Modelling Diffusion of Wind Power Technology

Submitted in partial fulfilment of the requirements

of the degree of

Doctor of Philosophy

By

Riddhi Panse

(10427005)

Advisor:

Dr. Vinish Kathuria

SHAILESH J. MEHTA SCHOOL OF MANAGEMENT

INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

2015

Approval Sheet

This thesis entitled "Modelling Diffusion of Wind Power Technology" by Riddhi Panse is approved for the degree of Doctor of Philosophy.

Examiners

(Prof Gopal Kadekodi)

(Prof. Kiran Momaya)

Advisor

(Vinish Kathuria)

Chairman

(Prof. NG Shah)

Date: 11th December, 2015

Place: IIT Bombay

DEDICATED

...

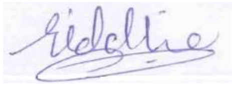
Smt. Ashwini Panse and Shri. Ajit Panse, my parents.

Words fall short in describing your kindness to me.

...

DECLARATION

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.



Signature

Riddhi Panse

Name of the student

10427005

Roll Number

DATED: ______________________

ABSTRACT

Present thesis is an effort to see the impact of policies causing diffusion of Wind Power Technology (WPT) at macro (aggregate) level and identify factors driving choice of adoption at micro (firm) level using theories of diffusion of innovations.

At macro level, the study involves modelling impact of policies on diffusion of WPT in two stages. In the first stage, comparative analysis of impact of policies on diffusion of WPT across five leading countries - namely China, United States of America (USA), Germany, India, and Spain - is performed to identify successful policies. One specific model for each country is proposed and model parameters are justified with corresponding policy initiatives in the country. Based on the identified models, the study also identifies the corresponding saturation point of diffusion for each country. Results indicate that popular traditional approach of “one size fits all” is not followed in diffusion of WPT and despite having same policy initiatives each country can indeed have a unique diffusion path owing its economic, social, and political objectives.

In the second stage, impact of key policies along with other State specific policies is modelled using econometric analysis on diffusion of WPT across seven selected States of India – namely, Tamil Nadu, Maharashtra, Gujarat, Rajasthan, Karnataka, Andhra Pradesh, and Madhya Pradesh - having significant wind potential. Aggregate index computed using four policies – Feed-in Tariff, Renewable Purchase Obligation, banking facility and wheeling charges - is found to have a positive impact on diffusion of WPT across these States of India. Additionally, unmet capacity and higher per capita income of a State are found to have a positive impact on the diffusion of WPT.

For the micro level study, factors influencing the decision of firms to choose a location to adopt WPT are identified through a case study for the State of Maharashtra in India. Five factors – namely, geographical, technological, infrastructure, societal, and bureaucratic - are identified through semi-structured interviews with six firms contributing to over 50 per cent of the installed capacity of WPT in Maharashtra. Subsequently, validation of the factors is

carried out through econometric analysis using the data for nine districts – namely, Satara, Sangli, Dhule, Nandurbar, Ahmednagar, Pune, Nashik, Beed, and Kolhapur. Results indicate that geographical characteristics indicated by gap between potential and installed capacity, technology perceptions indicated by expected Plant Load Factor (PLF), societal attitude indicated by density of Scheduled Tribes population, and bureaucratic approach indicated by proportion of Members of Legislative Assembly (MLAs) of ruling party determine the location choice of adoption of WPT by firms in a district. Interestingly, while unmet capacity has a positive impact on diffusion at macro level, it has exactly opposite influence on adoption of WPT at micro level. In other words, our analysis points a risk averseness of firms while investing in WPT.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Abbreviations

Abbreviation	Meaning
AD	Accelerated Depreciation
AP	Andhra Pradesh
AWEA	American Wind Energy Association
bn	Billion
CAGR	Compound Annual Growth Rate
CERC	Central Electricity Regulatory Commission
CPUC	California Public Utilities Commission
CWET	Center for Wind Energy Technology
EIA	Environment Impact Assessment
EU	European Union
FE	Fixed Effect
FGLS	Feasible Generalized Least Squares
FIT	Feed-in-Tariff
GBI	Generation Based Incentive
GDP	Gross Domestic Product
GHG	Green House Gas
GJ	Gujarat
GoI	Government of India
IREDA	India Renewable Energy Development Agency
K	Karnataka
Ke	Kerala
kW	Kilo Watts
kWh	kilo Watt hour
LAD	Local Area Development
MEDA	Maharashtra Energy Development Agency
MERC	Maharashtra Electricity Regulatory Commission
MH	Maharashtra
MLA	Member of Legislative Assembly
MLP	Master Limited Par
MNRE	Ministry of New and Renewable Energy
MP	Madhya Pradesh
MP	Member of Parliament
MSEDCL	Maharashtra State Electricity Distribution Company Ltd.
Mtoe	Million tonnes of oil equivalent
MW	Mega Watts

Abbreviations (Contd..)

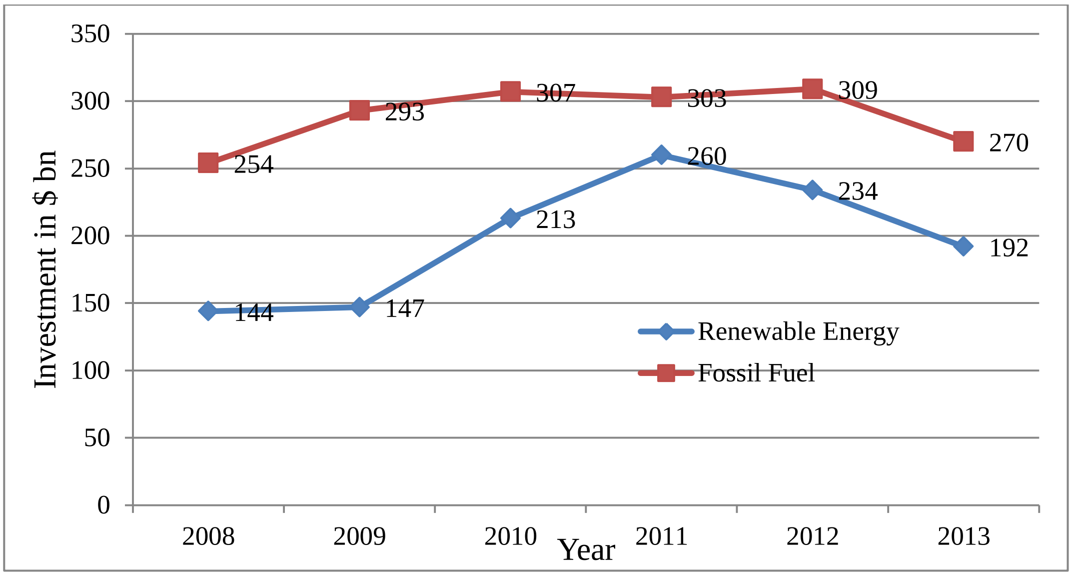
MWh	Mega Watt hour
NFFO	Non Fossil Fuel Obligation
NIMBY	Not In My Back Yard
NIWE	National Institute of Wind Energy
OCED	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
PBF	Public Benefit Fund
PCA	Principal Component Analysis
PCNDDP	Per Capita net District Domestic Product
PCNDP	Per Capita Net State Domestic Product
PLF	Plant Load Factor
PPA	Power Purchase Agreement
PTC	Production Tax Credit
PURPA	Public Utility Policies Regulatory Act
R&D	Research and Development
RE	Random Effect
REC	Renewable Energy Certificates
REIT	Real Estate Investment Trusts
RJ	Rajasthan
RNE	Renewable Energy
ROW	Right of Way
RPO	Renewable Purchase Obligation
RPS	Renewable Portfolio Standard
SERC	State Electricity Regulatory Commission
SLDC	State Load Dispatch Centre
SNA	State Nodal Agency
SPV	Solar Photo Voltaic
ST	Scheduled Tribes
TGC	Tradeable Green Certificates
TN	Tamil Nadu
UK	United Kingdom
USA	United States of America
WGEEP	Western Ghats Ecology Expert Panel
WPD	Wind Power Density
WPT	Wind Power Technology
WTTS	Wind Turbine Test Station

Chapter 1

Introduction

Concerns about climate change and insufficient supply of energy to fuel economic growth have gained appreciation among industry, academia, and governments (Dalla Valle and Furlan, 2011; GWEC, 2012). For example, the United Nations Framework Convention on Climate Change has estimated that US$ 200-210 billion (bn) in investments will be required annually by 2030 to meet global Green House Gas (GHG) emissions reduction targets (UNFCCC, 2007), whereas according to Faundez (2008), an estimated US$16 trillion would need to be invested in the World's energy systems over the next 25 years in order to satisfy an expected 60 per cent growth in energy demand. The projected growth in future demand has also stimulated debate about the inability of fossil fuels to fulfil the energy requirement (IRENA, 2012). Amidst this picture, Renewable Energy (RNE) technologies offer an interesting alternative to generate power by reducing carbon footprint. Usually in RNE technologies following are included: all biomass, geothermal and wind generation projects of more than one Mega Watt (MW), all hydro projects of between 0.5 and 50 MW, all solar projects of more than 0.5 MW, all marine energy projects, and all biofuel projects with a capacity of 1million litres or more per year (UNDP, 2010).

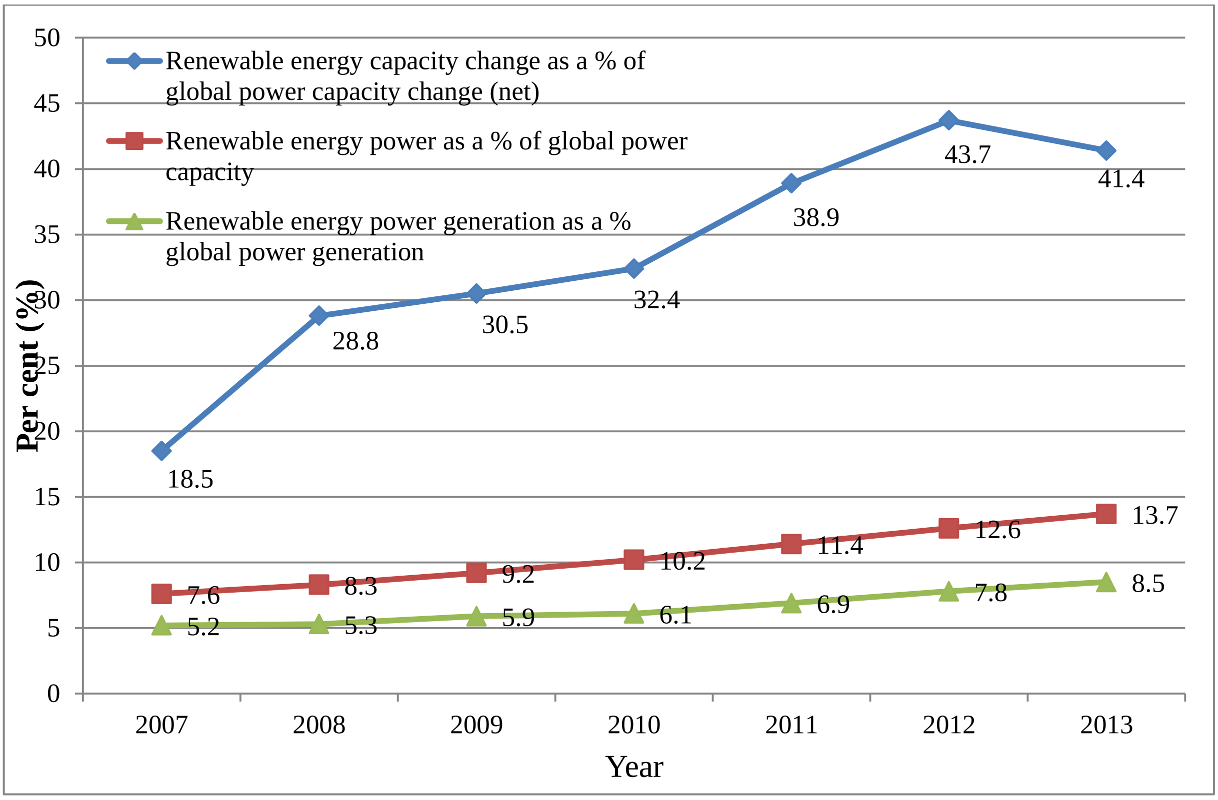
The increased role of RNE technologies gets manifested from the investment data. Globally, investment in RNE technologies in last five years has been consistently over 50 per cent of investment in fossil fuel. It rose from US$ 144 bn in 2008 to US$ 260 bn in 2011 and thereafter fell to US$ 192 bn in 2013. In percentage terms, investment in RNE grew from over 50 per cent of investment in fossil fuel in 2008 to over around 85 per cent of fossil fuel investment in 2011 and thereafter falling to over 70 per cent in 2013 (Figure 1.1).



Data Source: UNDP, 2014

Figure 1.1: Renewable Energy Power Investment Compared to Gross Fossil Fuel Power Investment, 2008-2013, US$ bn

Consequently, the share of global installed capacity using RNE technologies to total installed capacity rose from around 7.6 per cent in 2007 to more than 13.7 per cent by 2013 (UNDP, 2014) (Figure 1.2). Installed capacity using RNE technologies grew at its fastest pace in 2012 reaching nearly 44 per cent (UNDP, 2014). Power generation using RNE technologies continued to grow steadily, reaching almost 8.5 per cent of the global mix in 2013, compared with 5.2 per cent in 2007. Technology advancement and rapid deployment of RNE technologies have demonstrated their credibility as alternate sources of power generation (UNDP, 2010).



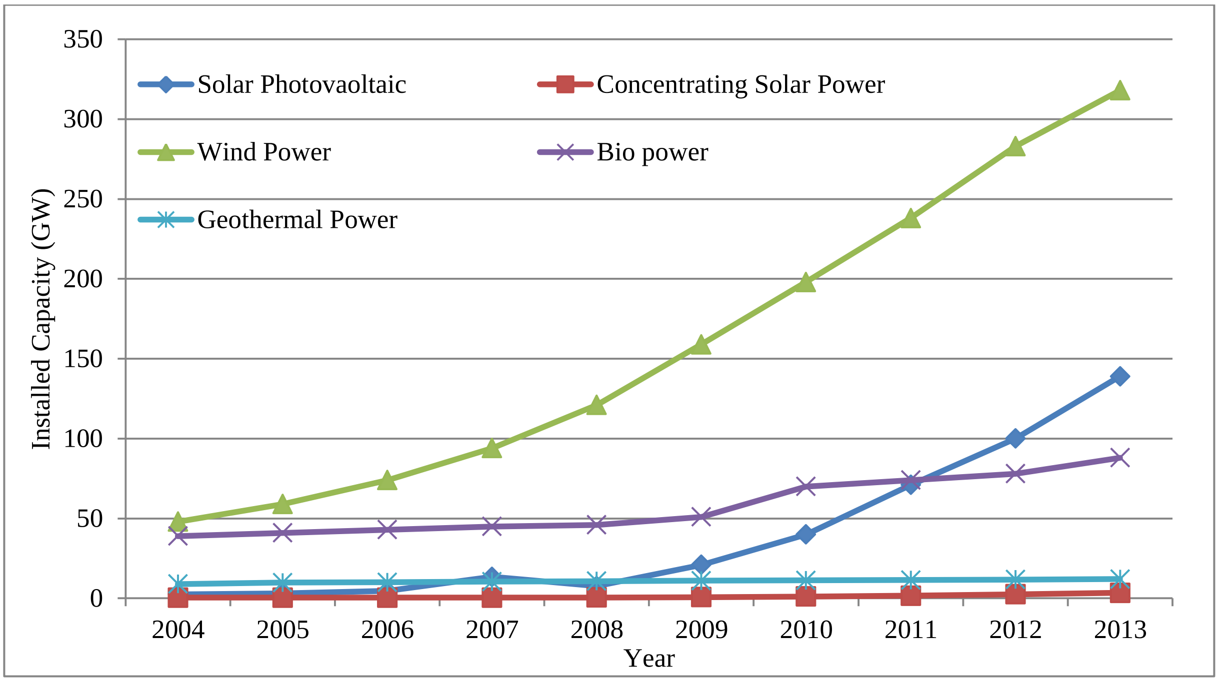
Data Source: UNDP, 2014

Figure 1.2: Power Generation using Renewable Energy and Capacity as a Share of Global Power, 2006-2013

Calderia *et al*. (2003) recognized RNE technologies as one of the critical element of a low GHG energy economy. Also according to Martinot and Beck (2004), the widespread adoption of RNE technologies would not only help to mitigate the negative environmental and social effects associated with fossil fuels but also has the potential to create substantial additional socio-economic benefits such as reducing local air pollution, increasing energy access and improving energy security.

