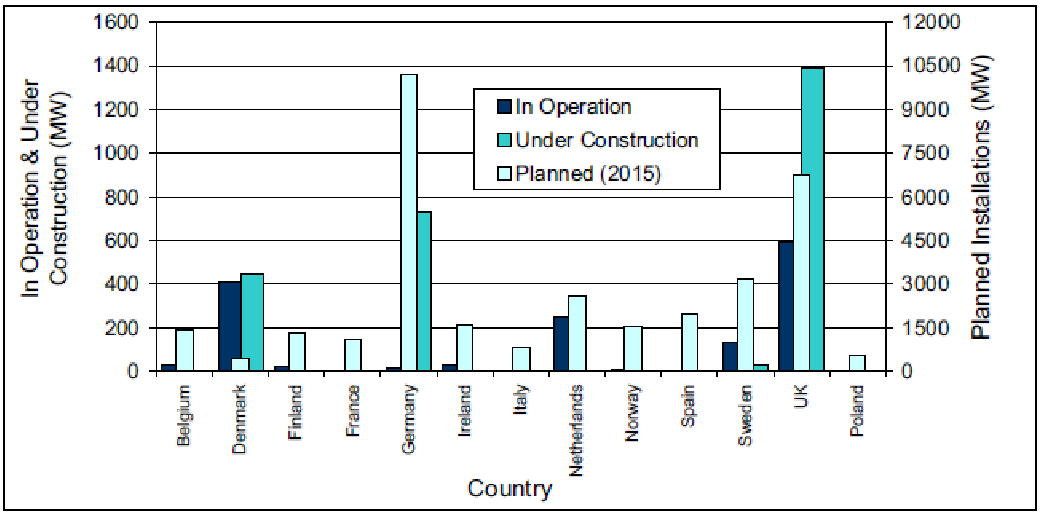
Source EWEA, 2009

(Krohn et al., 2009) calculated the electricity generation costs from onshore and offshore wind parks and concluded that cost of generation of electricity from offshore wind farms are at least 50% costlier compared to the costs from onshore wind farms. However, critical mass and advancement in technology will reduce the cost of electricity from offshore wind parks. (Swider et al., 2008) compares the costs of grid connection in seven countries in the Europe and concluded that cost of construction of evacuation infrastructure for offshore wind parks are prohibitively high and would be a show-stopper for the growth of offshore wind farms if the state expects the developer to invest in grid connectivity. The authors suggest that to accelerate the growth of offshore wind energy, the cost of grid connection must be borne by the grid operator and not the project developer. These costs can then be socialized over the population, factoring the grid connection costs in the tariff. (Burer & Wustenhagen, 2009) suggest that the state and policy makers need to have deep appreciation for the risk-reward perception of project developers so that appropriate policies can be tailored to meet the expectation of the project developers. That according to the authors is the best way to increase private sector investments to meet renewable energy targets.

Prassler & Schaechtele (2012) argue that national policy and local geographic site conditions in the country affects profitability of offshore wind energy farms. The focus of their analysis is five European countries Belgium, Denmark, Germany, France and the UK. The results of their analysis indicate that, currently, UK and Germany have the most progressive offshore wind energy policies and is the most attractive destination for offshore wind farm developers. Introduction of geographic conditions is seminal in this research work (Prassler & Schaechtele, 2012) as local conditions like distance of the offshore wind energy farm from the coast, water depth at the farm and wind speeds determine the cost and output of the farms and hence the profitability. (Green & Vasilakos, 2011) also mentioned water depth and distance to the shore as the most important factors driving the investment costs of offshore wind farms. (EEA, 2009) has shown that as the distance to the coast increases, it increase the cost of the foundation, and hence the overall cost of the offshore wind farms, as more sophisticated foundations are needed at deeper waters. Also, the installation costs increases as more sophisticated vessels are needed to install foundations in greater water depth (EEA, 2009).

In some European countries it is the TSO (Transmission system operator) who bears the cost of grid connection while in a few countries it is the offshore wind developers while in others the grid connection costs are split between the TSO and the offshore wind farm developer. (Blanco, 2009) has shown that the variable costs of offshore wind turbines constitute a major proportion of the overall cost incurred during the lifetime of the turbine. There are different figures quoted in literature for the variable costs of offshore wind turbine. The variable costs are lower during the first 2 years of a turbine's lifetime and are estimated between 3% of total investment cost and 5% in EWEA (2009) while the variable costs are 4% as per Junginger (2005). (Alishahi et al., 2011) propose a different method for tailoring incentives for investment planning in competitive electricity markets, as different methods of structuring incentives have bearing on the investment strategies. Fixed incentives like feed-in tariff gives a stable, albeit lower returns and has found favour with several developer because of the certainty of the income, variable incentives like renewable certificates helps generate electricity when it is needed most (Alishahi et al., 2011). Riding on the generous policies to grow offshore wind energy sector, EU is likely to achieve its short-term plans of 33 GW of offshore wind energy by 2015 mainly supported by Germany and UK (figure 2.13), which shall further increase the contribution of wind energy of EU wind farms (Kaldellis, 2011) (Figure 2.13).

Figure 2.13 - Offshore wind energy in Europe, 2011



Source: Kaldellis et al, 2011

The summary of literature review undertaken for offshore wind energy in Europe is summarised under various themes in Table 2.4 below.

Table 2.4 - Summary of literature review of offshore wind energy in Europe categorized under themes

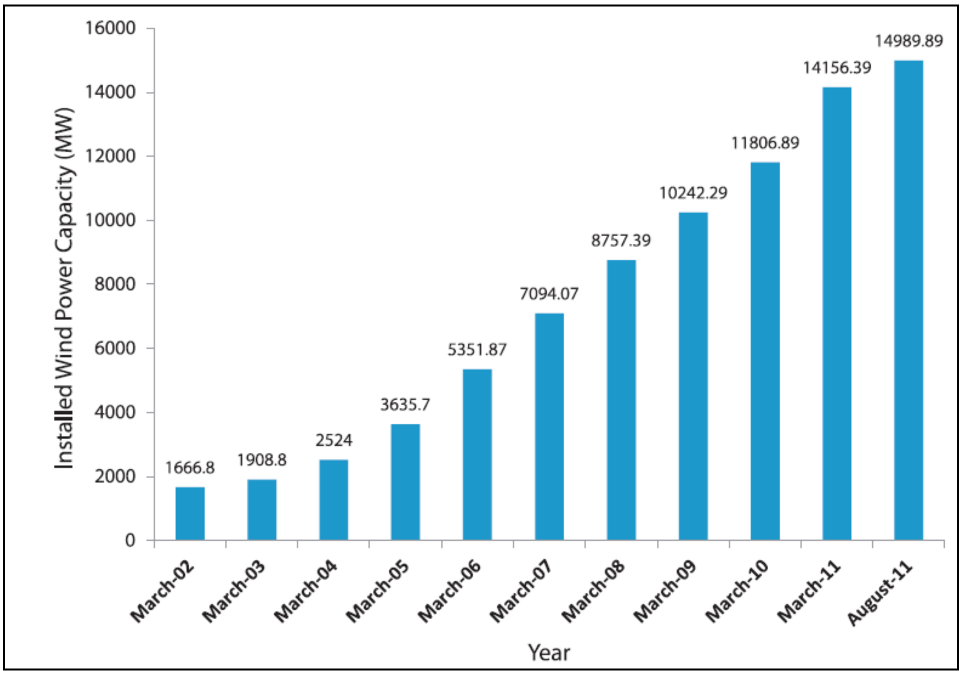
S.No	Themes	Select Author(s)	Context	Inferences
1	Offshore wind energy status in Europe	EWEA (2012), REN 21, (2012), Moller (2011).	Europe	Offshore wind energy has reached almost 4000 MW of installed capacity today with close to 6000 MW likely to be commissioned by end of 2012 with UK being the leader followed by Denmark, Netherlands and Germany.
2	Policies adopted by countries in Europe for the offshore Wind energy sector	(Green & Vasilakos, 2011), (Esteban et al., 2011), Lewis & Wiser (2007), Luthi & Prasseler (2011), Dinica (2006), Huber (2004), Held	Europe	Talks about how having a consistent and cogent policy have helped grow the offshore wind energy sector in Europe. Gives details of these policies.

		(2006), Ragwitz (2006), Mitchell (2006), Toke (2011), Sperling (2010), Prassler & Schaechtele (2012), Buen, 2007; kaldellis (2011).		
3	Possible Challenges to growth of offshore wind sector	Krohn et al.,(2009), Swider et al., (2008), (Green & Vasilakos, 2011), (EEA, 2009), (Blanco,2009), (Markard & Petersen, 2009)	Europe	High electricity costs, grid connectivity, foundation costs, environmental clearances, multiple agencies to obtain clearances, water depth, distance to the coast, O&M costs are all some of the challenges faced in offshore wind energy sector .
4	Factors that aided the growth of offshore	Prassler & Schaechtele (2012), (Bergek & Jacobsson, 2003), Foxon et al. (2005), (Wolsink, 2000), (Warren et al., 2005), Aitken (2010), (Warren et al., 2005), (Krohn, 2009)		How permit procedures, grid connectivity, public support and environmental clearances are critical factors in growth of offshore. Also different policies need to be adopted for different stages in the evolution of offshore wind sector.
5	Stability of policies for long term helped growth of wind energy	(Boyle, 2007)	Europe	Adoption of a specific target and keeping it for long term

2.6 Wind Energy in India

Wind energy constitutes the largest share among the renewable energy pie in India with about 67% share of the renewable basket (MNRE, 2011). However, almost all the 17,000 MW of wind energy today is onshore wind (figure 2.14) (A Sharma et al., 2011). Currently, India ranks among the top 5 countries in the world in terms of installed wind energy generation capacity (MNRE, 2011). One of the reasons for the impressive growth of onshore wind energy is due to the proactive policies adopted by the Government of India (World Bank reports, 2010). Wind energy installations grew rapidly after 2004 when supportive policies were announced. The most important piece of legislation that helped the growth of renewable sector and more so wind energy sector in India is the Electricity Act 2003.

Figure 2.14 –Wind energy scenario in India (MW) in 2011



Source: A. Sharma et al, 2011

Subsequently, wind energy specific policy interventions like accelerated depreciation, capital subsidy schemes, tax holidays, excise and customs duty exemptions, GBI(Generation based incentive) and several other policies have helped wind energy grow in India (WISE, 2011). Details of the proactive policies that helped grow the onshore wind energy sector in India are given in the following section.

Limited research available in India also concurs with the view that policies helped to grow the onshore wind energy sector in India. (Usha Rao & Kishore, 2008) used the concept of diffusion of innovation to study the evolution of wind energy in different regions in India. They calculated a composite policy index based on several variables such as availability of land, tariff structure, wheeling of power and incentives which had an impact on the diffusion in wind energy in different regions. They concluded that there is a direct link between the diffusion parameters and the composite policy index. Hence the strong policy framework is a prerequisite for the growth of wind energy in India. As per (Goyal, 2010) onshore wind energy in India grew over 27% when dedicated policies for wind energy sources like the feed-in-tariffs were declared by the state and a package of fiscal and monetary incentives were announced. The results of the policy initiatives have been significant as India's wind energy sector registered extraordinary growth between 2003 and 2010. As stated by (Pillai & Banerjee, 2009) onshore wind energy sector has grown largely because of the enabling policies announced by the Government of India. Initially many of the sites that came up for wind energy installations were done with an eye to save tax and take advantages of the accelerated depreciation policy. They also mention that survey of wind installations in Tamil Nadu and Gujarat corroborated the view that many of these installations were motivated mainly by tax savings. However, the installed capacity of wind increased from 41MW in 1992 to 16,000 MW in 2011(Pillai & Banerjee, 2009).

Schmid (2012) discusses about the policies that have been useful in the growth of renewable energy power in India in nine states that were identified. The author concluded that Tariff Policy 2006, state-level policies, RPOs and private sector participation enabled the growth of renewable energy power in the nine States adopted for the study. (World Bank, 2010; Schmid, 2012) have showed the importance of national policies to create a conducive environment for clean energy development in India, however the pace of development will depend on the policies adopted by the State governments and regulatory support provided to clean energy. Feed-in-Tariff and RPO constitute the two major policy initiatives of a majority of States to promote renewable energy in India (Schmid, 2012). (Mabel et al., 2011) have recommended that wind power must be utilized to meet the base load demands, so that fossil fuel needs can be reduced thereby reducing the carbon footprint. They arrived at this conclusion after analysing the reliability of wind power generation in the country. (Srinivasan, 2009) has stated that the use of banking channels to route the interest subsidy by the MNRE for clean energy has achieved much better results compared to the capital subsidy given to these systems through the government controlled channels. Also, incorrect focussed policies to promote renewable energy actually end up harming the sector than aiding it.

Nevertheless, policy initiatives in renewable helped grow that sector in India. As per (Bhide & Monroy, 2011) discussed about the fiscal and quota based incentives that have been extended to the wind energy sector in India including accelerated depreciation, tax benefits, duty waivers, preferential tariffs and generation based incentives apart from state specific policies to encourage the growth of renewable energy. (Purohit & Purohit, 2009), highlights the need for stable and uniform policies to make wind project financially viable and attractive across the country. In any case, minimum level of remuneration is needed to encourage wind power deployment. At present, there are several financial and fiscal incentives provided to the wind power producers at the central and state government level. In the past some of the policies increased the perception of investments risk among the developers - such as lack of legally enforceable payment mechanism, no mandate or penalty for unused RPO quota – which affects the growth of the wind energy sector in the country. (Singh & Sood, 2008) gives the comparative overview of all existing regulatory policies for the promotion of electricity generation from renewable energy sources that are either implemented or in the process of implementation. Several literatures (Singh & Sood (2011); World Bank (2010); GENI (2010); Lalwani & Singh (2010); Bhattacharya and Jana (2009) talk about the renewable energy potential in India and give an overview of current status and policies. However, there are no literature or policy documents that are available around the offshore wind energy policies of India; even though the experiences of various countries around the world suggest that offshore wind energy holds huge potential compared to its onshore counterpart.

The summary of literature review undertaken for wind energy in India is summarised under various themes in Table 2.5 below.

Table 2.5 - Summary of literature review of wind energy in India categorized under themes

S.No	Themes	Select Author(s)	Context	Inferences
1	Wind Energy Scenario in India	MNRE (2011), Bhattacharya & Jana (2009), Bhide & Monroy (2011), Rao & Kishore (2009), Singh & Sood (2011), World Bank (2010), REN 21, GENI (2010), Lalwani & Singh (2010), WISE (2009-11), A Sharma et al., (2011), (Mabel et al., 2011)	India	Details about the immense wind energy potential that can be harnessed by India.
2	Impact of policies on the growth of wind energy sector in India	MNRE (2011), Bhide & Monroy (2011), Rao & Kishore (2009), Goyal (2010), Singh & Sood (2008), World Bank (2010), Schmid (2012), Pillai & Banerjee (2010).	India	Discusses about how various policies initiated by India helped wind energy sector grow a compounded annual growth of more than 25% in the last 10 years.
3	Details of various components of wind energy policies in India	Bhide & Monroy, (2011), WISE (2011), Schmid (2012), Purohit & Purohit (2009).	India	Talks about the various components of wind energy policies like Feed-in-tariff, Accelerated depreciation, Quota obligation, Tax incentives, Duty waivers etc.
4	Critique of various	Singh & Sood (2008), Srinivasan (2009),	India	Delves deeper into the various components of the

	elements of wind energy policies in India	Schmid (2012), WISE (2012).		wind sector policies to highlight Accelerated depreciation was single most important policy for the growth of wind energy sector in India.
5	Gap in availability of literature		India	Wind energy policies discuss about onshore wind energy sector in India. No literatures on offshore wind energy policy for India are available, as the policies are themselves yet to be framed.

2.7 Renewable Energy Policy in India

The landmark act that accelerated the growth of renewable sector in India, more so, the wind energy sector was the enactment of the Electricity Act (EA) in 2003. There were a few more legislations that followed the enactment of EA, which coupled with EA 2003 were responsible for promotion of RE sources in India. These policy initiatives are given below.

2.7.1 Legal and Policy Initiatives

Electricity Act 2003: The Electricity Act, (EA), 2003, was the watershed legislation that accelerated development of grid connected renewable in India. EA 2003 mandated the SERCs as the responsible body for the promotion of generation of electricity from renewable sources of energy. The SERCs were responsible for tariff regulations in their respective states. The SERCs have in turn mandated (termed as Renewable Purchase Obligation (RPO) or

Renewable Purchase Specification (RPS)) the distribution utilities to source a certain pre-defined percentage of electricity from renewable generators.

National Electricity Policy: National Electricity Policy recognizes the urgent need to promote generation of electricity from renewable energy sources. The policy also states that the overall share of renewable sources especially, small-hydro, wind and biomass sources, needs to be increased in the electricity mix. Hence efforts will be made to encourage private sector participation through suitable promotional measures. The policy highlights that efforts to reduce the capital cost of projects based on non-conventional and renewable sources of energy will be made by encouraging competition among these sources, while adequate promotional measures would be taken for sustained development of these sources.

National Tariff Policy (NTP): This policy deals with tariff fixing, providing adequate returns on investments to the generator, cost of debt, depreciation charges, multi-year tariffs and promoting renewable energy sources. As it would take time for the renewable energy sources to compete with fossil fuels in terms of cost of electricity, the act specifies that renewable energy needs to be sourced by distribution utilities at preferential tariffs determined by the appropriate Commission as far as possible through competitive bidding process among the similar sources.

13th Finance Commission Incentive for RE: The 13th Finance Commission for the period 2010–15 has recommended three grants of Rs 5,000 Crore each to motivate the states into adopting renewable energy sources, improving water management systems and preserving forests. The Commission was of the opinion that a substantial increase in the supply of electricity is important and hence made a recommendation for a forward looking grant of Rs.5000 crores to be paid as incentive to states that increase the share of electricity generated from renewable sources between 2010 and 2014.

National Clean Energy Fund: The Government has announced a national clean energy fund that will finance clean energy projects and research ventures that can help reduce the carbon footprint of India. This fund created through a clean energy cess of Rs 50 per tonne of coal, lignite and peat, both domestic and imported will be used to finance renewable project identified by high powered panel. The fund is likely to have Rs 6500 crores by 2012 that will be leveraged to promote renewable energy projects

Incentives for Solar Photovoltaic Manufacturing under Semiconductor Policy: A semiconductor policy to attract investment, with suitable incentives, to the semiconductor sector was announced. The policy, which encourages semiconductor and solar PV manufacturing, offers a capital subsidy of 20% for manufacturing plants in SEZs and 25% for manufacturing outside SEZs. The scheme covered manufacturers of semiconductors, displays and solar photovoltaic technologies using semiconductor devices for solar cells. It is expected that the solar PV manufacturing capacity in India would increase from around 700 MW to over 4000 MW per annum when this policy gets implemented. Till date 12 proposals have been cleared under this policy.

National Action Plan on Climate Change (NAPCC): The National Action Plan on Climate Change (NAPCC) has 8 national missions as part of this framework. National solar mission is directly related to renewable energy. As per NAPCC, renewable electricity injected to the grid has to be set at 5% at the beginning of FY 2009–10 and has to be increased at 1% per annum in the subsequent years to reach 15% at the end of FY 2019–20.

Jawaharlal Nehru National Solar Mission: The Jawaharlal Nehru National Solar Mission (JNNSM) aims to increase share of solar energy in India's energy mix. JNNSM plans to promote the development of solar energy for grid connected and also for the off-grid power generation. The aim of the program is to have 20,000 MW of solar energy by 2022. It plans to achieve this objective by

- Promotion of commercially viable solar heating systems by making them mandatory in buildings
- Promotion of solar off-grid and decentralized solutions for rural electrification program
- Encouragement of research and application in the field of solar technology

2.7.2 Incentives for RE by the Central Government

Foreign Direct Investment (FDI): India permits FDI up to 100 per cent in the renewable energy sector under the automatic route subject to the provisions of the Electricity Act, 2003. This means foreign companies interested to invest in renewable energy generation and distribution projects need not obtain prior approval of regulatory authorities in the country.

Capital Subsidy: Some technologies like solar PV (Off-grid), small hydro and biomass systems have been provided support through capital subsidy scheme which is based on installed capacity of the project.

Accelerated Depreciation: The Government earlier permitted accelerated depreciation at the rate of up to 80% in the first year on a written-down value (WDV) basis for equipment of wind power projects. Wind projects installed after 31 March 2012 will be eligible for depreciation of 15 percent instead of 80 percent on written down value method. Further, the companies have been provided with an option to claim depreciation under straight line method as well if they so desire.

Generation Based Incentive (GBI): GBI scheme of Rs 0.50 per kWh, with to an upper limit of Rs.15 lakhs per MW per year, totalling Rs.62.5 lakhs per MW to be availed up to 10 years of the project life was available to wind energy developers. GBI can be availed by those wind power projects that have not availed accelerated depreciation benefits and have been commissioned before 31 March 2012. A similar GBI scheme was offered to solar power projects for small capacity of 50 MW. However, the scheme was withdrawn after the introduction of JNNSM.

Income Tax Holiday: Companies involved in generation and/or distribution of power has been offered a 10-year tax holiday, within a block of first fifteen years during the life cycle of all infrastructure projects, for renewable energy plants if it begins to generate power before 31 March 2013. However, a minimum alternative tax at the rate of approximately 20 percent needs to be paid, which can be offset in future years. Expenditure based incentive to business of generation, transmission or distribution of power is also available as an alternative incentive facility to companies. In this, most of the revenue and capital expenditure will be allowed as tax deduction upfront instead of claiming depreciation on the capital expenditure.

Excise Duty Exemption: India has provided 100% exemption in Excise Duty for most project components of renewable energy projects. The components that are exempted from payment of excise duty are mentioned under List 9 of Section No. 237 of the Central Excise Tariff Act, 1985. The regular rate of Excise Duty for such components is 16%.

Customs Duty Exemption: India has allowed concessional Customs Duty of 5% for selected components of renewable energy power projects. The machinery and electrical components used in these projects attracts Customs Duty between 7.5% and 10%. Similarly, the Government of India has also offered concessional Customs Duty for all machinery imported for the setting up of a solar power project.

Deduction in Taxable Income: Under Section 10(23G) of the Income Tax Act, income from an infrastructure capital fund or company or a cooperative bank (from the assessment year 2002/03) by way of dividends, interest, or long-term capital gain from investments made in infrastructure business, etc., is exempt till 2012.

Renewable Regulatory Fund (RRF): Wind and solar power projects are allowed limited deviation from their schedule without any penalty unlike regular fossil fuel projects. If a renewable generator defaults on power schedule, the state utility will be compensated the applicable unscheduled interchange (UI) penalty from a renewable regulatory fund created for this purpose. This facility is advanced so that the renewable energy developer is not penalized due to the infirm nature of clean energy sources.

India has several policies to promote renewable energy sources as discussed above which has helped renewable energy to reach 12% of total installed capacity in the country (WISE, 2010). Some of the critique and comments of the renewable energy policy of India is given below

1. Accelerated depreciation was the preferred incentive used by several wind farm developers to set up wind parks in India
2. Lack of a policy to provide legally enforceable payment mechanism to the project developers, is one of the gaps in the policy framework that needs to be fixed by India
3. Electricity in India is a concurrent subject (comes under the jurisdiction of both the Central and the State governments) and not all State governments have a dedicated renewable energy policy
4. Policy to accord priority sector tag to renewable energy sector is missing which is preventing banks and other financial institutions to lend capital at attractive rates of interest
5. Policies on human resource development, curriculum formulations, establishing institutes of higher learning exclusively on renewable, skill development, R&D, Masters, Bachelors and Diploma programs on renewable need to be brought out to train resources on renewable technologies

6. Enforceable RPO mechanism with suitable penalties needs to be added to the existing RPO policies to give confidence to the investors in renewable projects
7. Policies to accord single window clearances for RE projects are also missing in the existing policy framework and can be considered to accelerate deployment of renewable

These are a few policy gaps in the renewable energy policy adopted by India which may be addressed when these policies are taken up for revision.

2.8 Variables found from literature survey

The following set of variables, as shown in table-2.6, was found from the literature survey that formed the building blocks of policy roadmap adopted by countries in Europe that had offshore wind energy operational. No one country has adopted all the variables but have picked a smaller set of variables that probably suited their local conditions. The operational definitions of these variables are given in chapter-3 of the thesis.

Table 2.6 - List of Variables identified through literature survey

SNo.	Components/Building Blocks/Variables
1	Feed in Tariffs (FiT)
2	Accelerated Depreciation
3	Generation based Incentives (GBI)
4	Legally enforceable RPO/REC
5	Faster approvals/Single Window Clearance
6	Continuity of policies for long term (more than 10 years)
7	Adequate evacuation infrastructure to transmit power from high seas
8	Tariff determination on wind speeds and not on Zones
9	Financial incentives like zero import duty, excise duty waiver
10	Availability of expert EPC contractors

11	Availability of local manufacturing expertise for Wind Turbine
12	Growth of ancillary units (eg Gear box)
13	Superior program execution skills of the developer
14	Accurate data on offshore wind potential sites and wind speeds
15	Skills development and training of human resources
16	Active Research institutions working on offshore wind energy
17	R&D facilities to localize production of expensive equipment
18	'Priority sector' tag to offshore wind energy sector
19	Availability of capital at attractive rates of interest
20	Creation of offshore wind energy fund to reduce cost of capital
21	Moratorium on interest payments for the first 5 years of project go-live

2.9 Research Gaps

India needs to increase power generation from the renewable energy sources substantially, to drive its economy; as continued dependence on fossil fuel is unsustainable in the long run. From the success India has achieved in the renewable story thus far, onshore wind energy has contributed over 75% to the renewable energy mix. There has been no contribution as yet from the offshore wind energy source. One reason could be due to lack of a coherent offshore wind energy policy in India. There are no research literatures available on the offshore wind energy policy in India. Also, detailed feasibility study of offshore wind energy farms in India has not been conducted. There is no study which is carried out to develop and empirically test a model of constituents of effective policy. This thesis would attempt to fill the gap of absence of literature on offshore wind energy policy for India by making a modest attempt to understand the nuances of the offshore wind energy policies of Denmark, UK, Netherlands and Germany to make suitable recommendations for a robust offshore wind policy for India.

2.10 Concluding Remarks

Several literatures reviewed, and highlighted in this chapter, have supported the need for policies to grow renewable energy sector in general and offshore wind energy in particular. Researchers have stressed the need to have different policies tailored to meet the requirements of different sources of renewable energy, and not to adopt a ‘one size fits all’ approach as even within the renewable energy basket, there are sources at different stages of maturity and hence needs disparate interventions. European countries success in adoption of offshore wind energy has been traced to the progressive policies adopted by those countries uniquely to harness offshore wind. India too has undertaken several steps to encourage the growth of renewable power in the country. However, what is missing is a robust offshore wind energy policy focussed to accelerate its adoption. Also the interesting point that has emerged from the literature survey is that even among the countries that witnessed remarkable growth of offshore wind energy the policies adopted were vastly different, though the result obtained were the same. Hence it is important to collate from the stakeholders of wind energy in India on what are the key drivers, unique to Indian context, to grow offshore wind energy. In the next chapter, a detailed research design is given on the approach adopted to capture the feedback of stakeholders of wind energy, through a questionnaire survey, on what could be the building blocks of a robust offshore wind policy for India. The sampling frame, multivariate models used for data analysis and the sources of data collection are also given.

3 CHAPTER 3 - RESEARCH DESIGN

3.1 Introduction

Research design is the framework that gives the overall blueprint of this study. Research designs are broadly classified into exploratory research and conclusive research. Conclusive research is further classified into descriptive and causal research. Exploratory research is more to do with qualitative study while conclusive research is associated with quantitative study. In this thesis, both these research designs have been employed in different degrees though conclusive research design (Quantitative) form the core part of the work, while exploratory research (Qualitative) was used during literature survey, development of the hypothesis, validating and finalising the variables for the study.

The research questions were framed keeping the objectives of the research in consideration. The research questions were followed by formulation of hypothesis, finalising the research methodology, identification of sampling procedures (Sampling frame, sample size), questionnaire design, scale formation, validity and reliability tests of the instrument, pilot testing, data collection and analysis of the data collected.

Hence the research design used for this research work was exploratory research for identification of variables followed by conclusive research design – single cross sectional design descriptive research, also known as sample survey research design.

3.2 Rationale of the study

Indian Economy has witnessed spectacular growth in the recent years and as energy is a biggest driver and necessary ingredient to sustain this growth; India needs to focus on building additional power generation capacity at a faster pace. India continues to experience power shortages which can prove to be a millstone around its neck if solutions are not found quickly to address the burgeoning power deficit. India has been proactive to try multiple solutions including demand side management, energy efficiency and growing the indigenous renewable energy sector to address this problem. While, India has to import several billion dollars of coal and oil to fire its thermal power plants, it is blessed with abundant natural resources like large coast line to encourage the growth of renewable sector. While, it is apparent that India has made use of several source of renewable power and a world leader today in onshore wind energy, there has been no contribution from offshore wind farms so far as they are non-existent at the moment. Given the pressing need to leverage every available source to generate power, India has to get the framework in place to generate power from offshore wind energy farms. But there is no policy roadmap, as yet, to exploit the potential offered by offshore wind energy farms. This research work attempts to bridge that gap by identifying the core building blocks of what could possibly constitute a comprehensive offshore wind energy policy for India.

3.3 Statement of problem

To develop an empirical model for predicting the growth of offshore wind energy sector in India after conducting an elementary feasibility study covering the market, technical, financial, economic and ecological viability of setting up of offshore wind farms in the country. To study the support of policies to grow onshore wind energy in India and identify the factors needed to encourage growth of offshore wind energy in India by leveraging the policy experiences of select countries in Europe in promoting the offshore wind energy sector.

3.4 Objectives of the study

The following are the objectives of the research work

5. Feasibility analysis of the suitability and efficacy of offshore Wind farms for the Indian context (Dhanuskodi in Tamil Nadu as the chosen area) – Analysis of the technical, financial, Economic, Environment and Market of offshore wind energy in India
6. To develop and empirically test a model of constituents of effective offshore wind energy policy.
7. Critique of policies adopted by select European countries (notably UK, Denmark, Netherlands and Germany) to encourage the growth of the offshore wind energy sector in their respective countries.
8. To study the support of policies in the growth of onshore wind energy sector in India.

3.5 Research questions

Based on the research objectives mentioned above, the following research questions have been identified that needs to be answered through this research work.

Central Research Question (RQ)

What are the factors that can contribute to the growth of offshore wind energy sector in India?

Additional RQ1 Is it feasible to set up offshore wind energy farms in India?

Additional RQ2 What are the existing renewable energy policies in India?

Additional RQ3 Are there a set of offshore wind energy policies, chosen from the policies of select European countries, which can be adopted by India, leading to substantial growth of the offshore wind energy sector in India (Universally acceptable)

Additional RQ4 Are there a set of offshore wind energy policies, identified from select European countries, which need to be uniquely tailored to Indian conditions, to grow the offshore wind energy sector in India.

3.6 Scope of the study

The scope of the study is limited to India geography, covering the Dhanushkodi area of southern peninsular India, for conducting the feasibility study for setting up of offshore wind parks in the country. Extensive literature survey of offshore wind sector in UK, Germany, Netherlands and Denmark (the top 4 countries to have offshore wind energy installed in the world) is conducted to understand the offshore wind policies adopted by these countries that helped growth of this sector. Using the knowledge gained, a questionnaire survey is carried out in India to elicit the responses of wind energy stakeholders on what could constitute supportive offshore wind policies.

3.7 Research model and hypotheses

The research model used in the analysis is quantitative model, as the nature of the study and the audience of the study, requires the use of an objective, experimental research model. In this study, data is collected quantitatively using instrument (questionnaire), analysed using statistical procedures to understand the relationship among the variables to judge the impact of independent variables on dependent variable. Hence quantitative research model is used in this study as stated above (Creswell, 2009).

3.8 The philosophical worldview proposed in the study

As stated by (Creswell, 2009) the present research work have characteristics of post- positivist worldview. The research work adopts a scientific way of doing research, holds a deterministic philosophy of cause and effect (policy caused growth of offshore wind), identify the causes that influence outcomes, reductionist in the intent to reduce ideas into a small, discrete set such as variables that comprise hypotheses and research questions. Measurement, objective analysis, collection of data on instruments based on measures completed by participants to develop relevant understanding of causal relationship of interest, adhering to the standards of reliability and validity, use of deductive logic are some of the hall marks of this worldview (Creswell, 2009). Similar process has been adopted in this research work making it closely align with the post-positivist worldview. The pragmatic worldview emphasises the research problem and uses all the approaches available to understand the problem (both qualitative and quantitative methods are adopted) (Creswell, 2009). In this research work, in a limited way qualitative approaches (expert views) have been incorporated with a predominantly quantitative method of data analysis giving it a mixed method flavour of inquiry. However, the research work is more closely linked to the concepts of post-positivist worldview – although these worldviews are not as mutually exclusive as they appear initially (Creswell, 2009).

3.9 Strategies of Inquiry

The strategies of inquiry are the types of qualitative, quantitative and mixed methods designs or models that provide specific direction for procedures in research design (Creswell, 2009). The quantitative research adopts survey research and experimental research among others as the two strategies of Inquiry. In this research work, survey and quantitative methodologies were adopted which identified variables, used closed ended predetermined questions for data collection and employed statistical procedures for testing a hypothesis. These are all characteristic of quantitative research methods. Though exploratory survey was used to validate the variables, the rest of the work relies on largely quantitative method.