1.1 Importance of Wind Power Technology

Over the last decade, among all RNE options Wind Power Technology (WPT) has emerged as the most reliable and efficient technology of power generation (Sharma *et al*., 2012). Figure 1.3 gives the trend in installed capacity of different RNE technologies. As can be seen from the figure, over the last decade, growth in installed capacity of WPT was highest among all other RNE options except hydropower (REN21, 2014) demonstrating importance of WPT.



Data Source: REN21, 2014

Figure 1.3: Installed Capacity of Renewable Energy Technologies

Additionally, WPT emerged as the environmentally most benign technology by having lowest CO_2 emissions over lifecycle as indicated in Table 1.1. Also, levelized costs for onshore WPT have fallen by 15 per cent since 2009.[1] This makes WPT quite competitive with combined gas turbine and coal fired generation even without taking into consideration environmental and social costs of carbon attributed to fossil fuels (UNDP, 2014) (Figure 1.4). Perhaps these are the reasons why WPT has received attention from many countries across the World.

Power generated using WPT began to penetrate commercial power markets – first in Denmark in 1970's, then in California in United States of America (USA) in 1980's followed by Germany and Spain in 1990's (NREL, 2012). This interest in WPT continued even in early 1990s, in spite of the current availability of plentiful and cheap resources of fossil fuels and nuclear energy (Sesto and Ancona, 1995). Overall by mid-2000, about 50 countries around the World were contributing in the global thrust for the development and harnessing of wind potential (Mabel and Fernandez, 2008). As a result, global installed capacity of WPT

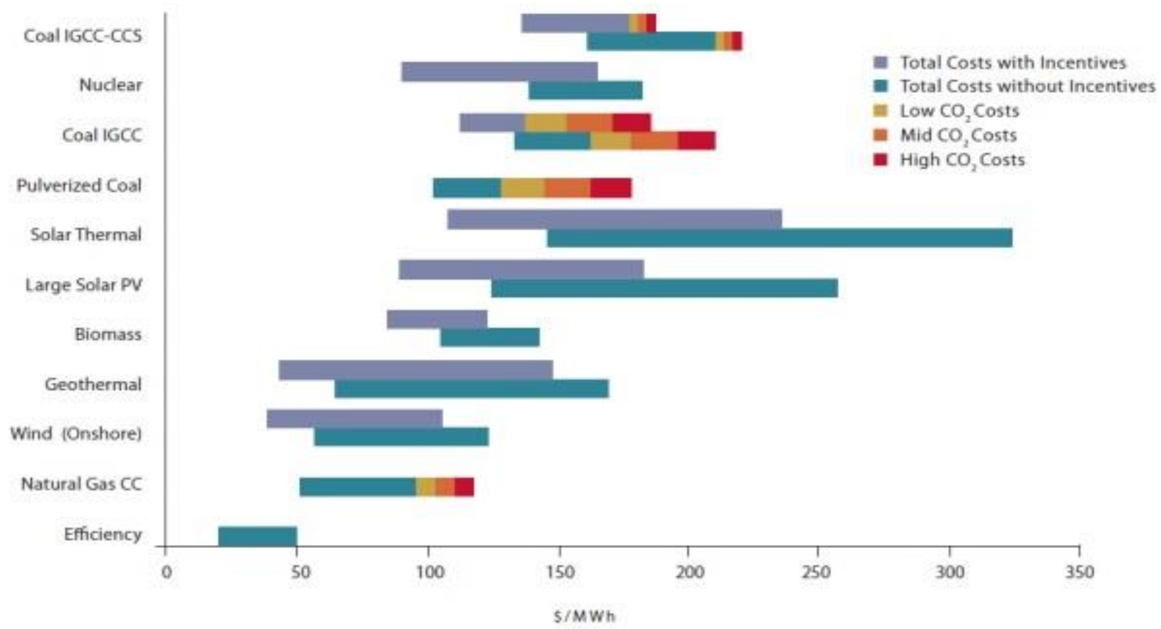
[1] Concept of levelized costs was introduced in 2009. Accordingly, figure is given since then (UNDP, 2014).

Table 1.1: Lifecycle Estimates of CO_2 emissions for Power Generating Technologies

Technology	Capacity/Configuration/Fuel	Estimate (gCO_2e/kWh)*
Wind	2.5 MW, offshore	9
Hydroelectric	3.1 MW, reservoir	10
Wind	1.5 MW, onshore	10
Biogas	Anaerobic digestion	11
Hydroelectric	300 kW, run-of-river	13
Solar Thermal	80 MW, parabolic trough	13
Biomass	Forest wood co-combustion with hard coal	14
Biomass	Forest wood steam turbine	22
Biomass	Short rotation forestry co-combustion with hard coal	23
Biomass	Forest wood reciprocating engine	27
Biomass	Waste wood steam turbine	31
Solar PV	Polycrystalline silicone	32
Biomass	Short rotation forestry steam turbine	35
Geothermal	80 MW, hot dry rock	38
Biomass	Short rotation forestry reciprocating engine	41
Nuclear	Various reactor types	66
Natural Gas	Various combined cycle turbines	443
Fuel Cell	Hydrogen from gas reforming	664
Diesel	Various generator and turbine types	778
Coal	Various generator types with and without scrubbing	960 – 1050**

Notes:* - gCO_2e = grams of CO_2 equivalent, ** - first figure with scrubbing and second without scrubbing

Data Sources: Gagnon *et al*., 2002; Pehnt, 2006; Fthenakis *et al*., 2008; Sovacool, 2008

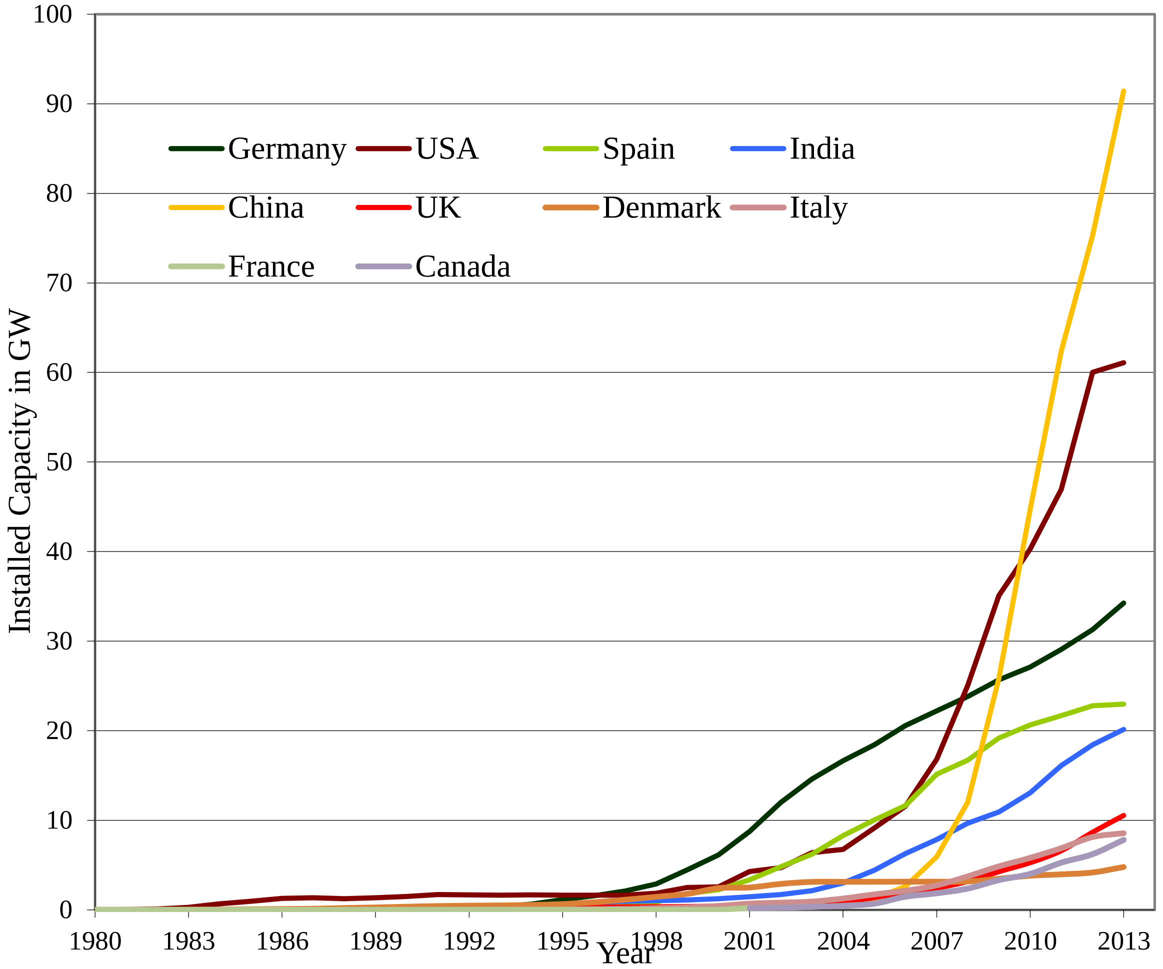


Source: UNDP (2014)

Figure 1.4: Levelised Cost of Power Generated using Different Technologies, 2009 to 2014, US$ per MWh

expanded rapidly from only 10 MW in 1980 to around 369 GW of installed capacity by 2014 (GWEC, 2014). Interestingly, 10 countries – namely, USA, China, Germany, Spain, India, Denmark, UK, Italy, France, and Canada – have been consistently contributing more than 85 per cent of the total installed capacity of WPT (Roney, 2013). Table 1.2 gives trend in installed capacity of WPT for these countries.

Figure 1.5 shows the growth in these leading countries consistently contributing more than 85 per cent of World's installed capacity of WPT. By 2013, China emerged as the leader experiencing tremendous growth since around 2007 followed by USA and Germany. Spain ranked fourth followed by India, UK, Italy, France, Canada and Denmark.



Data Source: Roney, 2013

Figure 1.5: Installed Capacity of Wind Power Technology in Leading Countries, 1980-2013

Table 1.2: Growth of Wind Power Technology in Top Ten Countries and World by Installed Capacity in MW, 1980 -2013

Year	China	USA	Germany	Spain	India	UK	Italy	France	Canada	Denmark	World	Share of top 10 countries
1980	n.a.	8	0	0	0	0	0	0	n.a.	5	13	100
1981	n.a.	18	0	0	0	0	0	0	n.a.	7	25	100
1982	n.a.	84	0	0	0	0	0	0	n.a.	12	96	100
1983	n.a.	254	0	0	0	0	0	0	n.a.	20	274	100
1984	n.a.	653	0	0	0	0	0	0	n.a.	27	680	100
1985	n.a.	945	0	0	0	0	0	0	n.a.	50	1,020	98
1986	n.a.	1,265	0	0	0	0	0	0	n.a.	82	1,347	100
1987	n.a.	1,333	5	0	0	0	0	0	n.a.	115	1,450	100
1988	n.a.	1,231	15	0	0	0	0	0	n.a.	197	1,580	91
1989	n.a.	1,332	27	0	0	0	0	0	n.a.	262	1,730	94
1990	n.a.	1,484	62	0	0	0	0	0	n.a.	343	1,930	98
1991	n.a.	1,709	112	5	39	4	1	0	n.a.	413	2,283	100
1992	n.a.	1,680	180	50	39	69	3	0	n.a.	458	2,510	99
1993	n.a.	1,635	335	60	79	n.a.	6	2	n.a.	487	2,990	87
1994	n.a.	1,663	643	70	185	n.a.	18	n.a	n.a.	539	3,490	89
1995	38	1,612	1,130	140	576	200	32	3	n.a.	637	4,780	91
1996	79	1,614	1,548	230	820	273	70	6	n.a.	835	6,100	90
1997	170	1,611	2,080	512	940	319	103	10	n.a.	1,120	7,600	90
1998	224	1,837	2,875	834	1,015	333	180	19	n.a.	1,443	10,200	86
1999	268	2,472	4,442	1,812	1,077	362	277	25	n.a.	1,771	13,600	92
2000	346	2,539	6,113	2,235	1,220	406	427	66	n.a.	2,417	17,400	91
2001	404	4,275	8,754	3,337	1,456	474	690	93	198	2,489	23,900	93
2002	470	4,685	11,994	4,825	1,702	552	797	148	236	2,889	31,100	91
2003	568	6,372	14,609	6,203	2,125	648	913	253	322	3,115	39,431	89
2004	765	6,725	16,629	8,263	3,000	888	1,255	390	444	3,123	47,620	87
2005	1,272	9,149	18,415	10,027	4,430	1,353	1,718	757	684	3,127	59,091	86
2006	2,599	11,575	20,578	11,623	6,270	1,968	2,123	1,711	1,460	3,136	73,938	85
2007	5,910	16,824	22,194	15,145	7,845	2,428	2,726	2,495	1,846	3,136	93,889	86
2008	12,020	25,076	23,826	16,689	9,655	3,161	3,736	3,577	2,369	3,158	1,20,62	86
2009	25,805	35,086	25,673	19,160	10,926	4,257	4,849	4,713	3,319	3,468	1,58,97	86
2010	44,733	40,298	27,097	20,623	13,065	5,259	5,797	5,977	4,008	3,801	1,98,00	86
2011	62,364	46,929	29,071	21,674	16,084	6,593	6,878	6,809	5,265	3,956	2,38,12	86
2012	75,324	60,007	31,270	22,784	18,421	8,649	8,118	7,623	6,204	4,162	2,83,19	86
2013	91,424	61,091	34,250	22,959	20,150	10,531	8,552	8,254	7,803	4,772	3,18,11	85
CAGR	54	31	40	47	33	43	51	52	36	23	26	

Note: n.a. – not available; CAGR – Compound Annual Growth Rate = [(Final value – initial value) $^{(1/\text{ (final year – initial year)})}$ – 1] * 100

Data Source: Roney, 2013

1.2 Policies to Promote Wind Power Technology Diffusion

Worldwide, the growth of RNE technologies including WPT has been facilitated by different types of policies. Developed countries were pioneer in introducing the promotion measures for RNE technologies and developing countries duly followed them (Martinot and Beck, 2004) .

Since late 1970s, developed countries started designing and implementing diverse types of price-based and quota-based mechanisms to promote RNE technologies' development. For instance, Denmark introduced subsidies, production incentives, testing and certification in the early 1980s whereas the USA implemented its first price based mechanism known as Feed-in-Tariff (FIT) policy in 1978 (under Public Utility Policies Regulatory Act, PURPA) and a quota mechanism known as Renewable Portfolio Standard (RPS) or Renewable Purchase Obligation (RPO) from 1983 (Azuela and Barroso, 2011).

FIT is the purchase rate of power generated using RNE technologies whereas RPO is the obligation on Utilities to buy certain quantum (of total power purchase) of power from RNE technologies. As of 2010, 31 of 50 States in USA had RPO in place. Whereas, in 1990 Germany became the first European country to introduce FIT, and since then many European countries experimented with either price-based or quota-based mechanisms (REN21, 2010). The United Kingdom (UK), in particular, introduced competitive tenders to fulfil RPOs during the 1990s (under the Non Fossil Fuel Obligation, NFFO[2]), but from 2002 the scheme was substituted for a type of RPO policy. Since then, RPO could also be fulfilled using tradable and/or non-tradable Renewable Energy Certificates (RECs) to create a market of environmental attributes. The use of RECs emerged as a market-based tool to facilitate compliance with the RPOs (*ibid*).

A few other developed countries applied the carbon taxes in order to indirectly incentivise alternate energy resources. For example, Netherlands and Scandinavian countries adopted

[2] The Non-Fossil Fuel Obligation (NFFO) refers to a collection of orders requiring the electricity Distribution Network Operators in England and Wales to purchase electricity from the nuclear power and RNE sectors (Azuela and Barroso, 2011).

carbon taxes in the beginning of the 1990s, and others – Canada, for example - have only recently started to apply them (Canadian Province of British Columbia) (*ibid*).

Developing countries began introducing policy tools to support RNE technologies in the early 1990s; when these countries introduced different incentives, especially FIT, to promote investments in RNE. By 2008, more than 30 developing countries had introduced different types of price-setting or quantity-setting instruments to increase the share of RNE in their energy mix (Kooten and Timilsina, 2009). The first four countries to introduce some type of price setting instrument or FIT were India (from 1993), Sri Lanka (from 1997), and Brazil and Indonesia (both from 2002) (REN21, 2010). By 2008, FITs are being implemented in about 49 countries around the World and are often cited as the most effective policy for attracting private investment towards RNE technologies.

On the other hand, quota mechanisms however have been less popular in the developing World and in countries in transition. For instance, a rigorous RPO (in which a quota or target is specified, a proportional obligation is imposed on Utilities or retail companies, and the price is competitively determined by the market) has only been introduced as such by a few countries, including India (from 2004), Chile (from 2008), Poland (from 2005), and Romania (from 2004) (Kooten and Timilsina, 2009).

Apart from FIT or RPS, the use of competitive schemes or auctions to promote RNE technologies in the developing World is less common. For example Argentina, Brazil, China, Peru, Thailand, and Uruguay are now testing the effectiveness of auction in their territory (Azuela and Barroso, 2011). A range of other supplementary measures is in use that directly stimulates investments in RNE, including fiscal and financial incentives, and voluntary measures. These have been adopted in parallel to price and quantity setting instruments in both developed and developing countries. Table 1.3 summarizes major policy initiatives in both developed and developing countries.

Developing countries are faced with the twofold challenge of energy security coupled with obligation to reduce carbon footprint at the same time. Among leading developing countries in installed capacity of WPT, India launched its RNE promotion program primarily as a response to the perceived rural energy crisis in the 1970s. It was initiated with a target-

Table 1.3: Major Policies for Renewable Energy Technologies: Adoption and Policy Shifts

Year	**FIT**	**RPS/REC**	**Auction**
1970s	**USA (PURPA) (1978)**		
1980s		**USA (first in Iowa in 1997)**	
1990s	Germany (1990), **Italy (1992)** Many European Countries India (1993)*, Sri Lanka (1997)	**Italy (1999)**	**UK (NFFO) (1990)**
2000-05	Brazil (2002), Indonesia (2002) Nicaragua (2004) Turkey, Ecuador, China (2005)	**UK (RPO) (2002)** Belgium, Austria, Japan, Sweden, Canada, Poland	**China (2003)**
2006-10	**USA (from 2006)**** Argentina (2006), **Philippines**, Kenya, South Africa + 11 developing countries (2008) **Italy (2007-08), UK (2010)**	Chile, Romania **Philippines (2008)** India (2010)	Brazil (2007) Peru(2008), Uruguay, Thailand **China (2010)** **India (2010)**
By 2012	About 42 countries	13-15 Countries	22 Countries

Notes: In bold- countries that have shifted from one mechanism to another or that are using them in parallel. *- Indian states introduced FIT gradually in the period 1993 to 2008. ** - Different USA States have started to introduce FIT from 2006.
Source: Adapted from REN21, 2010; Azuela and Barroso, 2011

oriented supply push approach with provision of direct cash subsidies for promotion of the RNE Technologies. In the early 1990s, under the economic liberalization process, the programme received an impetus with a shift in emphasis from purely subsidy-driven dissemination programs to technology promotion through commercial route (Jagadeesh, 2000).

The initial strategy for promotion of RNE in India was through fiscal incentives and elimination/reduction of direct subsidies, encouragement to private entrepreneurs for investing in RNE technologies through measures like Accelerated Depreciation (AD) and reduced import duties, and funding assistance from multilateral and bilateral agencies (Jagadeesh, 2000). Given that power (electricity) is a concurrent subject[3] in India, both the

[3] Under the Constitution of India, electricity is a concurrent subject at entry number 38 in the List III of the Seventh Schedule. For concurrent subjects, both central and State government have jurisdiction in the matter (http://business.gov.in/infrastructure/power.php).

centre and the State have formulated policies to promote WPT. Since the enactment of Electricity Act 2003, the market is being regulated by State regulators. For example, regulators introduced Generation Based Incentive (GBI) in 2009 as an alternative to AD. GBI was meant to incentivise higher efficiency by allowing increase in FIT for power fed into the grid above expected level. Also, since 2010 the regulator at central level (known as Central Electricity Regulatory Commission – CERC) has implemented REC mechanism. In the REC mechanism, each State Utility is obligated to fulfil RPO as specified by its regulators (known as State Electricity Regulatory Commission – SERC) by purchasing either RNE directly or equivalent Certificates (RECs) as an indirect means of supporting power generation through RNE. The prices of these certificates are discovered in a national platform of the Power Exchanges (Sharma *et al*., 2012).

1.3 Motivation for the Work

Though WPT has emerged as the leader in RNE technologies and being supported by numerous policy initiatives globally, the diffusion of WPT seems to be far lower than its actual potential. Numerous studies provide estimates of the immense global potential of power generation using WPT (see for example, Archer and Jacobson, 2005; GWEC and Greenpeace International, 2006; IEA, 2008). Archer and Jacobson (2005), in particular, claimed that the earth has enough wind resources to meet current energy demand for all purposes (6995 to 10,177 Mtoe[4]) and over seven times the World's total installed capacity in 2005 (1.6-1.8 TW). Another study initiated by the United Nations' Environment Program (UNEP) estimated that the wind potential in only 19 African countries could reach 53 TW (InWEnt Consulting, 2004). Though it could be argued that these theoretical resource estimates are often limited in reality by land-use constraint, still many countries across the World have not been able to meet their respective capacity targets even after assuming land constraints (GoI, 2012; Dept. of Energy U.S., 2008; EWEA, 2013). Additionally, despite around 140 countries having wind resource and enacting policies for WPT diffusion, distribution of installed capacity of WPT is highly skewed with only 10 countries consistently

[4] Mtoe = Million tonnes of oil equivalent. It is the energy obtained by burning 1 million tonnes of oil (IEA, 2008).

contributing more than 85 per cent of the total capacity of WPT. This suggests that along with policy initiatives, there could be other factors which influence the choice of adoption of WPT by a firm.

Study of diffusion of WPT would help identify the factors hindering the growth and facilitate widespread adoption towards achieving its potential. Diffusion of WPT can be studied under study of diffusion of an innovation. This is because WPT in literature has been considered as an innovation. WPT seems to possess five attributes that Rogers (1962) used to define an innovation. The five attributes are: relative advantage (in terms of cost and cleanliness), compatibility (with existing grid), complexity (intricacies involved in decision making), trialability (may be difficult for a limited time period) and observability (development of new power plants is useful in decision making) (Dalla Valle and Furlan, 2011). Accordingly, present thesis is an effort to see the impact of policies causing diffusion at macro (aggregate) level and identify factors driving choice of adoption at micro (firm) level using theories of diffusion of innovations.

1.4 Research Objective

As can be seen from previous section, growth of WPT across the World is phenomenal in the last few decades. Several policy mechanisms have been introduced by many countries. A developing country like India despite being faced with dual challenge of energy security and carbon footprint has made its mark in WPT adoption. Given the importance of promoting RNE deployment in general, and the high financial costs often associated with support, it is essential for governments to know how policies are contributing to diffusion of WPT in actual vis-à-vis the expectations. Also, an understanding of underlying factors responsible for adoption of WPT by firms is essential to design and implement policy mechanisms. Such an evaluation can help identify potential adaptations and allocate scarce financial resources as efficiently as possible (IRENA, 2012b). Accordingly, the objective of the study is to understand the dynamics of diffusion process of WPT both at macro (aggregate) and micro (firm) level.

At macro level, aim is to evaluate impact of policies in two stages. First international comparative analysis of policy designs across countries is conducted. This is followed by second stage of modelling of policies' parameters for their relative attractiveness within a country. Whereas, micro level study is aimed at identifying factors determining decision of firms to invest in WPT. Accordingly, the study has three research questions.

1. *Is WPT diffusion pattern same across countries?*
2. *What role policies play for diffusion of WPT across States of India?* and lastly,
3. *Whether local differences have any influence on the decision of firms to adopt WPT?*

1.5 Research Methodology

The study is conducted using empirical research methodology to address above research questions. As stated, the research can be broadly compartmentalized into macro and micro level.

At macro level, study involves modelling diffusion of WPT and seeing impact of policies in a sequential manner as stated by first two research questions. For the first research question, comparative analysis of impact of policies on diffusion of WPT across five leading countries - namely China, USA, Germany, India, and Spain - is performed to identify successful policies. Accordingly, secondary quantitative data for the period 1980 to 2012 is collected and non-linear regression is performed using three diffusion models - Gompertz, Logistic, and Bass - for each country. Consequently, one specific model for each country is selected using statistical inference and model parameters are justified with corresponding policy initiatives in the country. Based on the identified models, the study also identifies the corresponding saturation point of diffusion for each country.

For the second research question, impact of successful policies (as identified in international comparative analysis) along with other State specific policies on their relative attractiveness is modelled using econometric analysis on diffusion of WPT across selected States of India. Seven States of India – namely, Tamil Nadu, Maharashtra, Gujarat, Rajasthan, Karnataka, Andhra Pradesh, and Madhya Pradesh - having significant wind potential are selected for the study. Using four key policies' parameters – namely, FIT, RPO, wheeling, and banking - for these States for the period 19 years (1993 to 2012), an aggregate policy index for each State is built using principal component analysis. Using this index which reflects relative attractiveness of selected policies and controlling for other State specific characteristics, econometric analysis is performed to examine policies' impact on their relative attractiveness on diffusion of WPT.

For the third research question which is a micro level study, factors influencing the decision of firms to choose a location to adopt WPT are identified by conducting a case study for the State of Maharashtra in India. Maharashtra is chosen because despite ranking second in terms of WPT installed capacity in India, it has been able to exploit only around 60 per cent of its potential. More interestingly, there is no correlation between wind potential in a district and corresponding installed capacity suggesting that there are other factors also influencing the decision of firms to adopt WPT in a district. Study of location choices of firms within Maharashtra would help identifying the barriers and consequently in widespread adoption of WPT within State and thereby contributing to the diffusion of WPT in India. Five factors are identified through semi-structured interviews with six firms contributing to over 50 per cent of the installed capacity of WPT in Maharashtra. Subsequently, validation of the factors is carried out through econometric analysis using the data for nine districts – namely, Ahmednagar, Beed, Dhule, Kolhapur, Nandurbar, Nashik, Sangli, and Satara - of Maharashtra for the period 2006 to 2013.

To answer research questions 2 and 3, econometric analysis has been performed using panel data techniques.

1.6 Contributions of the Research

At macro level, international comparative analysis among five selected countries shows that popular traditional approach of "one size fits all" is not followed in diffusion of WPT and despite having same policy initiatives each country can indeed have a unique diffusion path owing its economic, social, and political objectives. In addition our analysis has identified successful policies across these selected countries. For example, quantity based instruments like significant Research and Development (R&D) grants in Germany and USA, capital subsidies in per cent of project cost in Spain and China, obligation on Utilities to buy RNE power in USA, Germany, and India are important for these countries. Interestingly, analysis has found relevance of price-based instrument like FIT in all five countries.

The international comparative analysis also indicates that diffusion of WPT is being hindered by issues in managing reserve capacity, underutilization of networks, and Not-In-My-Back-Yard (NIMBY) attitude indicating the need to build nexus between various stakeholders. Also, forecasts which are generated using the selected models show that the selected leading countries are reaching their diffusion limit within a decade from now despite having various policy initiatives in place. This saturation limit is well below the future targets set by the respective countries and far less than the potential estimates for power generation using WPT. Such a finding additionally justifies the need to study factors - apart from policies - which are dominant at micro level and which determine the choice of adoption of WPT at micro level.

Across the States of India, the aggregate index computed using policies – namely, FIT, RPO, banking facility and wheeling charges - is found to have a positive impact on diffusion of WPT across States of India. Additionally, unmet capacity and higher per capita income of a State are found to have a positive impact on the diffusion of WPT. Such a finding shows the important role of States in implementing policies in diffusion of WPT.

Micro level analysis identifies that geographical characteristics, technology perceptions, societal attitude, and bureaucratic approach in a location determine the choice of adoption of WPT by firms in a district. Interestingly, while unmet capacity has a positive impact on diffusion at macro level, it has exactly opposite influence on adoption of WPT at micro level. Such a finding suggests towards the tendency of firms by choosing already established locations and not willing to exploit new locations within a State. In other words, our analysis points a risk averseness of firms while investing in WPT.

1.7 Scope of the Work

The study is focussed on the diffusion of WPT as indicated by installed capacity. The scope of the study is to evaluate policies to promote WPT and identify determinants of choice of adoption of WPT by firms both at macro and micro level.

1.8 Organization of the Thesis

The rest of the thesis is organized as follows. Chapter 2 describes the various policy initiatives taken to promote WPT across the World. Chapter 3 analyses the existing literature of diffusion of WPT and points out addressable gaps. The literature review questions the tendency of existing research of proposing one model to define diffusion for all countries. Also identified is a lack of quantitative study on evaluation of policies for a developing country like India. At micro level, a gap indicating lack of comprehensive study on factors affecting choice of adoption of WPT in India through stakeholders' engagement has been identified.

Chapter 4 deals with modelling diffusion of WPT in five leading countries by using three diffusion models (Gompertz, Logistic and Bass). One specific model for each of the selected countries is picked using statistical inference and model parameters have been justified using policy initiatives in the country. Also, the chapter identifies successful policies by comparing diffusion of WPT between selected leading countries and highlights the barriers for widespread adoption of WPT.

Chapter 5 deals with modelling of the impact of policies on diffusion of WPT across selected seven States of India.

Chapter 6 is a micro level study using case study methodology and proposes the factors influencing the decision of firms to adopt WPT arrived by interviewing firms. The chapter describes the relevant factors for choice of location of firms while investing in power capacity of WPT at a location in Maharashtra. Chapter 7 validates the proposed factors in previous chapter through econometric analysis. Chapter 8 gives conclusions of the study. The chapter also lists contributions to theory and practice followed by specific recommendations to policy makers. The chapter ends with possible directions for future work.