3.10 Operating definitions of the variables found from literature survey

The operating definition of the variables found from literature survey is given in the table 3.1, to give a common understanding and better clarity on what they mean. All these variables are independent variables (which load on 5 factors as shown in factor analysis chapter-4) with growth of offshore wind energy in India being the dependent variable

Table 3.1 - Operating definitions of variables identified through literature survey

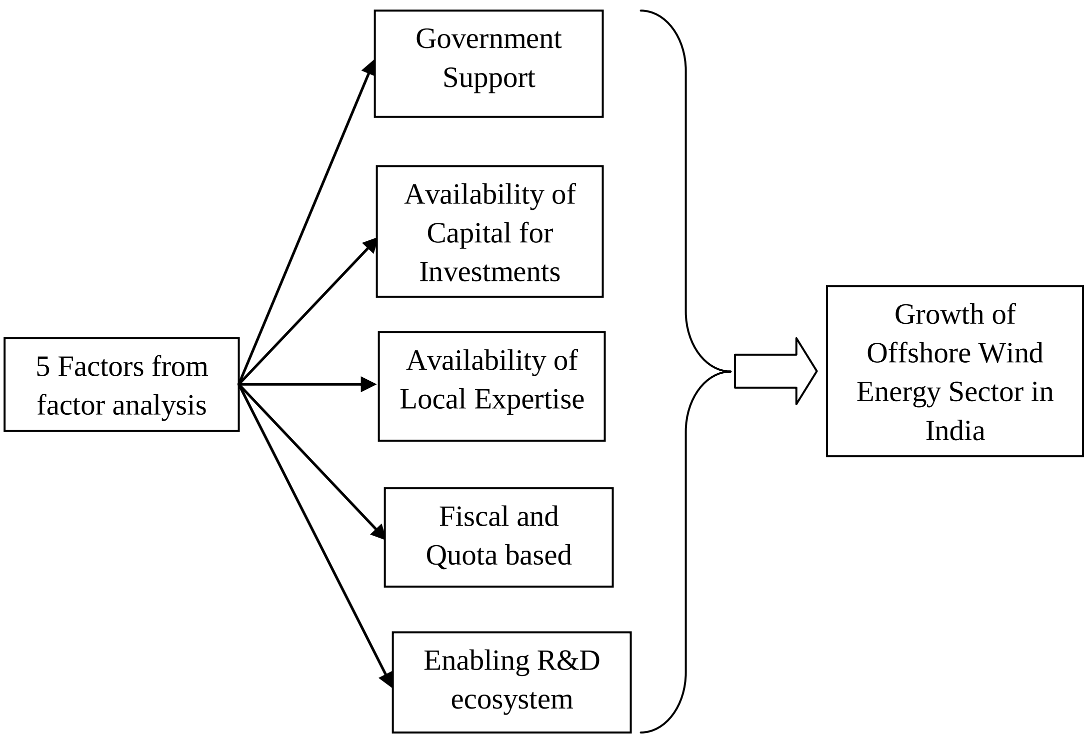
SNo.	Components/Building Blocks/Variables
1	**Feed in Tariffs (FiT):** Feed in Tariff is the rate at which the renewable energy developer will be paid by the utilities/distribution companies for every unit of electricity fed into the grid.
2	**Accelerated Depreciation (AD):** Companies that are setting up a renewable energy projects can avail depreciation at higher rates (80% in the case of wind farms) in the first year of operation.
3	**Generation based Incentives (GBI):** GBI is a bonus payment given per unit of power injected into the grid to the renewable energy generator, over and above the FiT system.
4	**Legally enforceable RPO/REC:** Renewable purchase obligation (RPO) mandates the distribution utilities to source a pre-decided quantity of electricity, usually a proportion of their supply, from renewable energy sources. Making this RPOs/REC legally enforceable will make it attractive for investors.
5	**Faster approvals/Single Window Clearance**: Providing single window clearances for setting up offshore wind energy projects will reduce the gestation period for project go-live and also enhance the ease of doing business.
6	**Continuity of policies for long term (more than 10 years):** Continuity of policies for a long term (10 years or more) for predictability and stability in the policy environment.
7	**Adequate evacuation infrastructure to transmit power from high seas:** Availability of and access to transmission infrastructure/Grid connectivity from the offshore wind parks to onshore substations.
8	**Tariff determination on wind speeds and not on Zones:** Specific tariff rates based on speed of the winds will help development of low wind speeds areas.

9	**Financial incentives like zero import duty, excise duty waiver**: Offering financial incentives like waiver of custom duty, import duties exemptions, tax related schemes for setting up of offshore wind parks
10	**Availability of expert EPC contractors:** Shortage of skilled resources to install offshore wind farms will invariably delays the commissioning of these farms which then has an impact on cash flows and profitability.
11	**Availability of local manufacturing expertise for Wind Turbine:** It is relatively inexpensive to source from domestic manufacturers compared to imports and it also reduces the supply chain wait time dependencies.
12	**Growth of ancillary units (eg Gear box):** Similar to the availability of wind turbines locally, growth of ancillary units that are locally present will accelerate reduction in costs of components thereby increasing adoption
13	**Superior program execution skills of the developer:** High quality program managers to supervise the installation and commissioning of offshore wind parks.
14	**Accurate data on offshore wind potential sites and wind speeds:** The power output from a wind farm varies directly to the cube of the wind speeds and hence impacts profitability. Hence accurate data on offshore wind speeds is important to judge the financial attractiveness of the project.
15	**Skills development and training of human resources:** Offshore wind energy project needs 20 people for every MW of capacity installed to manage the project. Skills development and training of these resources is important to ensure smooth functioning of these offshore wind farms.
16	**Active Research institutions working on offshore wind energy:** Research institutions that focus on innovation and technology advancement of the offshore wind sector components, research on advances in foundation engineering etc. are vital to accelerate the growth of the offshore sector.
17	**R&D facilities to localize production of expensive equipment:** Growth of R&D facilities that work on finding ways to localize production of all components of offshore wind equipment to reduce the overall costs of offshore wind farms.
18	**'Priority sector' tag to offshore wind energy sector:** Declaring offshore

	wind as a priority sector will help the sector access funds from banks at attractive rates thereby increasing the attractiveness of the investments in offshore wind.
19	**Availability of capital at attractive rates of interest:** If capital is made available at attractive rates, in the absence of priority sector tag - that would help reduce the overall debt servicing burden for the offshore wind energy project developers.
20	**Creation of offshore wind energy fund to reduce cost of capital:** Creation of offshore wind energy fund, using the cess levied on coal and other fossil fuels, and using the accrual to lend to offshore wind energy projects will ease the burden on the developers.
21	**Moratorium on interest payments for the first 5 years of project go-live:** The offshore wind project developers being offered a 5 year moratorium on interest payment after the project goes-live will help in de-risking the investment from the vagaries of learning curve which is inevitable in any project with large capital investments.

The sequential framework adopted for the research is given in figure 3.1

Figure 3.1 - Sequential Framework



3.11 Hypothesis

Null Hypothesis: H0: Fiscal & Quota based incentives, Government support, Availability of local expertise, R&D ecosystem and Availability of capital for investments do not predict the growth of offshore wind energy in India.

Alternate Hypothesis: H1: Fiscal & Quota based incentives, Government support, Availability of local expertise, R&D ecosystem and Availability of capital for investments predict the growth of offshore wind energy in India

3.12 Research Methodology

Descriptive research (Conclusive research) was the chosen research methodology as it renders itself to analysis using statistical tools. Since the strategy of inquiry used was survey (as explained in the earlier part of this chapter) employing predominantly close ended questions, predetermined approaches and numeric data, quantitative research methodology was the chosen one. Also, since the present research work involved identifying variables of the study, framing of research model, testing of hypotheses, validity and reliability of the instrument apart from extensive use of statistical tools to arrive at the conclusion, quantitative approach to research design and methods was concluded as the appropriate methodology to adopt for this thesis.

3.13 Sampling Procedures

3.13.1 Target population

The target population for the survey was any organization or individual having interest in the wind energy industry in India. This included companies that have an active presence in India and all those who are keen to set up base in India to exploit the wind energy potential offered by the country.

3.13.2 Sampling frame

The respondents who have a stake in wind energy in India and who have an active presence in India were identified as part of the sampling frame. The stakeholders of wind energy industry include Wind turbine manufacturers, policy makers, R&D institutions, project developers, consultants, academia, wind industry associations, regulatory agencies, financial institutions, EPC contractors, thought leaders in wind energy and independent power producers. Organisations that do not have base in India and are only in the exploratory mode with no immediate timeframe to set up base in India were also excluded from the analysis though their opinion was sought on the clarity and completeness of the questionnaire.

3.13.3 Sampling Element

Since the survey was designed to elicit perspectives on offshore wind energy policy that will drive investment decisions in the sector, the sampling element was defined as people those who were in the executive decision making authority in their respective companies/organization. Middle management and junior management professionals who are not decision making authorities of large investment projects were excluded from the survey.

3.13.4 Sampling Unit

The sampling unit was defined as those in executive leadership roles in organisations with interest in wind energy in India, who actively participates in large industry conferences as speakers or panel discussions chair or as session chair. Since thought leaders from wind industry were usually invited to these prestigious conferences, access to these leaders and therefore the data collection exercise became easier and more robust.

3.13.5 Extent

The extent of data collection exercise was restricted to Indian geography

3.13.6 Time period

The data collection exercise was targeted at senior thought leaders with over 10 years of experience in wind energy sector and a minimum of 3 years in the Indian wind energy sector.

3.13.7 Sampling Technique

Proportionate stratified sampling was used during the data collection process. The population was divided into different strata (Policymakers, Academia, Wind turbine manufacturers, association members) and number of elements from each stratum in relation to its proposition in the total population was selected. The exact percentage of these stakeholders in the sample size is given below.

3.13.8 Sample Size

To calculate the sample size needed for the research, Yamane’s formula is used (Yamane, 1967). The formula is given below.

$$n= N/1+N.e^2$$

n= Sample size needed

N = Size of the population

e= Level of precision (.05 at 95% confidence level

Overall 300 people were identified as the target population for the survey, those who had interest in wind energy in India and were senior management professionals in their respective organizations. Incorporating N = 300 and e= 0.05 in the above equation, sample size was arrived at 171.

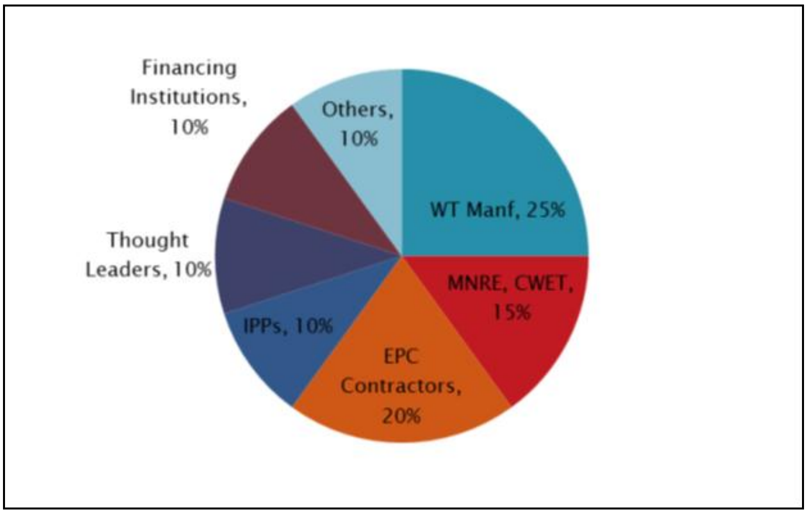
Originally the questionnaire was administered to 240 respondents but some of the responses received were incomplete. So, those who submitted incomplete questionnaire were removed from the list. Finally, 181 respondents were found to have submitted their responses that were complete in all respects - a response rate of 60% is achieved which is acceptable (Malhotra, 2010). Also to conduct factor analysis, it is the norm (Malhotra, 2010) to have 8 respondents for each variable. In this survey there are 21 variables which would need 168 respondents to participate in the survey. 181 respondents are higher than the number needed to do factor analysis and therefore satisfies that condition.

The breakup of the respondents (figure 3.2) is

1. Wind Turbine Manufacturers – 25%
2. Policy Makers, MNRE, R&D Institutions – 15%
3. Project Developers & EPC Contractors – 20%
4. Independent power producers – 10%

5. Thought leaders – 10%
6. Financing Institutions (IREDA, EXIM Bank) – 10%
7. Others (Captive users, Regulatory agencies, Electricity Boards) – 10%

Figure 3.2 – Break-up of the respondents of the questionnaire



3.14 Instrument design

The instrument that was used in the data collection exercise for this research was a questionnaire which contained 30 questions in 7 sections. The questionnaire had all the questions with pre-defined choices. The details of the instrument development, scale formation, questionnaire format, data collection, validity and reliability test are given in the subsequent sections.

3.14.1 Questionnaire development

Structured – undisguised questionnaire was used in the survey - as they are reliable, standardised, simple to administer, easy to tabulate and analyse - where the responses permitted to the respondents were predetermined on a 1-7 likert scale.

Information sought: The list of variables found from literature survey was presented to the respondents in the form of questions and they were asked to choose an option (in the 7 point likert scale) whether a particular variable would aid the growth of offshore wind energy in India (Strongly disagree to strongly agree rating). There were questions on their perspective on offshore wind energy in India to judge the integrity of answers and to prevent mechanical answers to the questions.

Method of administration: The questionnaire was handed over predominantly in person at wind energy conferences in India, so that access to the right stakeholders and their response rates could be better compared to mail interview. The respondents completed answering the questionnaire at their convenience. However, questionnaire was also sent by email to respondents who specifically requested for mails.

3.14.2 Scale formation

In this research, the variables identified from the literature survey are converted into questions that were administered to the wind energy stakeholders in India. The respondents then were asked to give their opinion on whether a variable will help in the growth of offshore wind energy or not. Since this is a one-dimensional activity, one of the uni-dimensional scaling methods needs to be chosen to develop the scales for the questionnaire. There are three such methods

- Thurstone or Equal-Appearing Interval Scaling
- Likert or "Summative" Scaling

- Guttman or "Cumulative" Scaling

Likert scale is predominantly used scaling technique as it is easier to construct and administer. Likert is widely used scaling technique if one is needed to test a hypothesis and is used for scoring purpose. Also, likert is an interval scale where the distance between attributes are constant and can be interpreted, subsequently exploited using quantitative techniques like factor analysis and regression. The items that need to be rated as part of the thesis were generated using literature survey (21 variables). Then a suitable rating (likert 1-7 scale) of the items were developed as 1-7 scales are most suitable for logistic regression models. The scales developed were

1 = 'strongly disagree'

2 = 'disagree'

3= 'somewhat disagree'

4= 'neutral'

5='somewhat agree'

6= 'agree'

7= 'strongly agree'

The responses from the stakeholders were captured and fed into am SPSS (v 16.0) software for further analysis (Cronbach, factor analysis and logistic regression)

3.15 Pilot testing

The questionnaire was pre-tested with 25 wind energy stakeholders in the country during an International conference. The responses were added in a dummy table to make sure the questions were understood correctly and the answers were in line with the questions asked. A couple of ambiguous questions were re-worded, ordering of the questions were changed as per the feedback received before the questionnaire was administered again.

3.16 Instrument reliability

Reliability is concerned with the consistency of the measurement, which means whether the questions in the survey get same type of response when the conditions remain the same. Reliability is also associated with internal consistency, which means whether the same characteristic is measured by different questions. There are four ways to estimate the reliability of the instrument (questionnaire). They are Inter-rater or Inter-observer reliability, Test-retest reliability, Parallel-forms reliability and Internal consistency reliability. Each of these estimates evaluates the reliability of the questionnaire differently. Among these internal consistency is the most frequently used method to validate the reliability of the instrument.

3.16.1 Internal Consistency - Reliability

The reliability of the instrument is estimated when similar results are obtained by the items that measure similar constructs. Hence a group of people are administered a single measurement instrument, with different items, to check whether the results are consistent, as they measure the same construct. There are several internal consistency measures that are used. One of the most frequently used estimates of internal consistency is Cronbach Alpha.

Cronbach Alpha

In this thesis, Cronbach alpha is used to estimate the reliability of the survey instrument. As the survey instrument used in the research work adopts a 7-point Likert-type scale, it is Cronbach's alpha coefficient is calculated to check the internal consistency and reliability of the instrument. Cronbach's alpha measures the inter-relatedness of the items within the test. In other words, Cronbach alpha measures how closely a set of variables are related as a group and the extent to which all the items in a test measure the same concept or construct. Cronbach's alpha reliability coefficient normally ranges between 0 and 1. The closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale. The alpha scores obtained for the questionnaire for this study is given in table 3.2.

Table 3.2 – Cronbach Alpha scores for the questionnaire

SNo.	Questions (Variables)	Factor Name	Cronbach Alpha (α)
1	Q6 to Q9 (FiT, AD, GBI, RPO)	Fiscal & quota incentives	0.843
2	Q10 to Q14 (Faster Approvals, Grid connectivity, Policy for longer term, Financial Incentives, Tariff based on wind speeds)	Government support	0.950
3	Q15 to Q18 (Expert EPC Contractors, Local manufacturing,	Available of local	0.829

	Growth of ancillary unit, Superior program execution)	expertise	
4	Q19 to Q21 (Accurate offshore data, Skill development, R&D to localise production)	Enabling R&D ecosystem	0.825
5	Q22 to Q26 (Capital at attractive rates, Moratorium on interest, Offshore wind fund, Access to capital, Priority sector lending)	Availability of capital	0.791

The alpha coefficient for all the sections in the questionnaire administered as part of the research work carried out was found to be more than 0.70 with no negative correlations seen among any of the items, thus suggesting that the items have relatively high internal consistency (George & Mallery, 2003; Nunnally,1978; Cortina, 1993; Peterson, 1994). The Cronbach alpha scores conclusively prove the reliability of the instrument used for the research purpose of this thesis.

3.17 Instrument validity

Validity deals with how accurate the measurements are per se, and also a reflection of sample representativeness. Validity is impacted by robustness of survey design and whether right questions are asked to, and understood by, the respondents. 'Whether the instrument is measuring what it is supposed to measure' is the core of validity estimation. There are several ways to estimate the instrument validity. Those include

1. *Construct Validity – Content*
    a. Face Validity

b. Content Validity

2. *Construct Validity – Criterion*

    a. Predictive Validity

    b. Concurrent Validity

    c. Convergent Validity

    d. Discriminant Validity

The details of the construct validity estimates (both content and construct) are given below

3.17.1 Face Validity (Construct Validity – Content)

Face validity is one of the most basic form of validity estimated which involves seeking the opinion of some respondents, whether the instrument looks complete. Most researchers do not consider face validity an adequate measure of proof of the validity of the instrument, even though face validity is easier to complete as a test. This questionnaire was given to the stakeholders of Energy industry in India (both renewable and conventional fuels) and their confirmation of their understanding of the questionnaire helped in establishing the face validity of the instrument.

3.17.2 Content validity (Construct Validity – Content)

Content validity is also a subjective measure but a much improved measure when compared to face validity. In content validity, respondents who have knowledge of the subject is given the instrument to seek their opinion on whether the instruments measures everything it needs to measure and whether everything that it is not intended to measure is excluded from the questionnaire. In this thesis 25 wind energy stakeholders were administered the questionnaire in the pilot stage to seek their inputs on the clarity and completeness of the instrument. Their positive validation of the questionnaire proved the validity of the instrument used in the research, although this may not be taken as a conclusive proof of validity from the analysis perspective but only a subjective feedback. Nevertheless, content validity was established during the data collection process by administering the questionnaire to 25 people during the initial stage itself.

3.17.3 Predictive Validity (Construct Validity – Criterion)

The instrument is supposed to qualify the predictive validity criterion if it is able to predict what it ought to predict. In the research undertaken it is seen that the items that have measure common characteristics needs to correlate highly with one another. For instance the items Q10, Q12, Q14, Q11 and Q13 (Faster Approvals, Grid Connectivity, Tariff on wind speeds, Policy for longer term, Financial Incentive) that in practice represented Government support for offshore wind energy actually predicted that Government support was correlated highly with one other (Table 3.2, Factor 1) (details of factor analysis tests are given in chapter-4 of this thesis). Similarly items that were to measure 'fiscal and quota based incentives' or 'enabling R&D ecosystem' or 'Availability of capital for investments' or 'superior program management skills' correlated highly with one another, as shown in the table 3.3, thereby conclusively proving that the instrument cleared predictive validity test – the ability to predict what it ought to predict.

Table 3.3 – Rotated component matrix showing the correlation (loading) of items (variables) on distinct factors

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Faster Approval	0.936				
Grid Connectivity	0.915				
Tariff on Wind speeds	0.901				
Policy for longer term	0.821				
Financial Incentives	0.777				
Priority Sector tag		0.883			
Capital at attractive rates		0.878			
Moratorium on Interest		0.768			
Offshore wind energy fund		0.551			
Access to funds		0.528			
Program management skills			0.857		
Expert EPC Contractors			0.836		
Growth of Ancillary units			0.770		
Manufacture locally			0.741		
Accelerated Depreciation				0.803	
Generation based Incentive				0.797	
Feed in tariff				0.668	
Legally binding RPO				0.580	
Skill Development					0.864
Accurate data on wind speeds					0.827
R&D for Innovation					0.745

Note: Extraction Method – Principal Component Analysis
Rotation Method – Varimax with Kaiser Normalisation

Rotation converged in 6 iterations

3.17.4 Concurrent Validity (Construct Validity – Criterion)

The instrument is supposed to qualify the concurrent validity criterion if it is able to able to distinguish between groups that it should theoretically be able to distinguish between as shown in Table 3.2. The items that measure the same construct correlate highly with each other and have no correlation with items that measure different construct. In the present research as seen in Table 3.2, items Q7, Q8, Q6, Q9 (FiT, AD, GBI and RPO) that measure fiscal incentives correlate highly with each other but do not correlate with items Q20, Q19 and Q21 (Data on wind speeds, Skill Development, R&D Institution) that measure enabling R&D ecosystem, even though these three items correlate among themselves thereby conclusively proving that instrument clears concurrent validity criterion. There are similarly other pairs of factors which can be shown to follow the example above.

3.17.5 Convergent Validity: (Construct Validity – Criterion)

The instrument is supposed to qualify the convergent validity criterion if measures of constructs that theoretically should be related to each other are, in fact, observed to be related to each other. Inter-item correlation matrix gives the degree to which two or more items are related to each other shown in Table 3.4. Items Q10, Q11, Q12, Q13 and Q14 (Faster Approvals, Policy for longer term, Grid Connectivity, Financial Incentive, Tariff on wind speeds) measure Government support in the research and they show a high degree of correlation (>0.50) among each other. Similarly, items Q19, Q20 and Q21

(Data on wind speeds, Skill Development, R&D Institution) measure R&D ecosystem which too show significant inter-item correlation thereby conclusively proving that convergent validity of the instrument is maintained.

Table 3.4 – Inter-item correlation matrix proving convergent validity of the instrument

Variable	Faster Approvals	Policy for longer term	Grid Connectivity	Financial Incentive	Tariff on wind speeds
Faster Approvals	1.000	0.852	0.958	0.683	0.935
Policy for longer term	0.852	1.000	0.855	0.654	0.797
Grid Connectivity	0.958	0.855	1.000	0.631	0.896
Financial Incentive	0.683	0.654	0.631	1.000	0.639
Tariff on wind speeds	0.935	0.797	0.896	0.639	1.000

Variable	Data on Wind speeds	Skill Development	R&D Institution
Data on Wind speeds	1.000	0.715	0.591
Skill Development	0.715	1.000	0.542
R&D Institution	0.591	0.542	1.000

3.17.6 Discriminant Validity: (Construct Validity – Criterion)

The instrument is supposed to qualify the discriminant validity criterion if the measures of the constructs that should not be related to each other are observed not to be related to each other. In other words, one can easily distinguish between constructs that are not similar to each other. Using the same example as shown above, Q10 to Q14 (Faster Approvals, Policy for longer term, Grid Connectivity, Financial Incentive, Tariff on wind speeds) (Government support) are related to each other and Q19 to Q21 (Data on wind speeds, Skill Development, R&D Institution) (R&D ecosystem) are shown to be related to each other (Table 3.5). However there is no correlation between the two groups and the inter-correlation matrix of all these 8 items should bring out the dissimilarity between these 2 groups. Table 3.4 shows the correlation matrix of all the 8 elements. It is observed that items Q19 to Q 21 (R&D ecosystem) have very low to negative correlation with Q 10 to Q14 (Government support) thereby conclusively proving that the instrument clears the discriminant validity measure. (Details of factor analysis tests are given in chapter-4 of this thesis)

Table 3.5 - Inter-item correlation matrix proving the discriminant validity of the instrument

Variable	Data on wind speeds	Skill Development	R&D Institution	Faster Approvals	Policy for longer term	Grid Connectivity	Financial Incentive	Tariff on wind speeds
Data on Wind speeds	1.000	.715	.591	.216	.268	.276	-.032	.202
Skill Development	.715	1.000	.542	.159	.232	.217	-.065	.195
R&D Institution	.591	.542	1.000	.170	.312	.168	.127	.201
Faster Approvals	.216	.159	.170	1.000	.852	.958	.683	.935

Policy for longer term	.268	.232	.312	.852	1.000	.855	.654	.797
Grid Connectivity	.276	.217	.168	.958	.855	1.000	.631	.896
Financial Incentive	-.032	-.065	.127	.683	.654	.631	1.000	.639
Tariff on wind speeds	.202	.195	.201	.935	.797	.896	.639	1.000

As the instrument has cleared both convergent and discriminant validity it conclusively proves that the instrument clears construct validity criteria. The instrument used for the survey (Questionnaire) clears both the reliability (Cronbach alpha) and validity (construct validity) tests.

3.18 Questionnaire format

The questionnaire has a total of 30 questions divided into 7 sections. The categories of the respondents are captured initially to record whether they are wind turbine manufacturers or policy makers or project developers. This is followed by Section- I, which has 5 questions that deal with India’s preparedness to tap the offshore wind energy potential in the country. The responses are coded on a (1-5) measure which is coded as ‘Yes’ (if the respondent gives a score of 4 or 5) and No (if the respondent gives a score of 1, 2 or 3). This code is fed into the logistic regression model as ‘1’ for Yes and ‘0’ for No against the dependent variable. Sections II to VI have questions on the 21 variables that the respondents answer on a 7 point likert scale (strongly disagree to strongly agree) which gets fed into the SPSS software for data analysis (factor analysis and logistic regression). Section VII has additional questions to check the integrity of answers received earlier (Table 3.6).

Table 3.6 – Break-up of the variables in the questionnaire

S No.	Name of the Variable	Number of questions	Questions number
1	Dependent Variable (Offshore wind energy growth)	5	1 to 5
2	Feed in Tariff (FiT)	1	6
3	Accelerated Depreciation (AD)	1	7
4	Generation based Incentive (GBI)	1	8
5	Legally binding Renewable purchase obligation (RPO)	1	9
6	Faster Approvals	1	10
7	Policies for longer terms	1	11
8	Evacuation infrastructure/Grid connectivity	1	12
9	Financial Incentives	1	13
10	Tariff based on wind speeds	1	14
11	Expertise of EPC Contractor	1	15
12	Manufacture of turbine components locally	1	16
13	Growth of ancillary units	1	17
14	Superior program execution skills	1	18
15	Accurate data on wind speeds	1	19
16	Institutions for skill development in offshore wind farms	1	20

17	R&D for innovation in offshore wind farms technology	1	21
18	Capital at attractive rates of interest	1	22
19	Moratorium on interest payment	1	23
20	Creation of offshore wind energy fund	1	24
21	Access to funds	1	25
22	Priority sector tag for offshore	1	26
23	Additional questions to validate the answers for the above	4	27 to 30

3.19 Questionnaire administration or Data collection

The questionnaire was administered to 240 wind energy stakeholders who were in senior executive leadership cadre in their organisations. The questionnaire was administered during several wind energy summit that took place which saw a large congregation of these stakeholders. Data for the study was collected from both primary and secondary sources. Data collection from primary sources was predominantly conducted through structured Interview method using a questionnaire that was developed using the variables that emerged from literature review. The validity and reliability of the questionnaire was pre-tested using Cronbach's alpha test and was found to be in compliance with the qualification criteria of $\alpha > 0.7$. Several scholarly journals, industry papers, conference proceedings, trade bodies, government publications were used for secondary data research.

Sources of data – Both primary and secondary data were used for data collection and analysis.

Primary data

The sources of primary data was a detailed questionnaire administered to

- Important policy makers in MNRE, Govt. of India
- Select Wind Turbine Manufacturers in India (Suzlon, Enercon, Vestas, Gamesa, GE)
- Scientists of Centre for Wind Energy Technology (C-WET)
- Indian Renewable Energy Development Agency – IREDA
- Wind Industry associations
- Independent thought leaders in the field of wind energy in India
- Independent Power Producers
- Project developers and EPC contractors
- Financial Institutions that fund wind energy projects

Secondary data

Secondary data was from reports and publications of these following organizations. There are several scholarly journals that were referred for the study. Details of these journals are given at the end of this report as bibliography.