Chapter 2

Policies to Support Renewable Energy Technologies

2.1 Introduction

The development of Renewable Energy (RNE) technologies is strongly driven by the policy frameworks, and the role of the governments is critical in developing adequate policy frameworks so as to attract large investments in the sector (IRENA, 2012). This chapter reviews history of policy and regulatory framework for RNE with a specific emphasis on Wind Power Technology (WPT).

Several researchers have classified policies to promote RNE in different ways (see, for example, Martinot and Beck, 2004; GWEC, 2012; REN21, 2014). Martinot and Beck (2004) classified RNE policies into three main categories: (1) price setting and quantity setting policies which mandate prices or quantities for RNE power; (2) investment cost reduction policies, which give incentives so as to lower the investment costs; and (3) public investments and market facilitation activities, which offer a wide range of public policies that reduce market barriers and facilitate or accelerate RNE markets. Along with these, national targets (also referred to as goals) have emerged as a political context for promoting specific combinations of policies from above categories. Targets may specify total primary energy from RNE or minimum RNE shares in the total power generation (*ibid*).

The remaining chapter is divided into six more sections. Sections 2.2 and 2.3 discuss price setting and quantity forcing policies, respectively. Section 2.4 talks about various types of cost reduction policies. Section 2.5 gives different modes of public investments and market facilitation activities. Section 2.6 discusses the various policies enacted in emerging and developing countries. Section 2.7 concludes.

2.2 Price Setting Policies

Price setting policies set favourable pricing regimes for RNE power relative to conventional power. Moreover, these prices are known to investors in advance. This way they assure guaranteed and favourable returns to investors. The two most popular price setting policies are Public Utility Regulatory Policies Act (PURPA) in the USA and Feed-In-Tariff (FIT) which exists in most countries promoting RNE technologies.

2.2.1 Public Utility and Regulatory Policies Act (PURPA) in USA

PURPA was enacted in 1978 in order to encourage power production from RNE owing to oil crisis in 1973. The Act required Utilities to purchase power from RNE and co-generators, termed as qualifying facilities of power generation, through a 10 year term contract at prices near to avoided cost of Utilities as defined and implemented by States. For example, the implementation of PURPA by the California Public Utilities Commission (CPUC) also spurred tremendous investment in WPT as discussed later. The CPUC showed strong support for PURPA and approved long-term contracts for RNE generators at very high prices because the avoided cost calculations were based on forecasted short-run costs of oil and natural gas. At the time, oil and natural gas prices were expected to rise to higher levels than they actually reached in subsequent years. Starting in about 1983, the most commonly granted contracts for independent RNE generators were Standard Offer #4 contracts, which included capacity payments for 20 to 30 years and fixed-priced energy payments for 10 years that ranged from about 5¢/kWh to more than 12¢/kWh. As of 1995, Energy Information Administration (EIA) estimated that California Utilities paid an average of 12.79¢/kWh for RNE from qualifying facilities under PURPA contracts (Bird *et al.*, 2003). This price was far more than the price of power generated using conventional sources like natural gas or coal (Dodge, 2006).

2.2.2 Feed in Tariff (FIT)

FIT typically make use of long term power purchase agreements (PPAs) and pricing tied to costs of production for RNE producers. By offering long-term contracts and guaranteed pricing, producers are sheltered from some of the inherent risks in RNE production.

Different forms of FITs emerged in EU in 1990s. For example in Germany, starting from 1991, RNE power producers could sell power to Utilities at 90 per cent of the existing retail market prices. Specifically, under a new German Renewable Energy Law of 2000, FIT for WPT was established with fixed prices for first five years after which they declined to encourage efficiency in generation. Similarly, beginning in 1992, Danish Utilities were required to buy power from WPT at 85 per cent of the net Utility power price (along with production subsidy of 0.1 DK/kWh) with the price paid varying across regions depending on average power rates (Martinot and Beck, 2004).

In 1992, Italy introduced CIP6/92 regulation that established FIT covering first 8 years of power generation from WPT. Interestingly, Spain introduced an alternate concept of FIT with a premium price in 1994 (GWEC, 2012). By early 2000s, eight more member countries of EU namely Austria, Belgium, Finland, France, Greece, Luxembourg, Portugal, United Kingdom (UK), and Sweden had adopted FIT (Reiche and Bechberger, 2004).

Elsewhere Turkey (which is found to have highest wind potential in EU) adopted FIT in 2005, whereas Australia and Japan adopted FIT in 2009 and 2012, respectively. FIT prices in Japan which are to be re-estimated annually by its Ministry for Economy, Trade, and Industry have remained unchanged at 23.1 yen[5]/kWh from 2012 to 2014. This tariff is more than 2.5 times the tariff offered in Germany, Ontario in Canada, and France (GWEC and Greenpeace International, 2014; REN21, 2014).

Another form of FIT is practised in the USA where public benefits for RNE development are raised through a systems benefit charge which is a per kWh levy on power consumption. The objectives of funds, known as Public Benefit Funds (PBF), are paying the difference between cost of RNE power and conventional power, reducing the cost of loans for RNE projects, providing low income energy assistance, and supporting R&D (Martinot and Beck, 2004). California, for example, raised PBF through 1 per cent surcharge with expected collection of US$ 135 million/year. It was initially established from 1998 to 2002 but later extended for 10 additional years 2012. Through the PBF collected till 2002, 4100 MW of RNE projects received financial assistance averaging 0.5 cents/kWh (*ibid*).

Another popular form of FIT is government procurement policies which can reduce uncertainty through long term contracts, pre-approved purchasing agreements, and volume purchases. For example, the Danish Ministry of the Environment mandated grid interconnection for WPT as early as 1979, and required Utilities to pay part of the connection costs as negotiated on a case-by-case basis (Neij, 1997). In 1990s under feed-in-law, Germany and Spain mandated Utilities to purchase power generated independently from WPT under favourable terms for investors. India too has encouraged 20 years PPAs between Government Utilities and WPT project developers. Canada adopted FIT in 2006 through Renewable Energy Standard Offer Program (also known as SOP or RESOP) where 20 year's power purchase prices were offered for RNE power (GWEC and Greenpeace International, 2006).

2.3 Quantity Forcing Policies

Quantity forcing policies, on the other hand mandate that the certain percentage or absolute quantity of generation to be supplied from RNE.

[5] 1 yen=0.63 INR (http://www.exchange-rates.org/Rate/JPY/INR/12-31-2012) [accessed on November 10, 2015]

2.3.1 Competitively-Bid Renewable-Resource Obligations

The first country to adopt obligation to RNE was UK. The UK launched Non Fossil Fuel Obligation (NFFO) scheme, a guaranteed price scheme with the added dimension of competitive bidding for the rate in 1990. Under the NFFO, power generators bid on providing a fixed quantity of RNE power, with the lowest-price bidder winning contract (Azuela and Barroso, 2011). Other countries with similar features of contracts include Ireland (under Alternate Energy Requirement Program in 2005), France (under the EOLE program in 1996), Mexico (under the law as for the Use of Renewable Energies and Financing of Energy Transition in 2008), and Australia (under the Renewable Energy Commercialization in 1997) (Martinot and Beck, 2004; IRENA 2012a).

2.3.2 Renewable Energy Portfolio Standard (RPS)

An RPS or RPO requires that a minimum percentage of power generation or capacity installed should be based on RNE sources. Obligated entities (which are typically Utilities) are required to meet the target either through their own generation or purchasing power from other generators or direct sales from third parties to the Utilities' consumers (Martinot and Beck, 2004). Alternately, the target could also be met with the equivalent amount certificates issued based on generation (for details, kindly see the next section).

In the USA, many RPS policies have been enacted since late 1990s as a part of Utility restructuring program, where Utilities are mandated to buy increasing quantum of power from RNE over the years. Nevada was the first State to enact RPS in 1997 (with initial target of one per cent which was later revised to five per cent in 2002) followed by Texas in 1999 and California in 2001. By 2004, around 12 States had enacted RPS ranging from one per cent to 30 per cent of power generation. Texas revised its RPS in 2000 directing 2000 MW of RNE capacity by 2008 (Martinot and Beck, 2004).

In Europe, the Netherlands is credited as pioneer in introduction of RPS in 1998 (which was later augmented with REC trading program in 2001). Dutch Utilities adopted RPS voluntarily, based on five per cent target of power generation by 2010 increasing to 17 per cent of power generation by 2020. The Netherlands was followed by the UK and Belgium in 2002. The UK's RPO on suppliers has been raised gradually from three per cent in 2003 to 10 per cent by 2010. In Denmark, RPO required end users to purchase 20 per cent of their power from RNE by 2003. The EU passed the Directive on Electricity Production from Renewable Energy Sources in 2001 and expanded it in 2007 to the EU-wide targets (although some member countries have adopted more aggressive targets as seen above) for RNE power to be 33 per cent and RNE capacity to be 20 per cent by 2020 (Reiche and Bechberger, 2004). Recently in 2010, Germany envisioned 30 per cent RNE capacity and 35 per cent RNE power by 2020 (REN21, 2014).

Among other countries, Australia has adopted RPS under Renewable Energy (Electricity) Act 2000 whereas Japan targeted 118 million kWh of RNE power under 1997 Act on the Promotion of New Energy Usage. The Republic of Korea adopted the Act on the Promotion of the Development, Use, and Diffusion of New and Renewable Energy since 2012 (IRENA, 2012a).

Elsewhere, smaller countries in Oceania continent like Palau, Cook Islands, Niue, Micronesia, Kiribati, Samoa, Solomon Islands, Marshall Islands, Vanuatu, Tonga, Fiji, Tuvalu have created national targets. In particular, Niue, Tuvalu and the Cook Islands are aiming for 100 per cent RNE power generation by 2020 (REN21, 2014).

2.3.3 Renewable Energy Certificates (RECs)

RECs, known as Green Certificates in Europe, have emerged as an option for Utilities and customers to trade RNE generation in order to meet RPS/RPO. Under RECs, certificates based on RNE generation are issued (in a standardized form) which can be traded in specific institutions with specific rules. Such a phenomenon essentially separates RNE market activities from actual power generation and flows. Accordingly, this allows for those who have not actually generated or purchased the power themselves to meet their RPO by buying from those who earn RECs by actual generation (Martinot and Beck, 2004).

An idea of fuel and environment attributes to be traded separately was first suggested in 1997 in New England, USA. In 1998, power from RNE was offered an independent trading platform in Automated Power Exchange in California. This was followed by other States including Texas and Massachusetts. In 1997, EnergieNed, the Dutch association of power

Utilities, developed a certificate trading program for Netherlands as a way to share the burden of meeting voluntary RNE targets. This program, which included an electronic tracking system to monitor progress, began operation at the beginning of 1998 and continued for three years (Holt and Bird, 2005). Out of this experience grew the idea for a REC System, which was proposed, in December 1998. Consequently, first RECs were issued in 2001. Finally, EU-wide REC trading system was operationalized during 2001 and 2002. The Renewable Energy Certificate System (RECS) was established as a formal association in December 2002 with over 100 members in 14 different countries. A RECS energy certificate is issued for every one MW-hour (MWh) of RNE power produced by an electricity generation facility that has been registered with the relevant national RECS issuing body (*ibid*).

Australia introduced REC mechanism under Australian Renewable Energy (Electricity) Act 2000. An internet based registry system known as the Renewable Energy Certificates Registry is endowed with: maintaining various registers (as set in the Act); and facilitating the creation, registration, transfer and surrender of RECs (KPMG, 2010).

2.4 Cost Reduction Policies

Martinot and Beck (2004) has classified cost reduction policies into five broad categories as: (1) reduce capital costs upfront (via subsidies and rebates), (2) reduce capital costs after purchase (via tax credit), (3) offset costs through a stream of payments based on power generation (via production tax credit), (4) provide concessionary loans and other financial assistance, and (5) reduce capital and installation costs through economies of bulk procurement.

2.4.1 Subsidies and Rebates

The objective of subsidies and rebates is to reduce the initial capital investment in RNE technologies. Denmark began with production subsidies as early as 1980s with 0.1 DKK/kWh[6] paid to Utilities. In fact, Danish R&D programs were combined with investment

[6] 1 DKK ≈ 0.14 USA $ (https://research.stlouisfed.org/fred2/series/AEXDNUSA) [accessed on May 20, 2015]

and production subsidies (similar to the FITs for RNE power used widely today) to create market for WPT by encouraging local actors like farmers and entrepreneurs. Whereas in USA by mid-2000s, at least 19 States in the USA were offering rebates at State, local, or Utility level (Martinot and Beck, 2004).

2.4.2 Tax Relief

Policies reducing taxes for RNE technologies have been employed globally in the USA, Europe, India, and Japan.

2.4.2.1 Investment Tax Credits

USA through American Recovery and Reinvestment Act of 2009 offered 30 per cent investment credits for manufacturers of RNE technologies. Also, WPT projects initiated in 2009 and 2010 can receive 30 per cent grant from the treasury department for the cost of the property (IRENA, 2012a). Whereas China in 2008 through the China Corporate Income Tax Law reduced tax rate for corporates investing in RNE (including WPT) to 15 per cent. In Europe, the Netherlands allows for deduction of 44 per cent of the amount of investment done in qualifying assets in WPT (ALCS, 2013).

2.4.2.2 Accelerated Depreciation (AD)

AD, as the name suggests, offers RNE investors to receive the tax benefits sooner than standard depreciation rules. In the USA, businesses can recover investments in WPT projects by depreciating them over 5 years compared to 15-20 year depreciation lives of conventional power projects. In 1990s, Germany too used AD but accompanied by technical standards for wind turbines and certification requirements (Martinot and Frederick, 2004).

Similarly France introduced AD where equipment used for generation of power from RNE acquired or constructed until January 1, 2011 can be depreciated in the first year, if certain conditions are met (article 39AB of French Tax Code) (KPMG International, 2013).

2.4.2.3 Production Tax Credits (PTC)

A PTC allows investor of qualifying facility with an annual tax credit based on the power generated by the facility. Denmark has been the pioneer in introducing PTC for WPT with 0.1

DK/kWh in early 1980s. In the USA, PTC was provided at federal level for all the WPT manufacturing facilities that entered service in 1992 through mid-1999, later extended to 2005 (Dodge, 2006). Between 2006 and 2012, PTC has been extended under various Acts (including the Energy Policy Act of 2005, Tax Relief and Healthcare Act of 2006, and American Recovery and Reinvestment Act of 2009). Elsewhere in China, power produced from WPT has been given 50 per cent exemption in Value Added Tax (VAT) since 2002 (ALCS, 2013).

2.4.2.4 Property Tax Incentives

More than 24 States in the USA have property tax incentives implemented at various administration levels such as State, county, city, town or municipality. These are offered in one of the following three ways – (a) RNE property is partially or fully excluded from property tax assessment, (b) RNE property value is capped at the value of an equivalent conventional energy system providing the same service, and (c) tax credits are awarded to offset property taxes.

The USA also has proposed Real Estate Investment Trusts (REITs) and Master Limited Partnerships (MLPs) for WPT projects. REITs and MLPs are tax efficient structures that can be traded publicly and thus have access to more capital market liquidity through individual, retail, and institutional investors (KPMG, 2010). In 2014 India announced REITs for WPT projects (IWTMA, 2014).

2.4.2.5 Personal Income Tax Incentives

Credits against the personal income tax are offered in the USA for purchase of or conversion to RNE systems. Further, in some cases taxpayers can deduct the interest paid on loans for RNE technology equipment (Martinot and Beck, 2004).