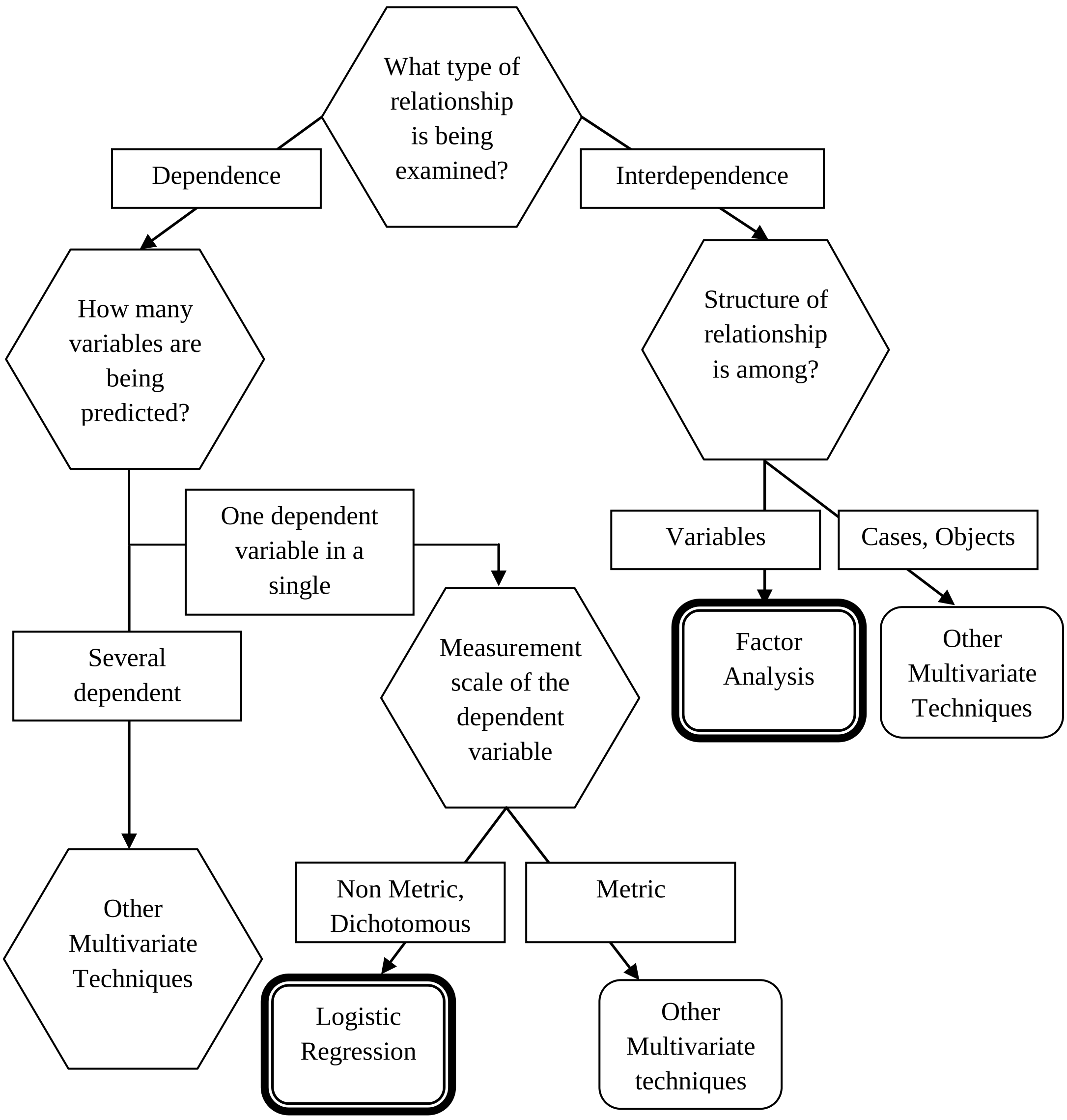
- Reports of Ministry of New and Renewable Energy, Government of India
- Danish Energy Agency and German Wind Energy Association
- The European Wind Energy Association (EWEA)
- Global Wind Energy Council (GWEC)
- World Bank reports
- International Energy Agency (IEA)
- National Renewable Energy Laboratory (NREL)
- Reports of Planning Commission of India
- Centre for Wind Energy Technology (C-WET, Government of India)
- Indian Renewable Energy Development Agency – IREDA
- Central Electricity Authority (CEA), Govt. of India
- Central Electricity Regulatory Commission (CERC), Govt. of India
- Indian Wind Turbine Manufactures Association – IWTMA
- Indian Wind Energy Association – INWEA
- Indian Wind Power Association – IWPA
- World Institute of Sustainable Energy – WISE
- Intergovernmental panel on climate change (IPCC)
- United Nations Environment Program

- Scholarly Journals (Renewable Energy, Renewable & Sustainable Energy Reviews, Energy Policy, Energy and others from Elsevier publishers)
- Reports of Ministry of Power, Ministry of Petroleum & Natural gases, Ministry of Environment and Forest
- Intergovernmental Panel on Climate Change (IPCC)
- EEA, Europe reports
- NREL, US Reports

3.20 Quantitative analytical tool used

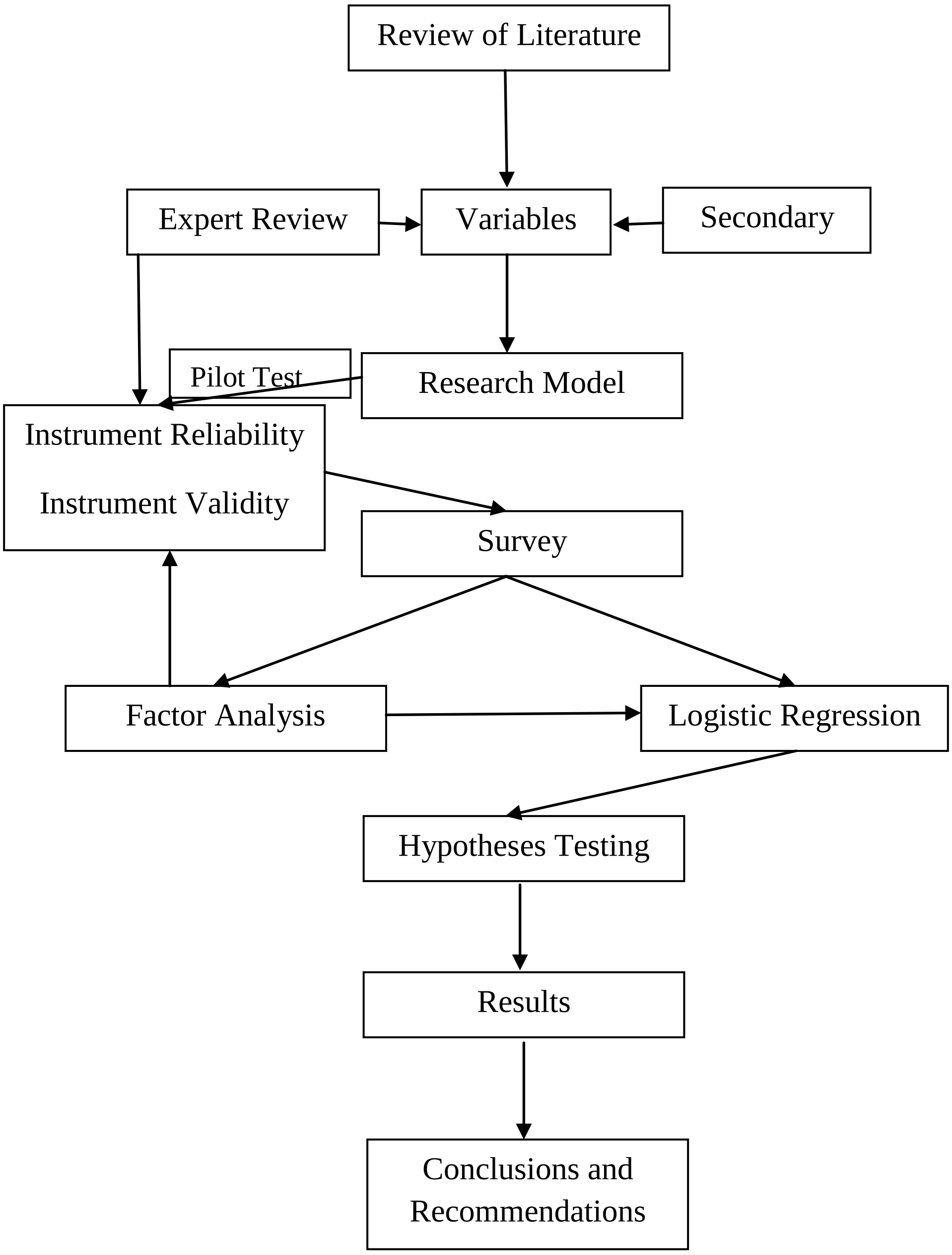
In this research two prime objectives of statistical analysis were to reduce the set of variables into fewer numbers of manageable factors and then use those factors as independent variables to predict the influence on a dichotomous dependent variable (growth of offshore wind sector in India). When the relationship that is being examined is interdependence and the structure of the relationship that is examined is among the variables, as is the case with this research, then the multivariate technique that needs to be used is factor analysis (as shown in the flowchart, figure 3.3). As stated earlier, there are 21 variables in this study whose interdependence was examined to reduce them to a set of 5 factors. If the relationship that is being examined is that of dependence and the number of variable that is predicted is one dependent variable, which is dichotomous, in a single relationship then the analysis that is to be used is Logistic Regression, as is the case with this research work (shown in figure). In this research the 5 factors that emerged from factor analysis was used as the independent variables and growth of offshore wind energy (Growth/No growth) was used as the dichotomous dependent variables. Details of the multivariate analysis factor analysis and logistic regression are given in chapter -4 of this thesis. SPSS software was used for analysis.

Figure 3.3 - Flowchart for selecting a multivariate technique



The research methodology adopted for this thesis is given in figure 3.4.

Figure 3.4 - Research Methodology Flow Chart



3.21 Concluding remarks

Research design is the core part of the thesis as it helps to fortify the overall framework of the research project. In this chapter, the research objectives, research questions, hypothesis, sampling frame, data collection procedure, data analysis tools were highlighted to give an overall direction of the research work. Beside the variables found from literature survey and the concepts of factor analysis and logistic regression, the two quantitative techniques data models that were used in the study, were elucidated. The next step is to evaluate the feasibility of setting up of offshore wind energy farms in India by studying the market demand for electricity in India, analysing the financial viability (by examining the NPV, IRR and break-even point of a 1MW offshore power project), evaluating the technical practicability of setting up of offshore wind farms, the economic feasibility and ecological analysis of offshore wind farms in India. These are addressed in detail in the next chapter

4 CHAPTER 4 - FEASIBILITY STUDY OF OFFSHORE WIND ENERGY SECTOR IN INDIA

4.1 Introduction

This chapter deals with the feasibility study of offshore wind energy farms covering the Market, Technical, Financial, Economic and Ecological feasibilities of setting up offshore wind energy farms in India. In the market feasibility study, the power needed to support the current economic growth over the period of next 20 years is adopted from planning commission reports. Current and expected future electricity deficits figures are obtained from the Central Electricity Authority (CEA) documents which reiterate that India needs to ramp up power generation capacities to meet present and future needs.

The technical analysis covers broadly the areas of wind speed forecast in the southern sea coast of India, availability of offshore wind turbines, laying of sub-sea cabling and foundations for the turbines. Several published articles are condensed together to enhance the understanding of the technical feasibility of offshore wind farms in India.

The financial feasibility analysis covers the NPV, IRR and break-even point calculations for setting up of a 1 MW offshore wind energy farm in India. Experiences of offshore wind farms in Europe are also mentioned to highlight the performance of existing offshore wind energy farms. The economic feasibility covers the benefits of adopting offshore wind energy farms in reducing foreign exchange outflow for importing expensive fossil fuels, creation of jobs and emission reduction advantages. The ecological feasibility covers the reduction in greenhouse gas emissions, decrease in use of water and land by moving away from fossil fuels and adopting offshore wind energy farms.

Overall, this chapter forms one of the core objectives of this research work and sets the foundation for proceeding to analysis of data and model testing in subsequent chapters.

4.2 Feasibility Study of Offshore wind energy farms in India

The feasibility study will focus on Market and Demand analysis, Technical analysis, financial analysis, Economic analysis and Ecological analysis.

4.2.1 Market and Demand Analysis

Demand Analysis for Electricity in India

For annual growth of 9%, the Planning Commission estimates that the electricity generation capacity installed in the country should be 960,000 MW by 2031 as compared to 202,000 as of April 2012 (Table 4.1). This figure is lower than the estimates of Ministry of power, Government of India – nevertheless a daunting task to accomplish almost 800 MW of new capacity additions per week for the next 20 years. The current proportion of renewable energy sources being a mere 12% of the total installed capacity would be unsustainable, as conventional energy fuels are fast depleting and their imports getting more expensive every year (MNRE, 2012). The proportion of renewable energy sources need to grow at a faster rate to obviate, partly, the dependence on imported fossil fuels. Offshore wind energy sector hence has a ready demand available in the country that needs to be catered to.

Table 4.1 – Estimated requirement of Electricity in India

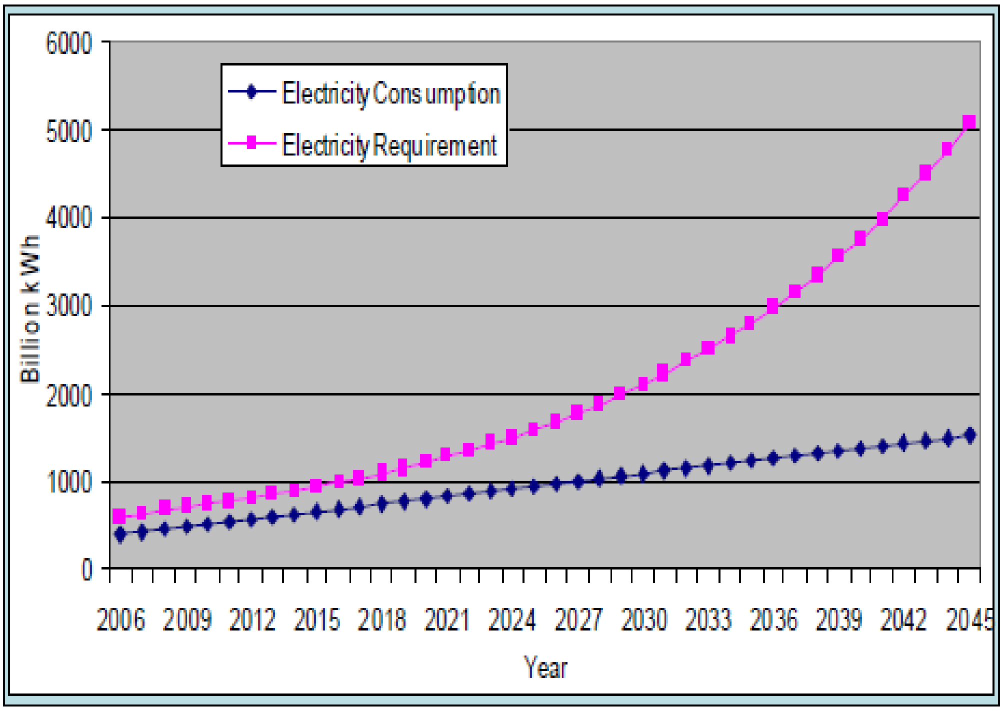
Year	**Billion Kwhr Total Energy Requirement**		**Projected Peak Demand (GW)**		**Installed Capacity Required (GW)**	
	GDP Growth rate		**GDP Growth Rate**		**GDP Growth Rate**	
	8%	9%	8%	9%	8%	9%
2003-04	633	633	89	89	131	131
2006-07	761	774	107	109	153	155
2011-12	1097	1167	158	168	220	233
2016-17	1524	1687	226	250	306	337
2021-22	2118	2438	323	372	425	488
2026-27	2866	3423	437	522	575	685
2031-32	3880	4806	592	733	778	960

Source: Integrated Energy Policy, Planning commission of India, 2006

India dependence on the fossil fuels for its energy requirements also contributes significantly to greenhouse gases emissions. Moreover, India has been experiencing huge power deficits for the past many years as the demand for electricity has always outstripped its supply. Dearth of electricity supply in India, in recent years, is becoming a major stumbling block to its industrial growth and also its economic progress. The power-generating capacity in India, at present, is not enough to meet the demand either now or in the future (Figure 4.2). In 2010–2011, India experienced a generation deficit of approximately 200 billion units of electricity. The gap between the electricity consumption (supply) and electricity requirement (demand) is likely to grow exponentially in the coming years to go up to 2000 billion units of power by 2030 with the availability of electricity around 1000 billion units (Figure 4.1) (CEA, 2010), thereby derailing the plans for significant economy growth.

With power shortages and electricity undersupply likely aggravate in the foreseeable future and with conventional fossil fuel based generations straining the exchequer, it is apparent that India needs to find additional sources of power generation to bridge this gap.

Figure 4.1- Demand and supply forecasts of power in India



Source: CEA, 2010

Increasing the contribution of renewable energy sources in the electricity generation mix will help India mitigate some of the challenges mentioned above apart from enhancing the energy security, diversifying the risks, reduce CO2 emissions and improving the overall quality of life for its citizens. India is attempting to leverage every source of renewable energy it has access to, including Onshore wind, Solar, Bio-mass, Small hydro; except offshore wind energy. Hence there is a huge, latent demand for electricity in India and offshore wind energy can step up to partially fill the deficit in power generation

4.2.2 Technical Analysis

There are four broad aspects that need to be addressed while setting up an offshore wind farm. They are

1. Accurate prediction of and availability of data on wind speeds
2. Availability of Offshore Wind Turbine Technology
3. Foundation Engineering
4. Building Evacuation infrastructure (sub-sea cabling to shore and also cabling between turbines)

Wind Speeds

India needs to build bankable data on wind speeds at the seas to predict the exact potential of offshore wind energy. Wind speeds are very critical to estimate the power output of the offshore wind farms which decides the cash flows and hence the viability of the project. As the power output varies directly to the cube of the wind speeds (as shown in figure 4.2), even a minor variation in estimating the wind speeds may results in huge deviation in the power output for the offshore wind farms.

Figure 4.2 – Relationship between power output and wind speeds

$P = ½ * \rho * A * V^3$ Where

P = Power output

ρ = Air density in kg/m^3

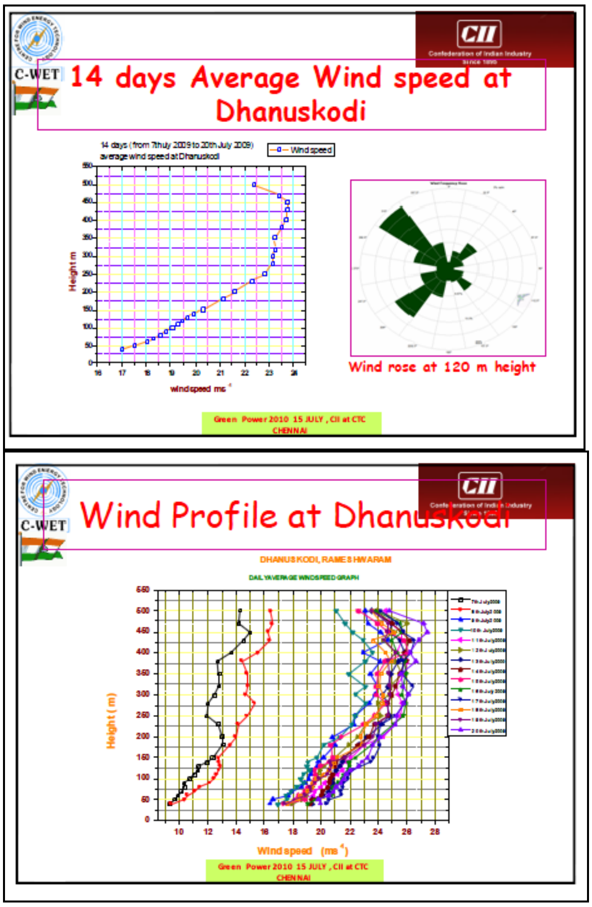
A = Area swept by Rotor in m^2

V = Wind speed in m/s

Hence Power output = ½ * air density * Area Swept by Rotor * Wind $Speed^3$

For instance, if the actual wind speeds at the site are higher by just 2m/s from the original estimation, the power output of the wind farm goes up by a factor of 8 (23) which will completely change the return on investments. Today there are several agencies involved in predicting the mean wind speeds for offshore wind farms in India. Currently, detailed analysis has been carried out by the ministry (CWET Chennai, INCOIS Hyderabad and MNRE) to get the offshore wind energy potential in India. GIS data and observation mast (post) data obtained from CWET study (Fig 4.3) shows significant offshore wind potential in the coast near Dhanaskodi, TN and in Kutch, Gujarat.

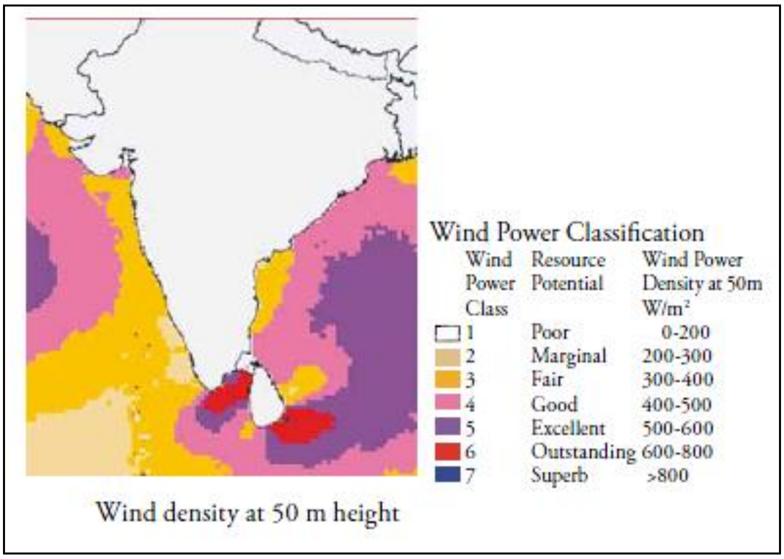
Figure 4.3 - Wind profile in Dhanuskodi, Tamil Nadu



Source: CWET, 2010

A study conducted for MNRE (Fig 4.4) shows good to outstanding wind speeds around the southern peninsula near Dhanashkodi, Tamil Nadu.

Figure 4.4 – Offshore wind potential zones in India

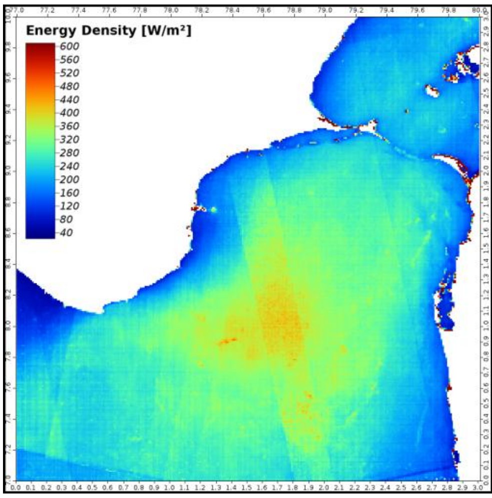


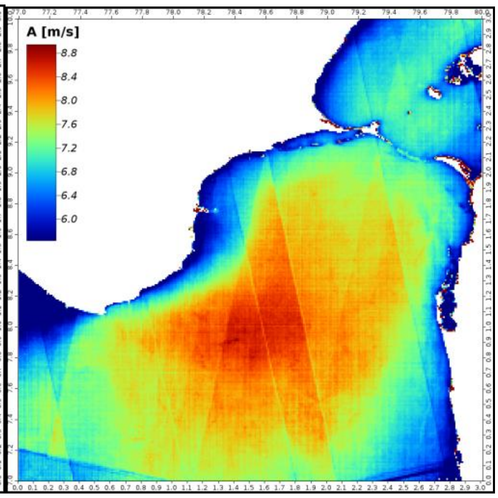
Source: MNRE, 2010

Figure 4.5 shows the wind power density (or wind energy density) calculated based on the 164 ENVISAT ASAR wind maps. The areas near peninsular India have WPDs (Wind Power Density) of around 200 W/m2, while higher WPD values up to more than 500 W/m2 are found further into the seas,.

Figure 4.5- Offshore wind power density observed in India

Figure 4.6 - Weibull (A) observed in offshore wind zones in India



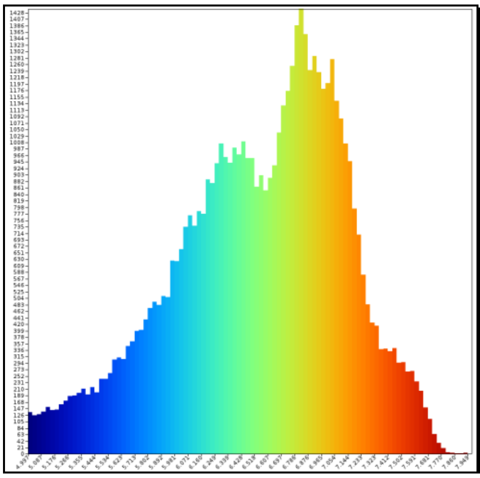


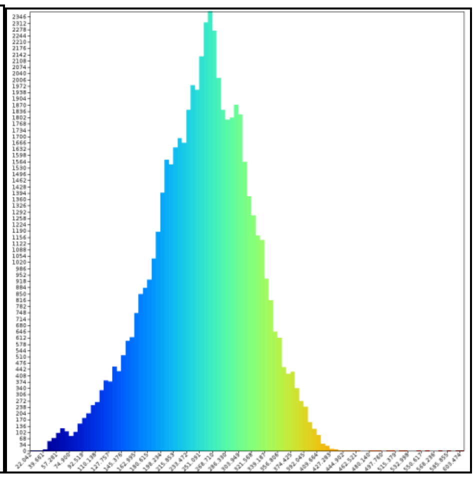
Source: RISO, 2012

The Weibull statistics scale shown in Figure 4.6 varies between 6 m/s and 8 m/s depending on whether the site measured is nearer to the coast or far into the sea. The mean wind speed and energy density are shown as histograms in Figure 4.7 and Figure 4.8, respectively. It is seen in Figure 4.8 there are two peaks, at 6 m/s and at 6.8 m/s wind speeds. These wind speeds also could point to measurement done at different seasons. Similarly, two peaks are witnessed for the wind energy density has two peaks at 260 W/m2 and at 300 W/m2. Generally, during the winter monsoon the winds blow from the northeast and during the summer monsoon the winds blow from the southeast.

Figure 4.7- Histogram of wind speed for offshore zones in India

Figure 4.8 - Histogram of wind energy density for offshore zones in India

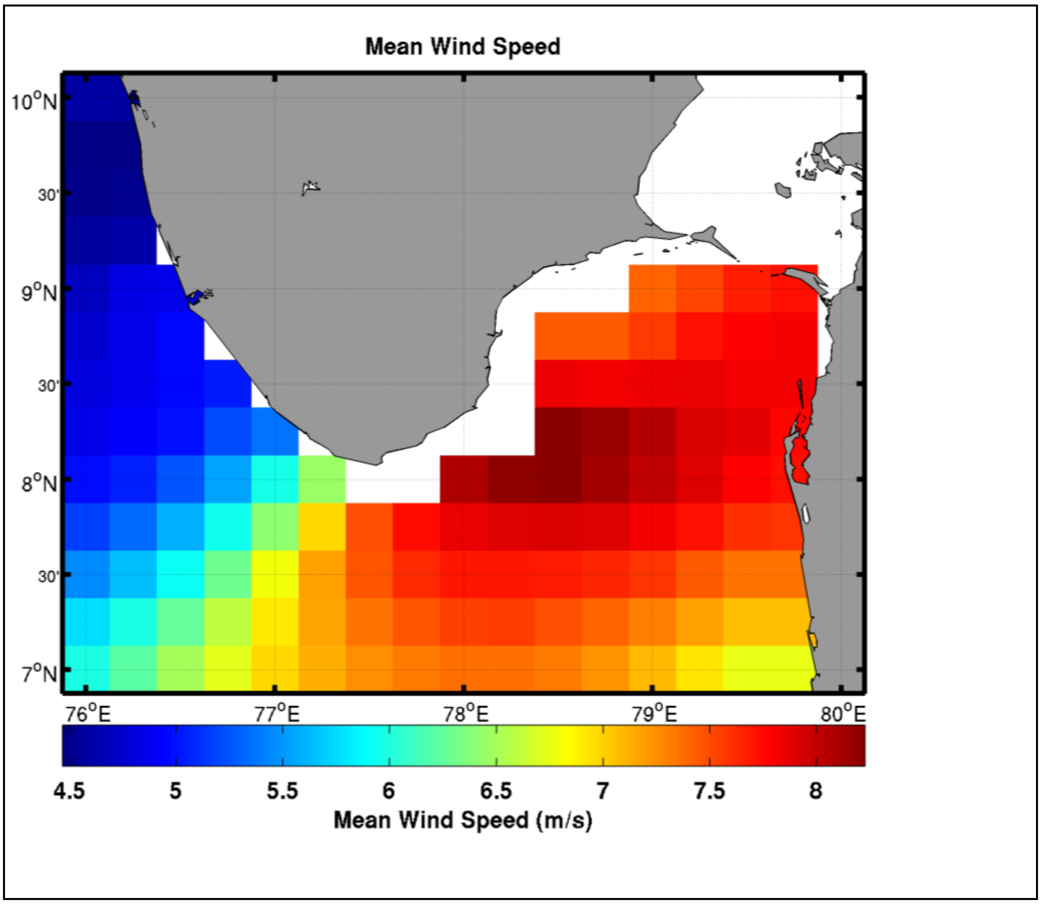




Source: RISO, 2012

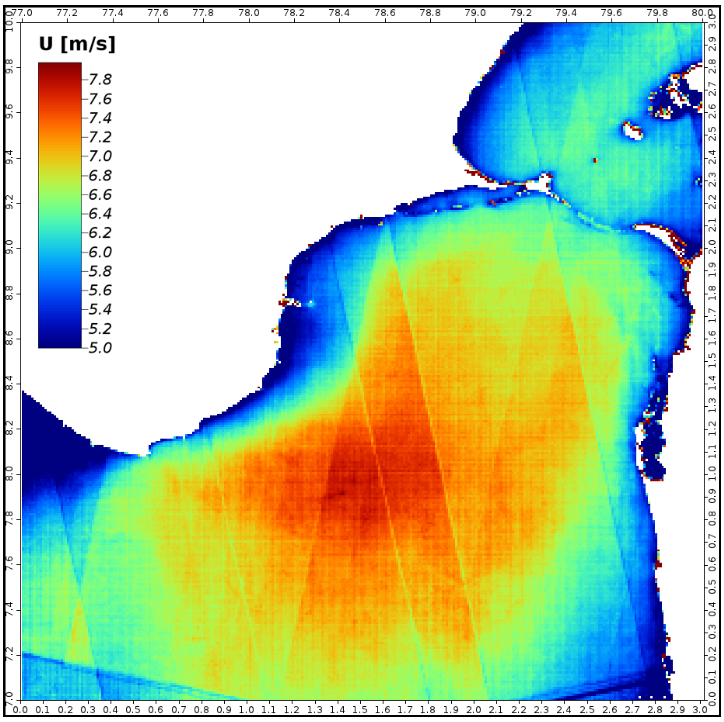
The 10-year (1999 -2009) historical wind map of the southern coast of India from Remote Sensing Systems (RSS) has been used by RISO to study the mean wind speeds (Figure 4.9 & 4.10). The QuikSCAT scatterometer on SeaWinds satellite of (NASA) was used during these 10 years to obtain the data which was analysed by RISO, Denmark. The data obtained again corroborated that the mean wind speed near the coast is around 5 m/s although up to a little less than 8 m/s was found further into the seas giving a WPD of about 200 to 500 W/m2 for a height of 10 m MSL. Using the data obtained 5 potential sites, 2 situated in the northern part and 2 in the southern part along the coast, were identified. The fifth is far into the sea and is more of a challenge to harness due to distance and lack of evacuation infrastructure. For four locations (Figure 4.11) identified, wind roses and monthly mean wind speed are extracted and 10-year averages for the wind speeds and wind direction were also obtained. These data were used to predict that the southern peninsular India has harnessable offshore wind energy potential which needs closer site investigations to arrive at a probable figure that is bankable

Figure 4.9 - Mean wind speed and wind direction of offshore winds in Southern Peninsular India



Source: RISO, 2012

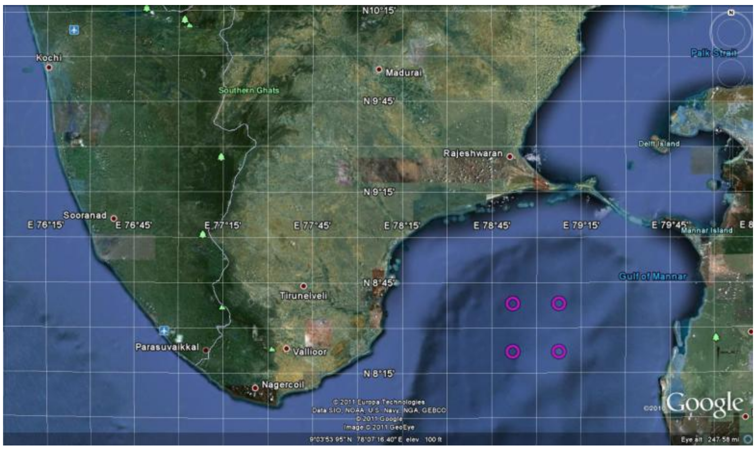
Figure 4.10 - Mean wind speed offshore wind in South India



Source: RISO, 2012

Sites 1 and 2 in the north and sites 3 and 4 in the south that are located near the coastline have good wind speeds that can be harnessed (Figure 4.12). Strong winds are also seen in the site marked 5 that is further into the sea. Due to challenges of transmission infrastructure site 5 may be taken up for consideration during phase -2 of offshore wind farm roll-out.

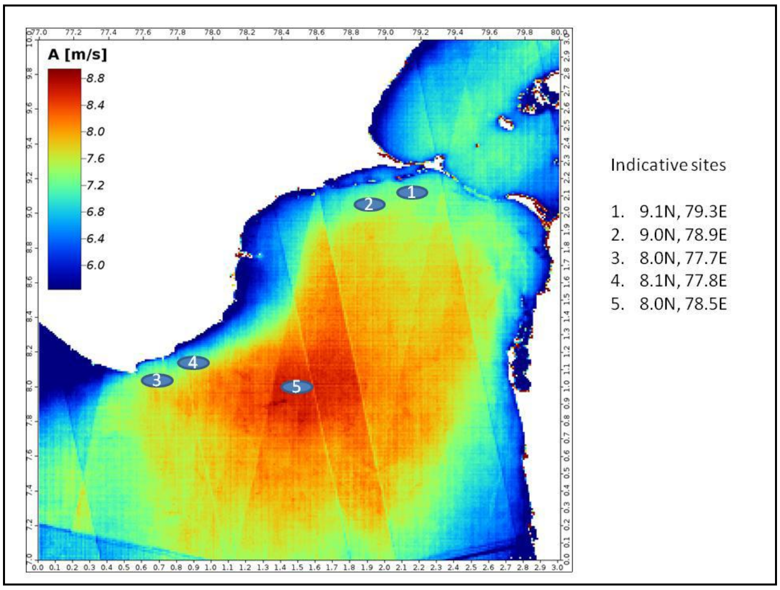
Figure 4.11 - 4 locations with good offshore wind energy potential in India



Source: RISO, 2012

The key observation is that these wind speeds are extracted for 10 m height. The offshore wind turbine heights will usually range upwards of 80 m and now closer to 120 m (especially offshore wind turbines of 7 MW capacities are becoming available in the world). Hence the wind speeds obtained for 10 m height needs to be extrapolated to the level of hub height to get the harnessable wind speeds. As we know that wind speed increases exponentially with height and the power extracted vary proportionately to the cube of wind speed. Thus, it is important to corroborate and validate the satellite data (obtained at 10m height) at the hub height of 80 m to calculate energy that could be extracted from these sites.

Figure 4.12 - Good potential sites for offshore wind park locations in India



Source: RISO, 2012

The findings of this study are that the winds observed by satellite compare well to the ground level data available. Wind speed and direction during year also corroborates the findings. The winds are predominantly from the southwest and the northeast directions. The mean wind speed near the coast is around 5 m/s going up to 7.5 m/s into the sea, indicating excellent wind resources availability of up to 500 W/m2 at 10 m height indicating a much bigger potential available at the hub height of 80 to 120 m. Immediately Five potential areas for setting up offshore wind farms have been identified and four of these can be taken up for the phase 1 of installations. The fifth is further offshore and may be taken up for subsequent phases as difficultly of evacuating power exist in this zone.

Similar conclusions on excellent offshore wind energy potential have been reached by a few more studies (Xi Lu et al. Hossain et al. and by Lawrence Berkeley National Laboratory) that have corroborated the findings of the studies conducted by the ministry. These studies are not official data of the Indian Government (and hence not bankable data for project loan sanctions) but can be used as a guide for policy analysis and framework. Incidentally, Lawrence Berkeley National Laboratory (Table-4.2) have done similar studies for the US and China geographies, which have been adopted by policy makers in the respective countries for framing their policies. According to Xi Lu et al, the potential of offshore wind energy in India is 502 GW. To put that in perspective, the current electricity generation in India, in 2012, is less than 220GW. So theoretically speaking, offshore wind energy, if harnessed to its potential, can drive all of energy needs of India.

As per the study done by Lawrence Berkeley National Laboratory, US, offshore developable potential in India is about 214,304 MW. This potential can be much more with the advent and use of better technologies. However, such prediction of high resource potential needs to be corroborated through field studies carried out in the actual site considering other factors.

Table 4.2: Potential of offshore wind energy in India

Country	Onshore (GW)	Offshore (GW)	Onshore (TWh)	Offshore (TWh)
Russia	54,794	10,502	120,000	23,000
Canada	35,616	9,589	78,000	21,000
US	33,789	6,392	74,000	14,000
China	17,808	2,100	39,000	4,600
UK	2,009	2,831	4,400	6,200
Germany	1,461	429	3,200	940
India	**1,324**	**502**	**2,900**	**1,100**
Japan	260	1,232	570	2,700
South Korea	59	452	130	990
Italy	114	73	250	160

Source: Lawrence Berkeley Labs, 2012

The outcomes of various potential assessment studies, even though gives very different figures for the overall potential, underline the fact that offshore wind energy potential is not a constraint to grow the sector in India. Finally, a study conducted by Ernst & Young Renewable Energy Country Attractiveness Indices (Table – 4.3) ranks India in the top 5 most attractive country worldwide in terms of offshore wind energy potential.

Table 4.3: E&Y country attractiveness indices for offshore wind energy

Country	All	Onshore	Offshore	Solar PV	Solar CSP	Biomass
China	71	79	69	67	40	58
USA	66	70	56	70	75	61
Germany	63	63	73	65	22	63
India	**63**	**71**	**42**	**68**	**63**	**58**
Italy	61	65	53	67	59	56

Source: E&Y, 2010

Also, INCOIS (Minsistry of Earth Sciences, Govt of India) has identified the locations with high wind speeds along the Indian coast by observing wind speed data for a period of 10 years using the satellite made available by NASA, USA. INCOIS has concluded that strong winds with speeds between 6m/s and 10 m/s were observed in several areas into the seas. The associated wind power density were mapped based on the daily winds derived from a satellite based scatterometer namely, QuikSCAT (of National Aeronautics and Space Administration, USA) also showed excellent Wind power density potential. These maps can be used to identify areas of high potential for setting up offshore wind energy farms in India.

To sum up, market availability and potential for offshore wind energy in India has been established by several sources. Based on these estimates, the actual harvestable potential of offshore wind energy in India varies between 200,000 MW and 500,000 MW based on several reports. Lawrence Berkeley labs with MNRE, CWET with SDI Scotland and INCOIS are involved in estimating the exact potential of offshore wind energy in India by mapping the satellite data on wind speeds. Several private consultants are also engaged in this exercise. Given that the project viability depends largely on the accurate prediction of mean wind speeds, India needs to pool in all the resources at its command to accurately predict the mean wind speeds in the seas.

Offshore Wind Turbine Technology

Wind turbine for offshore is very similar to onshore wind turbine in terms of components but are built to endure severe climate in the sea. High wind speeds combined with ocean waves create huge stress on the turbine blades. The availability of world class wind turbines is very important for the growth of sector. Most of the global offshore wind turbine manufacturing majors (Table 4.4) like Vestas, GE, Gamesa, Goldwind, Sinovel and Suzlon, who have successfully installed offshore wind farms in the world, have presence in India. Hence access to proven offshore wind turbines is not a problem in India.

Table 4.4 - Commercial Offshore Wind Turbines

Turbine Manufacturer	**Turbine model and rated power (in MW)**	**Date Available**	**Offshore operating status**
Siemens	SWT – 2.3	2003	Available
Vestas	V90 – 3.0	2004	Available
Siemens	SWT – 3.6	2005	Available
RE Power	5 M – 5.0	2005	Available
Multibrid	M5000 – 5.0	2005	Available
Sinovel	SL 3000 – 3.0	2009	Available
BARD	BARD – 5.0	2010	Available
General Electric	GE 4.0 – 4.0	2012	Commercial sales announced

Source: NREL, 2009

But most of these turbines will have to be imported initially, till such time offshore wind energy takes off in India and world turbine manufacturers sets up local facilities for production of these turbines. Once critical mass of offshore wind farms are reached many of the components used in the wind turbine, and subsequently the turbine itself, can be manufactured in India. Hence availability of offshore wind turbine creates no major challenge for the growth of offshore wind farms in India.

Foundation Engineering

There are three basic options for the foundation design of offshore wind farms globally, depending on water depth. They are (as shown in Figure 4.13 and Figure 4.14)

Concrete gravity based foundations: These rely on gravity to keep the turbine in an erect position. Most existing offshore wind farms in Europe use gravity foundations.

Monopile foundations: These are single steel pile with a diameter of approx. 3 m. Monopiles are commonly used when not much of seabed preparation is required.

Tubular framed structure foundations: Tubular structures are suitable for water depths that are greater than 20 mts. These are three or four-legged steel jackets as shown in figure 4.14.

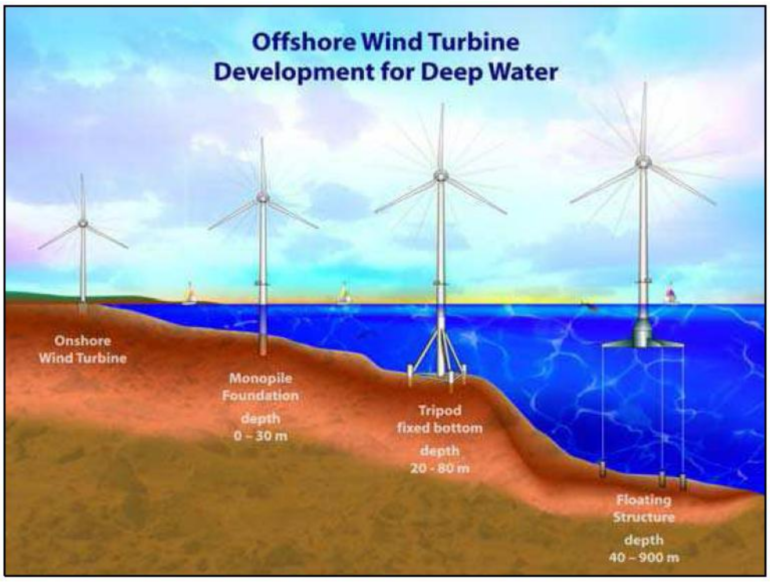
Figure 4.13- Examples of foundation designs

	Monopile	Concrete Gravity Base	Tripod	Tri-pile	Jacket	Floating
Design	0-30m	0-40m	0-40m	0-50m	0-50m	>60m
Examples	Greater Gabard (UK) Egmond ann Zee (NL)	Nysted (DK) Thornton Bank (BEL)	Borkum West (DE)	Bard Offshore 1 (DE)	Beatrice (UK)	None Although used in oil & gas
Pros	• Simple design • Extended offshore tower	• Cheap • No drilling required	• More stability than basic monopile	• Can be installed by traditional jack-up barge • Piles can be built at any dock or steel mill	• Stability • Relatively light	• Allows deep water use • Uses less steel
Cons	• Diameter increases significantly with depth • Drilling difficulties	• Seabed preparation required	• More complex installation	• Cost	• Cost	• Cost

Used in increasing water depths

Source: Delft University of Technology, 2010

Figure 4.14 – Examples of Offshore wind foundations at different depths



Source: NREL, 2009

There are several large EPC contractors available in India who are adept at foundation engineering by virtue of having executed large oil and gas installations in offshore. Their expertise can be tapped to build foundations for offshore wind farms. Availability of technical expertise and relatively inexpensive manpower ensures a trouble free, cost effective foundation construction for offshore wind farms in India.

<u>Building evacuation infrastructure</u>

Cables need to be installed both between the turbines and to the substation in the coast. There are a several methods used for installation of cables considering factors like nature of the seabed, other cables/pipelines in the vicinity and the overall ecological sensitivity of the area. Techniques like jetting/ploughing the cables into position or trenching are used for cable setting in the seas depending on the needs of the topography of the seabed.

Serious thought needs to be given for the protection measures that shall be adopted for the safety of the cables, pipelines that cross, existing subsea infrastructure, marine channels etc. and agreements need to be reached with third party owners.

However, cable installation in sub-sea environment does not pose any technical challenge as Indian engineers have, for many years, laid cables for their software communication in sub-sea strata. India's booming software industry benefitted hugely by the expertise of communication infrastructure contracts undertaken in the sea which connects India to the rest of the world. While power cables are different from communication cables but the functionality of engineering is by and large the same.

Technically, there are no major challenges likely to be faced for growth of offshore wind energy in India. Nevertheless, site specific challenges, those are operational in nature, are likely to be encountered. These will certainly not be 'show-stoppers' for the growth of offshore wind in India

4.2.3 Financial Analysis

For offshore wind farms to be established, three components cost the most (the wind turbine, foundations costs and grid connection costs). There are literatures available that details the cost incurred for a specific offshore wind farm project in Europe. However, broad pointers of the break-up of a typical offshore wind project and the comparison with an onshore wind farm is shown below in Table 4.5

Table 4.5: Cost estimates for onshore and offshore wind farms

Item	**Onshore – Share of total investments costs (%)**	**Offshore – Share of total investments costs (%)**
Turbine	74-82	30-50
Foundation	1-6	15-25
Installation	1-9	10-30
Grid Connection	2-9	15-30
Consultancy	1-3	
Land	1-3	
Road construction	1-5	
Others	1-5	8
Total	**INR 6 Crs./MW**	**INR 12 Crs./MW**

Source: Adapted from EEA, 2009

The actual costs incurred for the installation and commissioning of two offshore wind farms (Horns Rev and Nysted) in Denmark, given in table 4.6, corroborates with the findings in Table 4.5.

Table 4.6: Details of investments per MW in Horns Rev and Nysted (Denmark) – Actual costs

Item	**Investments per MW for Offshore in Euros**	**Investments in INR**	**Share (%) of overall costs**
Turbines, including transport and erection	815,000	Rs 550 Lakhs	49
Transformer station and main cable to coast	270,000	Rs 180 Lakhs	16
Internal grid between turbines	85,000	Rs 57 Lakhs	5
Foundations	350,000	Rs 230 Lakhs	21
Design and Project Management	100,000	Rs 67 Lakhs	6
Environmental Analysis	50,000	Rs 33.5 Lakhs	3
Miscellaneous	10,000	Rs 6.7 Lakhs	< 1
Total	€1,680,000	**~ Rs 1125 Lakhs**	100

Source: Adapted from EEA, 2009

1 Euro = INR 70 (Indian Rupees)

However, these costs (Table 4.5) are expected to reduce in the years to come as critical mass of offshore wind farms will be reached. Turbines costs are expected to fall, apart from the costs of foundations and grid connections, thanks to the experiences gained from previous installations. Junginger (2005) has estimated overall cost reductions for the year 2020 based on projected costs of different parts of the wind farm (e.g. foundation, grid connection, cable, installation) and concludes that the cost of electricity from offshore wind farms could be reduced by almost 40% by 2020. Assuming average turnkey costs of Rs 120,000/kW at present, this results in Rs 72,000/kW by 2020 (in 2012 Rupee terms). For the period to 2030, a conservative estimate of 1 % cost reduction per year is used, resulting in turnkey costs of about Rs 65,000/kW (in 2012 prices as per Junginger (2005)).

Costs of offshore wind farms tend to increase with the distance to the coast and with the water depth increases. EEA has given the likely increase to the cost of offshore wind farms as the distance to the coast (in Kms) increases as shown in Table – 4.7

Table 4.7- Offshore wind project cost escalation due to distance to coast

Item	**Distance to coast (Kms)**							
	0-10	**10-20**	**20-30**	**30-40**	**40-50**	**50-100**	**100-200**	**>200**
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	70	81	82	84	85	87	88	89

Total Costs €/KW	1800	1839	1878	1918	1956	2131	2534	2878
Total Costs Rs/MW	12 Cr	12.3 Cr	12.4 Cr	12.8 Cr	13.1 Cr	14.2 Cr	17 Cr	19.2 Cr
Scale Factor	1	1.022	1.043	1.065	1.086	1.183	1.408	1.598

Source: Adapted from EEA, 2009

Similarly, the costs of offshore wind farms tend to increase as the depth of the water (in mts) increase as shown in Table – 4.8

Table 4.8- Offshore wind project cost escalation due to water depth

Item	**Water Depth (M)**			
	10-20	**20-30**	**30-40**	**40-50**
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 Costs (€/KW)	1800	1920	2227	2514
Total Costs (Rs/MW)	12 Cr	12.8 Cr	15 Cr	16.8 Cr
Scale factor	1	1.067	1.237	1.396

Source: Adapted from EEA, 2009

Table 4.9 gives the scaling factor combining the impact of both the distance to the coast (given in Kms) and the water depth (in mts). Hence, if an offshore wind farms is to be situated at 10-20 Kms from the coast with a water depth of 20-30 mts then the overall costs of the offshore wind farm goes up by a factor of 1.090 compared to the costs of the offshore wind farms established on the coast. Based on the combination of scaling costs for distance to shore and the depth the current offshore (Table -4.8) investment costs can vary between Rs 120,000–270,000/kW. They can further decrease to Rs 60,000–150,000/kW by 2030 (EEA, 2009).

Table 4.9- Cost escalations due to both water depth and distance to coast (factor multiplier)

Depth (M)	**Distance to the coast (Kms)**							
	0-10	**10-20**	**20-30**	**30-40**	**40-50**	**50-100**	**100-200**	**>200**
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, 2009

Operations and Maintenance (O&M) costs for offshore wind farms are about 2–4.4 % of the overall investment costs (Junginger, 2005). EWEA reports based on experiences in several European countries, that O&M costs are, estimated to be approximately Rs 1/kWh of produced wind power over the total lifetime of a wind farm. O&M costs are around 2–3 % of total investment costs in the early years of the farm and around 5 % towards the later part of the project life (EWEA, 2009). Discussions with leading project developers in India and with CWET have shown that the cost to set up 1 MW of offshore wind farm will be around Indian Rs 15 Crores (CWET, 2010). Offshore wind farms are expected to have Plant load factor (PLF) of 35 – 40% due to higher wind speeds in the sea, as observed in farms in the Europe. NPV (Table 4.10) and IRR (Table 4.11) for setting up a 1 MW offshore wind farm in India are shown below.

<u>Sample cash flow calculations</u>

The cash flows are calculated as follows.

Net Cash flow for any Year = Cash inflow for the year – Cash outflow for the year = Total units generated * (price/unit – O&M Cost) =MW x 1000 (KW) x 365(days) x 24 (hours/day) x PLF x [Price of Electricity (Rs/KWhr) - O&M cost/unit]

Cash flow for Year 1 = 1 MW x 1000 x 365 x 24 x 0.35 x [Rs 11/unit – Re1/unit] = Rs 30,66,0000

Table 4.10 - NPV calculation for 1 MW offshore wind farm

Net Present Value (NPV)						
						NPV
Capex	**-150,000,000**	**Year**	**PLF**	**Discount Rate @**	11%	Rs. 91,222,939.79
Cash Flows Y1	30660000	1	35%		12%	Rs. 76,430,327.78
	35040000	2	40%		13%	Rs. 63,111,653.15
	35040000	3	40%		14%	Rs. 51,083,446.32
	24528000	4	28%		15%	Rs. 40,188,369.69
	28032000	5	32%		16%	Rs. 30,291,124.08
	26280000	6	30%		17%	Rs. 21,275,045.23
	26280000	7	30%		18%	Rs. 13,039,267.07
	30660000	8	35%		**19%**	**Rs. 5,496,351.23**
	30660000	9	35%		20%	Rs. -1,429,698.70
	33288000	10	38%		21%	Rs. -7,805,104.73
	30660000	11	35%		22%	Rs. -13,687,718.27
	33288000	12	38%		23%	Rs. -19,128,204.66
	33288000	13	38%			
	30660000	14	35%			
	30660000	15	35%			
	24528000	16	28%			
	24528000	17	28%			
	28032000	18	32%			
	35040000	19	40%			
Cash Flows Y 20	30660000	20	35%			

Note:
1. At 19% discount rate the NPV is +ve.
2. Plant load factor (PLF) varies during the life of the project.
3. The economic life of an offshore wind farm is assumed to be 20 years.
4. The calculation shown is for 1 MW project @ Rs 15 Crores per MW and net tariff @ Rs10/unit [Rs11/unit – Re 1/unit O&M Charges]

The cost of the wind farm is taken as Rs15 Crores per MW (CWET, 2010) as per published data. PLF between 28% and 40% is assumed over a period of 20 years (the economic life of an offshore wind farm). The electricity generated is assumed to be sold at Rs 11/unit (cost of solar during round- I bidding was Rs 11/kwhr and the same benchmark is taken for offshore wind energy farms for modelling and scenario building purpose). At 19% cost of capital, NPV is positive (which is easily achievable) and the IRR is approx. 19.8%, again very attractive.

Table 4.11 - IRR Calculation for 1 MW offshore wind farm

IRR Calculation			
Capital Expenditure	**-150,000,000**		
Cash Flows Y1	30660000	**PLF @ Y 1**	35%
Y2	35040000	Y2	40%
Y3	35040000	Y3	40%
Y4	24528000	Y4	28%
Y5	28032000	Y5	32%
Y6	26280000	Y6	30%
Y7	26280000	Y7	30%
Y8	30660000	Y8	35%
Y9	30660000	Y9	35%
Y10	33288000	Y10	38%
Y11	30660000	Y11	35%
Y12	33288000	Y12	38%
Y13	33288000	Y13	38%
Y14	30660000	Y14	35%
Y15	30660000	Y15	35%
Y16	24528000	Y16	28%
Y17	24528000	Y17	28%
Y18	28032000	Y18	32%
Y19	35040000	Y19	40%
Y20	30660000	Y20	35%
	IRR	**19.787%**	

The break-even tariffs at different level of investments are shown in Table 4.12 below. It can be seen that at Rs 6.62/unit of power, break even is achieved for Rs 15 Crore/MW investments. Break-even tariff of Rs 6.62/unit is very close to the cost of electricity generated from plants using fossil fuel. The cost of fossil fuels is bound to increase due to higher fuels costs. As seen from the NPV, IRR and BEP calculations, offshore wind energy, can achieve parity with the cost of electricity generated from fossil fuels and is a viable proposition.

Table 4.12 - Break-even tariff calculation for 1 MW offshore wind farm

		Discount Rate	**k=**	**12%**			
Years	**PLF**	**Kwhr**		**PVIF**	**Cash Flows**	**Capex /MW**	**BEP Tariff**
1	35	3066000		0.892857143	2737500	200000000	8.83
2	40	3504000		0.797193878	2793367.347	190000000	8.39
3	40	3504000		0.711780248	2494077.988	180000000	7.95
4	28	2452800		0.635518078	1558798.743	170000000	7.51
5	32	2803200		0.567426856	1590610.962	160000000	7.07
6	30	2628000		0.506631121	1331426.586	**150000000**	**6.62**
7	30	2628000		0.452349215	1188773.738	140000000	6.18
8	35	3066000		0.403883228	1238305.977	130000000	5.74
9	35	3066000		0.360610025	1105630.337	120000000	5.30
10	38	3328800		0.321973237	1071784.51	110000000	4.86
11	35	3066000		0.287476104	881401.7352	100000000	4.42
12	38	3328800		0.256675093	854420.0494		
13	38	3328800		0.22917419	762875.0441		
14	35	3066000		0.204619813	627364.3455		
15	35	3066000		0.182696261	560146.737		
16	28	2452800		0.163121662	400104.8122		
17	28	2452800		0.145644341	357236.4394		
18	32	2803200		0.13003959	364526.979		
19	40	3504000		0.116106777	406838.1462		
20	35	3066000		0.103666765	317842.3017		
				Total Cash Flows	**22643032.78**		

4.2.4 Economic Analysis or Social Cost Benefit Analysis

Energy Security and Foreign Exchange savings

India's present power generation is almost entirely dependent on fossil fuels (coal and oil) which pose a threat towards achieving energy security as India imports over 60% of its oil and around 100 Million tonnes of coal per annum. India's coal production capacity during 2010/11 was 600 Million metric tonnes, and import was 100 Million metric tonnes (Ministry of Power, 2011). The total import bill of fossil fuels to power Indian thermal plants was over $125 Billion (Ministry of Power, 2011). The continued reliance on fossil fuels will completely drain India's foreign exchange reserves. Hence, higher energy penetration in the electricity mix from offshore wind farms and other renewable will ensure a secure energy system. Wind as a fuel is available free of cost. Also, unlike fossil fuels, there are no transportation or storage costs associated with wind energy. After payback of the initial capital investments, these wind energy projects will have very low running costs and have the potential to supply electricity at competitive rates on a long-term basis without endangering the country's foreign exchange reserves.

Employment generation (Green Jobs) and Development of local community:

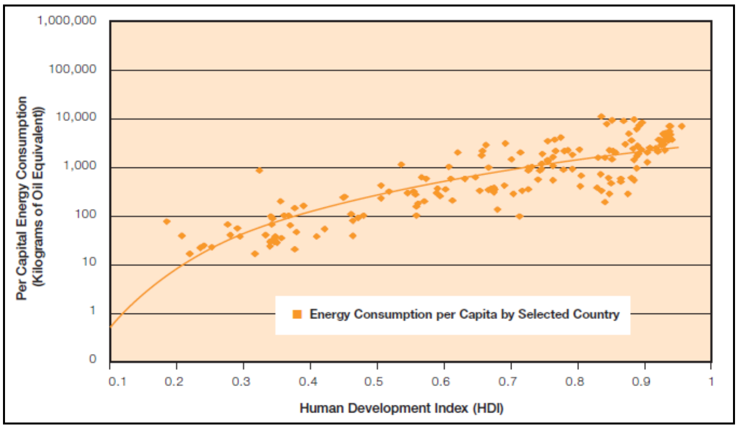
Renewable technologies, more so offshore wind energy projects, are labour intensive and generate much higher employment compared to conventional power generation technologies. The thumb rule is that renewable can generate an average of 20 jobs per MW (CWET, 2011), including both direct and indirect jobs. Almost 1 million jobs can be created through offshore wind farms in the next few years – assuming a target of 50,000 MW of power generation from offshore wind farms. These offshore wind energy projects help in creating infrastructure and developing community facilities, besides creating direct and indirect jobs in rural areas along the coast, which would be the nearest shore to the offshore wind parks. This leads to investment flow to the hitherto underdeveloped areas along the coast as companies set up their ancillary units and manufacturing plants at the coastal areas near the actual site (WISE, 2011).

Energy access and human development

There is a critical link between energy and economic activity; and low levels of energy consumption have a negative bearing on the quality of life of the people and also on other drivers of livelihood. There is a strong correlation between higher commercial energy consumption and UNDP's Human Development Index which is a composite index that reflects higher life expectancy, educational achievements and improved quality of living as shown in (Figure 4.15).

There is a direct linear relationship between energy and development of the people in the country that the population living below the poverty line in developing countries reduces as one moves from a low level of electrification to higher levels (Srivastava & Rehman, 2005)

Figure 4.15– Correlation between Energy Consumption and Human Development



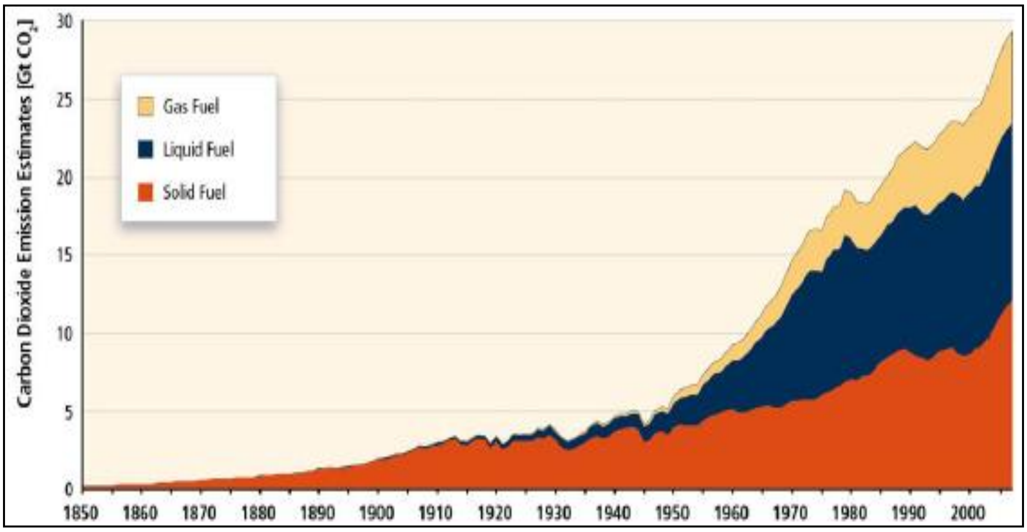
Source – UNDP, 2009

4.2.5 Ecological Analysis

Climate Mitigation

India is targeting an emissions reduction of 20%–25% by 2020 on 2005 levels. Various studies show that India's per capita emissions will be around 2.5 tonnes of CO2e by 2020 and around 3.5 tonnes of CO2e by 2030 (IPCC, 2011). Concentration of CO2 in the atmosphere is increasing mainly due to the consumption of fossil fuels (as shown in the figure 4.16 and 4.17) The Intergovernmental Panel on Climate Change (IPCC) has recommended that steps be taken to stabilize CO2 at 550 ppm (parts per million) by 2050. If India ignores environmental concerns to chase higher economy growth, not only it affects the economic progress but also would pose challenges to the health of the population (Pode, 2010). Currently, India's emissions are around 1 ton of CO2 per person per year (MoEF, 2010). The global per capita average is about 4 tons while developed countries are emitting about 10–20 tons per capita as shown in figure 2.2. Nevertheless, 4 tons per capita emissions over a population of more than a billion people, India is responsible for about 4% to global emissions (MoEF, 2010).

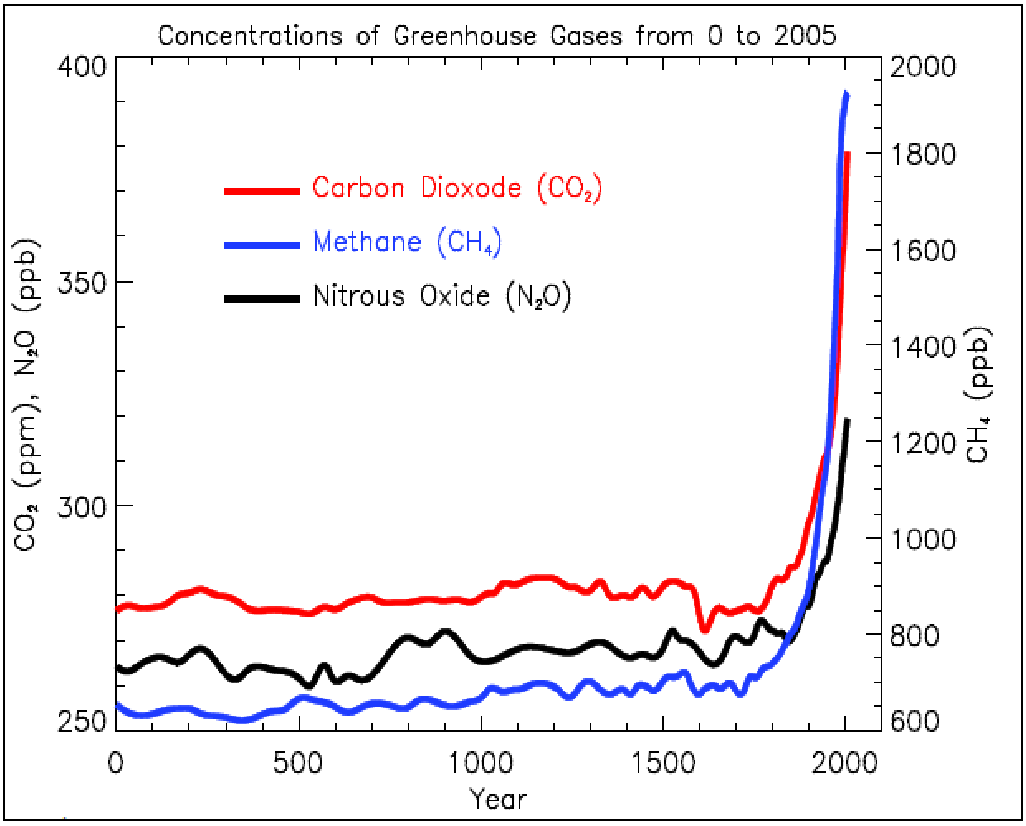
Figure 4.16 - Global CO2 emissions from fossil fuel use for last 150 years



Source: IPCC, 2011

The total Greenhouse gas emissions including CO_2 are shown in figure 4.17.

Figure 4.17 – Greenhouse gases concentration for the last 20 centuries



Source: Solomon et al; 2007.

Hence, holistic efforts are required to achieve the emissions reduction targets. As the power sector is a major source of GHG emissions, adoption of clean/renewable energy by the power sector in a bigger way will help to achieve these targets. Energy-sector GHG emissions accounted for 57% of the total gross GHG emissions in 2007, with 65% of emissions generated from electricity (WISE, 2010). The energy sector GHG emissions are as shown in the Table 4.13. The scenario 1 is where wind is a dominant player in the energy mix for India, scenario 2 is where biomass is the dominant player and scenario 3 is when Solar is a dominant player in the energy mix (WISE, 2010).

Table 4.13 - Energy sector emissions and annual avoided due to Wind energy in India

Sector	**CHG emissions**
Electricity	719.31
Transport	142.04
Residential	137.84
Other energy	100.87
Energy Subtotal	1100.06

Annual Avoided Emissions after 2016/17 (in million tonnes of CO_2)

RE Source	Scenario 1	Scenario 2	Scenario 3
Wind	83.07	60.75	60.75
Biomass	17.76	23.49	18.16
Small Hydro	14.46	18.50	14.68
Bagasse co-gen	19.17	22.96	19.17
Waste to Energy	0.74	0.91	0.91
Solar	6.62	16.56	28.96
Total	**141.82**	**143.16**	**142.64**

Source: WISE, 2010

There are mainly two instruments that are influencing the deployment of clean energy technologies in India. National Action Plant on Climate Change (NAPCC), which recommends that up to 15% of India's energy could come from renewable sources by 2020, is the first instrument. The second instrument is the Clean Development Mechanism (CDM) of the Kyoto Protocol which encourages development of renewable energy projects in India. India has ambitious plans to add 50 GW in the next 5 years from renewable energy sources with wind being the likely leader in the renewable energy mix with planned capacity additions of over 4000 MW per year from the present 2000 MW/year. India has also drawn up plans to enhance solar energy installations, bio-mass plants and small hydro projects as part of the five year plans, which will see substantial investments of several billion dollars in the renewable energy sector in the next few years (MNRE, 2006). The NAPCC has plans to increase renewable energy generation by 1 percent per year, every year (NAPCC, 2006) which may require about 80 GW of additional installation of renewable energy capacity by 2017 (World Bank 2010). The JNNSM (the solar mission) has set a target of adding 20GW of solar capacity by 2022, up from current installed capacity of 1 GW which is most likely to be achieved sooner than 2022 if the current momentum witnessed in round -2 bidding of solar projects is any indication (MNRE, 2011).

Offshore wind energy adoption will decrease the emission levels from the power sector substantially. Fossil fuels generation is the emission of greenhouse gases (GHGs) that are linked to global climate change. A shift of this magnitude in the electricity generation mix (in favour of renewable over the fossil fuels) would facilitate avoidance of approximately 140 million tonnes of CO2 emissions annually from 2017 onwards (WISE, 2010).

Land use

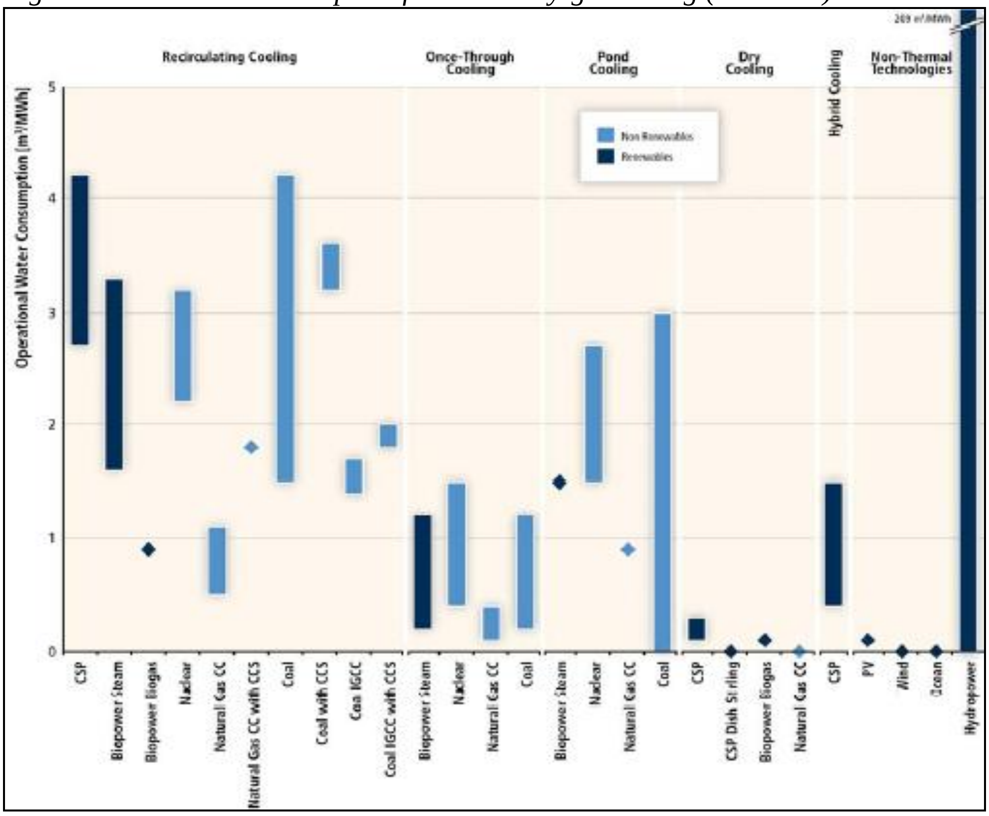
Most energy technologies, more so fossil fuels have substantial land requirements when the entire supply chain is included. Also, land acquisitions for all the infrastructure projects including energy run into long drawn litigation process that have delayed the commissioning of those projects. Also, the gestation period (from concept to commissioning) for fossil fuel plants take several years, compared to 12-18 months for renewable energy projects, and the potential delays due to litigations add to severe cost and time overrun. At the same time, as land is in short supply in India, the costs of contiguous parcels of land for energy projects have gone up multi-fold, thereby adding substantial to the project costs.