2.4.2.6 Sales Tax Incentives

Many States in USA provide retail sales tax exemptions for eligible RNE systems. Some States offer 100 per cent of the sales tax for capital expenses whereas some specify maximum or minimum sizes for eligible systems. States of India – namely, Gujarat, Madhya Pradesh, and Maharashtra too had offered sales tax incentive for WPT in 1993 (Jagadeesh, 2000).

2.4.2.7 Pollution Tax Exemptions

In Europe, the Netherlands exempted green power from a new and rising fossil fuel tax (USA 5 cents/kWh) on power generation that is paid by end users since 2001 (Martinot and Beck, 2004).

2.4.2.8 Other tax Policies

A variety of other tax incentives exist such as income tax exemptions on income of RNE power, excise duty, and sales tax exemption on equivalent purchase and reduced or zero import tax duties on assembled RNE equipment or on components. For example, India has allowed 5-year tax exemptions on income from sales of power from WPT (Jagadeesh, 2000).

2.4.3 Grants

In 1979, Denmark provided rebates of up to 30 per cent of capital costs for WPT which declined over time (Reiche and Bechberger, 2004). The USA under treasury grant program 1603 (under American Recovery and Reinvestment Tax Act of 2009) has provided cash grants (instead of tax credit) of up to 30 per cent investment costs for eligible WPT projects (IRENA, 2012b).

In 1990s, Denmark offered direct grants and project development loans to qualified importing countries for use of Danish turbines through licencing arrangement. This tied aid has been offered to countries including India, Egypt, China and Somalia (Sawin, 2001). For example, in India the wind turbine manufacturer, Suzlon, located research centres in the Netherlands and Germany and established their international headquarters in Denmark whereas in China, a wind turbine producer, Goldwind, developed know-how by sending employees abroad to obtain advanced training (*ibid*).

2.4.4 Loans

Loan programs offer financing for the purchase of RNE technology equipment. Loans can be provided at market rate, at low interest (below market rate), or waived. In USA, government subsidized loans that offer below market interest rate are common. Some States, Iowa for example provided a 20 per cent forgivable loan combined with 80 per cent loan at prime rate for RNE projects (Martinot and Beck, 2004).

The World Bank has offered financing for RNE technologies' projects usually in association with commercial lending in China, India, Sri Lanka (Martinot and Beck, 2004). One of the successful examples is of India Renewable Energy Development Agency (IREDA) which was formed in 1987 to provide assistance in obtaining international multi agency loans and in helping private investors commercial loans for WPT (Rajsekhar *et al*., 1999).

2.5 Public Investments and Market Facilitation Activities

2.5.1 Infrastructure Policies

2.5.1.1 Site Prospecting, Review, and Permitting

Since 1980s, Denmark promoted the development of a domestic market through wind resource mapping, grid connection regulations, guidelines and regulation on municipal planning (governing the permitting process), and information activities (IRENA, 2012a). Notably, India has large wind assessment program with more than 800 stations in 25 States informing developers about best sites suitable for WPT projects (MNRE, 2015). In the USA, the Utility Wind Resource Assessment Program funds 50 per cent of the cost of wind resource assessments.

2.5.1.2 Equipment Standard and Contractor Certification

A variety of equipment related standards and certification measures have been applied to ensure uniform quality of equipment and installation. For example, in 1978, the Test Station for Wind Turbines was established at the Risø National Laboratory, and from 1979 the Danish Energy Agency authorized Risø to develop a certification process for wind turbines which they could then issue and administer. The Risø National Laboratory's role in testing turbines, together with their more traditional forms of R&D, led to a fruitful three-way interaction between actors in industry, policy and research, with Risø providing manufacturers with essential technical and scientific support (Neij, 1997).

Like Denmark, the Netherlands introduced subsidies and set up a test station already in 1981. However, the Dutch approach was focused on supporting a competitive market, and manufacturers did not receive any support on how to improve the turbines (Kamp *et al.*, 2003). India established Center for Wind Energy Technology (CWET) (name later changed to National Institute of Wind Energy (NIWE)) in 1998 to offer services to WPT development through research. NIWE has established a Wind Turbine Test Station (WTTS) at Kayathar in Tamil Nadu with the technical and partial financial support from Denmark[7].

2.5.2 Customer Education and Mandated Generation Disclosure Information

USA's restructuring and deregulation policies require that consumer be informed about choice of power providers and characteristics of power being provided (fuel type and emissions). In many States, general education to raise awareness about RNE and environmental impacts of RNE is required, typically via websites and printed materials (Martinot and Beck, 2004). This way, consumers can make an informed choice of buying power generated from RNE.

2.5.3 Power Grid Access

As a part of prioritizing RNE power, network operators are mandated to grant access to RNE generators over conventional power. Denmark was the first country in EU to mandate grid access to RNE is 1979 followed by Germany in 1990 and Italy in 1992. USA adopted grid access for RNE in 1992 (IRENA, 2012a).

Table 2.1 gives the status of policies as discussed above in leading eight developed countries as of 2014.

[7] *Source*: http://niwe.res.in/aboutus_bd.php [accessed on May 24, 2015]

Table 2.1: Major Policies in the Leading Developed Countries for Wind Power Technology as of 2014

Policy type	**Policy**	**USA**	**Germany**	**Spain**	**Denmark**	**Italy**	**UK**
2.2 Price setting	Feed-in-tariff (FIT)		√	√	√	√	√
	Premium or adder system		√	√	√		
	Auction or tendering system			√			√
	Tax based production incentives	√					
	Spot market trading		√	√	√		√
2.3 Quantity setting	Tradable green certificate (e.g. REC/TDC)	√					√
	Renewable Energy Portfolio Standard or Purchase Obligation	√	√				√
	Federal or State wise targets	√	√	√	√		√
2.4 Cost reduction	Concessionary finance through government supported agencies	√	√				
	Concession on import duty						
2.5 Public Investment and Market Facilitation	Project siting guidelines	√	√	√	√		√
	Project permitting process	√		√	√		√
	Priority access to the grid		√	√	√		√
	Grid code		√	√	√	√	

Source: Adapted from IRENA, 2014

2.6 Policies enacted in emerging and developing countries

Developing countries began introducing policy tools to support RNE technologies in the early 1990s; when these countries introduced different incentives, especially FIT, to promote investments in RNE. By 2008, more than 30 developing countries had introduced different types of price-setting or quantity-setting instruments to increase the share of RNE in their energy mix (Kooten and Timilsina, 2009). The first four countries to introduce some type of price setting instrument or FIT were India (from 1993), Sri Lanka (from 1997), and Brazil and Indonesia (both from 2002) (REN21, 2010). By 2008, FITs are being implemented in about 49 countries around the World and are often cited as the most effective policy for attracting private investment towards RNE technologies. Recent countries adopting FIT include Kenya (2008), South Africa (2009), and Egypt (2014). FIT for WPT in Kenya is valid for 20 year period from the beginning of PPAs approved by energy regulatory commission. Interestingly, South Africa too offered FIT under PPA for 20 year period and its tariffs for WPT was one of the most attractive Worldwide. For example, the tariff for WPT is 1.25 ZAR/kWh (€0.104/kWh, $0.14 USAD/kWh, $0.17 CAD/kWh[8]) is greater than that offered in Germany (€0.092/kWh) and more than that proposed in Ontario, Canada ($0.135 CAD/kWh) (GWEC, 2014; REN21, 2014).

In India, nine States - namely, Maharashtra, Gujarat, Madhya Pradesh, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Uttar Pradesh, and West Bengal having more than 95 per cent of wind potential - introduced FIT in 1993 under the guidelines of central ministry solely dedicated for development of RNE (known as Ministry of Non-conventional Energy Sources later changed to Ministry of New and Renewable Energy - MNRE) (Jagadeesh, 2000).

Quota mechanisms, however, have been less popular in the developing World and in countries in transition. For instance, a rigorous RPO (in which a quota or target is specified, a proportional obligation is imposed on Utilities or retail companies, and the price is

[8] 1 ZAR ≈0.083 USA $, 1 € =1.12 USA $, 1 CAD = 0.83 USA $ (http://www.xe.com/currencyconverter/). [accessed on June 5, 2015]

competitively determined by the market) has only been introduced as such by a few countries, including Brazil (from 2001), India (from 2004), Chile (from 2008), Poland (from 2005), and Romania (from 2004) (Kooten and Timilsina, 2009). Brazil in 2001 mandated its national Utilities to purchase more than 3000 MW of RNE capacity by 2016 (Martinot and Beck, 2004) whereas India launched its first RPO in the State of Maharashtra in 2006 (with initial target of six per cent with increase of one per cent for next four years). Gradually, six other States of India adopted RPO at various levels (Sharma *et al*., 2012). India also adopted RECs as an option to fulfil RPO in 2010.[9]

Among cost reduction policies, subsidies have been popular among developing countries. For example, Thailand provided subsidies for small RNE power producers starting in 2000, soliciting bids for 300 MW of small RNE power and providing production subsidies above standard power purchase rates for the first five years of operation. States of India including Andhra Pradesh, Kerala, Karnataka, Madhya Pradesh, and Maharashtra offered subsidies as a percentage of capital costs (setting a certain cap on capital costs) beginning in 1993 (Jagadeesh, 2000). Whereas, China in 2008 introduced a rebate on VAT and import tariff on the import of certain wind turbine components (ALCS, 2013).

Among other cost reduction policies, India introduced AD in 1993 aggressively allowing 100 per cent depreciation in the first year itself. This was later reduced to 80 per cent in 2002 and was dropped in 2012 only to be reinstated again in 2014. China under NDRC's National Debt Wind Program 2001[10] used national debt with favourable interest subsidy conditions to build wind farms with locally manufactured turbines. Additionally, the Ministry of Science and Technology (MOST) has subsidized WPT R&D expenditures at varied levels over time (Liu *et al*., 2002). In an effort to help Chinese turbine manufacturers develop products and technologies, MOST funded research to develop 600 kW wind turbines during the Ninth Five-

---

[9] *Source*: http://www.mydigitalfc.com/opinion/why-india%E2%80%99s-rpo-mechanism-failing-990 [accessed on December 10, 2014]

[10] It supported China's Ride the Wind Program initiated by that the State Development and Planning Commission (now the NDRC) to promote a model of "demand created by the government, production by joint venture enterprise, and ordered competition in the market". The technology transfers carried out through this program started with a 20 percent local content requirement and a goal of an increase to 80 percent as learning on the Chinese side progressed (Lew, 2000).

Year Plan (1996-2000). Interestingly, only those turbines manufactured using a certain per cent of local content were eligible for subsidy. In 2005, China under the Renewable Energy Law created financial subsidies and tax incentives for RNE development including WPT (*ibid*).

China (under the Wind Concession program in 2001) invited international and domestic investors to develop large wind farms (ranging from 100-400 MW) through a tendering procedure aimed at bringing down the cost of WPT power generation. Moreover, developers bidding on the concession projects in September 2004 had to demonstrate the ability to utilize WPT that met 70 per cent local content requirement (Martinot, 2010).

Apart from FIT or RPS, the use of competitive schemes or auctions to promote RNE technologies in the developing World is less common. An alternate form of competitive bidding is being practiced by some South American countries since 2004 (including Brazil, Chile, Peru, and Columbia) known as auctions (Moreno *et al*., 2010). The case for auctions is similar to that for bidding. Competitive bids generally incorporate a weighting of price and non-price factors, while auctions are awarded solely on the basis of lowest price (sometimes after a number of bidding rounds) among qualified bidders (Eberhard *et al*., 2014). Interestingly, the number of countries turning to public auction has increased from nine in 2009 to 55 as of early 2014 (REN21, 2014) (Azuela and Barroso, 2011).

2.7 Conclusions

Table 2.2 shows summary of policies adopted Worldwide to support RNE technologies. Four prominent classes of policies – namely, price setting or quantity setting, cost reduction, public investment or market facilitation, and power grid access – have been implemented worldwide.

Table 2.2: Summary of Policies Adopted to Promote Renewable Energy Technologies

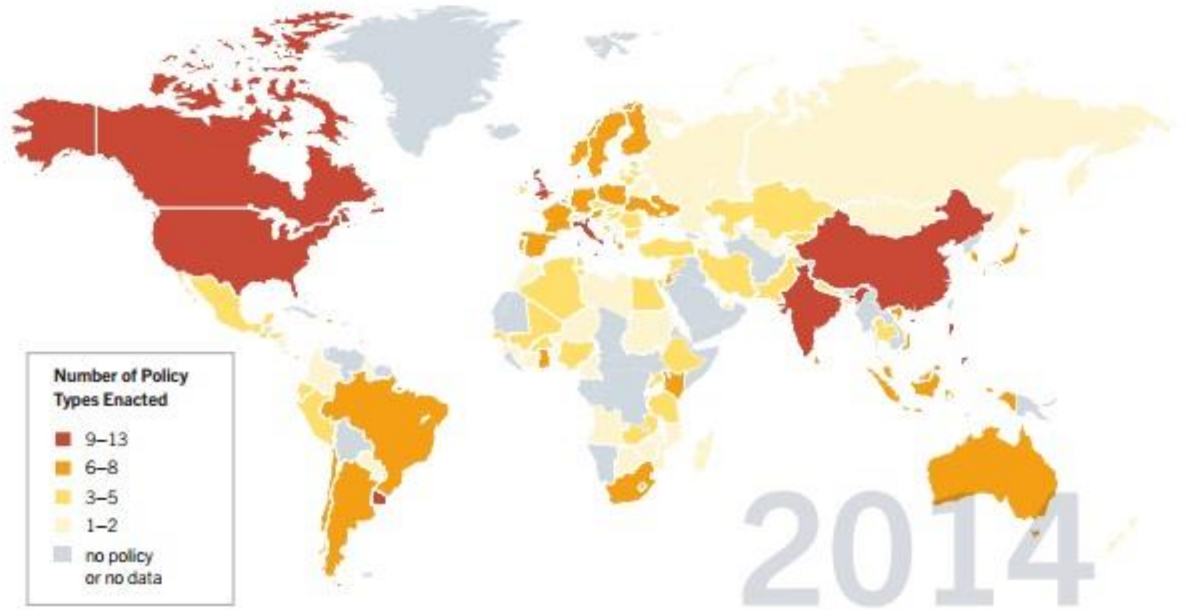
Policy	**Description**	**Types**	**Countries**
Price Setting or Quantity Setting	Offers guaranteed purchase of power at fixed prices or require a fixed share of capacity or generation.	• Price setting: Feed in Tariff (FIT), Premium or adder system, Auctions or tendering systems, Spot market trading. • Quantity setting: Renewable Energy Portfolio Standard or Purchase Obligation, Tradable green certificate, Federal or State wise targets.	• Price setting: USA (1978), Germany (1990), India (1993), Brazil (2002), China (2005), Japan (2012). • Quantity setting: USA (1997), Netherlands (1998), Italy (1999), Australia (2000), UK (2002), India (2010), UK (2002), Philippines (2008), Korea (2012)
Cost Reduction Policies	Reduces investment costs through subsidies, rebates, grants, loans, and tax relief.	Tax based production incentives, Investment subsidy or Tax credit, Concession on import duty, Concessionary finance through government supported agencies.	• Subsidies and Rebates: Denmark (1980) • Investment Tax Credit: China (2008), USA (2009) • Accelerated Depreciation: India (1993), France (2011) • Production Tax Credit: USA (1992). • Pollution Tax Exemption: Netherlands (2001) • Grants: Denmark (1979), USA (2009)
Public Investment or Market Facilitation Activities	Provide public funds for direct investments, or for guarantees, information, training, etc.	Public benefit funds, Project siting guidelines, Project permitting process, Equipment standards.	• Public Benefit Fund: USA (1998) • Siting Review: Denmark (1981), India (1993) • Equipment Standards: Denmark (1979), Netherlands (1981), India (1998)
Power Grid Access	Mandates grid access to power.	Priority or equal access to the grid, Grid code.	Denmark (1979), Germany (1990), USA (1992), Italy (1992), India (1993)

Source: Martinot and Beck, 2004; GWEC, 2012; REN21, 2014

As can be seen, a range of support mechanisms have been developed and implemented to promote the use of WPT since the late 1970s. These include tax incentives (tax credits, production incentives, AD etc.), preferential tariff regimes, quota requirements and trading systems, among others. Since around 2004, the number of countries promoting RNE including WPT has nearly tripled 48 to around 140 (REN21, 2014). While the early expansion of policies was led by developed countries in EU and USA, developing and emerging economies have led the expansion over the last decade. The number of these countries increased from 15 in 2005 to 95 by early 2014 (*ibid*).