Availability of large parcels of contiguous land has become a challenge even in tier-II cities in India. Many a time agricultural, arable land is taken over for energy projects that may in the long run cause food shortages. The limited evidence available suggests that lifecycle land use by fossil energy chains can be comparable and higher than land use by RE sources, when land requirements of the supply chain is also factored in. For instance to set up a fossil fuel plants using Coal, the land requirements for the supply chain activities which includes mining, transportation, storage and logistics, is substantially large (WISE, 2010). When land is in short supply and expensive in India, offshore wind energy will obviate the need for any kind of land acquisition thereby contributing indirectly to the society.

<u>Reduction in Water use</u>

In 2006, the energy and industrial sectors accounted for 45% of freshwater withdrawals in developed countries and 10% of freshwater withdrawals in developing countries (Gleick, 2008). Thermal power plants are one of the largest users of fresh water in India, as the turbines need continuous supply of water for cooling purposes while wind power plants need the least (figure 4.18). India already experiences severe water shortages and plunging ground water tables to cater to the ever growing needs of its population and extra demands for water from thermal plants may precipitate the crisis.

Figure 4.18 - Water consumption for electricity-generating (m3/MWh)



Source: IPCC, 2011

As the energy sector is likely to witness exponential growth to support its growing economy, India would need to find alternative ways of power generation than relying on water guzzling coal thermal plants. Offshore wind energy can step up to fill the gap if right policies are put it place to encourage its growth.

Externalities due to offshore wind farms

Regarding the ecological implications of an offshore wind farm, there are also a few important points that may have a negative impact, which needs to be considered as well:

1. Impact on tourism
2. Impact on fishing activities
3. Proximity and impact to commercial ports
4. Visual impacts
5. Interferences with aviation radars

In terms of disturbing the fragile marine ecosystem, it is important to ascertain the offshore wind farms impact on the areas designated for nature preservation especially the marine ecology and the impact on bats, birds and whales. While it is true that birds hits due to the turbine rotor blades have been reported, they are far and few in-between and the mortality of birds due to offshore wind farms is less than what otherwise happens to these birds due to extensive air pollution and indiscriminate use of pesticides (Greenpeace, 2008). Offshore wind farms are located a few kilometres away from the human settlement and hence the noises generated due the operations of the wind farms are unlikely to affect the population as much as the onshore wind farms. The visual impact is a real challenge if the offshore wind parks are planned closer to the coast. However, the visual impact for the population residing along the coast is minimal if the offshore wind farm is at about 8km further from shore (Dhanju, 2008). Irrespective of some challenges that need to be faced due to installation of offshore wind projects, the positive aspects of an offshore wind farm far outweigh the negative aspects. Offshore wind farms have the least cost of externalities (Table 4.14) compared to other sources of generation of electricity. Not only offshore wind farms allows the reduction of the GHG emission and the dependency on imported fossil fuels but also invigorates the local economy by way of additional job creation.

Table 4.14- External costs (US cents/kWh) due to electricity production based on RE sources and fossil energy @ 90 USD/t CO2

	PV (2000)	PV (2030)	Hydro 300 kW	Wind 1.5 MW Onshore	Wind 2.5 MW Offshore	Geo-thermal	Solar Ther-mal	Lignite η=40%	Lignite Comb.C η=48%	Coal η=43%	Coal Comp.C η=46%	Natural Gas η=58%
Climate change	0.86	0.48	0.11	0.09	0.08	0.33	0.11	9.3	8.0	7.4	6.9	3.4
Health	0.43	0.25	0.075	0.09	0.04	0.15	0.11	0.63	0.35	0.46	0.33	0.21
Eco-systems	green	green	green	green	green	green	green	yellow	yellow	yellow	yellow	yellow
Material damages	0.011	0.008	0.001	0.001	0.001	0.004	0.002	0.019	0.010	0.016	0.01	0.006
Agricultural losses	0.006	0.004	0.001	0.002	0.0005	0.002	0.001	0.013	0.005	0.011	0.006	0.005
Large accidents	green	green	green	green	green	green	green	green	green	green	green	green
Pro-liferation	green	green	green	green	green	green	green	green	green	green	green	green
Energy security	green	green	green	green	green	green	green	green	green	green	green	yellow
Geo-political effects	green	green	green	green	green	green	green	green	green	green	green	yellow
Sum	~1.3	~0.74	~0.19	~0.18	~0.12	~0.49	~0.22	>9.9	>8.4	>7.9	>7.2	>3.6

Notes:
● 'green light': no significant impacts or external costs worth mentioning (Krewitt and Schlomann, 2006)
● 'yellow': impacts will arise that cannot be neglected and that will cause external costs
Comb.C: combined gas turbine and steam cycles; η: efficiency factor

Source: Krewitt and Schlomann (2006)

4.3 Concluding remarks

A feasibility study was conducted to ascertain the viability of offshore wind farms in India. The study covered the market & demand analysis, technical, financial, economic and ecological feasibilities of setting up offshore wind farms and concluded that prima facie offshore wind energy farms are a viable business proposition in India. The NPV (positive at 21% cost of capital) and IRR (returns of almost 22%) calculation showed that offshore wind energy sector holds promise as an alternative avenue of investment in the Energy sector in India. Break-even tariff calculation of Rs 6.62/unit of electricity for the investment of Rs 15 Crores to achieve the break-even point is also attractive as fossil fuel tariffs in some states in India is very close to Rs 6/unit at present. The cost of externalities further increases the cost of use of fossil fuels. The offshore wind energy sector as an investment opportunity is enhanced, when the emission reduction, negligible water and land use for the purpose of power generation and additional employment generation prospects are considered.

Now that the feasibility of offshore wind energy sector in India is established, the next step is to analyse the data collected during the survey, using the SPSS tool and report the key findings of the analysis. Identification of the variables through literature survey, seeking responses on the variables through a questionnaire, feeding the response into the tool for factor analysis and then using the factors as independent variable to predict the growth of offshore wind in India, using a logistic regression technique is the approach adopted in this research work. That part is covered in detail in the next chapter.

5 CHAPTER 5 - MODEL TESTING

5.1 Introduction

This chapter deals with analysis of the data which includes checking the validity of the questionnaire using Cronbach alpha, conducting a factor analysis using the SPSS tool to identify the underlying structure of the data and finally use logistic regression equations to develop a model to predict the odds of growth of offshore wind energy in India.

A questionnaire was designed using the 21 variables that were identified through literature survey and through exploratory research conducted to identify the basic elements or the core components of offshore wind energy policy adopted by countries in Europe. The questionnaire was then administered to wind energy stakeholders in India and 181 valid responses were received. These responses were fed into the SPSS tool for factor analysis wherein all the 21 variables loaded on 5 factors. Logistic regression model needs a set of independent variables (that are categorical or metric) and a dependent variable that is dichotomous to complete the analysis. The 5 factors from factor analysis of the data collected were treated as the independent variables and fed into the logistic regression equation to check whether they predict the growth of offshore wind energy in India (the dependent variable). The result obtained was used to test the hypothesis as well.

5.2 Development of a model to predict the log-odds of growth of offshore wind energy in India

In this section the analysis and findings of the research work will be discussed in detail. The questionnaire was administered to stakeholders of wind energy in India. The responses received were subjected to cronbach alpha test to measure the internal consistency and reliability of the instrument and then subjected to factor analysis to identify the underlying structure of the variables for data reduction. The factors that emerged from the analysis were treated as independent variables in the logistic regression model to calculate the odds of the growth of the offshore wind energy sector in India.

5.2.1 Cronbach Alpha test

When using Likert-type scales it is important to calculate Cronbach's alpha coefficient to check the internal consistency and reliability of the instrument – in this case the questionnaire. Cronbach's alpha is a measure of internal consistency, that is, how closely x a set of variables are related as a group. Internal consistency describes the extent to which all the items in a test measure the same concept or construct and hence it is connected to the inter-relatedness of the items within the test. A "high" value of alpha is often used as an indication that the variables measure an underlying (or latent) construct. Cronbach's alpha reliability coefficient normally ranges between 0 and 1. The closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale.

Cronbach's alpha can be written as a function of the number of test items and the average inter-correlation among the items. The formula for the standardized Cronbach's alpha is:

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

Where N is equal to the number of items, c-bar is the average inter-item covariance among the items and v-bar equals the average variance. From this formula it can be observed that if the number of items increases Cronbach's alpha increases. Additionally, if the average inter-item correlation is low, alpha will be low. As the average inter-item correlation increases, Cronbach's alpha increases as well (holding the number of items constant). The size of alpha is determined by both the number of items in the scale and the mean inter-item correlations. George and Mallery (2003) provide the following rules of thumb: "$\alpha > .9$ – Excellent, $\alpha > .8$ – Good, $\alpha > .7$ – Acceptable, $\alpha > .6$ – Questionable, $\alpha > .5$ – Poor, and $\alpha < .5$ – Unacceptable". The cronbach alpha test conducted for all the sections of the questionnaire is given in the subsequent pages. The alpha coefficient for all the sections is around or above 0.8, (as shown in Table 5.1) suggesting that the items have relatively high internal consistency.

Table 5.1– Cronbach Alpha test to check the validity of the questionnaire

Case Processing Summary

		N	%
Cases	Valid	181	100.0
	Excluded[a]	0	.0
	Total	181	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.843	.846	4

Item Statistics

	Mean	Std. Deviation	N
FiT	6.5359	.50009	181
AD	5.7735	.46971	181
GBI	5.6961	.46120	181
RPO	6.4917	.50132	181

Inter-Item Correlation Matrix

	FiT	AD	GBI	RPO
FiT	1.000	.614	.541	.361
AD	.614	1.000	.835	.570
GBI	.541	.835	1.000	.554
RPO	.361	.570	.554	1.000

Case Processing Summary

		N	%
Cases	Valid	181	100.0
	Excluded[a]	0	.0
	Total	181	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.950	.950	5

Item Statistics

	Mean	Std. Deviation	N
Faster_Approvals	5.9779	.68277	181
Grid_connectivity	5.8287	.59484	181
Policy_for_longer_term	4.9724	.67849	181
Financial_Incentives	6.5193	.50101	181
Tariff_based_on_wind_speeds	5.9779	.72996	181

Case Processing Summary

		N	%
Cases	Valid	181	100.0
	Excluded[a]	0	.0
	Total	181	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.829	.828	4

Item Statistics

	Mean	Std. Deviation	N
Expert_EPC_Contractors	6.4917	.50132	181
Local_manufacturing	5.8564	.41005	181
Growth_of_ancillary_unit	5.7293	.44556	181
Superior_program_execution	6.5801	.49491	181

Case Processing Summary

		N	%
Cases	Valid	181	100.0
	Excluded[a]	0	.0
	Total	181	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.825	.828	3

Item Statistics

	Mean	Std. Deviation	N
Accurate_offshore_wind_speeds	6.5580	.49800	181
Skill_development	6.3923	.48961	181
RD_Ecosystem	5.8066	.53868	181

Case Processing Summary

		N	%
Cases	Valid	181	100.0
	Excluded[a]	0	.0
	Total	181	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.791	.794	5

Item Statistics

	Mean	Std. Deviation	N
Capital_at_attractive_rates	6.6022	.49080	181
Moratorium_on_interest_payment	5.8177	.38718	181
Offshore_wind_fund	6.5249	.50077	181
Access_to_capital	5.6243	.48564	181
Priority_sector_lending	5.5580	.49800	181

5.2.2 Factor Analysis

Factor analysis is a statistical procedure used to study the underlying structure of the variables. The concept of factor analysis is to reduce a large set of variables into a group of fewer factors based on the inter-correlation among the variables. Factor analysis hence is also a method of data reduction, although that is not the only objective of factor analysis. Factor analysis does data reduction by seeking underlying unobservable (latent) variables that are reflected in the observed variables (manifest variables).

There are several methods that can be used to conduct a factor analysis (such as principal axis factor, maximum likelihood, generalized least squares, unweighted least squares). However, principal component analysis is the widely used method in research in the world. There are also many different types of rotations that can be done after the initial extraction of factors, including orthogonal rotations, such as varimax and equimax and oblique rotations, such as promax, which allow the factors to be correlated with one another. Again, orthogonal rotation varimax is widely used procedure in factor analysis.

The amount of variance a variable shares with all other variables included in the analysis is referred to as communality. The covariation among the variables is described in terms of a small number of common factors plus a unique factor for each variable. If the variables are standardized, the factor model may be represented as

$$X_i = A_{i1}F_1 + A_{i2}F_2 + \ldots + A_{im}F_m + V_iU_i$$

Where

X_i = ith standardized variable

A_{ij} = Standardized multiple regression coefficient of variable i on common factor j

F = Common factor

V_i = Standardized regression coefficient of variable i on unique factor i

U_i = the unique factor for variable i

m = number of common factors

The unique factors are uncorrelated with each other and with the common factors. The common factors themselves can be expressed as linear combinations of the observed variables

$$F_i = W_{i1}X_1 + W_{i2}X_2 + W_{i3}X_3 + \ldots + W_{ik}X_k$$

Where

F_1 = estimate of the ith factor

W_i = weight or factor score coefficients

K = number of variables

Factor analysis usually proceeds in two stages. In the first, one set of loadings is calculated which yields theoretical variances and covariance that fit the observed ones as closely as possible according to a certain criterion. These loadings, however, may not agree with the prior expectations, or may not lend themselves to a reasonable interpretation. Thus, in the second stage, the first loadings are “rotated" in an effort to arrive at another set of loadings that fit equally well the observed variances and covariance, but are more consistent with prior expectations or more easily interpreted (Malhotra, 2011).

A method widely used for determining a first set of loadings is the principal component method. This method seeks values of the loadings that bring the estimate of the total communality as close as possible to the total of the observed variances. Finally, the factor scores are fed into the logistic regression equations as independent variables.

The response were taken in a 7- point likert scale and were subjected to factor analysis to reduce and logically align these 21 variables into smaller set of related factors. The KMO stands for the names of statisticians Kaiser-Meyer-Olkin and is a measure of sampling adequacy. It assesses the adequacy of the correlation among the variables to be eligible for factor analysis. KMO measure of sampling adequacy of 0.50 or more is recommended. In this exercise KMO output of 0.726, as shown in table 4.15 is adequate to proceed with factor analysis.

The Bartlett test of sphericity is a statistical measure which tests the statistical significance of the inter-correlation among the variables submitted for factor analysis. It verifies the null hypothesis that the variables are independent of each other. If the null hypothesis is accepted it would mean that the variables are independent, and therefore, there is no likelihood of any factor emerging. This null hypothesis of independence of variable should be rejected to conform to the factor analysis assumption that there exists significance correlation among the variables. In this research the Bartlett test of sphericity is significant which reject the null hypothesis that the variables are independent. This means that they variables are correlated, which is a necessary condition to proceed with factor analysis. Both KMO and Bartlett score, as shown in Table 5.2 gives the confidence to proceed with factor analysis.

Table 5.2- KMO & Bartlett test of sphericity

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.726
Bartlett's Test of Sphericity	Approx. Chi-Square	3197.603
	df	210
	Sig.	.000

The communalities table provides the initial and extraction values of communalities. The initial communalities of 1.0 for each variable suggest that all the variables are fully involved in the factor analysis solution. The extraction communalities, usually less than the initial communalities, indicate the proportion of variation in the variable that is accounted for by the factor whose eigenvalues are greater than 1.0. These values are the proportions of the variance in the variables (represented as Q 6 to Q 26 in Table 5.3) accounted for by the first factor.

Here it is observed that all the selected variables are largely contributing to the factor-solution model. Any variable whose extraction communality is less than 0.40 can be considered for removal as those variables have nothing much to contribute to the development of factor analysis. The removal of such low extraction communality variable will greatly improve the factor analysis solution. In this exercise there is no such variable that can be considered for removal and hence all are retained.

Table 5.3- Communalities - proportion of variation in the variable that is accounted for by the factor

Communalities

	Initial	Extraction
FiT	1.000	.592
AD	1.000	.848
GBI	1.000	.849
RPO	1.000	.530
Faster_Approvals	1.000	.948
Grid_connectivity	1.000	.864
Policy_for_longer_term	1.000	.926
Financial_Incentives	1.000	.667
Tariff_based_on_wind_speeds	1.000	.894
Expert_EPC_Contractors	1.000	.803
Local_manufacturing	1.000	.579
Growth_of_ancillary_unit	1.000	.688
Superior_program_execution	1.000	.818
Accurate_offshore_wind_speeds	1.000	.780
Skill_development	1.000	.785
RD_Ecosystem	1.000	.670
Capital_at_attractive_rates	1.000	.804
Moratorium_on_interest_payment	1.000	.728
Offshore_wind_fund	1.000	.401
Access_to_capital	1.000	.458
Priority_sector_lending	1.000	.805

Extraction Method: Principal Component Analysis.

The total variance explained in table gives the amount of variance explained by each component after the initial and extraction part of the analysis. In the initial eigenvalue column, 21 components, representing 21 variables, are included. The total variance explained by all the components (in Table 5.4) amount to 100% of the variance, first component has the highest (30%) percentage of the total variance in the factor solution. The second component accounts for 15% of the variance, the third component 13.6%, the fourth 9% and the fifth 5.35%. So the five factors account for close to 75% of the total variation in the 21 variables.

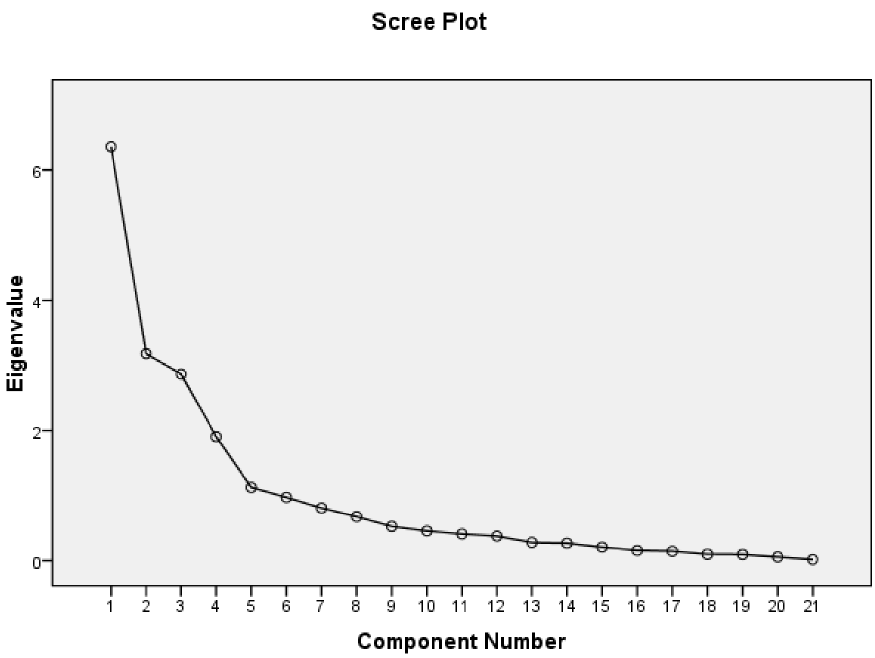
Table 5.4 – The total variance explained by all the components

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.360	30.283	30.283	6.360	30.283	30.283	4.326	20.599	20.599
2	3.182	15.152	45.436	3.182	15.152	45.436	2.935	13.977	34.576
3	2.865	13.644	59.080	2.865	13.644	59.080	2.802	13.344	47.920
4	1.906	9.074	68.154	1.906	9.074	68.154	2.764	13.162	61.082
5	1.124	5.353	73.507	1.124	5.353	73.507	2.609	12.425	73.507
6	.972	4.630	78.137						
7	.809	3.850	81.987						
8	.676	3.220	85.207						
9	.528	2.515	87.722						
10	.459	2.185	89.907						
11	.411	1.957	91.864						
12	.379	1.805	93.669						
13	.281	1.337	95.006						
14	.270	1.285	96.291						
15	.208	.992	97.284						
16	.157	.747	98.031						
17	.145	.690	98.721						
18	.099	.472	99.192						
19	.095	.451	99.644						
20	.057	.270	99.914						
21	.018	.086	100.000						

Extraction Method: Principal Component Analysis.

Figure 5.1- Scree plot showing the bending of the curve after 5 factors



The Scree test plots (Figure 5.1) the eigenvalue against the number of factors, in their order of extraction, and is yet another way to determine the number of factors to be retained in the factor-analysis solution. From figure- 5.1, it can be observed that the curve drops sharply at first and then levels off as it approaches horizontal axis. In this exercise, the graph starts to flatten after factor 5, indicating that five factors are sufficient to explain the variations in the variables.

Table 5.5- Rotated component Matrix showing that the variable load on one factor

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
Faster_Approvals	.936				
Policy_for_longer_term	.915				
Tariff_based_on_wind_speeds	.901				
Grid_connectivity	.821				
Financial_Incentives	.777				
Priority_sector_lending		.883			
Capital_at_attractive_rates		.878			
Moratorium_on_interest_payment		.768			
Offshore_wind_fund		.551			
Access_to_capital		.528			
Superior_program_execution			.857		
Expert_EPC_Contractors			.836		
Growth_of_ancillary_unit			.770		
Local_manufacturing			.741		
AD				.803	
GBI				.797	
FiT				.668	
RPO				.580	
Skill_development					.864
Accurate_offshore_wind_speeds					.827
RD_Ecosystem					.745

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

The varimax rotation distributes the variations equally across the five factors. The rotated component matrix, Table 5.5, shows that each variables load significantly on only one factor. The factors and the variables that load on these factors are given below.

Variables grouped under various factors

1. *(Factor 1) - Government Support*

    - Faster approvals and Single window clearance mechanisms for offshore wind energy projects
    - Sustainability of policies environment for a longer term (10 years or more)
    - Constructing evacuation Infrastructure and facilities for storage of electricity not injected into the grid
    - Extending financial incentives like subsidies, moratorium on interest payment, zero duty on imports, excise duty waiver and tax benefits for offshore wind energy projects
    - Tariff determination on wind speeds and not based on zones

2. *(Factor 2) - Availability of capital for Investments*

    - Availability of capital at attractive rates of interest similar to what is extended to priority sector projects
    - Moratorium on interest payments for the first few years of project go-live.

- Offshore wind energy fund from cess levied on carbon emissions or a Government backed guarantee to reduce the cost of capital
- Financial Institutions willing to lend to offshore wind projects as priority sector

3. *(Factor 3) - Availability of local expertise*
    - Expertise and availability of EPC contractors for commissioning of the wind farms
    - Manufacture and availability of offshore wind energy components, locally
    - Growth of ancillary units
    - Superior program execution skills and capabilities

4. *(Factor 4) - Fiscal and Quota based incentives*
    - Feed –in Tariff (Higher tariff for offshore wind vis-a'-vis other renewable)
    - Accelerated depreciation
    - Generation based incentives (GBI)
    - Enforcement of Renewable purchase obligations (RPO)/Renewable energy certificates (REC)

5. *(Factor - 5)- Enabling R&D ecosystem*
    - Skills development and training of the human capital on offshore wind systems

- Research institutions to build accurate data on offshore wind potential sites and wind speeds (Wind Resource map and Bathymetric data)
- R&D to localize production of expensive equipment to bring the overall costs down

5.2.3 Logistic Regression

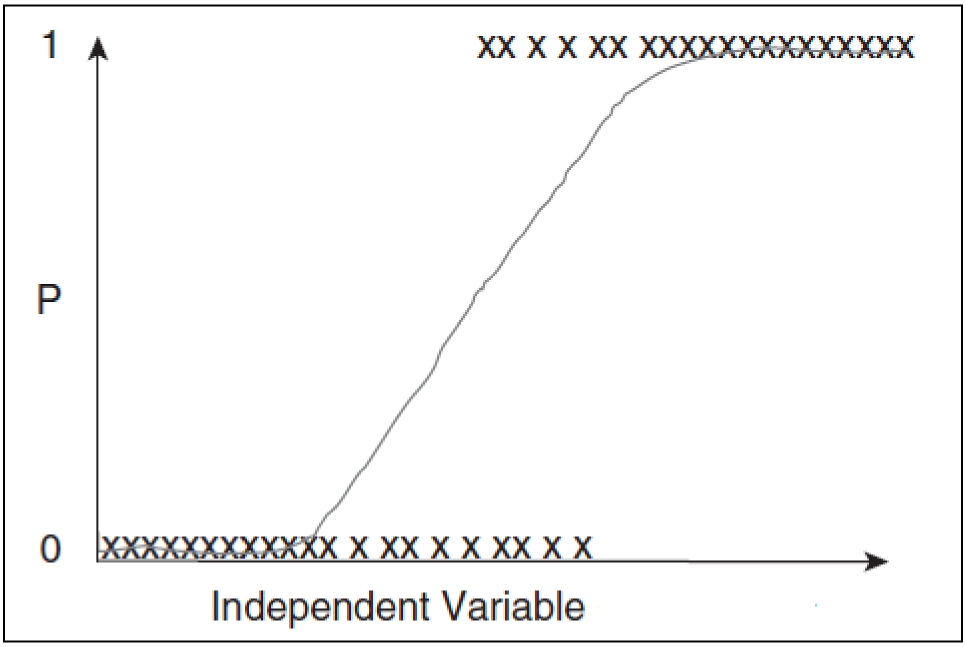
Logistic regression is used to find out the influence of metric or categorical independent variables on binary dependent variable(s) (that are dichotomous). These independent variables can be presented one after the other (step-wise logistic regression) to perform the analysis or simultaneously at once. Logistic regression predicts the probability of an observation belonging to one group than the other by employing binomial probability theory. Growth or no growth of offshore wind energy in India, in this case.

Given the regression coefficients, the Logistic regression uses the maximum likelihood method, to form the best fitting line that maximizes the odds of correctly classifying the observation into the right group. Here the objective is to correctly predict the membership of the individual observations by using the most parsimonious model. To achieve this goal, an equation that has all the independent variable is created that can predict the membership of the binary dependent variable. Because the binary dependent variable has only the values of 0 and 1, the predicted value (probability) must be bounded to fall within the same range. To define a relationship bounded by 0 and 1, logistic regression uses the logistic curve to represent the relationship between the independent and dependent variables (Figure 5.2).

This is a smoother 'S- Shaped' curve which now fits a cumulative probability curve, i.e. adding each new probability to the existing total. At low levels of the independent variable the probability approaches 0 but never reaches 0. Likewise, as the independent variable increases, the predicted value increases up the curve, but then the slope starts decreasing so that at any level of the independent variable the probability will approach 1 but never exceed it. The linear models of regression cannot accommodate such a relationship, as it is inherently nonlinear.

The linear relationship of regression, even with additional terms of transformations for nonlinear effects, cannot guarantee that the predicted values will remain within the range of 0 and 1. The solution is to convert these results into probabilities and plot the probabilities of dependent variable (Y) for each value of independent variables (X) as shown in figure 5.2.

Figure 5.2- S-shaped curve of logistic regression



Source: Malhotra, 2011.

This log transformation of the p values to a log distribution enables the researcher to create a link with the normal regression equation. The log distribution (or logistic transformation of p) is also called the logit of p or logit (p). Logit(p) is the log (to base e) of the odds ratio or likelihood ratio that the dependent variable is 1. This is represented as

$$\text{Logit}(p) = \log [p / (1 - p)] = \ln [p / (1 - p)]$$

Whereas p can only range from 0 to 1, logit (p) scale ranges from - ∞ to + ∞ and is symmetrical around the logit of .5 (which is zero).

The form of the logistic regression equation is:

$$\text{Logit}\{p(x)\} = \log [p(x) / (1 - p(x)] = a + b_1x_1 + b_2x_2 + \ldots + b_nx_n$$

Logistic regression uses the maximum likelihood method to estimate the parameters so as to maximize the likelihood or probability of observing the actual data, given the fitted regression coefficients, which is different from the principles of ordinary least squares (OLS) followed by linear regression models to estimate the best fitting line. A consequence of this is that the goodness of fit and overall significance statistics used in logistic regression are different from those used in linear regression.

Model Fit

Logistic regression commonly used measures of model fit are based on the likelihood function and are Cox & Snell R2 and Nagelkerke R,2 both these measures are similar to the R2 in multiple regression. The Cox & Snell R2 is constrained in such a way that it cannot equal 1 even if the model perfectly fits the data. This limitation is overcome by the Nagelkerke R.2 If the estimated probability is less than 0.5, then the predicted value of (Y) is set to 0. On the other hand if the estimated probability is greater than 0.5, then the predicted value of (Y) is set to 1. The predicted value of Y can then be compared to the corresponding actual values to determine the percentage of correct predictions (Malhotra, 2011).

Significance Testing

The testing of individual estimated parameters or coefficients for significance is based on Wald's statistic. This statistic is a test of significance of the logistic regression coefficients based on the asymptotic normality property of maximum likelihood estimates and is estimated as

$$\text{Wald} = (ai/SE\ ai)^2$$

Where

ai = Logistical coefficient for that predictor variable

SEai = Standard error of the logistical coefficient

The Wald statistic is chi-square distributes with 1 degree of freedom if the variable is metric and the number of categories minus 1 if the variable is non-metric.

'P' can be calculated with the following formula

$$P = \exp(a + b1x1 + b2x2 + ... + bnxn) / 1 + \exp(a + b1x1 + b2x2 + ... + bnxn)$$

p = the probability that a case is in a particular category,

a = the constant of the equation and

b = the coefficient of the predictor variables

Logistic regression – involves fitting an equation of the form to the data:
$\text{Logit}(p) = a + b_1x_1 + b_2x_2 + b_3x_3 + \ldots + b_nX_n$

Logistic Regression is undertaken when there are several Independent variables that are metric or categorical while the dependent variable is dichotomous. In the present research, the dependent variable is growth of offshore wind energy (Growth/No growth) and the independent variables are the five factors that emerged from factor analysis of the 21 variables identified through literature survey.

Hypothesis Testing

Logistic regression will be used to test the hypothesis of this research work. They are given below.

Null Hypothesis: H0: Combination of factors from the factor analysis (Independent Variables – Fiscal & Quota based incentives, Government support, Availability of local expertise, R&D ecosystem and Availability of capital for investments) does not predict the growth of offshore wind energy in India (Dependent Variable).

Alternate Hypothesis: H1: Combination of factors from the factor analysis (Independent Variables) predicts the growth of offshore wind energy in India (Dependent Variable)

Table 5.6 – Case processing summary shows no missing data/entry

Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	181	100.0
	Missing Cases	0	.0
	Total	181	100.0
Unselected Cases		0	.0
Total		181	100.0

a. If weight is in effect, see classification table for the total number of cases.

Dependent Variable Encoding

Ori...	Internal Value
0	0
1	1

The regression model has considered all the entries with no missing cases as shown in Table 5.6. The first model in the output is a null model, that is, a model with no predictors (Table -5.7). The constant in the table labelled ‘Variables in the Equation’ gives the unconditional log odds of growth (i.e., growth=1). The table 5.8 labelled ‘Variables not in the Equation’ gives the results of a score test, also known as a Lagrange multiplier test.

The column labelled Score gives the estimated change in model fit if the term is added to the model; the other two columns give the degrees of freedom, and p-value (labeled Sig.) for the estimated change. Based on the table 5.8, Factors 1, 4 and 5 are expected to improve the fit of the model, significantly.

Table 5.7 – Null model with no predictors

Block 0: Beginning

Classification Table[a,b]

Observed			Predicted: Growth 0	Predicted: Growth 1	Percentage Correct
Step 0	Growth	0	0	46	.0
		1	0	135	100.0
	Overall Percentage				74.6

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	1.077	.171	39.769	1	.000	2.935

Table 5.8 - Factors 1, 4 & 5 have significant impact on the growth of offshore

Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	FAC1_1	33.030	1	.000
		FAC2_1	.313	1	.576
		FAC3_1	.377	1	.539
		FAC4_1	77.230	1	.000
		FAC5_1	18.180	1	.000
	Overall Statistics		129.130	5	.000

The ‘omnibus test of model coefficients’ (Table 5.9) gives the overall test for the model that includes the predictors. The chi-square value of 167.903 with a p-value of less than 0.0005 indicates that the model as a whole fits significantly better than an empty model (i.e., a model with no predictors).

Nagelkerke’s R2 of .891 indicated a strong relationship between prediction and grouping. Prediction success overall was 96.1% (91.3% for no growth and 97.8% for growth of offshore wind energy).