Figure 2.1 shows the RNE policy map as of 2014. India, China, USA, and Canada have enacted more than nine policies whereas South America and EU have implemented six-eight policies. Rest of the regions including major countries in South America (including Argentina, Chile, Brazil for example), South Africa, Middle East, Rest of Asia (excluding

India and China), and Australia have less than five policies for RNE. Interestingly, in contrast to many other countries, New Zealand lacks policy support for entry of small investors in WPT. In fact, due to power market regulations that inhibit market entry for independent developers, New Zealand's WPT development has been limited to primarily large wind farms developed by a handful of power Utilities (Schaefer *et al.*, 2012).



Source: REN21, 2014

Figure 2.1: Countries with Renewable Energy Policies as of Early 2014

Growth of WPT has been phenomenal over last three decades. Global installed capacity of WPT grew from mere around 10 MW in 1980 to more than 360 MW by 2014 (Roney, 2013). Perhaps these policies have led this phenomenal growth of WPT. Accordingly, detailed literature review is conducted in next chapter to understand the theory of diffusion and impact of policies on diffusion of WPT.

Chapter 3

Review of Literature

As seen in the previous chapter, various types of policies have been enacted to promote Renewable Energy (RNE) technologies. Policies play a crucial role in the process of diffusion of RNE technologies (Janicke, 2011). In other words, innovations and markets for RNE technologies are policy induced rather than market power which is the case with consumer goods (Janicke, 2010, Porter, 1973). Hence, policy analysis forms an integral part of the study of diffusion of RNE technologies. Such an analysis can act as a feedback for policy learning and change within political system or new policy formulations which will in turn induce greater diffusion of RNE.

Accordingly, this chapter describes the process of diffusion of innovations and discusses the existing literature on diffusion of Wind Power Technology (WPT) both at macro level which involves policy analysis and micro level which describes local factors influencing adoption of WPT. The chapter is organized as follows. Section 3.1 first gives different theories of diffusion of an innovation followed by discussion on mathematical models formulated to capture diffusion process. Section 3.2 focusses on literature on comparative analysis of policies for WPT diffusion across countries. Section 3.3 gives research dedicated to policy assessment across States of India. Section 3.4 talks about factors proposed in the literature as drivers of diffusion at micro level. Section 3.5 concludes by identifying gaps in the current literature.

3.1 Diffusion of an Innovation - Theories

The diffusion of an innovation is defined as the process by which that innovation is communicated through certain channels over time among the members of a social system (Rogers, 1962). The theoretical treatment of this process has focused on factors that determine the rates of diffusion for a range of innovations that cut across different domains such as consumer goods, agriculture, automobiles (Fisher and Pry, 1971; Meade and Islam, 1998).

Rogers (1962) suggests that 49 to 87 percent of the variance in the rate of diffusion can be predicted based on an innovation's five characteristics: Relative advantage, Compatibility, Complexity, Trialability, Observability. The remaining variation can be attributed by a wide spectrum of factors such as "the type of innovation-decision, the nature of communication channels diffusing the innovation at various stages in the innovation-decision process, the nature of the social system, and the extent of change agents' promotion efforts in diffusing the innovation".

- Relative advantage is defined as "the degree to which an innovation is perceived as being better than the idea it supersedes". This is the most straightforward measurable diffusion parameter, and can be expressed in either monetary or social advantages, depending on the nature of the innovation. The higher the innovation's relative advantage, the higher is its rate of diffusion. Rogers then identifies two categories that reflect this characteristic: profitability, and status. He argues that status, a trait especially related to highly visible innovations, is important at the beginning of the diffusion process, but its importance decreases with time as more and more people adopt it and its status begins to decline (Rogers, 1962 - p. 213).

- Compatibility is “the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters”. The higher the compatibility of the innovation with the already established practices, the lower is the uncertainty and thus the higher the potential for diffusion. The compatibility criteria relate to the sociocultural values and beliefs, the previously introduced ideas, and the client needs for innovations. Rogers suggests that it is positively related to the rate of diffusion, but that the statistical evidence does not illustrate it as a major diffusion determinant (Rogers, 1962 - p. 223).

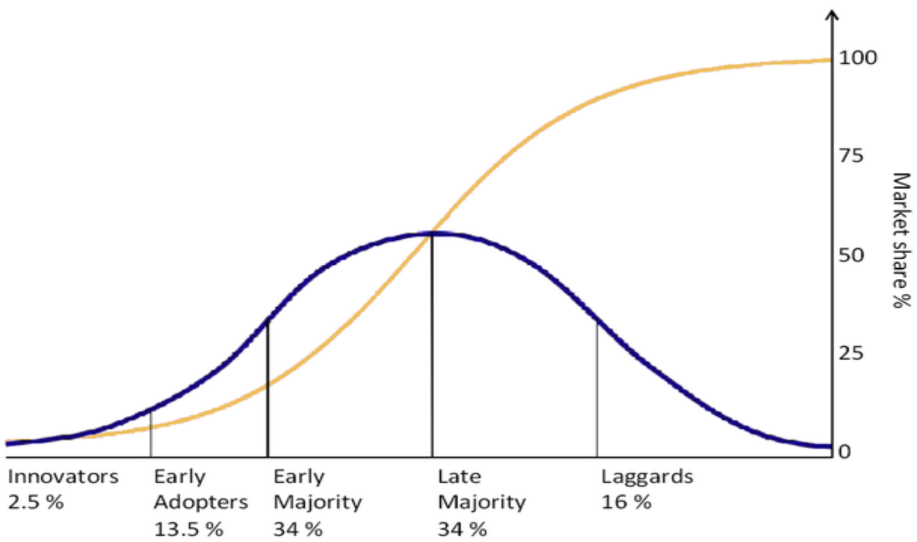
- Rogers (1962) defines complexity as “the degree to which an innovation is perceived as relatively difficult to understand and use”, and argues that it is negatively related to the rate of adoption (p. 230).

- Trialability is “the degree to which an innovation may be experimented with on a limited basis” (Rogers, 1962 - p. 231); the higher its degree of trialability, the lower the uncertainty that surrounds the innovation and thus the greater likelihood of adoption. Moreover, the importance of this characteristic decreases with the number of adopters, and it is assumed to be more important at the early adoption stage.

- Observability is “degree to which the results of an innovation are visible to others” (Rogers, 1962 - p.232). He argues that the more visible a technology is to members of a social group, the higher its rate of diffusion.

Diffusion modelling captures the diffusion process or behaviour in a mathematical form that allows quantifying the diffusion parameters for further diffusion analysis. Models can be used to explain the diffusion rates and estimate parameters that measure the coefficients of diffusion in a given context. Different diffusion models have been used, particularly since the 1960s to capture this diffusion trend in the form of mathematical equations (Meade and Islam, 2006). These models have been applied to study various diffusion processes that include population of cars, television, computers, consumer goods, etc. as well as frequency of economic booms and busts, number of fatal car accidents, incidence of major nuclear accidents, technological change in the computer industry and number of deaths from AIDS (Fisher and Pry, 1971; Meade and Islam, 1998; Mahajan *et al.,* 2000). These processes correspond to different stages of consumers’ adoption during market development classified as innovators/early adopters, early and late majority and laggards according to the time of adoption, since the technology is introduced in the market as shown in Figure 3.1.

According to a model proposed and validated by Bass (1969), approximately 9.5 to 20 per cent would be early adopters, 29.1 to 32.1 per cent belong to early majority, 29.1 to 32.1 per cent late majority and 21.4 to 23.5 per cent would be laggards.



Source: Adapted from Rogers (1962)

Figure 3.1: Different Stages of Technology Adoption during Market Development

As can be seen from the above figure, the cumulative adoption of innovation over a time period (also viewed as rate of diffusion) follows an S-shaped (Sigmoid) curve. The curve generally comprises of three distinct phases: i) a slow growth over a long period, ii) a rapid take-off period and iii) a flattening of the curve, signifying a near completion of diffusion.

Geroski (2000) classifies diffusion models as epidemic models, probit models, legitimation and competition models, and information cascades models. The underline principle behind each of these is as follows:

- Epidemic models emphasize on information contagion while presupposing agent homogeneity.
- Probit models attempt to eliminate the assumption of agent homogeneity in Epidemic models and propose to capture agent heterogeneity. Recently some authors (see for

example, Cantono and Silverberg, 2009 among others) have proposed a percolation model, which incorporates both information contagion and agent heterogeneity.

- Legitimation and competition models posit the existence of two forces affecting the birth and death of organizations over time: competition and legitimation. Competition arises whenever resource constraints limit the number of organizations which can survive in a particular market or social setting; whereas legitimation indicates the recognition or taken-for-granted attitude of that group of organizations (Mansfield, 2012).
- Information cascades deal with two variants of a technology which may threaten the existing technology by causing herd like adoption (Bikhchandani *et al.*, 1992).

These models have been used for variety of products such as pharmaceutical, grocery, computer, etc. Table 3.1 lists the various studies pertaining to diffusion models used, along with their underlined approach, for different technologies and products. As can be inferred from Table 3.1, not all models have applicability for studying diffusion of RNE (where unit of analysis is cumulative installed capacity). Last column of the table ranks the models in terms of their applicability for WPT. Models like Probit have individual as a unit of analysis where individuals make a choice between adopting and non-adopting. Similarly, since we are looking at diffusion of WPT in general and not at the technological variants like whether the wind turbine is horizontal axis or vertical axis, information cascade models will not be applicable. The table based on the ranking shows that Epidemic models have an advantage over other approaches with respect to the technology (WPT) and data availability (installed capacity).

In the epidemic models the number of adopters of an innovation is assumed to increase over time as non-adopters come in contact with the adopters and gather information about the innovation. Diffusion in epidemic models is thus determined by the “epidemic” spread of the information among the potential adopters. The theoretical specification of epidemic models leads to standard S-shaped curves which estimate the speed of diffusion and size of market (Rao and Kishore, 2009). WPT fits best to the applicability of S-shaped curves, as shown in the Figure 3.2, that they depict the life cycle of a new technology entering a market: growth starts off slowly, then accelerates, and finally slows down again until the saturation level is reached (*ibid*).

Table 3.1: Diffusion of Products/ Technologies – A comparison

MODEL TYPE			***Authors(s)***	***Product/ Technology***	***Region/ Country***	***Applicability for wind energy diffusion****	
						Degree	*Reason(s) –* {+: Positive, -: Negative}
Epidemic Diffusion Models	Internal Influence (a)	Logistic Growth (a1)	Desiraju *et al*, (2004)	Pharma drugs	15 (developed & developing)	Moderate	• +:Uniformity among adopters • +:Aggregate/cumulative data • -: Slow initial diffusion • -:No direct consideration of policies
			Teng *et al*. (2002)	IT	USA		
		Gompertz Curve, Hazard models	Chow (1967)	Computers	USA	Moderate	• +: Same + as (a1) • +: Slow initial diffusion-asymmetric diffusion • -:No direct consideration of policies
			Lamberson (2008)	Hybrid Vehicles	USA		
	External Influence (b)	Exponential Form	Fourt and Woodlock (1960)	Grocery Products	USA	Moderate	• +: same + as (a1) • -:no internal influence
	Mixed influence (c)	Bass Model, Generalized Bass Model	Bass (1969)	TVs, dishwashers, & clothes dryers	USA	High	• +: Same as for (a1) • +: Considers both policies' influence + adopters' influence
			Guidolin & Mortarino (2010)	Solar PV	USA,EU,AU, JP		
Rank Approach	Agent perspective (d)	Probit Function	Vij *et al*. (1991)	Electricity	India	Low	• +: same as for (a1) • -: a rational choice making
			Wittman and Bruckner (2009)	Energy supply	Germany		
Epidemic + Rank Approach	contagion aspect + agent perspective (e)	(c) + (d)	Cantono and Silverberg (2009)	Eco-innovations			• -: looking at adoption by firms
Inclusion of stock & order effects		Game theory	De Vries (2003)	Eco-friendly technologies	EU & USA	Low	• -: looking at adoption by firms
Legitimate & Competition	Case study (f)	Qualitative	Guérard and Langley (2007)	Medical technology	Quebec/ Canada	Low	• -: looking at adoption by firms
Information Cascades	Agent perspective (g)	(d)	Walden and Browne (2002)	E-commerce	USA	low	• -: variants of wind technology
Lead market model	Case study (f)	Qualitative	Beise and Rennings (2005)	Wind power, fuel efficient passenger cars	Developed and developing	low	• -:looking at adoption from lead and lag perspective

Source: Own compilation

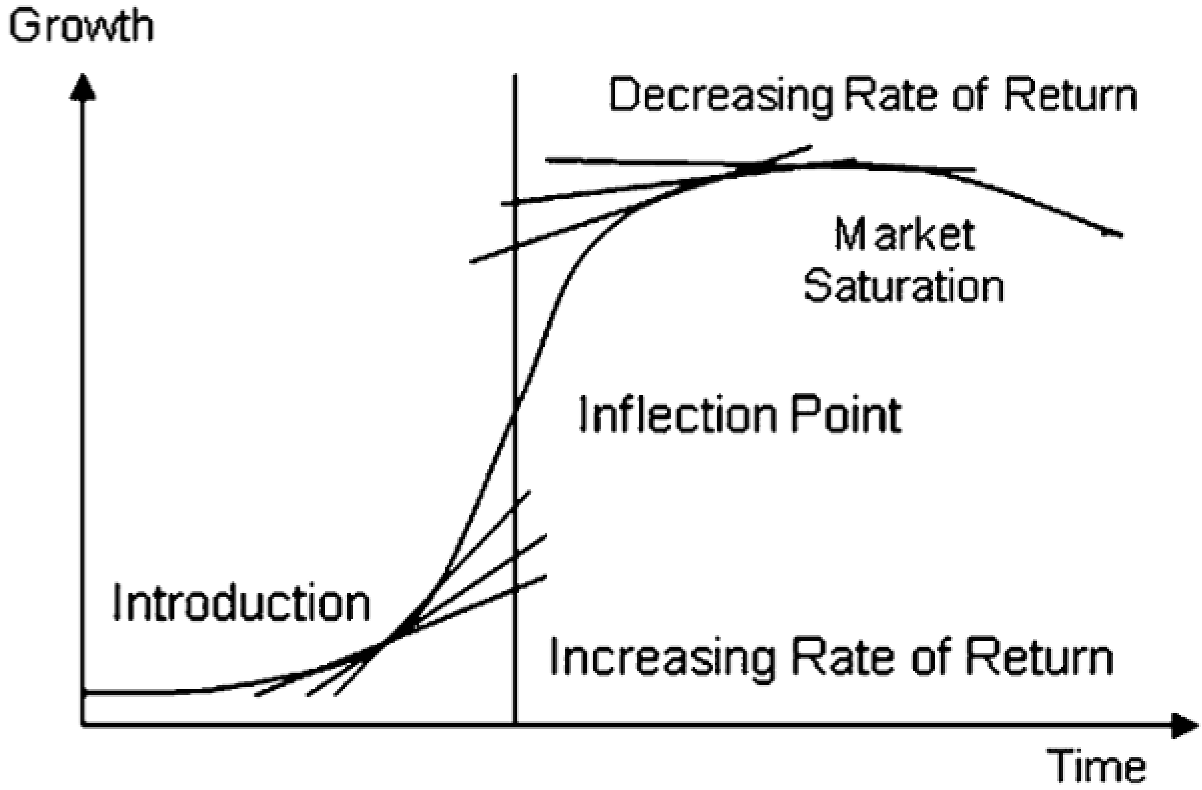


Figure 3.2: S Shaped Curve for Technology Diffusion

Mathematically, there are several equations that can be used to represent an S- shaped curve. The two most common equations are the Gompertz curve and logistic curve[11] as given below:

$$y_t = \alpha \exp[-\beta \exp(-\gamma t)] \text{ .... Gompertz curve}$$

$$y_t = \frac{\alpha}{1+\beta \exp(-\gamma t)} \qquad \text{......Logistic curve}$$

In these equations, α is a positive parameter that indicates the saturation level of the product/ technology, β and γ are also positive parameters and indicate location and shape, and t is a linear time trend (t = 1, …., T). Both these curves involve estimation of three parameters, and range between lower asymptote of 0 and an upper asymptote of α.