Table 5.9 - Predictors introduced in the equation have significant impact than constant only model

Block 1: Method =

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	167.903	5	.000
	Block	167.903	5	.000
	Model	167.903	5	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	37.293[a]	.605	.891

a. Estimation terminated at iteration number 8 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	3.426	8	.905

Hosmer and Lemeshow test (sig of .905) confirms that the model is a very good fit for the data. In the table labelled 'Variables in the Equation' (Table 5.10) the coefficients, their standard errors, the Wald test statistic with associated degrees of freedom and p-values, and the exponentiated coefficient (also known as an odds ratio) are given. Factor 1 (Government Support), Factor 4 (Fiscal and Quota based incentives) and Factor 5 (Enabling R&D ecosystem) are statistically significant. The logistic regression coefficients give the change in the log odds of the outcome for a one unit increase in the predictor variable. For every one unit change in Government support, the log odds of offshore wind energy growth (versus non-growth) increases by 3.168. For a one unit increase in fiscal and quota based incentives, the log odds of offshore wind energy growth in India increases by 3.337. Similarly, for one unit increase in R&D ecosystem, the offshore wind energy growth increases by 2.510.

Table 5.10 - Classification table with predictors included and below gives the B coefficients

Classification Table[a]

Observed			Predicted Growth 0	Predicted Growth 1	Percentage Correct
Step 1	Growth	0	42	4	91.3
		1	3	132	97.8
	Overall Percentage				96.1

a. The cut value is .500

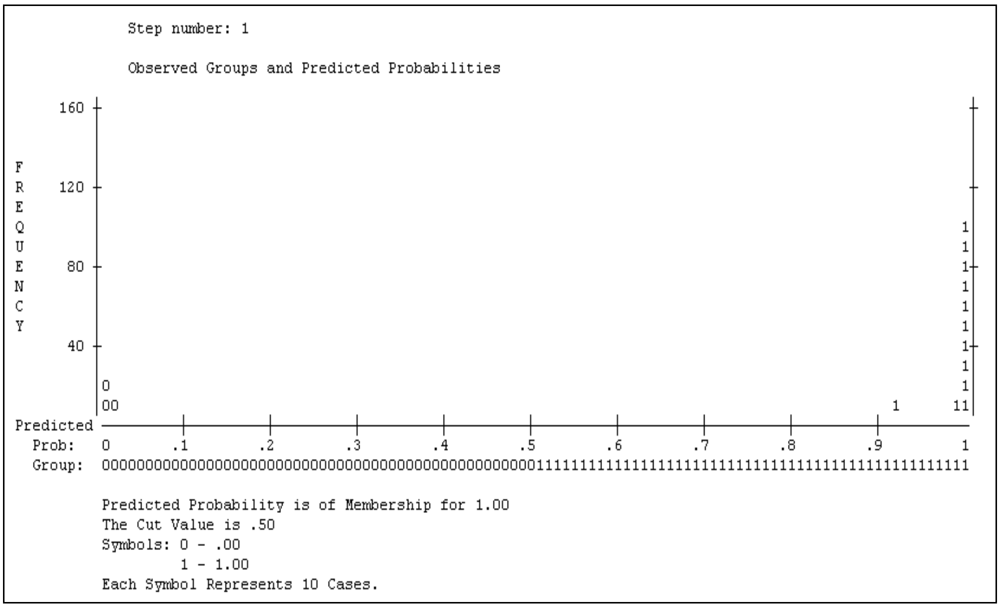
Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B) Lower	95.0% C.I.for EXP(B) Upper
Step 1[a]	FAC1_1	3.168	.766	17.117	1	.000	23.758	5.297	106.555
	FAC2_1	.573	.580	.976	1	.323	1.773	.569	5.526
	FAC3_1	.340	.519	.428	1	.513	1.405	.508	3.885
	FAC4_1	3.337	.646	26.653	1	.000	28.145	7.928	99.918
	FAC5_1	2.510	.842	8.893	1	.003	12.304	2.364	64.046
	Constant	3.695	.790	21.850	1	.000	40.247		

a. Variable(s) entered on step 1: FAC1_1, FAC2_1, FAC3_1, FAC4_1, FAC5_1.

The classification plot (figure 5.4) or histogram of predicted probabilities provides a visual demonstration of the correct and incorrect predictions. The X axis is the predicted probability from .0 to 1.0 of the dependent being classified '1'. The Y axis is frequency: the number of cases classified. Inside the plot are columns of observed 1's and 0's. The resulting plot is very useful for spotting possible outliers. A U-shaped rather than normal distribution is desirable, as is the case with figure 5.3. A U-shaped distribution indicates the predictions are well-differentiated with cases clustered at each end showing correct classification.

Figure 5.3 - Classification plot



Logistic Regression equation that gives the growth of offshore wind energy in India will be

$$\textbf{Log (p/1-p)} = 3.695 + 3.168 \times F_1 + 0.573 \times F_2 + 0.340 \times F_3 + 3.337 \times F_4 + 2.510 * F_5$$

Government Support (F_1), Fiscal & Quota based incentives (F_4) and ***enabling R&D ecosystem (F_5)*** have high impact on the growth of offshore wind energy in India.

$$\text{Probability of growth of offshore Wind energy in India} = \frac{e^{\{3.695 + 3.168 \times F_1 + 0.573 \times F_2 + 0.340 \times F_3 + 3.337 \times F_4 + 2.510 * F_5\}}}{1 + e^{\{3.695 + 3.168 \times F_1 + 0.573 \times F_2 + 0.340 \times F_3 + 3.337 \times F_4 + 2.510 * F_5\}}}$$

Thus the logistic regression analysis conducted to predict the growth of offshore wind energy in India using Government support, fiscal & quota based incentives, availability of local expertise, enabling R&D ecosystem and availability of capital for investments as predictors shows significant contribution from Government support, Fiscal incentives and R&D ecosystem towards the growth of offshore wind energy sector in India. As combination of factors from the factor analysis (Independent Variables – Fiscal & Quota based incentives, Government support, Availability of local expertise, R&D ecosystem and Availability of capital for investments) could predict the growth of offshore wind energy in India (dependent variable), **the null hypothesis is rejected**.

5.3 Concluding remarks

21 variables that constitute the core building blocks of an offshore wind energy policy, adopted by several European countries, were identified from extensive literature survey. A detailed questionnaire was developed and administered to wind energy stakeholders (Project developer, Wind turbine manufacturer) in India. Their responses were factor analysed to find the underlying structure of the data. Five factors (Government support, Fiscal and quota based incentives, availability of local expertise, capital for investments and an enabling R&D ecosystem) emerged from the analysis. A logistic regression analysis was conducted to predict the growth of offshore wind energy in India using the 5 factors that predicted the growth of offshore wind energy in India. The next chapter critiques the policies adopted by select European countries to support the growth of offshore wind energy farms in their respective countries and also evaluates the existing wind energy policies that encouraged the growth of onshore wind farms in India. Critique of EU offshore policies can be leveraged to draw suitable lessons for India.

6 CHAPTER 6 - CRITIQUE OF EU OFFSHORE WIND POLICY & INDIAN ONSHORE POLICY REVIEW

6.1 Introduction

Europe is the world leader in offshore wind energy today, in terms of installed capacity. Also, the first offshore wind energy farms in Europe (Denmark) was installed in the late 1980s giving it almost 2 decades of experience in generating electricity from offshore wind farms. Over 3800 MW of capacity offshore wind farms have been installed and operational in Europe. 9 offshore wind farms with over 2500 MW are close to go-live phase and are expected to start generating electricity shortly (EWEA, 2012). Another 3000 MW are in the different stages of construction. When these projects go live, it would give Europe a little over 10,000 MW of offshore wind capacity (EWEA, 2012). It would be appropriate to highlight that Europe has the lead and experience as far as offshore wind energy sector is concerned and hence provide excellent insights on the policies to promote offshore wind energy including consent procedures, award criteria, tender model, subsidies, environmental and regulatory clearances apart from grid connections. In this chapter a critique of the offshore wind energy policies of four European countries are presented. The countries whose policies were reviewed are

- The UK
- Germany
- Denmark
- Netherlands

At the end of the section the findings are summarized that compare and contrast proactive policies that have helped these countries to become a leader in offshore wind energy. From these policies of Europe, a set of policies have been identified that can be adopted by India to grow the offshore wind in the country and another set of policies were also identified that needs to be tailored to suit the unique needs of India.

The next part of this chapter discusses the support of policies to grow the onshore wind energy sector in India. There is a clear and direct correlation between policies and growth of onshore wind energy over the years in the country. This provides yet another validation of the importance and the impact of policies to promote renewable energy adoption in a country. Similarly, it is conceivable that having robust policies will accelerate the diffusion of offshore wind energy adoption in India.

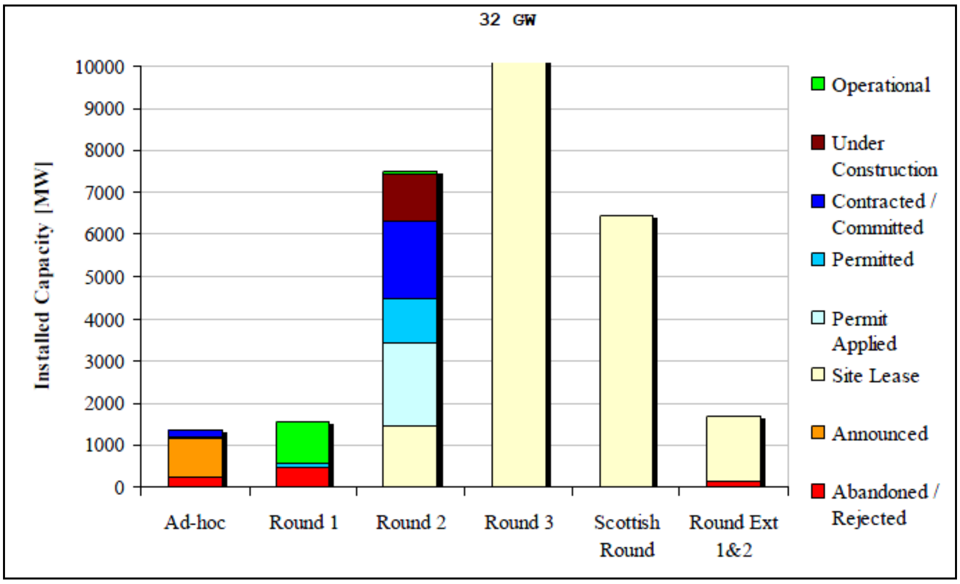
6.2 Critique of offshore wind energy policies adopted by select European countries

6.2.1 The UK

UK has one of the most favourable wind resources but since 1970s placed emphasis on harnessing other renewable like Wave energy (Renewables UK, 2010). But in the 1980s attention shifted to Wind energy partly due to the success of countries like Denmark and Germany in wind energy (Boyle, 2007). After the privatization in 1989, wind energy picked up momentum which accelerated after the introduction of Renewable purchase obligation in the year 2000 (EWEA, 2010). Like most countries in the world, the UK has predominantly fossil fuel based sources for electricity generation. However, security of supply, decarbonisation targets and depleting fossil fuel resources have made it imperative for the UK to adopt aggressive targets to promote renewable energy sources (Deloitte, 2011). The UK is a signatory to the Kyoto Protocol, committing to reducing greenhouse gases by 12.5% (vis-a-vis 1990 levels), by 2012 (BWEA, 2011). In 2007, all EU countries have agreed to cut overall CO2 emissions by 20%, to increase energy efficiency by 20% and to increase the share of renewable energy to 20%, by 2020 (REN 21, 2012). To help achieve the Europe-wide target, the UK has committed to a 30% reduction in CO2 emissions by 2020. This means that the UK needs to generate additional 38 GW of power from renewable sources by 2020 (DECC, 2011). These ambitious targets, coupled with relatively simpler consenting procedures and excellent offshore wind potential is driving the growth of offshore wind energy in the UK – which now is a world leader in offshore wind energy today (Figure 6.1). In round 3 (unlike in round 1, where only 1.5

GW was tendered and in round 2, where no capacity was given but was still small) of offshore wind energy tender, the Government has issued significantly large amount (25,000 MW) of licensees so that the developers will have visibility into the project pipeline and quantum of work that is available for them. Such proactive policy helped in increased investors interest, improves supply chain efficiencies, optimum planning and resources allocation to harness offshore wind energy (Renewables UK, 2010).

Figure 6.1 - Offshore wind energy in the UK in 2010

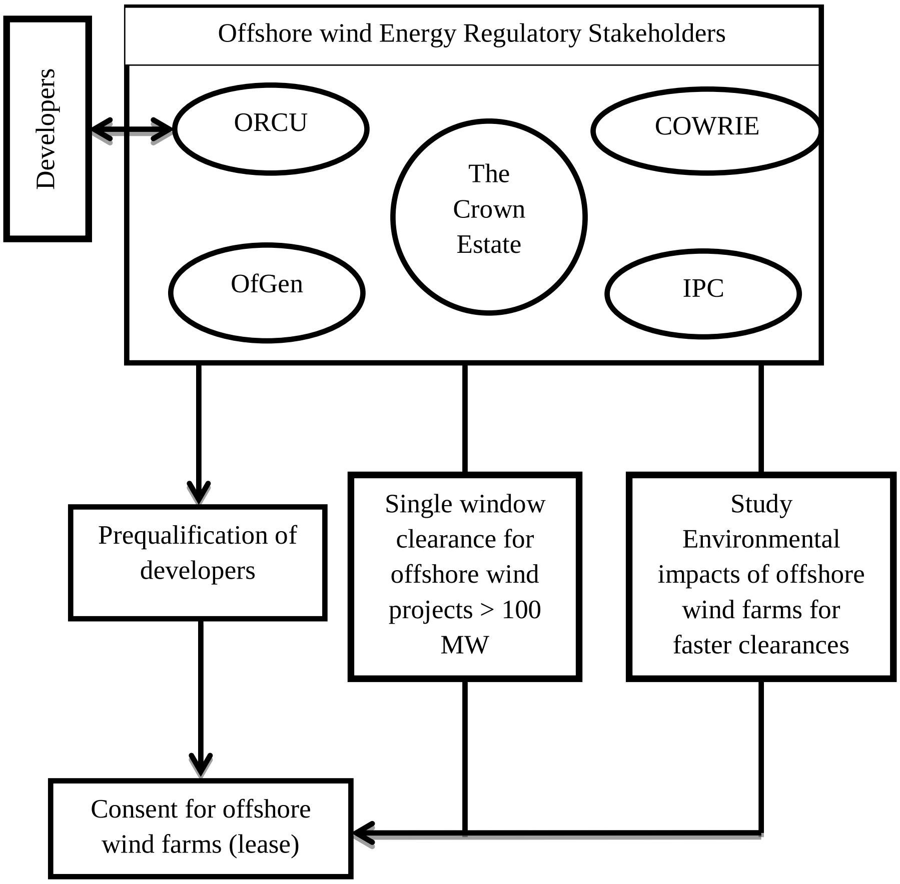


Source: Deloitte, 2010 and DECC, 2010

Consent Procedures

The Crown Estate (TCE) owns most of the near-shore and offshore sea bed up to 12 nautical miles in the UK and awards lease agreements to offshore wind parks in these areas. In 2001 and 2003 the TCE brought out 2 tenders for Round 1 and Round 2 bidding for offshore wind parks. In Round 1 the developers identified the sites that are within 12 nautical miles from the shores, with a project size of a minimum of 20 MW having maximum of 30 turbines, covering an area of maximum 10 sq kms (Renewable UK, 2011). The developer needs to factor in shipping lanes and fisheries and had 3 years to obtain consent and clearances. Post obtaining all clearances the agreement of leases is converted into full lease. In Round 2 the crown estate proposed the zones after conducting the strategic environmental assessment (SEA). The developers needed to get the agreement of lease as per the procedures in Round 1 but were to restrict themselves to the zones identified (BWEA, 2010). Totally 33 projects were awarded during the 2 rounds of tenders. In 2009, UK brought out Round 3 tenders for offshore wind projects and those companies that were authorized by Office of gas and electricity markets (Ofgen) could participate in these tenders (Deloitte, 2011). So some sort of pre-qualification of the developers was done at this stage. Initially, the consent procedure required multiple permits and licenses even though the clearances and evaluation were done very quickly. The infrastructure planning commission (IPC) was set up to streamline the planning system for nationally significant infrastructure projects including offshore wind energy sector in the UK (Renewables UK, 2011). The IPC is responsible of giving single consent to offshore wind farms that are greater than 100 MW (KPMG, 2009). The UK government also set up a dedicated body, Collaborative Offshore Wind farm Research into the Environment (COWRIE) to study the environment impacts of offshore wind farms so that it would be easier to accord environmental clearances without much delays. To help the investors obtain the required consents for offshore wind parks, the UK government has set up a single window clearance agency in the form of the Offshore Renewables Consents Unit (ORCU). The flowchart of the consent procedure is given in Figure 6.2.

Figure 6.2 - Flowchart of the consent procedures in the UK



Grid connectivity

In the UK the developers have to negotiate the grid connectivity with the network operators. Several models were considered. Since renewable generation does not get special priority grid access in the UK, unlike in other countries in the Europe, grid connectivity always remained a challenge and was cause of delays during round 1 and 2 tenders (Toke, 2011). The government has decided to unbundle generation and transmission so that bids can be invited for offshore transmission from operators who are willing to design, build and operate offshore transmission assets for a revenue stream, based on use of system by offshore wind park developers (Prassler, 2012).

Financial Incentives

The main incentive for renewable generation (and also for offshore wind energy) in the UK is the Renewable Obligation (RO), established in 2002, a tradeable certificate mechanism which provides a premium payment to renewable generators based on the market price of electricity (KPMG, 2009). The RO places an obligation on electricity suppliers to source some proportion of electricity from renewable energy sources (Toke, 2011). Suppliers must surrender Renewable energy certificates/Renewable obligation certificates to prove compliance (Lund, 2011). These certificates are issued to generators of renewable energy and are sold in the open market. If the suppliers have not met their quota of sourcing renewable power then they opt to pay the buy-out price (Toke, 2011). This money gets added to a levy fund and repaid to the suppliers on a pro-rata basis, depending on their share of renewable energy purchase to incentives supplier those who supply renewable power. The buy-out prices increases as the years go along (Renewables UK, 2011).

The RO system has been extended for the next 25 years (till 2037) while the support for individual project has been extended for 20 years, so as to instill confidence in the investors (Deloitte, 2011). Since the introduction of RO in 2002, the government decided to introduce 1 ROC for every MWhr of energy consumed from renewable energy sources. Since different renewable energy sources were in different stages of maturity in terms of technological maturity and expansion potential, it was decided to introduce the concept of "ROC banding" (Toke, 2011). Offshore wind which is positioned in the post demonstration category was awarded 1.5 ROCs for every MWhr of power supplied, which was then enhanced to 2 ROCs/MWhr (for those projects that obtain full accreditation between 1st April 2010 and 31st March 2014) to increase adoption of offshore wind farms. The UK government also introduced a Feed-in-tariff system for smaller generators (up to 5 MW) to encourage them to invest in offshore farms (KPMG, 2009). In addition to RO the investors in offshore wind parks also received tax relief in the form of ley exemption certificates. These certificates exempt offshore wind farm developers from climate change levy (CCL) applicable to other fossil fuel generators. Climate Change Levy for all non-RES, levels the playing field for offshore wind farms at least to some extent. Recently, the government has allotted grants from the Environmental Transformation Fund (ETF) to build offshore wind infrastructure (Prassler, 2012).

Overall, UK has the most attractive support for offshore wind energy sector in terms of incentives (Deloitte, 2011). The downside is the dependency on the market to decide the price of ROCs. However having a quota for renewable energy sources, this risk is mitigated to a large extent. Several research (KPMG 2010, Deloitte 2011) have established that the UK government has been most proactive to resolve developer grievances or concerns which have made doing business in the UK much easier for the offshore wind developers and investors.

Impact of these policies initiatives

The policies have been one of the major reasons why the UK has become the largest market for offshore wind energy in Europe, and also in the world, with over 2,000 MW installed, which is more than 50% of the installed offshore wind capacity in Europe (EWEA, 2012). Transparency in award criteria and openness to dialogue has been the hallmark of the revamped UK offshore wind policy (KPMG, 2010). The developers deal with ORCU which acts as a single touch point for regulatory approvals thereby simplifying the mandatory approval process. The 25 year runtime for the Renewable obligation has given the much needed impetus for the sector in the UK, which was a late entrant in offshore wind energy in Europe but now is the leader in terms of installed capacity (Toke, 2011).

Summary of the offshore wind energy policies in the UK

The UK has one of the best combinations of offshore wind energy policies among the countries in Europe (Deloitte, 2011). The UK has set ambitious and specific goals for capacity increase in offshore wind parks (BWEA, 2011). Such clarity of intent gives visibility to project developers of likely business opportunity in the UK offshore wind energy sector which in turn helps them to scale their investments in the sector. Another important feature of the UK offshore wind energy policy is the tradable green certificates which give the project developer market related returns on the investments. Also, offshore wind energy gets a premium compared to other renewable energy sources (1 MWhr of offshore wind energy consumed gets 2 ROCs for the utilities) making it attractive for project developers. The regulatory approval mechanisms have been simplified making it almost a single window clearance for project developers.

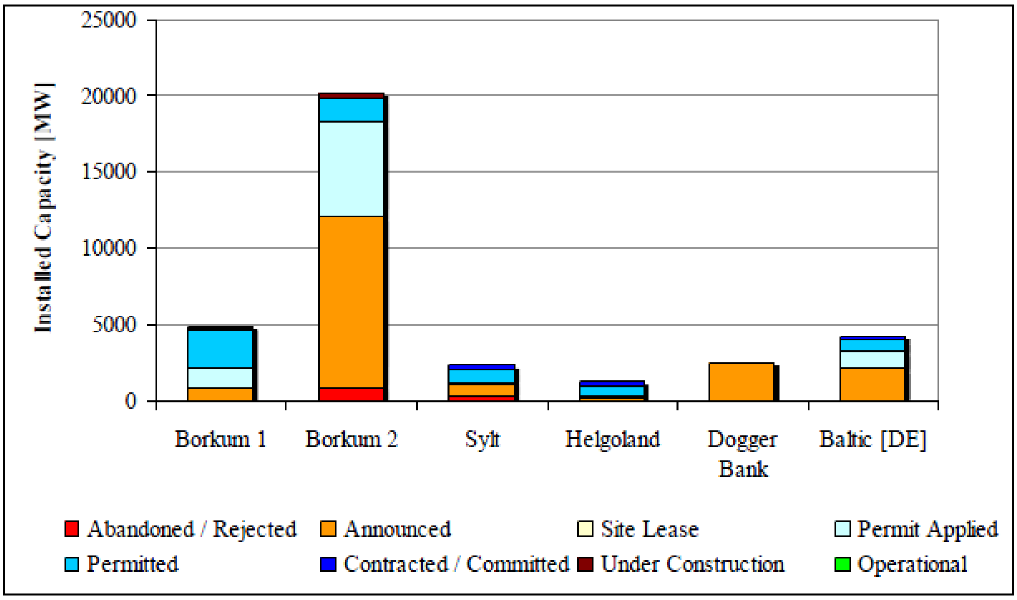
6.2.2 Germany

The German government has an ambitious target to reduce greenhouse gas emissions by 40% by 2020 and by 80% by 2050 compared to the 1990 levels (EWEA, 2012). Germany has a target of 30% of energy consumption to come from renewable by 2020 and to continuously increase that share thereafter (Deloitte, 2011). Germany is most likely to meet this number due to several proactive policies to encourage renewable energy sources. The main policy support for the promotion of renewable energy is the Renewable Energy Act, 2000 (amended in 2004 and in 2009) (Erneuerbare Energien Gesetz, EEG). The German government has also set an aspirational target of increasing electricity consumption from offshore wind farms to 15% of overall consumption by 2030 by installing about 10 GW by 2020 and 25 GW by 2030 of offshore wind energy projects (Deloitte, 2011). The existing offshore wind projects of Germany are given in Figure 6.3.

Consent procedures

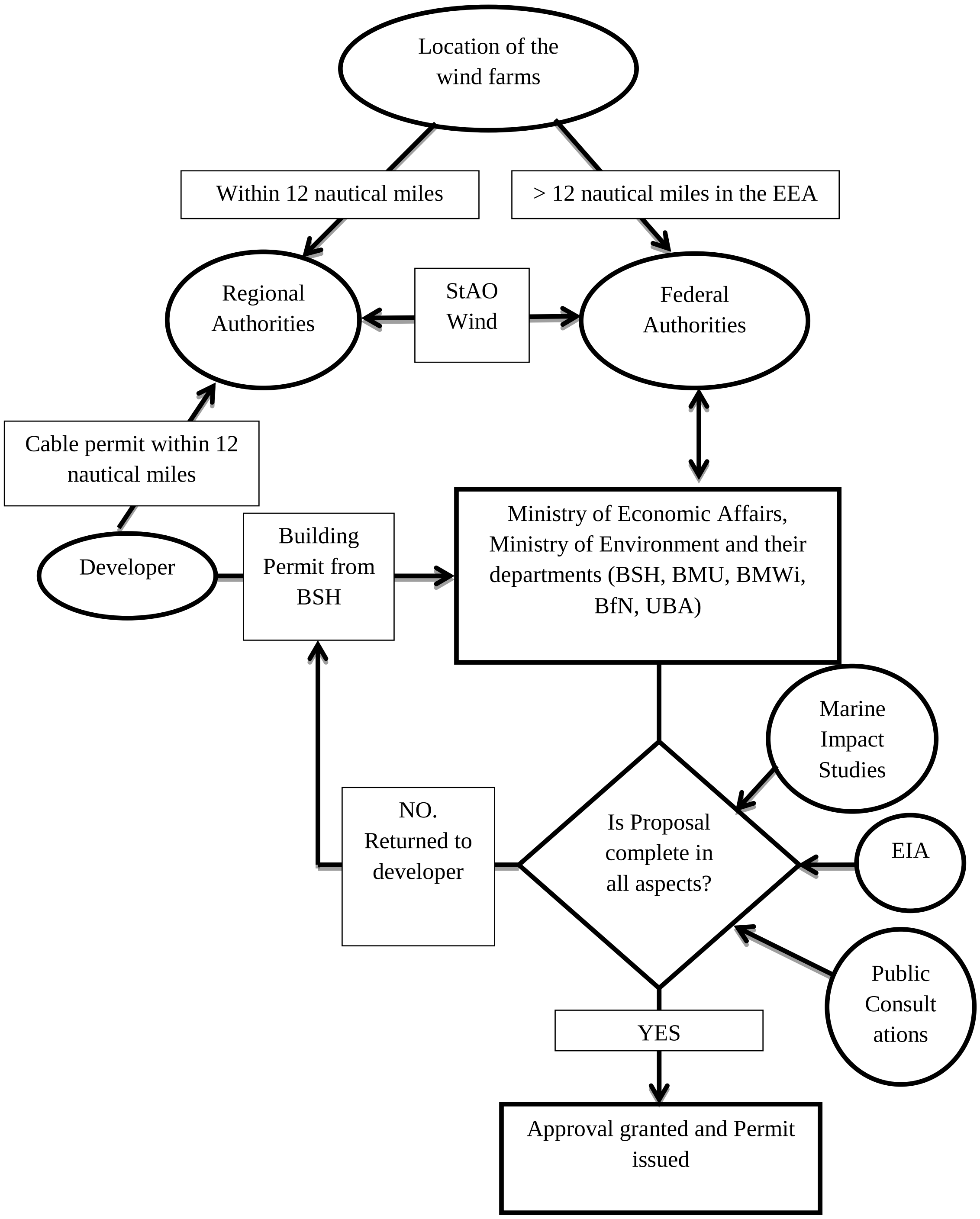
The ministry of Economic affairs and the ministry of Environment and their attendant departments are responsible for consent of offshore wind farms in Germany (EEG, 2009). If the project is located within 12 nautical miles, the respective state governments are responsible for providing the consent. If the project is located beyond 12 nautical miles then the federal government is responsible for providing the consent (EEG, 2009). The developer needs to obtain both building permit and cable permits. Once application is received by the BSH and complete in all respects (including marine impact studies, EIA and public consultations), approval is accorded to the developer. If the proposal is incomplete, it is sent back to the developer for additional information. To makes sure there are no “squatters” in the seas and to prevent hoarding of licenses for offshore projects the German government plans to renew licenses only when there is an evidence of implementation steps demonstrated by the investor. Otherwise the sites will be awarded to other competing players. Also, the government plans to provide all mandatory permits through issues of a single license (EEG, 2009). Figure 6.4 gives the consent procedure in Germany.

Figure 6.3 - Offshore wind projects in Germany (2010)



Source: Deloitte, 2011 & KPMG, 2010

Figure 6.4 - Flowchart of consent procedures of offshore wind farms in Germany



Grid connectivity

In Germany, the transmission operator has been mandated to provide grid connectivity to the offshore wind farms within the Exclusive Economic Zone (EEZ) up to the nearest onshore substation if the offshore wind parks satisfies the following conditions. The construction of the wind parks should have begun before 31st December 2015 and the developer must have secured funding for the project. Also, the developer must have secured all permissions from the authorities, have a reasonably likely schedule of project completion at hand and have done full site investigations as per standards (EEG, 2010). The costs of the offshore and onshore transmission costs of these offshore wind parks are borne by the grid operators and charged to the Federal grid agency of Germany if the offshore wind farm construction commences before the end of 2015. But to avail this concession the project must have reached an adequate stage of development and will be commissioned by the deadline. Grid connectivity by TSOs is likely to reduce upfront capital costs up to 30% depending on the distance from shore (EEG, 2010). Availability of grid connection to offshore wind farms have opened a floodgates of investments and interest from several investors, thereby signaling that the incentives are substantial enough to build multi-MW offshore wind parks. The grid connections are shared by all the TSOs in Germany and are more likely to be clustered to reduce costs.

Financial Incentives

The government has plans to provide more liquidity for first 10 offshore wind projects by setting up a dedicated credit line that can be leveraged by these developers (EWEA, 2011). KfW, one of the leading financial institutions in the world that fund clean energy projects, has plans to launch a special program to fund offshore wind energy with a total of five billion euros (Deloitte, 2011).

The promotion of renewable energy in Germany is through a Feed-in Tariff (FiT) system unlike the UK which predominantly relies on the RO certificates (Toke, 2011). The FiT was increased to 13ct€/unit of electricity supplied for the initial period of 12 years. And if the offshore wind parks are commissioned before 1st Jan 2016 and additional 2ct€/unit is given as "sprinter bonus" to encourage quicker commissioning of these wind farms (EEG, 2009). As a disincentive to delay, these FiTs will reduce by 5% every year from 1st Jan 2016 till commissioning. Depending on the distance of the Offshore Wind Parks (OWP) from the shore, the initial FiT period is extended by 15 days for each nautical mile beyond the 12 nautical mile boundary and by 1.7 months for each additional full meter in depth beyond 20m (EEG, 2010). After the 12 year period the tariff drops to 3.5 ct€/unit of electricity supplied. The rates of the FiT for offshore wind parks are given in the table 6.1.

Table 6.1 - Feed-in tariff Structure for Offshore Wind Farms up to 2018 in Germany

Starting year	**Initial tariff (€ct/kWh)**	**Early bird bonus (€ct/kWh)**	**Total tariff for the first 12 years (€ct/kWh)**	**Basic tariff (after 12 years) (€ct/kWh)**
2014	13	2	15	3.5
2015	12.35	1.90	14.25	3.33
2016	11.73	0.0	11.73	3.16
2017	11.15	0.0	11.15	3.00
2018	10.59	0.0	10.59	2.85

Source: EEG, 2010

However, the developer has the option to leave the FiT facility, by giving a 30 day notice, and opt to supply electricity directly to the market if the rates then are substantially more than 3.5 ct€/unit. Likewise, the developer has the option to come back to the FiT regime by giving a 30 day notice to the authorities (KPMG, 2009). All these policies augur well for Germany.

Impact of these policy initiatives

Germany has made the consenting process for setting up of offshore wind farms considerably easier with single window clearance, added sprinter bonus for faster completion of the offshore wind energy projects and offered free grid connectivity till 2015 to accelerate the deployment of offshore wind farms. All these proactive policies have made Germany one of the most attractive markets, after the UK, for setting up of offshore wind energy farms. Currently over 200 MW of offshore wind energy farms are operational in Germany (EWEA, 2012) and many more in the pipeline.

Summary of the offshore wind energy policies in Germany

Germany has adopted several investor friendly policies to promote investments in offshore wind energy farms. For instance, Germany has adopted an open door policy where an investor finds and proposes the site for development within the EEZ. The investors are provided free grid connections if the projects are in the EEZ, fully financed by the state till 2015. Similarly to accelerate the implementation of offshore wind energy projects, the Government is offering sprinter bonus for all projects till 201, declining thereafter. To make grid connections easier, Germany has identified several clusters where offshore wind energy farms can be set up so that a single cable connection can be used to evacuate power from

6.2.3 Denmark

Since the energy crisis of 1970s, Denmark has given special attention to decentralized generation of electricity and has always mandated grid connection for renewable sources (DEA, 2007). Denmark published its first renewable energy policy following the oil crisis which focused on creating entrepreneurs at the ground level and formation of cooperatives to boost the growth of renewable energy (DEA, 2007). Feed-in tariffs, agreements with the utilities to support decentralised power generation in 1979, has since accelerated the growth of wind energy in the country. Denmark announced its offshore wind energy policy in 1996 and had a target of 4000 MW of generation from offshore wind by 2030 (DEA, 2007). In 1997, Denmark identified 5 areas for proof of concept projects to ascertain the efficacy of offshore wind energy farms which have been reduced to two (DEA, 2009). In 1999, the Electricity Reforms agreement allowed private sector participation in wind energy projects thereby inviting competition to the sector (DEA, 2009). In 2003, starting of emission trading system by Denmark also helped to country to adopt renewable energy sources in the country. In 2004, Denmark announced that future of renewable energy for the country lies in offshore wind parks and fully pledged to support the sector (DTE, 2004). Denmark has set an ambitious target of 30% of electricity sourced from renewable by 2020 (DEA, 2009). Denmark is a signatory to the Kyoto protocol and also a part of the overall European Climate and Energy policy of Co2 emission reduction targets of 20% by 2020 (1990 baseline scenario). Denmark has an internal target of 50% Co2 reductions by 2050 by trying to become fossil fuel independent by 2050 (DEA, 2007). A combination of proactive policies, awareness creation and subsidies has made Denmark one of the leading players in Wind energy today. Denmark has been a pioneer of exploiting wind energy for more than 2 decades which has resulted in one of the highest wind power penetration levels in the world, close to 25 % (EWEA, 2011). Following the likely commissioning of Horns Rev 2, Nysted/Rødsand 2 and the Djursland/Anholt projects, by 2012, the cumulative off-shore wind capacity in Denmark will be around 1300 MW (EWEA, 2012).

Consent Procedures

Danish Energy Authority (DEA) acts as the single window agency for awarding consent for offshore wind projects. The sites are chosen by DEA and tenders invited which the developers bid against each other. The developers are also free to choose their own sites outside the zones identified by the DEA (Deloitte, 2011). However, the developers are responsible for getting all the clearances including the Environmental clearances themselves. The DEA has the authority to award licenses and permits by consulting all the concerned stakeholder departments in the Government. There is a pre-qualification of the developers on the financial, legal and technical competence and those who pass muster are invited to bid for the tenders.

Negotiations are held with developers who successfully go past the pre-qualification stage and the developers are selected based on the price per unit of power, their credibility of the schedule and the chosen location. The successful applicant is granted a permit to survey the area but still has to do an

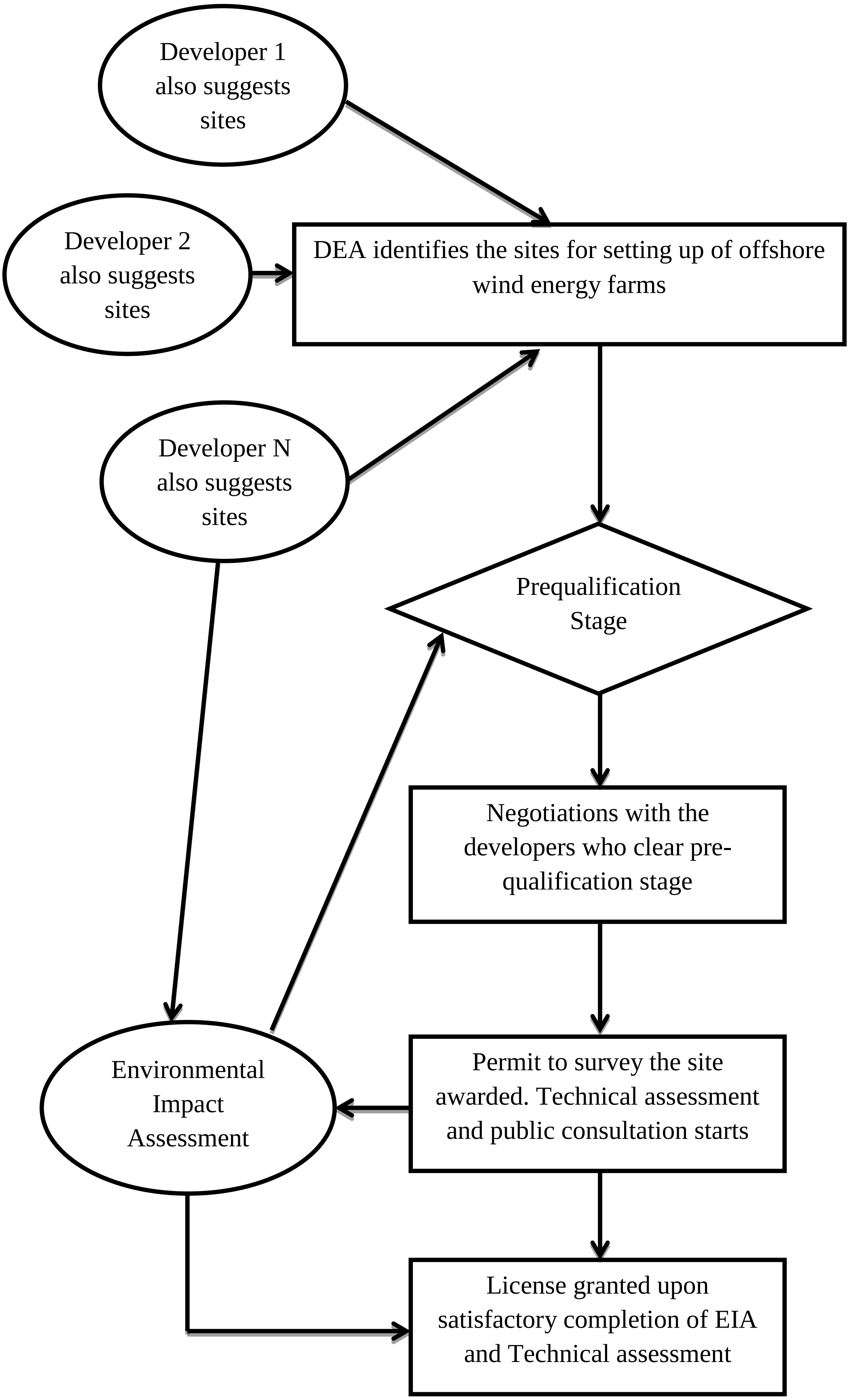
Environmental Impact Assessment (EIA) as well as technical assessments as needed. The developers then await the public consultation process after submitting the complete application with the EIA. After this, once the permit holder proves that all preconditions are met - the DEA will give the licence to establish the offshore wind farm, under specified conditions, after getting satisfied with the preliminary investigation reports submitted by the developer. The flowchart of consent procedure is given in Figure 6.5.

Grid Connectivity

The responsibility of the grid connection depends on the nature of project award route taken by the developer (DEA, 2009). If the project was awarded through a tender, then the responsibility of the evacuation infrastructure from the offshore wind farms to the nearest point onshore is that of the TSO, who spreads the costs incurred for grid connectivity over the population of Denmark. So the cost of grid connection is socialized. The developers are guaranteed financial compensation if the TSO is unable to utilize the power they produce (KPMG, 2009). However, the internal grid of the farm is the responsibility of the developer, which consists of the cabling between the turbines and the offshore transformer station that is based inside the project zone.

But if the project was awarded through the open door route then the responsibility of grid connectivity and attendant strengthening of the grid at the onshore locations lies with the developers. The developer gets revenue based on onshore wind farm rules (Deloitte, 2011).

Figure 6.5 - Flowchart of the consent procedure in Denmark



Financial Incentives

Depending on the age of the turbine and when it was connected to the grid the financial subsidy varies. The turbines connected to the grid from February 2008 are given a premium of 0.25 DKK/kWh for 22,000 full load hours on top of the market price of electricity, and an allowance of 0.023 DKK/kWh for balancing power costs (DEA, 2009). Cooperative owned wind turbines get additional incentives in terms of waiver of income tax for revenue up to DKK (Danish Krone) 7000, which helps to diversify the ownership of wind turbines and increase public acceptance of wind projects.

Offshore wind farms have been supported in three broad ways

1. The standard tariff as mentioned above with no changes. The cable cost will be borne by the network operator in the tender mode. Two offshore wind farm projects have opted for this pricing strategy
2. The standard tariff for an long duration, effectively a negotiated cost-plus basis as opted by a couple of large offshore wind farm developers
3. Competitive tendering - a variable tariff, applicable to the first 50,000 full load equivalent hours as opted by three large offshore wind farm projects

The future offshore wind farm projects are likely to go the tendering and negotiated tariff way for a specific number of full load hours of power generated. Table 6.2 gives the current status of the offshore wind energy sector in Denmark.

Table 6.2 - Current status of offshore wind in Denmark

Status	Capacity [MW]
Operational	877
Under Construction	0
Contracted	0
Permitted	400
Permit Applied	4218
Site Lease	18
Announced	1200
Total	**6713**

Source: DEA, Denmark, 2011

Impact of these policy initiatives

1. *Single Window Clearance*: DEA is the sole authority for awarding the permit for offshore wind energy projects. The developers need to deal with one authority, the DEA, which not only reduces the time and efforts but also ensure there are no divergent policy confusion that normally emanates when there are multiple authorities to deal with.

2. *Tendering process*: The tendering process has ensured that lowest bids get awarded which reduces the cost of power supplied to the people and also drive innovation in the sector.

3. *Environmental assessment*: The EIA done by the State helps the developers to quickly install and commission the offshore wind energy parks, which have resulted in growth of offshore wind energy in Denmark.
4. *Grid Connectivity*: Socialising the cost of grid connectivity over the population has resulted in lower capital costs needed to set up offshore wind projects.

Summary of the offshore wind energy policies in Denmark

Denmark has actively supported the growth of offshore wind energy sector in the country by adoption of several proactive measures. Environmental impact assessment usually delays the offshore wind projects, which now is the responsibility of the state. Similarly, grid connectivity to offshore wind farms is huge challenge faced by developers if they have to bear the cost, where in Denmark the grid connectivity is guaranteed by the state at no cost to the project developers. Also, single window clearance mechanism and transparency in the bids have made Denmark an attractive destination for offshore wind energy investments. However, the only downside to the policy initiative is not adopting tradable green certificates mechanism to give the project developers a premium on the power generated and instead adopting the steady, albeit lower revenue generating mechanism of feed-in –tariffs. Nevertheless, Denmark has one of the most progressive policy initiatives to encourage the growth of offshore wind energy sector in their country.

6.2.4 Netherlands

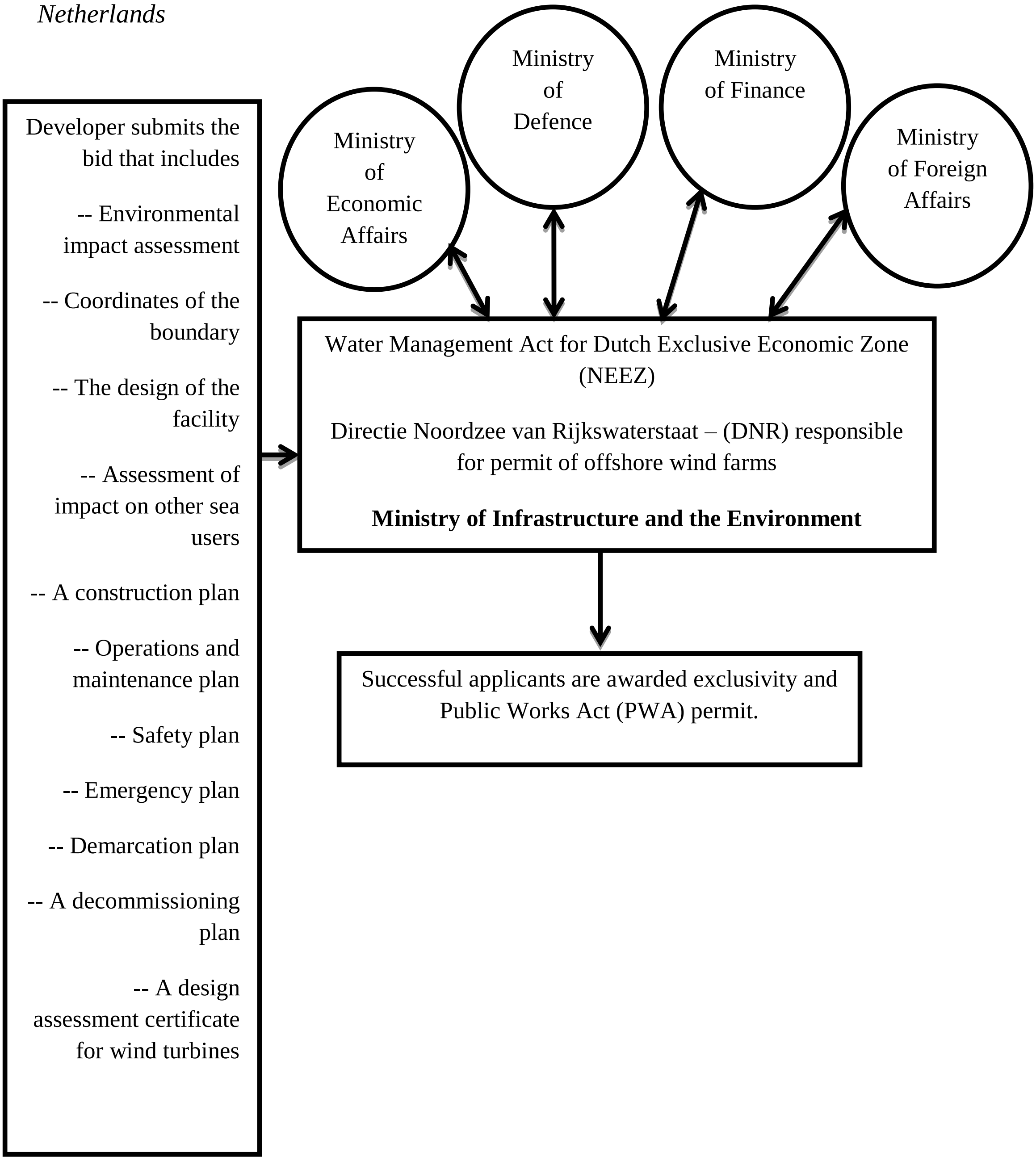
Netherlands has had definite R&D programs and policies to support innovation in wind turbine manufacturing, since 1976, which led to the growth of production of wind turbines in the country. Investment subsidies granted in 1988 (which was based on the capacity of the plant installed) also boosted the growth of wind energy sector. The investment subsidy was later changed to generation based incentive to boost actual production (DTI, 2009). In 1989, the electricity law mandated grid access to wind energy farms which saw growth of wind energy projects (DTI, 2009). Netherlands has set a target of

14% of electricity from renewable by 2020 as part of the overall EU commitment to reduce greenhouse gases and increase the share of renewable in the electricity mix (Deloitte, 2011). Netherlands has set an ambitious target of 6000 MW from offshore wind parks and 6000 MW from onshore wind farms by 2020 (EWEA, 2012). This target of 6000 MW for offshore wind ranks third in Europe after that of UK and Germany (EWEA, 2012). Netherlands has very good wind resources and long experience of over two decades harnessing wind power. However, absence of regulatory clarity of sustainability of policies on a long term basis, concerns about the tendering process itself, is hindering the growth of offshore wind projects in Netherlands (Toke, 2011).

Consent Procedures

Public works and water management act (WBR) is the key legislation under which consent can be given to offshore wind parks for the entire Dutch Exclusive Economic Zone (NEEZ), except sweet water (KPMG, 2009). The National Water Department for the North Sea, now part of Ministry of Infrastructure and the Environment, is the body responsible for the permitting of activities within the NEEZ. An Environmental impact assessment must be submitted along with the application (which contains the design of the facility, coordinates of the boundary, environmental impact assessment, assessment of impact on other sea users, a construction plan, operations and maintenance plan, safety plan, emergency plan, demarcation plan, a decommissioning plan and a design assessment certificate for wind turbines) to obtain consent (Deloitte, 2011). Several permissions need to be taken by the developers before they get the go-ahead from the government. However, to ease the procedure the government has nominated a nodal agency that will coordinate communication between the applicant and relevant administrative bodies to get all necessary approvals. If the application is successful, the Ministry of Infrastructure and the Environment awards permit for installation and commissioning of the offshore wind parks to the developers. The flowchart of consent procedure is given in Figure 6.6

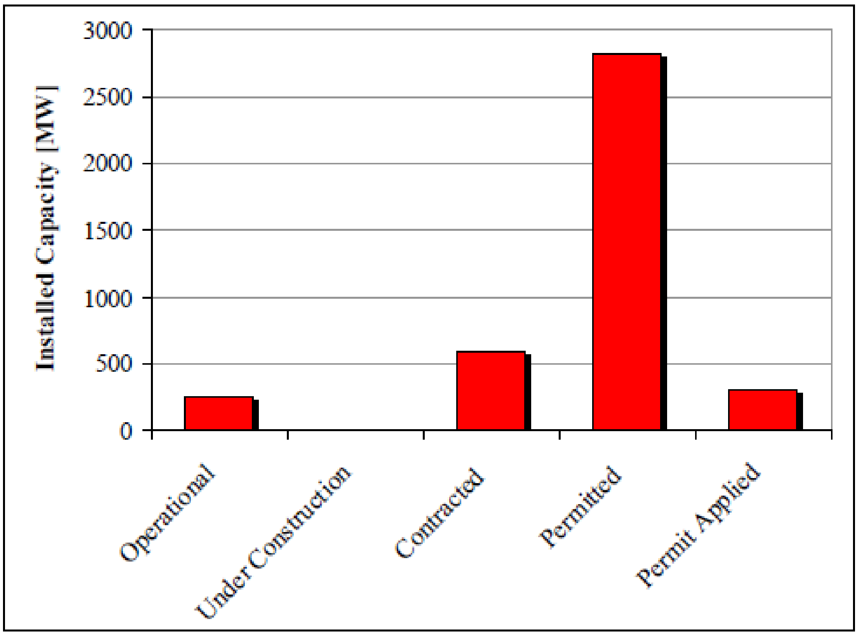
Figure 6.6 - Flowchart of the consent procedure for offshore wind parks in Netherlands



Grid Connectivity

TenneT is the onshore grid owner and regulator. The developer of offshore wind parks must pay for cabling and offshore grid infrastructure, the costs of which have to be factored in during the bid itself (IEA, 2009). While, some suggestions about Tenne T building the offshore grid infrastructure were also made, it has not been made into a law. So the wind farm developers have to make an application to build the offshore grid to Tenne T (KPMG, 2009). The Government's mandate of higher priority for access for clean energy producers by TenneT in times of network capacity shortage will also help offshore wind farm developers. Netherlands has a highly evolved grid infrastructure in place with suitable cross-country interconnections as of today (IEA, 2009). The only challenge will be lack of availability of onshore space for more high voltage lines and underground cables for future expansions (Deloitte, 2011). The current offshore wind sector is given in Figure 6.7.

Figure 6.7 - Offshore wind sector in Netherlands



Source: Deloitte, 2011

To increase availability of offshore wind energy in future the Netherlands will require good control of the grid and sound interconnections with the rest of Europe. There are several plans by TenneT to have inter-country grids in place with other EU countries like Germany, Norway and Denmark (DTI, 2011).

Financial Incentives

Initially, the subsidy was based on the name plate capacity (KW of capacity installed) of the offshore wind projects. But this lead to over-dimensioning of projects to get higher incentives, and hence was changed to generation based incentive (KWhr of electricity produced) (Deloitte, 2011). This has helped in the growth of wind energy projects in Netherlands. Under the new scheme, those projects that received approval, participated in a tender process for subsidy offered by the Government (IEA, 2010). The project that has the lowest tariff in its bid won the tender and was allocated the subsidy until the amount reached the predefined limit. Should any developer not accept the partial subsidy it will be offered to the developer next in the order and this process continues till full subsidy is disbursed (KPMG, 2009).

The subsidy is offered for a period of fifteen years subject to several conditions. There is a base electricity price (average spot market price of electricity) and the tariff value as defined by the competent authority (DTI, 2010). The subsidy helps to bridge the gap between the electricity floor price and the tariff value. If the existing rate is below the floor price, the developer gets a sum of floor price and subsidy which may be less than the tariff value. If the existing rates is more than the tariff value, then the developer get the existing rates but no subsidy (EWEA, 2011). Table 6.3 gives the feed-in tariff bonus by distance from shore to the offshore wind park.

Table 6.3 - Tariff bonus by distance to coast in Netherlands

Distance	**€ / MWh**	**Distance**	**€ / MWh**
< 30 km	-	60 km << 65 km	8.75
30 km << 35 km	1.25	65 km << 70 km	10.0
35 km << 40 km	2.5	70 km << 75 km	11.25
40 km << 45 km	3.75	75 km << 80 km	12.50
45 km << 50 km	5.0	80 km << 85 km	13.75
50 km << 55 km	6.25	85 km <	15.00
55 km << 60 km		*7.5*	

Source: EWEA, 2011

Also offshore wind energy projects get a maximum subsidy for 3180 hours of production (80% of 3975) thereby creating an upper limit for subsidies. In a different manner this incentivizes lower generation from offshore wind farms as they tend to get a bigger proportion of the subsidy.

The commissioning of the project should begin within 5 years of subsidy being offered failing which the government retains the right to revoke the bid bond of € 20 Million offered during the bidding process (EWEA, 2010). In addition the government gives innovation grants to those projects which can demonstrate innovative approaches in foundations, turbine designs etc. These are given to spur innovation in offshore wind energy projects.

Impact of these policies initiatives

Uncertainty in the policy environment has slowed the adoption of offshore energy sector in Netherlands even though the Dutch had an earlier mover advantage. The developer has to complete the Environmental impact assessment at their cost and also has to bear the grid connection expenses which is a substantial part (close to 30%) of overall project costs (Deloitte, 2011). Regulatory approvals are now one stop shop where the developer interfaces with just DNR which in turn interfaces with other ministries. Clarity on policies for long term and continuity of these policies are needed for Netherlands to exploit the offshore wind energy potential that exist in the country.

Summary of the offshore wind energy policies in Netherlands

The award criteria and regulatory approvals for setting up of offshore wind energy farms in Netherlands have been simplified with a single Government interface provided. But the evacuation infrastructure and environmental clearances adds to the project costs and delays. Additional tariff given for increasing distance from the shore, liberal timeframe for setting up of offshore wind farms, easy depreciation rule are some of the positives in the policy adopted by Netherlands to encourage the growth of offshore wind energy in country.

The summary of the offshore wind energy policies of the UK (largest offshore installation), Denmark (pioneer and oldest offshore wind farm that's operational), Germany (leader in offshore wind energy) and Netherlands are given (in Table 6.4) below.

Table 6.4 – Comparison of Offshore Wind Energy policies adopted by select European countries (Denmark, Netherlands, UK and Germany)

Key Factor	UK	Germany	Denmark	Netherland
Government plans for expansion of offshore wind energy	Specific plans in place. Ambitious targets with excellent visibility to future projects	Long terms plans have been drawn which are stretch goals	Modest plans for expansion but the target is well known	Promising target by several delays and uncertainties.
Tender model	Multisite tender rounds Zones are identified by the State. Investor proposes the site within these zones	Open-door procedure. Investor proposes sites but overall 5 clusters have evolved where offshore wind energy is operational	Single site auction and project based. Site identified by the state	Multisite / open selection auction Investor proposes sites
Award Criteria	Call for tender after prequalification Projects awarded based on developer's ability	First come, first served Permission needed in advance	Based on price/tariff. Prequalification done and then developers who pass the stage are called for negotiation	Based on tariff Permission needed in advance
Time frames for use/ establishment	Fixed but enough headroom	Flexible and spacious	Fixed and rigid (2-3 window for establishing the far post the award)	Fixed, but moderate (3 gestation period for construction to start)
Subsidy settlement for sale of electricity	Renewable obligation certificates (ROC) gives enough headroom for profit for the investors as they are market linked. ROC over and above	Fixed and, uniform tariff (at least12 years ahead) Extension of subsidy period depending on distance to shore and depth	Fixed settlement price 10-15 years) Full set-off of electricity income	Fixed tariff as per winning tender(15 years) Addition for distance to shore Partial set-off of electricity income

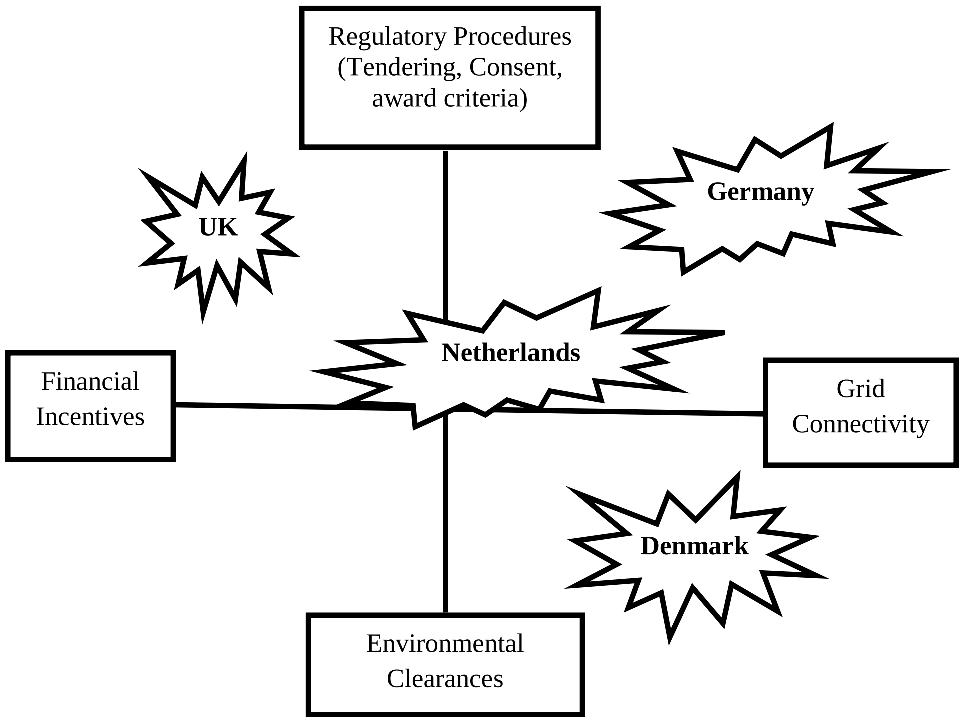
	the electricity prices till 2037 2ROCs/MWhr for offshore wind, which is twice the amount of other renewable			
Supplemental incentives (penalty, sprinter bonus, etc.)	Exemption of Climate Change Levy for buyers Lease payment for sites Application fee and guarantee provision	Sprinter bonus (declining on taking into operation after2015)	Keep-open penalty Delay penalties	Easy depreciation rules for investments Keep-open penalty Innovation bonus
Grid connection	Investor is in charge of and bears expense of grid connection	Grid connection costs borne by the TSO – based on developer meeting conditions	Free connection; state performs, finances and guarantees	Investor bears expenses of grid connection Plans to get the TSOs bear the cost.
EIA	Performed in continuation of tender and funded in parts by the state and the investor.	Performed along with the application of interest and funded by the investor	Completed before the call for tender and fully funded by the state	Performed prior to auction and funded by the investor.
Regulatory procedures and planning	ORCU established to act as a single window for clearances, although multiple clearances are required. ORCU reduces the time for obtaining permits	Depending on the distance to the coast, some approval are awarded by regional state agencies (if less than 12 nautical miles), some by Federal (if greater than 12 nautical miles)	DEA acts as a single window clearance agency.	Ministry of Economic affairs to co-ordinate approvals. Multiple approvals needed. Process getting streamlined to make the approvals smoother

Source: Deloitte Reports (2011), EEA (2010), EWEA (2011)

Perceptual map of attractiveness for offshore wind sector in Europe

The Perceptual map of attractiveness of the countries UK, Germany, Netherlands and Denmark as a destination for offshore wind energy investments on four key parameters (Regulatory Procedures, Financial Incentives, Grid connectivity and Environmental clearances) is shown below in Figure 6.8

Figure 6.8 - Perceptual Map of relative position of the 4 European countries



UK has the most attractive offshore wind energy policy when it comes to financial incentives and regulatory procedures, while Germany is attractive from the point of view of grid connectivity and ease of regulatory procedures. Denmark has the most hassle free Environmental clearance mechanism (done by the Government) and the cheapest access to grid (free of cost access for the project developer) while Netherlands has easier regulatory clearances but

6.3 Set of offshore wind energy policies from EU that can be adopted by India

The best practices in offshore wind energy policies of select countries in Europe that can be adopted by India are given below

'Single Window Clearance' procedure: In all countries investigated, the pre-exploitation (pre-construction) procedure necessitates input from at least 7 different administrations – whether this be only in a consultative or advisory capacity or in a more extended capacity, such as being a direct awarding body, for instance in the granting of a permit, domain concession or lease. At present, the UK has put into place a 'one stop shop' procedure to ease the procedural difficulties for project developers. Denmark is also aiming for a one-stop procedure. India has around 20 departments that are stakeholders of approval process. Single window clearances will go a long way to speed up growth of offshore wind energy.

Transparency in levies*:* The fee, lease, administrative charges etc. need to be known to developers in advance so that there are no surprises while executing the project. Several European countries have opaque charges and levies which causes grief for the project developer leading to delays in completion.

Risk mitigation: Financial incentives for new technologies, such as offshore wind energy in India, should secure investments to cover for pioneering risks. In so doing, investments are assured a guaranteed ROI for the first generation of projects. Both fixed feed-in tariffs and renewable energy certificates, implemented in a secured environment, have been shown to attract the required investments when combined with legally enforceable purchase contracts for typically 15 to 20 years. India needs to adopt these inducements to motivate developers to look at offshore wind energy.

Risk hedging schemes: Offshore wind energy projects, at least during the initial stages, are risky in India as these are new technologies. Developers will face challenges to get Insurance cover on their own, especially from private insurance agencies. For the first 'wave' of developments, the public sector insurance companies (with overt support from the Government) could play an important role by initiating risk hedging schemes in association with insurance companies – as is currently done for mature sectors such as shipping and air-traffic.

'No squatter' clauses: Concession legislation should prevent early offshore wind developments being hindered or prevented by speculative concessions. This can be achieved by imposing deadlines – accompanied with penalties or loss of the concession – for follow-up action, for instance by requiring that the developer start building activities within a limited period of time after the required permissions have been granted. This will ensure that there are no 'squatters' on potential wind farms sites as seen even in onshore wind energy.

6.4 Set of offshore wind energy policies that need to be uniquely tailored by India

Early completion bonus: Bonus for early completion and commissioning of offshore wind farms needs to be included to incentivize developers to accelerate completion of projects. Currently, in EU, there's a penalty for delay in completion but no bonus for completing work ahead of schedule. Since 'Risk' and 'Reward' go together, policy makers need to announce sprinter bonus for developers

Environmental clearances*:* Environmental clearances significantly delay many infrastructure projects in the country. Hence the Government need to accord environmental clearances to the proposed project sites even before inviting bids from interested developers.

Accurate data to predict the offshore wind energy potential*:* Currently, accurate data on offshore wind energy potential in the country is unavailable. Wind energy potential in a site is an important parameter for obtaining funding from financial institutions for a project developer. Hence efforts should be made to obtain accurate data.

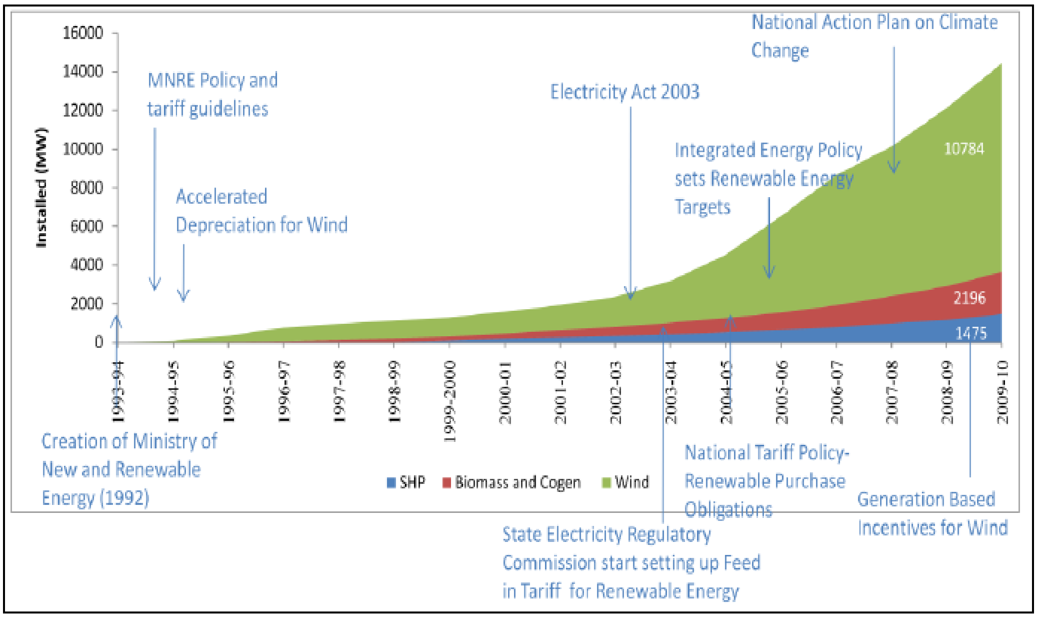
Building evacuation infrastructure: One of the most important, and probably as expensive, in an offshore wind energy project is to develop evacuation infrastructure from the seas to the grid onshore. As this will be prohibitive for any developer, Government could consider building the evacuation infrastructure to encourage growth of offshore wind energy sector.

Legally enforceable payment mechanism*:* Another important feature, unique to India, is the poor financial health of most of the State Electricity boards (SEBs) that buy power from offshore wind farms. There have been several cases in the case of onshore wind farms, where the developers have not been paid for the power purchased for several months. Such delays in realizing payment for huge infrastructure projects (that run into several million US dollars) will adversely affect the working capital and cash flows of project developers forcing them to take additional loans at high interest to keep the business going. Hence, legally enforceable payment mechanism needs to be put in place to give confidence to investors and project developers. These are some of the areas that are needed to be uniquely tailored to Indian context to accelerate the growth of offshore wind energy farms.