The inflection point for the above curves occurs at time $t^* = \frac{\log \beta}{\gamma}$ and corresponding ordinate at the point of inflection is $y_t = \frac{\alpha}{exp}$ in the Gompertz curve, and $y_t = \frac{\alpha}{2}$ in the logistic curve.

[11] Logistic curve is derived from a differential equation where the relative growth rate of a product decreases monotonically with time, while in the case of the Gompertz curve the relative growth rate decreases in an exponential fashion (Gamboa and Otero, 2009).

Another prominent model built around the S shaped curve is the Bass model which assumes the process of diffusion is driven by two forces, namely force of innovation and force of imitation. The mathematical form is given by,

$$y_t = \alpha \frac{1 - e^{-(p+q)t}}{1 + \frac{q}{p} e^{-(p+q)t}}$$

y_t and α are same as explained earlier in logistic and Gompertz models whereas and p and q correspond to coefficient of innovation and coefficient of imitation, respectively. Specifically p indicates the rate of change of adoption by innovators per unit fraction of population while q indicates the rate of change of adoption by imitators per unit fraction of potential adopters population per unit of existing adopters. In other words, p reflects the fraction of adopters who are innovators and q reflects the pressure operating on imitators as the number of previous buyers increases. For the Bass model, the point of inflection is given by

$$t^* = \frac{\ln(\frac{q}{p})}{p + q}$$

3.2 Diffusion at Macro Level – Analysis across Countries/ States

Empirical research approaches studying diffusion of WPT at aggregate level with respect to the policies aimed to support it. These studies are conducted at international or national level. At international level, analyses usually compare different policy mechanisms across countries to identify successful policies driving diffusion. Whereas, analyses carried out at national level usually involve measuring relative impacts of similar policies within a country or region.

International comparative studies have addressed technological learning and wind turbine development and how policy mechanisms have enabled investments in WPT growth and its market developments (Kamp *et al*., 2004; Dinica, 2003; Lauber, 2005; Mitchell *et al*., 2006; Toke, 2005). A growing number of international comparative studies place the advance of WPT (industry, market, technology) in a broader context of national political, economic, technological and institutional developments, with a view to improving our understanding of the complexity of contextual factors that influence the diffusion of WPT (Est, 1999;

Jacobsson and Johnson, 2000; Suck, 2002; Bergek and Jacobsson, 2003; Lauber and Mez, 2004).

Ibenholt (2002) compared utilization of wind potential in three countries – namely, Denmark, Germany, and the UK - by applying learning curve to study empirical relationship between costs and accumulated production or capacity. By combining an analysis of learning curves with an analysis of policy programmes, the study concludes that utilization of wind potential in different countries greatly differs due to aerodynamic conditions and differing policies. Lund (2007) estimated financial resource required for RNE technologies based on an analysis of costs and returns on per unit production cost and cost reduction due to learning by doing.

Diaz-rainey and Tzavara (2009) attempt to define diffusion patterns based on logistic and log-logistic models in USA, few European Union (EU) countries, and Canada; whereas Söderholm and Klaassen (2006) employ a simultaneous innovation-diffusion econometric model, based on a learning curve, to selected European countries. Beise and Rennings (2005) propose a lead-lag (leader-follower) model for WPT markets by proposing Denmark as the lead market in technology development and Germany, Spain, Netherlands, and UK as the lag markets. They specifically study the role of policies and regulations in penetration of WPT in these countries. Dalla Valle and Furlan (2011) emphasize the role of both the exogenous and endogenous mechanisms in diffusion of WPT and argue that Generalized Bass Model (GBM) is better equipped to explain the diffusion process. Their work is focussed on USA and few European countries. Delaportas (2012) has used hazard models to explain the difference in the speed of diffusion of WPT for total of 130 countries and attempts to identify factors driving and differentiating diffusion across selected countries.

Río and Unruh (2007) surveyed the diffusion of WPT and solar Photovoltaic power technology in Spain using an evolutionary economic model. They argue that economic and institutional factors play crucial and key roles in fostering or inhibiting diffusion. Bird *et al.* (2005) provide descriptive work focused on both policy and market factors that are influencing WPT adoption within United States of America (USA). They argued that State tax and financial incentives along with Renewable Portfolio Standards (RPS) are important policies to encourage WPT adoption. In addition, they contended that lower costs for WPT projects are due in part to technological improvements in wind turbines and in part to federal tax incentives including the Federal Production Tax Credit (PTC).

Menz and Vachon (2006) carry out an Ordinary Least Squares (OLS) analysis of policies of 39 States of USA covering the time period from 1998 through 2003. The authors include a binary indicator for each regulation and a control for wind potential. Study finds that RPS and mandatory green power option programs are positively related to increase in WPT adoption. Marques and Fuinhas (2012) assess the role of public policies in selected European countries towards use of RNE as per cent of primary energy supply and find that public policy measures contribute, as a whole or disaggregated, to wider use of RNE.

Table 3.2 summarizes the selected studies across various regions, their methods, and main results.

3.3 Diffusion at Macro Level – Analysis across States of India

For developing countries like India, barring few exceptions, there has been hardly any attempt made to model diffusion of WPT. Ravindranath *et al*. (2000) analysed policies for RNE technologies and point out to the continuing barriers to the large scale adoption of RNE technologies in India. In the Indian context, there are only a handful of empirical studies that have attempted to see the role of government policies on RNE development (see for example, Schmid, 2012; Jagadessh, 2000). Schmid (2011) study on the impact of two national level policies - The Electricity Act 2003 (EA'03) and the Tariff Policy in 2006 - in growth of grid connected RNE resources. The study concludes that both the policies have positively influenced growth of RNE. The study also appreciates of the State level policy in encouraging RNE. Further the paper suggests that incentive like Renewable Purchase Obligation (RPO) has contributed to growth of RNE resources while Feed-in-Tariff (FIT) is relatively ineffective.

Table 3.2: Summary of Selected Empirical Literature on Evaluation of Policies for Wind Power Technology

Author(s)	**Method and Type of Data**	**Region**	**Variables**	**Omitted Explanatory Variables**	**Main Results**
Menz and Vachon (2006)	OLS, cross section data	USA	**Dependent**: Capacity variation in a three year period **Explanatory**: Policy variables and potential	Generation costs, admin barriers, major changes in RNE support policies	Significant and positive relationship between explanatory variables and WPT development.
Yin and Powers (2010)	Panel data, (1993-2006)	USA	**Dependent**: % of RNE capacity **Explanatory**: Presence of RPS in the State, other policy variables, no. of years RPS is active, power price, state income, environmental preference, net import of power	Potential and admin. barriers	Import dependency is only '+'ly significant for RNE investments, other variables not: electricity price (-), environmental awareness (-), GDP (+), policy experience (-). The policy variable significantly affects RNE investments in some specifications and negatively in others. Allowing TGCs* would weaken impact. The no. of years policy is in place not significant.
Carley (2009)	Panel data, (1998-2006)	USA	**Dependent**: % of RNE generation **Explanatory**: RNE support policies, potentials, State GDP, deregulation, environmental awareness of State, power use per person and price	Costs of RNE technologies, levels of policy support, major changes in support policies, admin barriers	RPS implementation is not a significant predictor of % of RNE generation. Policies, potentials, State GDP, deregulation, environmental awareness, power use per person, and price significantly related to RNE deployment.
Marques *et al.* (2010)	Panel data, (1990-2006).	21 EU countries	**Dependent**: Contribution of RNE to energy supply, as a % of total primary energy supply **Explanatory**: CO_2 per capita, energy import and consumption per capita, importance of nuclear and conventional power, surface area, fossil fuel prices and GDP	Public policies, social acceptability, and RNE generation costs per country, potential (captured through proxy variable surface area)	Variables significantly related to RNE in most model specifications: CO_2 emissions (-), energy per capita (+), the lobby of the traditional energy sources (oil, coal, and natural gas, proxied by their share) (-) and import dependency (-). Not significantly related in at least 2 of the 4 specifications: GDP (with erratic signs), coal and oil prices (-), gas prices (+) and area (erratic sign).

Table 3.2 (Contd…)

Author(s)	**Method and Region**	**Variables**	**Omitted explanatory variables**	**Main Results**
Mulder (2008)	Panel data, (Neo-classical investment model), EU-15 (1985–2005).	15 EU countries' policies and industry development.	**Dependent**: WPT capital stock in a given year **Explanatory**: generation costs of WPT and policy variable	Policy stability, social acceptability, climate of investment climate, potential & admin. barriers.
Popp *et al*. (2011)	26 OECD countries (1991–2004). Panel data	**Dependent**: Impact of technological change (measured through patents) **Explanatory**: A measure of the global knowledge stock for each technology, GDP per capita sector, the growth rate of power consumption, the %s of power by nuclear power and hydropower, the availability of fossil fuels, % of energy imported and a vector of policy variables.	Levels of RNE support, costs of technologies, potential and admin barriers.	Technological advances lead to greater WPT investment, but the effect is small. GDP per capita is also positively and significantly related to RNE investments. Investments in nuclear serve as substitutes for RNE only in one of the five specifications. Not significant in any of the five specifications: RNE support policies, growth in power consumption (with a '–' sign), % of power from hydro and % of energy imported.
Johnstone *et al*., (2010)	Panel data, 25 OECD countries (1978–2003).	**Dependent**: innovation measured through patents in RNE technologies **Explanatory**: RNE policies, R&D investments, trends for power consumption, signing of Kyoto Protocol, price of power and overall patent applications	Generation costs per country, potential, admin barriers, changes in policies and general investment climate	TGCs to induce innovation in WPT. FITs are needed to induce innovation on more costly energy technologies (i.e., solar power). Variables significantly related to WPT patents: total patent applications, R&D expenditures, RNE support policies (both FITs and TGCs) and signing of the Kyoto Protocol. Not significant: power consumption with prices and other policies.
Delaportas (2012)	Panel data, 130 countries (1990 – 2009), Hazard models	**Dependent:** Power from WPT **Explanatory**: power consumption and trade, FDI, RNE policies, crude oil prices, CO_2 emissions, GDP per capita, wind potential, years of schooling, technology capability.	**Dependent**: late or secondary adoption of WPT.	CO_2 emissions, environmental awareness, wind potential, power consumption and trade, FIT policy, natural resource rent as % of GDP.

Source: Own Compilation

Rao and Kishore (2009) fit Bass model and compute composite policy index for four States of India – namely, Andhra Pradesh (AP), Gujarat (GJ), Maharashtra (MH), and Tamil Nadu (TN) - using data on installed capacity WPT from 1991 to 2001. They find this index to bear strong relationship with of ranking of the States according to diffusion parameters of Bass model. Recently, Barik and Murugesha (2012) have proposed logistic curve to model diffusion of WPT for one particular State of India.

Benecke (2008) analyzes two apparently opposite States in terms of WPT capacity, TN and Kerala (Ke). The study focuses on issues in design and execution of policies in these States which strongly influence WPT adoption. Ke is rarely faced with power shortage and therefore has less incentive to promote RNE. Benecke further argues that legislations in the State take huge time to get implemented and policies are sticky in nature. Further, the establishment of ANERT (Agency for Non-Conventional Energy and Rural Technology) as the State Nodal Agency (SNA) lacks the skilled and permanent staff coupled by no definite objectives for development (*ibid.*). The neighbouring State, TN, has been the leader in adopting WPT because of two reasons – one better functioning SNA encouraging private participation since its inception; and another overall conducive environment for wind industry (a vast coastline ensures excellent resource availability and collaboration of *in-situ* manufacturers with international wind turbine suppliers (*ibid*).

Jagadeesh (2000) using case study approach identifies determinants of high growth and a subsequent fall in WPT diffusion in TN and AP till mid-1990s. The study suggests that internal factors such as capital incentives, technical assistance, infrastructure, timely execution of projects along with external factors like growth in textile and cement industry are the reasons for the boom. Later fall in growth is attributed to decline in capital assistance or incentives, unsound technical assistance along with import of unsuitable turbines, unwarranted expansion of wind mills and the economic slowdown in cement and textile industry in these two States.

Recently, Kathuria *et al*. (2015) have examined the impact of States' policies on Foreign Direct Investment (FDI) in WPT across eight Indian States – namely, TN, MH, AP, Karnataka (K), Ke, GJ, Rajasthan (RJ), and Madhya Pradesh (MP). They find the policy index to bear a positive relationship with FDI in WPT. Table 3.3 presents summary of studies on diffusion of WPTwith respect to States of India.

Table 3.3: Summary of Literature Examining Impact of States' Policies on Diffusion of Wind Power Technology in India

Author	Year	Indicator for Investment	Proposed Method/ Model	Country (time period)	Significant variables
Kathuria *et al*.	2015	FDI in wind	Random effects covariance decomposition	India (eight States) (2004 – 2011)	State policies
Schmid	2011	Installed capacity	OLS	India (nine States) (2001-2009)	Tariff Policy, RPO
Benecke	2008	Installed capacity	Case Study	India (Tamil Nadu and Kerala) (up to 2008)	Pro-activeness of govt., power shortage, industry culture
Jagadeesh	2000	Installed capacity	Case study	India (Tamil Nadu and Andhra Pradesh) (till 1999)	Capital incentives, industry culture, skilled manpower
Rajsekhar *et al*.	1999	Installed capacity	Case Study	India (till 1998)	Adequate regional power stations, production based incentives

Source: Own Compilation

3.4 Diffusion at Micro Level: Influence of Local Differences

A literature review is carried out to understand the preferences of firms while choosing a location for WPT project. Many studies have acknowledged that successful adoption of WPT by a firm requires numerous decisions which are determined by local conditions affecting project siting process (Hull, 1995; Wolsink, 1996 Pasqualetti, 2001; Khan, 2004). Compared to conventional power supply, WPT involves relatively small-scale, decentralised and location-dependent applications. In addition, a certain degree of support and approval from actors with ‘a stake in the locality’ is needed. The first reason for this is that even less powerful local actors can deploy means to delay or halt implementation (Breukers and Wolsink, 2007). Alternately, relevant actors bring in their knowledge and experiences, which can improve the quality of the plan and design. The outcomes of all local decision-making processes eventually make up the diffusion at aggregate level (*ibid*).