6.5 To study the support of policies in the growth of onshore wind energy sector in India

India has put together several policy and regulatory measures to promote renewable energy as elucidated in chapter -2 of this report. The Electricity Act 2003 was a watershed policy which not only unbundled the power sector but also encouraged competition and private sector to invest in wind farms. Two important developments, de-licensing power generation and allowing open access, have helped wind energy sector to grow rapidly in India. The act also mandated the State Electricity Regulatory Commissions (SERC) to decide on the tariff to be paid to renewable projects at different rates. The SERCs have in turn mandated the distribution utilities to source a certain pre-defined percentage of electricity from renewable generators called the RPO. The proactive policies announced by the Government also allowed captive generation, established frameworks for power trading, and allowed open access to both transmission and distribution. All these steps had a substantial impact on attracting private investment into the power sector. As a result, wind energy capacity grew dramatically. One of the reasons for the impressive growth of onshore wind energy is due to the proactive policies adopted by the Government of India (World Bank reports, 2010). As seen in the figure - 6.9 below, Wind energy installations showed rapid progress after the year 2003-04 when supportive policies were introduced.

Figure 6.9 - Impact of policies on the growth of wind sector in India since 2003



Source: World Bank Report, 2010

The incentives extended to the wind energy sector in India are given in the Figure 6.14 and the policies of various state governments in India to encourage wind energy development are given in Figure – 6.10.

Figure 6.10 - Financial Incentives for the Wind energy sector in India

Tax Incentives for the Wind Energy Sector

Description of Goods		Rates
INDIRECT TAXES		
I.	Wind operated electricity generators upto 30 kW and wind operated battery chargers upto 30 kW	5%
II.	Parts of wind operated electricity generators for manufacturer of wind operated electricity generators, namely	
	a. Special bearing	5%
	b. Gear Box	5%
	c. Yaw Components	5%
	d. Wind turbine controllers	5%
	e. Parts of the goods specified at (a) to (d) above	5%
	f. Sensor	25%
	g. Brake hydraulics	25%
	h. Flexible coupling	25%
	i. Brake callipers	25%
III.	Blades for rotor of wind operated electricity generators for the manufacturers or the manufacturers of wind operated electricity generators.	5%
IV.	Blades for rotor of wind operated electricity generators for the manufacturers or the manufacturers of wind operated electricity generators.	5%
V.	Raw materials for manufacturer of blades for rotor of wind operated electricity generators	5%
VI.	Customs Duty on Permanent magnets for Wind Operating Electricity Generators	5%
DIRECT TAXES		
I.	80% Accelerated Depreciation on specified Non-conventional Renewable Energy devices/systems (including wind power equipment) in the first year of installation of the projects.	
II.	Tax Holiday on Power Projects.	

IREDA Financing Norms for Wind Power Projects

Financing for	Interest Rate	Max. repayment period	Min. promoters contribution	Lending norms	Remarks
Development and setting up of wind farms (including off - shore wind projects)	11.25% to 11.90%	10 years	30%	Upto 70% of total project cost	Projects set up by manufacturers or their subsidiaries with minimum capacity of 5 MW, may avail additional loan up to 15%, secured by Bank Guarantee/FDR and generation guarantee is provided for entire loan period to the Borrowing Company and the same is assigned to IREDA.
Manufacturing of equipments and parts for wind energy	12.75%	10 years	30%	Upto 70% of total project cost	Maximum moratorium of 2 years
Market Development Programme for Wind: SPV hybrid system	12.75%	10 years	20%	Upto 80% of total project cost	Maximum moratorium of 1 year. MNRE may also provide interest subsidy.

Source: IREDA

Source: IREDA and EXIM Bank, India 2010

Subsequent policies that followed the Electricity act 2003 like the National Electricity policy (encouraging private sector competition), National Tariff policy (preferential tariff for wind energy), Accelerated depreciation, tax subsidies, duty waivers, generation based incentives etc, apart from state specific policies (Figure 6.11) have enormously helped the growth of wind energy sector in India.

Figure 6.11 - Key policies of various state governments to promote wind energy in India

Policies by State Governments for Setting-up of Wind Power Projects

State	Wheeling[a]	Banking[b]	Buyback[c]	RPS[d]	Others
Andhra Pradesh	5% of energy	Not allowed	₹ 3.5 / kWh frozen for 10 years	--	Industry status granted
Haryana	2% of energy	Allowed	₹ 4.08 / kWh with escalation	--	
Karnataka	5% of energy	2% p.m. for 12 months	₹ 3.40/kWh fixed for 10 years	3%	Exemption from electricity duty
West Bengal	₹ 0.30 / unit which may be revised	6 months	To be decided on case to case basis	--	
Madhya Pradesh	Allowed: 2% of energy + charges	Allowed	₹ 4.03 / kWh, reducing @ 17 paisa/year	--	Exemption from electricity duty
Maharashtra	2% of energy + charges	12 months	₹ 3.50 / kWh with escalation clause	--	Subsidy for power evacuation arrangement
Rajasthan	10% of energy	3 months	₹ 3.67 - ₹ 3.71/kWh	--	Exemption from electricity duty
Tamil Nadu	5% of energy	12 months	₹ 2.90 / kWh	--	--
Gujarat	4% of energy	Monthly settlement	₹ 3.37 / kWh fixed for 20 years	--	Exemption from electricity duty
Kerala	5% of energy	9 months	₹ 3.14 / kWh for 20 years	--	--
Punjab	2% of energy	Allowed	₹ 3.66 / kWh with five annual escalation	--	--

Source: MNRE, State Policies

[a]Wheeling: Charges imposed on entities using power for captive consumption at their sites routed through the state grid
[b]Banking: Storage of power generated by producers with the State Electricity Boards which can be drawn for future use
[c]Buyback guarantee from State Electricity Grids for purchase of wind power generated
[d]Renewable Portfolio Standard – State utilities have to purchase a certain portion of their energy from green sources

Source: IREDA and EXIM Bank, India, 2010

Apart from the financial incentives mentioned, India also established enabling institution ecosystem to foster the growth of renewable energy in the country and wind energy benefitted immensely by these efforts. India is the first country in the world to have a dedicated cabinet level nodal ministry (MNRE) to propel the growth of renewable in the country. MNRE has played a key role in setting the vision, framing supportive policies, creating the R&D infrastructure (CWET), managing the oversight of funding renewable projects (IREDA), resources mapping exercise and acting as a catalyst to expedite India's journey to embrace renewable sources.

Agencies for promoting renewable energy have been set up in most states as well. The impact of these policies has been positive so far, with legally enforcement payment mechanism and mandatory sourcing of RPOs are the two missing pieces in the policy puzzle. The wind sector which grew initially as a tax saving instrument has morphed into a commercially viable venture as substantiated by the advent of several IPPs in the wind energy projects.

Thus there is a direct and positive correlation between policy initiatives and growth of onshore wind energy in India.

6.6 Concluding Remarks

Europe is a pioneer and the world leader in offshore wind energy sector as of today. Each of the countries reviewed have their own policies to support this sector and they vary considerably from country to country. The support mechanisms can be broadly classified into Tender based system (Denmark & Netherlands), ROC based (UK) and Feed-in tariff based systems (Germany).

Each support mechanisms have their own advantages and disadvantages. Apart from the financial support, several other factors like grid connectivity, continuity of policies for the long term, award criteria, visibility into future project pipeline and host of other factors come together to make a country attractive for offshore wind farm developers. India would do well to understand the nuances of the perception of risks that project developers of OWP have and draft policies accordingly based on wealth of information and experiences gained in Europe to promote offshore wind energy sector in their respective countries. Also, experience with the onshore wind energy has shown that the sector grew multi-fold, over the years due to the proactive policies adopted by the Government of India. Hence there is a direct relationship between supportive policies and growth of renewable in India. Supportive policies for offshore wind energy will give the necessary impetus to promote the sector in India.

7 CHAPTER 7 – CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

India needs every avenue of energy source to power its economy. However, offshore wind Energy is an untapped source. Initial studies show harnessable potential exists for offshore wind energy in India. Dhanuskodi (in Tamil Nadu) and Kutch (in Gujarat) are most promising for sites for Phase – I of offshore wind exploration. Preliminary feasibility, covering Market, Financial, Technical, Social Cost Benefit and Ecological, conducted to study the viability of offshore wind energy is encouraging. Offshore wind energy policy formulation for India must cover five broad areas of Government support, Fiscal and quota based incentives, availability of local expertise, capital for investments and an enabling R&D ecosystem. However, Government Support (F1), Fiscal & Quota based incentives (F4) and enabling R&D ecosystem (F5) has high impact on the growth of offshore wind energy in India.

7.2 Conclusions

Based on the research study and analysis the following conclusions have been reached.

Captive Market for Electricity in India: It can be concluded from the market analysis of power scenario in India that, as long as the demand and supply gap for electricity continues to grow, as it is at the present, there will be a captive market of consumers available in India for power generators to cater to, at the right price points (which varies from Rs 3/unit for fossil fuels to Rs 18/unit for Diesel generators). Offshore wind energy developers will find that a ready market in India to consume electricity generated by their offshore wind projects, if the pricing and reliability of supply are addressed, and therefore lack of demand may not a factor that would put the project at risk.

Financial feasibility of offshore wind parks in India is encouraging: The financial feasibility of offshore wind parks, as shown in the data analysis chapter, is very encouraging. Project IRR of almost 22% and break even tariff of Rs 6.62/unit of power is attractive for the investors to consider offshore wind parks as one of the lucrative avenues for investments. It must be mentioned that these data are from initial studies and detailed analysis, taking into account exact site conditions, need to be undertaken to corroborate these findings. However, the immediate conclusion that can be drawn is that offshore wind parks are financially attractive to be given a detailed consideration.

Offshore wind parks in India are technically feasible: It can be concluded from the study that a favourable case can be made on the technical feasibility of setting up of offshore wind farms in India. Long coastline (more than 7000 Kms) with steady wind speeds (greater than 8m/s), availability of large wind turbine manufacturers, presence of experienced EPC contractors, access to R&D institutions for skills training and existence of experienced project managers point to the fact that technically, there are no major challenges. Absence of grid connectivity from the sea to the mainland is a concern that needs to be addressed when the offshore wind farms are consented.

Growth of offshore wind farms is economically valuable for India: India imports expensive coal and oil (total of $ 125 Billion in 2011) to power its thermal plants, which not only strains the exchequer but also affects the environment. Offshore wind energy growth can reduce, if not eliminate, the need to import expensive fossil fuels apart from encouraging additional job creation, thereby proving beneficial for the economy as well.

Offshore wind farms are ecologically beneficial for India: Offshore wind farms reduces the need for land, which can be used for other productive activities, reduces the use of water in power generation (coal based thermal power plants use large quantities of water for cooling) and substantially reduces the carbon emission - thereby proving to be beneficial, ecologically for India.

Policies tailored to suit local conditions spur the growth of offshore wind energy sector in a country: Based on several literature that were studied as part of this research work, it can be concluded that policies are needed to encourage the growth of renewable energy sector, more so offshore wind energy sector in a country. Critique of offshore wind energy policies of the UK, Germany, Denmark and Netherlands have shown that each of these countries adopted unique incentive mechanism to grow offshore wind energy in their respective countries. Hence policies need to be tailored to suit local conditions and what works best for one country may not the best for another.

Policies for offshore wind energy can be broken down into smaller components: From the research it can be concluded that policies of offshore wind energy can be broken in smaller, manageable components. 'Government support', 'Fiscal and quota based incentives', 'availability of local expertise', 'capital for investments' and an 'enabling R&D ecosystem' all integrate to form the possible policy composition for growth of offshore wind energy in India.

7.2.1 Relating Conclusions with Theoretical Constructs

The core elements of offshore wind energy policy formulation, identified through literature survey, positively predict the growth of offshore wind energy in India thereby corroborating the hypotheses. Critique of offshore wind policies of select EU countries revealed that some combination of the variables identified through literature survey was used in their offshore wind energy formulation, thereby validating the accurate identification of these variables. Countries all over the world continue to use attractive policies to encourage the growth of renewable in their countries has been conclusive proven in the case of offshore wind energy as well – which is the core reason for undertaking this research work. Onshore wind energy in India experienced an accelerated growth only after supportive policies were put in place there by strengthening the case for a set of dedicated offshore wind energy policies for the country.

7.3 Observations

The following are the observations recorded during the research work.

1. Interest on the offshore wind energy sector in India is increasing among the stakeholders in the country, which is a positive sign.

2. Several large foreign developers of wind farms are showing interest in the wind energy industry in India – which means

improved access to technology and capital to develop offshore wind energy in the country.

3. Some of the best wind energy research institutions (NREL US, Berkeley Labs US and DTU Denmark are working closely with MNRE to identify offshore wind energy potential and chart its growth – this is a validation of the affirmative intent from all the stakeholders to make Indian offshore wind energy sector, a success.

4. Some of the largest financial institutions that fund renewable energy projects around the world, including EXIM Bank US, KfW Germany, World Bank, are very active in their support of India exploring offshore wind energy – a healthy sign that funds may not be a constraint for the right project.

5. A few large companies in India apart from ONGC have expressed interest in tapping the offshore wind energy in India after the communication of policy measures – a growing confidence of the potential this sector holds for India

6. Some of the large wind turbine manufacturers in the world have expressed interest to work on a partnership with project developers to exploit the offshore wind energy potential in India – another proof of the potential this sector holds for India.

7. Government needs to identify and create an exclusive zone in the sea for the dedicated use of installing offshore wind energy parks, with all necessary clearances from the stakeholder ministries, environmental clearances, local substations, grid connections to the mainland and suitable allowance made for shipping channels. Such 'turnkey' site preparation will help in accelerated deployment of offshore wind energy farms.

7.4 Recommendations

The following recommendations are made to encourage growth of offshore wind energy in India.

Nodal agency for faster approvals: India needs to create a nodal agency, under MNRE, to act of the "single window approval" authority for all offshore wind energy projects, similar to what has been done in Denmark, which will liaise with other government agencies as needed to secure all necessary approvals and consent for offshore wind energy farms. There are several ministries or departments in India that needs to be approached to obtain consent by the developers of offshore wind energy projects. Such cumbersome procedures will delay the commissioning of these projects resulting in substantial cost and time overruns, which could not be afforded by developers who have sunk in huge capital costs for offshore wind farms. Expecting a project developer to obtain these approvals from multiple agencies will be a daunting, show-stopper experience. Hence, it is important that a nodal agency under the ministry of new and renewable energy should be created to provide a single window clearance for offshore wind energy projects. This nodal agency should liaise with other stakeholders for necessary approvals. Many of the challenges in obtaining approvals can be resolved if MNRE identifies a large chunk of area in the seas that have all the clearances in place prior to inviting bids to installation of offshore wind energy technology park.

Accurate data on wind speeds: India needs to build bankable data on wind speeds at the seas to predict the exact potential of offshore wind energy. Wind speeds are very critical to estimate the power output of the offshore wind farms which decides the cash flows and hence the viability of the project. As the power output varies directly to the cube of the wind speeds, even a minor variation in estimating the wind speeds may results in huge deviation in the power output for the offshore wind farms. Hence the need to predict the wind speeds as accurately as possible.

Evacuation Infrastructure: Several research papers have concluded that availability of evacuation infrastructure is one of the most important criteria for growth of offshore wind energy in any country. Numerous projects in Europe are facing delays due to non-availability of adequate evacuation infrastructure. Also, transmission infrastructure costs are quite high for offshore wind farms, as sub-sea cabling requires superior engineering skills. For instance, the cost of grid connection in onshore wind farms, as a percentage of total costs is 2-9%, while the cost of grid connection for offshore wind farms as percentage of overall project costs is 15-30%. European countries have adopted different models for sharing the prohibitive costs associated with construction of evacuation infrastructure. In Denmark, for instance, the costs associated with evacuation infrastructure are being borne by the Government, whereas in Netherlands the project investor bears the costs fully and in Germany it is being borne by the Transmission System Operator. Research conducted by independent agencies like EWEA, EEA suggest that investors prefer the Denmark model of government fully contributing to the building of transmission infrastructure while recovering the costs from the public via a small increase in tariff. Similar model ('Socialising the costs') can be thought of in India, as the capital investments needed for setting up offshore wind energy farms are prohibitive vis-à-vis other renewable energy technologies. So a project developer will not be able to bear the additional costs of building the evacuation system as well.

Develop and communicate policy intent for long term (10 years or more): Published research has shown that having a focused policy for offshore wind energy farms and having a continuity of these policies for longer term has helped offshore wind energy sector to grow in countries compared to those countries that had "Traffic signal" type of 'start-wait-stop-start' policy measures. Policy continuity for long term gives the investors assurance of support from the government for the sector; thereby reducing the risk of future cash flows. Uncertainties in continuation of benefits have slowed down investments in several countries like Sweden and Netherlands in Europe. Even in India, when accelerated depreciation (AD) for onshore wind energy projects was withdrawn, investments have slowed down. Now project developers in India not only want accelerated depreciation to be re-introduced but they also want an assurance from the government that such fiscal benefits will continue for long term to make further investments in the onshore wind energy sector.

Legally enforceable payment mechanism: Onshore wind energy developers in India have faced long delays in realising payments from the state distribution companies/electricity boards that purchase the electricity generated by these wind farms. This delay has severely affected the cash flows and working capital of project developers. As offshore wind energy projects are much more capital intensive than the onshore wind farms, delays in releasing the payment on time will put the overall viability of the project in jeopardy. Unfortunately, the financial health of most of the distribution companies in India is poor, which restricts their payment capacity on time. The project developers are then left with no problem resolution mechanism to realize the money due to them, in the event of a default or delay by the state electricity boards or distribution companies. Hence suitable legal armour needs to be provided for the project developers to induce confidence that the money due to them will be disbursed on time by the SEBs. Legally enforceable payment mechanism will offer the necessary problem resolution protection and a means of escalation mechanism, which can be exercised in the event of severe delays of accounts receivables for project developers, which is lacking at the moment.

Encourage R&D in offshore wind energy: India needs to encourage R&D efforts to accelerate learning, bring down the costs of components, build knowledge base, develop skills in offshore wind farms and localize production of wind turbines. Offshore wind energy would need 20 additional resources for every MW of capacity added. So if India hopes to harness 50,000 MW of offshore in the next few years, it would need about 1 million trained and skilled human resources. India has started well to establish CWET (Centre for Wind Energy Technology, R&D arm of MNRE) to encourage skill development in wind energy. Similarly, R&D efforts to localize production of various components of wind turbine (like gearbox like instance) that are currently being imported at expensive rates, setting up of ancillary units to support the offshore wind industry are needed to accelerate the growth of offshore wind sector in India. Several countries in the world like China have reduced the overall cost of setting up of wind farms by as much as 50% due to localization. India needs to build R&D capability to achieve similar objectives.

Fiscal and Quota based incentives for offshore wind energy: All the project developers surveyed for this research have expressed their views that offshore wind energy in India would need a higher incentive (higher Feed –in Tariff vis-à-vis other renewable as adopted by Germany), higher Renewable obligation certificates (for example 2 ROCs for every 1 MWhr of offshore wind energy as adopted by the UK) at least in the initial few years to be established as another avenue for electricity generation. Accelerated depreciation of 80% of capital cost in the first year, which has been discontinued recently for onshore wind farms, can be re-introduced. Generation based incentives (GBI) with a generous cap of (10% the cost of project as envisaged in select countries in Europe) over the life of project can be considered. More importantly, legal enforcement of Renewable purchase obligations (RPO)/Renewable energy certificates (REC) needs to be considered to boost the investors’ confidence in the sector.

Financial incentives: Offshore wind energy sector in India can be declared as a 'priority sector' by the Government to help developers' access inexpensive bank loans. A priority sector tag, similar to what is given to agriculture, will entail an interest rate of 2% for loans from the banks. Presently, IREDA charges around 12% interest on the sum lent for renewable energy projects in the country. As a MW of offshore wind farm is likely to cost Rs 20 Crores, project developers will find it hard-pressed to service loans at higher rates of interest. Hence declaring offshore wind as a priority sector will ease a huge amount of burden on project developers and encourage them to take debt on their balance sheets. Cost of capital can also be reduced by levying a cess on fossil fuels and using the sum collected to partly fund offshore wind energy projects in India. Moratorium on interest payments for a period of minimum 5 years were another expectation from the project developers to invest in offshore wind sector in India. Apart from these the Government needs to extend the same benefits given to onshore wind energy sector to offshore as well – in terms of zero import duty on equipment and excise duty waivers to kick start the growth of the sector.

Technology, Market, Potential and Finances are available in India for offshore wind energy to grow in an accelerated trajectory. What is needed is a robust policy framework.

7.5 Research contribution

This research has attempted to make useful contribution in the following areas of offshore wind energy sector in India

1. Identified the basic elements of what could constitute the offshore wind energy policy for India. Developed a data collection instrument with its validity checked, which can be used by other researchers.

2. Identified the 5 broad levers of policy intervention needed for growth of offshore wind energy sector in India, which is a pioneer work to the best of researcher's knowledge.

3. Developed a model to predict the probability of growth of offshore wind energy sector in India which gives the relative impact of the 5 factors on the growth. Policy makers have the list of factors arranged on the order of their impact on the growth of offshore wind energy in a country and can thus focus their attention on those factors that make significant impact on the growth of offshore wind sector.

4. Feasibility study of setting up of offshore wind energy farms in India was conducted, covering the market, technical, financial, economic and ecological feasibilities was conducted, which has no published precedence and hence a unique contribution of this research

5. Critique of offshore wind energy policies adopted by UK, Germany, Denmark and Netherlands to identify the best of breed policies that boosted the growth of offshore wind in those countries, which can be used as a reference guide by the policy makers in India when they design the offshore wind policy for the country. The knowledge of

what worked in Europe and what are the challenges faced in offshore wind policy can accelerate the understanding of the nuances of various policy initiatives.

7.6 Limitations of the Study

The research is limited to India geography for the current period of study. So, while the overall model espoused in this study to calculate the log odds of growth of offshore wind energy sector in a country - identifying the variables, doing a factor analysis followed by logistic regression to arrive at log-odds - has universal appeal, the results obtained is specific to the sample size undertaken in the survey and restricted to India geography. The results cannot be directly extrapolated or tweaked for another country. Similar study, if done, for other countries in the world may yield different results, as conditions may be different.

Research work in offshore wind is at a nascent stage in India. Very little literature is available on offshore wind energy in India**.** So there will be some learning curve for all the respondents of the survey. Different factors may gain importance about offshore wind energy in India, once the learning is incorporated as the survey is perception based and are likely to change.

Force majeure conditions are not considered in the study – Risk premiums to insure some of these unforeseen conditions are possible solutions but that may drive the cost of the project. Quantification of carbon credits due to use of offshore wind energy and using this credit to bring down the cost of capital and hence the attendant impact of overall project NPV and IRR has not be considered.

Presently, there is very little official data available on the offshore wind energy potential in India. This research has used available, published data to do the feasibility study at an elementary level.

7.7 Future Scope of the Study

Detailed research can be carried out in subsequent studies by other scholars to quantify each factor in the logistic regression equation. Once these factors are quantified through separate research, they can be incorporated in the logistic regression equation to calculate the exact probability of growth of offshore wind energy in India. Currently, this thesis has arrived at the fundamental equation to calculate the log-odds of growth of offshore wind sector.

Detailed study can be carried out for each of the feasibility area. Deeper sensitivity analysis can be conducted to arrive at the feasibility analysis of offshore wind farms in India that mimics the exact site conditions, factoring different wind turbine available in the market etc. Currently the feasibility analysis is done at an elementary level covering the five areas of technical, market demand, financial, ecological and economic. Each of these five areas can be a focused area by itself for future work.

Quantification of the carbon credits from offshore wind farms has not been done as part of this study and can be carried out by future researchers. The money realized through carbon emission credits can be ploughed back into the venture to improve the project IRR.

7.8 Concluding Remarks

The study has identified the basic elements or building blocks of what could constitute an effective offshore wind energy policy intervention in India. Five levers - Government support, Fiscal and quota based incentives, availability of local expertise, capital for investments and an enabling R&D ecosystem – were advocated as focus areas to be encouraged, to accelerate the growth of offshore wind energy in the country. Out of these five, Government Support, Fiscal & Quota based incentives and enabling R&D ecosystem were recognized as the key components to be supported, as they had the highest impact on the growth of offshore wind energy in the nation. However, the other two levers; availability of local expertise and capital for investments also impacts the growth of offshore wind energy in the country and hence cannot be ignored. Overall, these five factors, and their sub-elements, will ensure that offshore wind farms takes off in a substantial manner in India. Preliminary feasibility analysis conducted indicates potential and project viability exists to promote offshore wind sector in India. This sector will be an additional power generation avenue for India which has been hitherto untapped. If done judiciously, offshore wind energy will go a long way to satiate the ever growing demand for energy from an emergent India.

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APPENDIX: QUESTIONNAIRE

Thanks for taking time to answer a set of questions on the Wind energy (offshore) sector in India. There are no ‘right’ or ‘wrong’ answers to these questions. Also, your exact identity will not be captured. So please feel free to respond to the best of your belief and conviction. The data collected will be used only for my PhD research work and will not be shared with any third party. It is likely to take about **10 – 12 minutes** to complete this questionnaire. Thanks.

You are an

a. Wind Turbine Manufacturer
b. Policy Maker (MNRE, Planning Commission)
c. Regulatory Agency (CERC, SERC)
d. Financing Institution (IREDA or other banks)
e. Academic and R&D Institution with interest in Wind Energy
f. Electricity board (Transmission and Distribution companies)
g. Project Developer
h. EPC Contractor
i. Independent consultant/Thought leader
j. Others (Please specify)

Section - I

1. India has good potential to grow the **offshore wind energy** sector in the country

( ) Strongly Disagree ( ) Disagree ( ) Neutral ( ) Agree ( ) Strongly Agree

2. For offshore wind energy sector to take-off, comprehensive **offshore wind energy policies** have to be initiated by the Government of India

( ) Strongly Disagree ( ) Disagree ( ) Neutral ( ) Agree ( ) Strongly Agree

3. Currently, **technology and capability** is available to harness the Offshore wind energy in India

( ) Strongly Disagree ( ) Disagree ( ) Neutral ( ) Agree ( ) Strongly Agree

4. **Capital and funds** are available to develop the offshore wind energy sector in India.

( ) Strongly Disagree ( ) Disagree ( ) Neutral ( ) Agree ( ) Strongly Agree

5. India has to eventually tap **offshore wind energy** to satisfy the ever growing demand for electricity in the country.

( ) Strongly Disagree ( ) Disagree ( ) Neutral ( ) Agree ( ) Strongly Agree

Section - II

For the questions below, please choose (on the 7 point scale) your response based on whether the variable proposed is an '**absolute must to have'** for the growth of offshore wind energy sector in India. Please 'tick' or 'circle' your response on the choice for e.g. Agree

6. Feed-in tariffs is 'an absolute must' to grow the Offshore wind energy sector in India

Strongly Disagree |Disagree |Somewhat Disagree |Neutral |Somewhat Agree |Agree |Strongly Agree

7. Accelerated depreciation has to be offered to grow the Indian offshore wind sector

Strongly Disagree |Disagree |Somewhat Disagree | Neutral | Somewhat Agree |Agree | Strongly Agree

8. Generation based incentives (GBI) must be offered to grow the offshore wind energy sector in India

Strongly Disagree **|** *disagree* **|***Somewhat Disagree* **|***Neutral* **|** *Somewhat Agree* **|** *Agree* **|** *Strongly Agree*

9. Legally binding Renewable purchase obligation (RPO/REC) is an essential prerequisite to see the growth of offshore wind energy sector in India

Strongly Disagree **|***Disagree* **|***Somewhat Disagree* **|***Neutral* **|** *Somewhat Agree* **|** *Agree* **|** *Strongly Agree*

Section - III

10. Faster approvals (like Single window clearance mechanisms) is an ‘absolute must’ to grow the offshore wind energy sector

Strongly Disagree **|***Disagree* **|***Somewhat Disagree* **|***Neutral* **|** *Somewhat Agree* **|** *Agree* **|** *Strongly Agree*

11. Sustainability of policy environment, on offshore wind, for a longer term (say 10 years or more) is very important to accelerate the growth of offshore wind energy sector

Strongly Disagree **|***Disagree* **|***Somewhat Disagree* **|***Neutral* **|** *Somewhat Agree* **|** *Agree* **|** *Strongly Agree*

12. Construction of transmission infrastructure to evacuate power from offshore wind farms in the seas, is an important prerequisite to grow the offshore wind energy sector

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

13. Extending financial incentives (like subsidies, moratorium on interest payment, zero duty on imports, excise duty waiver) for offshore wind projects is a must.

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

14. Tariff determination on wind speeds, and not based on zones, is an essential pre-requisite for the growth of offshore wind energy sector

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

Section - IV

15. Expertise and availability of EPC contractors for commissioning of the offshore wind farms will be a determining factor in the growth of offshore wind energy sector in India

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

16. Manufacture and availability of offshore wind energy components (like gearbox), locally, will be very important to grow the offshore wind energy sector in India

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

17. Growth of ancillary units is key to grow the offshore wind energy sector in India

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

18. Superior program execution skills and capabilities available for execution of projects is critical to grow the offshore wind energy sector in India

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

Section - V

19. Research institutions to build accurate data on offshore wind potential sites and wind speeds (Wind Resource map and Bathymetric data) is critical to grow the offshore wind energy sector in India

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

20. Institutions focussing on Skills development and training of the human capital, needed to work on offshore wind farms, will be needed to grow the offshore wind sector

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

21. R&D investments to localize production of expensive equipment, to bring the overall costs down, will be crucial to grow the offshore wind energy sector in India

Strongly Disagree **|***Disagree* **|***Somewhat Disagree* **|***Neutral* **|** *Somewhat Agree* **|** *Agree* **|** *Strongly Agree*

Section - VI

22. Availability of capital at attractive rates of interest, similar to what is extended to priority sector projects, is 'an absolute must' to grow the offshore wind energy sector in India

Strongly Disagree **|***Disagree* **|***Somewhat Disagree* **|***Neutral* **|** *Somewhat Agree* **|** *Agree* **|** *Strongly Agree*

23. Moratorium on interest payments for the first 5 years of project go-live, is needed to grow the offshore wind energy sector in India

Strongly Disagree **|***Disagree* **|***Somewhat Disagree* **|***Neutral* **|** *Somewhat Agree* **|** *Agree* **|** *Strongly Agree*

24. Creation of an offshore wind energy fund, from cess levied on carbon emissions or a Government backed guarantee to reduce the cost of capital, will be needed to grow the offshore wind sector

Strongly Disagree **|***Disagree* **|***Somewhat Disagree* **|***Neutral* **|** *Somewhat Agree* **|** *Agree* **|** *Strongly Agree*

25. Access to funds (from financial institutions) is not a problem to set up offshore wind energy farms in India.

Strongly Disagree **|***Disagree* **|***Somewhat Disagree* **|***Neutral* **|** *Somewhat Agree* **|** *Agree* **|** *Strongly Agree*

26. Declaring offshore wind energy sector as a “priority sector” for lending will help in the growth of offshore wind energy in India

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

Section VII - Additional Questions

27. Offshore wind energy sector can still grow in India without dedicated policies for the sector.

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

28. It’s still premature to talk about offshore wind energy in India. Time has not come as yet to tap the offshore wind power in India.

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

29. Offshore Wind energy policies adopted successfully by select European countries (Germany, Denmark and the UK) can be used as a reference by India for bringing out its own offshore wind policy.

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

30. I/my company will not consider investments in offshore wind energy sector in India, until dedicated offshore wind energy policies are put in place in India.

Strongly Disagree |*Disagree* |*Somewhat Disagree* |*Neutral* | *Somewhat Agree* | *Agree* | *Strongly Agree*

PROFILE OF THE AUTHOR

Swaminathan Mani is a Doctoral student with University of Petroleum and Energy Studies (UPES), Dehradun, India. He has done his BE (Hons.) from Birla Institute of Technology and Science (BITS) Pilani and MBA from Bharathidasan University, Trichy.

He has more than 18 years of full time Industry work experience (14 years in the software industry and 4 years in the non –IT sector). During his stint of 18 years, he has had exposure to managing C- level relationships in client and partner organizations.

He is presently working with Mahindra Satyam as Head – Marketing for the Business Value Enhancement consulting group.

He has deep interest in the Renewable energy space, especially in the wind energy sector, and is keen to work towards exploiting the fullest potential that renewable has to offer to safeguard the energy needs of India.

Swaminathan Mani has published research papers in international and national journals of repute and has also been invited as a speaker in international renewable energy conferences held in India.

Paper Publication

- Mani, S., & Dhingra, T. (2012). Diffusion of innovation model of consumer behaviour – Ideas to accelerate adoption of renewable energy sources by consumer communities in India. **Renewable Energy**, 39(1), 162-165. (ISSN: 0960-1481).

- Mani, S., & Dhingra, T. (2012). Integrated strategies to accelerate adoption of Renewable Energy sources by consumer communities in India. **Energy Blitz,** Vol -1 (VI), pages 24-28. (ISSN 2249-2992)

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- Mani, S., & Mishra, M (2012). Human Resources capacity building to accelerate the growth of RE Industry in India –Conference on Power Sector Reforms - Published by **Macmillan publishers** (ISBN 978-935-059-026-3)