One of the most important factors in siting a WPT project is the availability of wind potential. Unlike conventional power, power production from WPT is affected by instantaneous variation in wind speed[12] which varies considerably over the year in any location (Palutikof *et al*., 1987). In fact, several studies report that (see for example, Archer and Jacobson, 2003; Baker *et al*., 1990, among others), usually in any region the overall yearly power from WPT may be almost exclusively generated in just a few months during the year. For example, over peninsular India, which is flanked on either side by sea, the western monsoon winds attain considerable speed in the lower atmosphere (0.5 to 1.5 km above mean sea level) from June to September. In July, the winds attain the seasonal maximum wind speed of 40 to 50 kilometres per hour. August has nearly the same wind speed, while June and September months experience lower wind speeds (Rangarajan, 1995). The monsoon winds provide the bulk of the wind energy in India (*ibid*). Accordingly, it can be seen that any changes in the local seasonal wind speeds at regional or local scales, as well as on annual or seasonal time-frames can have a significant impact on the efficiency and reliability of power generation from WPT (Greene *et al*., 2010).

Wind speed also has an influence on the land requirement for WPT project. Land requirement for a WPT project is typically governed by wind speed, hub height, and technology in use, and land type. In general, wind increases its speed when it moves up the windward slope of a hill or a ridge and as a result the land requirement for a wind turbine is reduced. For example, projects on ridgelines near hilly terrains may require as little as 2 acres/MW of land whereas land requirement increases to an order of around 30 acres/MW for sites with WPD greater than 250 W/m^2 (Sovacool, 2008).

Another key attribute as highlighted in the literature is acceptance of WPT by concerned stakeholders, in particular the local residents and communities. Studies like Bosely and Bosley (1988), and Wolsink (1987) focussed on issues such as the lack of support from key stakeholders, reluctance among policy makers to dedicate themselves to consistent and effective policy making, and the lack of understanding of roots of public attitudes towards WPT. The issue regarding public opposition is based on specific acceptance of siting decisions of WPT projects by local stakeholders, particularly residents and local authorities.

[12] The power generated from WPT is proportional to the cube of wind speed (Palutikof *et al*., 1987).

This is the arena where the debate around Not In My Back Yard termed NIMBYism unfolds, where some argue that the difference between general acceptance and then resistance to specific projects can be explained by the fact that people support RNE technologies as long as it is not in their own backyard, while others argue that this is at least an over-simplification of people's actual motives (Bell *et al*., 2005).

Another reason causing social opposition is due to the inherent physical nature (shape and weight) of wind turbine components. Table 3.4 shows the specifications of a typical 1.8 MW wind turbine which weighs around 230 tons (CanWEA, 2006). Because of such enormous weights of components and constant flow of traffic, especially on the small country side area near a windy location, damage to road becomes inevitable which in turn often leads to social unrest in the surrounding locality (*ibid*).

Table 3.4: Typical Specification of Components of 1.8 MW Wind Turbine

Component	**Nacelle**	**Blade**	**Tower**	**Foundation**
Length or Depth (meters)	-	Length – 63	Depth – 65	Depth – 10, Length - 4
Weight (tons)	63	12	132	-

Source: CanWEA, 2006

Transport of wind turbine components and accompanying costs also has implications of overall cost of a WPT project. For example, according to American Wind Energy Association (AWEA), transport and logistics is one of the main reasons why the US WPT market promoted domestic content for wind turbines instead of import. As a result, by 2013, more than 550 manufacturing facilities were built contributing to around 67 per cent of content for wind turbines (Daubney, 2013). In fact at a local level, transport can represent as much as 10 per cent of the capital outlay of a WPT project because of which US manufacturers wanted to set up factories as close as possible to the ultimate delivery point (*ibid*). Moreover as the blades, nacelles, and towers grow in size with increase in capacity, the corresponding challenges of transporting them to a project site grow. In Europe, for example, towers present one of the greatest challenges for transportation because the largest part of the flange is too big to pass through many bridges (*ibid*).

Further, coordination between different actors and attitude of local administration during different stages of a WPT project has also been found to have an important role. In many countries, different regions have differing permitting rules for oversize load. Transporting wind turbine components from a manufacturing facility to a project site requires close coordination between supplier, transport and logistics provider, State and local transport authorities, and port authorities if any part is imported (Cotrell *et al*., 2014). In this respect, Benecke (2008), as discussed earlier, seems to be arguing that factors like efficiency of authorities and transportation have played an important role in growth of WPT in TN in India.

3.5 Conclusions

From literature on international policy assessment, it is clear most researchers have picked one particular epidemic model to explain diffusion of WPT. Such "one size fits all" approach while seemingly convenient from modelling perspective may ignore certain aspects of influence of policy development on diffusion of WPT. Further, it could be argued that even though countries design similar kind of policies, the resulting diffusion may be different owing to the social, economic, financial structure and objectives of countries.

It can be seen from the literature on WPT diffusion in States of India that while crucial role of policies and proactive attitude of government has been appreciated in diffusion, most of the studies follow either the case study approach or correlation to find link. Moreover, while studies have been carried out to compare deployment of wind power across few States of India, there is a lack of a comprehensive study examining impact of policies of all major States together except Kathuria *et al.* (2015). However, they study the impact of policies on foreign investment only and not at the overall investment which includes domestic investment as well.

At micro level, there seems to be no attempt to identify determinants of decision making of firms behind location choices while investing in a WPT in India. Though, numerous attempts have been made to identify barriers to widespread growth of WPT in few States of India; many of them are pure case study offering a qualitative analysis. To the best of our knowledge, a comprehensive empirical study through incorporation of all stakeholders is yet to be undertaken.

Chapter 4

Diffusion at Macro Level: Analysis across Countries

4.1 Introduction

As seen in the chapter 2, various countries have adopted different types of policy measures to promote RNE. Further, literature review in chapter 3 has revealed that most researchers have picked one particular model to explain diffusion of Wind Power Technology (WPT) at macro level. For example, Diaz-rainey and Tzavara (2009) attempt to define diffusion patterns based on logistic and log-logistic models in United States of America (USA), few European Union (EU) countries, and Canada; whereas Söderholm and Klaassen (2006) employ a simultaneous innovation-diffusion econometric model, based on a learning curve, to selected European countries. Beise and Rennings (2005) propose a lead-lag (leader-follower) model for WPT markets by proposing Denmark as the lead market in technology development plus export share and Germany, Spain, Netherlands, and UK as the lag markets. They specifically study the role of policies and regulations in penetration of WPT in these countries. Dalla Valle and

Furlan (2011) emphasize the role of both the exogenous and endogenous mechanisms in WPT diffusion and argue that Generalized Bass Model (GBM) is better equipped to explain the diffusion process. Their work is focussed on USA and few European countries. Delaportas (2012) has used hazard models to explain the difference in the diffusion speed of WPT for total of 130 countries and attempts to identify factors driving and differentiating diffusion across selected countries. For developing countries barring few exceptions, there has been hardly any attempt made to model diffusion of WPT. Rao and Kishore (2009) use bass model to study WPT diffusion in India from 1991 to 2001. Recently, Barik and Murugesha (2012) have used logistic curve to model diffusion of WPT for one particular State of India.

Such “one size fits all” approach while seemingly convenient from modelling perspective may ignore certain aspects of influence of policy development on WPT diffusion. Further, it could be argued that even though countries design similar kind of policies, the resulting diffusion curves may be different owing to the social, economic, financial structure and objectives of countries.

Accordingly, this chapter addresses research question one of the thesis stated as - *Is diffusion pattern same across countries?*

As can be seen, this chapter deals with stage 1 of the macro level analysis and hence focusses on international comparative analysis of diffusion across leading countries. The purpose of the chapter is to understand which diffusion models explain the growth of WPT in various countries and to compare impacts of policies on the resulting diffusion curves.

The remaining chapter is divided into four sections as follows. Section 4.2 briefly states the methodology employed during the analysis. Section 4.3 presents the data used for the purpose of analysis. Based on the quantum of installed capacity of WPT, the study picks up USA, Germany, China, Spain, and India. Section 4.4 outlines the results for each of these countries and suggests possible link between diffusion and policy. Section 4.5 compares diffusion parameters of selected countries. Section 4.6 concludes.

4.2 Methodology

Though a number of models exist to see the diffusion of a particular product or process, not all models can be applied to study diffusion of WPT as analysed in section 3.1. Three prominent models – namely, bass, Gompertz, and logistic – have been identified suitable to study diffusion of WPT. These three models have been used to analyse diffusion of WPT. While selecting a particular model, three model selection criteria, namely Akaike Information Criterion (AIC)[13], Baysian Information Criterion (BIC), and adjusted R^2 have been used. These criteria quantify the trade-off between complexity and goodness-of-fit, so as to identify the simplest model that explains the data. The lower the value of AIC and BIC, the more predictive the model is (Hirotugu, 1974). On the other hand, accuracy increases with R^2.

4.3 Selection of Countries and Data

As of 2012, out of World's 282,275 MW of WPT installed capacity, 74 per cent of the turbines are located in the top five countries – China, USA, Germany, India, and Spain as shown in Table 4.1. Since 1995 onwards, World has seen wide fluctuation in their respective shares. China has been the main driver of growth for WPT for the past several years. In 2006, it had around 2.5 GW of installed capacity comprising four per cent of the global share. Since then, it has added 62 GW reaching to approximately 35 per cent of installed global capacity – a 25 fold increase, while rest of the World expanded by a factor of 2.6 (GWEC, 2012). On the other hand, share of USA decreased from 34 per cent in 1995 to 20 per cent in 2011. Nonetheless, WPT comprised 42 per cent of the total capacity addition in USA in 2012 (EIA, 2013). The EU power sector has continued to move away from fuel oil, coal and nuclear by decommissioning more power plants running on these technologies than installing. Since 2000, in EU, 51.2 per cent of new capacity installed has been RNE in which 27.7 per cent has been of WPT and 91.2 per cent RNE and gas combined (EWEA, 2013). Annual installations

[13] AIC and BIC are defined as: $AIC = -2\,log(\hat{L}) + 2K$ and $BIC =: -2\log(\hat{L}) + \log(N)K$, where K is the number of parameters estimated, N is the sample size, and $\hat{L}$ is the maximized value of log likelihood. Given the estimated models for the data, the preferred model is the one with minimum AIC and BIC values (Hirotugu, 1974; Schwarz, 1978).

have increased steadily over the last 12 years, from 3.2 GW in 2001 to 11.9 GW in 2012, at Compound Annual Growth Rate (CAGR) of 11.6 per cent. As of 2012, Germany continues to be the leader in EU with the largest WPT installed capacity followed by Spain, UK and Italy (EWEA, 2013). Among developing countries, besides China, India raised its meagre 41 MW of WPT in 1991 to over 19,000 MW by 2013 (Sharma *et al.*, 2012; IWTMA, 2013). Given this differentiated growth of wind power in these countries, it makes an interesting case to see which model explains their diffusion pattern.

Table 4.1 shows the data on installed capacity of WPT in the five chosen countries. While World's average growth rate of installed capacity since 1995 stood at around 28 per cent, China has achieved more than double of the World's average growth rate (59 per cent) because of remarkable capacity addition since 2004. Spain has second highest growth rate of 37 per cent. On the other hand, installed capacity growth rates of USA, Germany, and India are incidentally equal (23 per cent) though slightly lower than the World average. However, the share of USA in World total has fallen from 79 per cent in 1991 to 20 per cent in 2011, whereas Germany's share increased from 0.8 per cent in 1987 to 38 per cent in 2002 and then fell gradually to 12 per cent in 2011. India has managed to increase its share from two per cent in 1991 to seven per cent in 2011. Spain's share increased from 0.2 per cent in 1991 to 18 per cent in 2004 and then gradually fell to nine per cent in 2011. China has increased its share from 0.8 per cent in 1995 to 26 per cent in 2011. The five selected countries can be consistently seen contributing cumulatively more than 70 per cent of installed capacity of WPT since 1995.

For each of these five countries, we have used installed capacity of WPT, y_t, to estimate the parameters α, β, γ of logistic and Gompertz model by minimizing sum of square of errors. Parameters of Bass model are also estimated using the same principle. After estimation, we select the best model using statistical inference and justify the model parameters with policy initiatives in selected countries. The five selected countries can be consistently seen contributing cumulatively more than 70 per cent of installed capacity of WPT since 1995.

Table 4.1: Installed Capacity (MW) of Wind Power Technology in Selected Countries

Year	China (1)	USA (2)	Germany (3)	Spain (4)	India (5)	World (6)	Cumulative % of World (7)
1980	n.a.	8 (80)	n.a.	n.a.	n.a.	10	-
1981	n.a.	18 (72)	n.a.	n.a.	n.a.	25	-
1982	n.a.	84 (93)	n.a.	n.a.	n.a.	90	-
1983	n.a.	254 (100)	n.a.	n.a.	n.a.	254	-
1984	n.a.	653 (100)	n.a.	n.a.	n.a.	653	-
1985	n.a.	945 (93)	n.a.	n.a.	n.a.	1,020	-
1986	n.a.	1,265 (99)	n.a.	n.a.	n.a.	1,270	-
1987	n.a.	1,333 (92)	5 (0.3)	n.a.	n.a.	1,450	-
1988	n.a.	1,231(78)	15(0.9)	n.a.	n.a.	1,580	-
1989	n.a.	1,332(77)	27(1.5)	n.a.	n.a.	1,730	-
1990	n.a.	1,484(77)	62(3)	n.a.	n.a.	1,930	-
1991	n.a.	1,709(79)	112(5)	5(0.2)	39(2)	2,170	-
1992	n.a.	1,680(67)	180(7)	50(2)	39(1.5)	2,510	-
1993	n.a.	1,635(55)	335(11)	60(2)	79(2.6)	2,990	-
1994	n.a.	1,663 (48)	643(18)	70(2)	185(5)	3,490	-
1995	38(0.8)	1,612(34)	1,130(23)	140(3)	576(12)	4,780	73
1996	79(1.3)	1,614(26)	1,548(25)	230(4)	820(13)	6,100	70
1997	170(2)	1,611(21)	2,080(27)	512(7)	940(12)	7,600	70
1998	224(2)	1,837(18)	2,875(28)	834(8)	1,015(10)	10,200	67
1999	268(2)	2,490(18)	4,442(33)	1,812(13)	1,077(8)	13,600	74
2000	346(2)	2,578(15)	6,113(35)	2,235(13)	1,220(7)	17,400	72
2001	404(1.7)	4,275(18)	8,754(36)	3,337(14)	1,456(6)	23,900	76
2002	470(1.5)	4,685(15)	11,994(38.5)	4,825 (15)	1,702 (6)	31,100	76
2003	568(1.5)	6,372(16)	14,609(37)	6,203(16)	2,125(5)	39,431	76
2004	765(1.6)	6,725(14)	16,629(35)	8,263(18)	3,000(6)	47,620	74
2005	1,272(2)	9,149(15.5)	18,415(31)	10,027(17)	4,430(7.5)	59,091	73
2006	2,559(3.5)	11,575(15)	20,622(28)	11,623(16)	6,270(8.5)	74,006	71
2007	5,871(6)	16,824(18)	22,247(24)	15,145(16)	7,845(8)	93,639	73
2008	12,020(10)	25,237(21)	23,903(20)	16,689(14)	9,655(8)	1,20,267	73
2009	25,805(16)	35,086(22)	25,777(16)	19,160(12)	10,926(7)	1,58,864	73
2010	44,733(23)	40,298(20)	27,191(14)	20,623(10)	13,065(7)	1,97,686	74
2011	62,733(26)	46,919(20)	29,060(12)	21,674(9)	16,084(7)	2,38,035	74
Growth rate (% since 1995)	**59**	**23**	**23**	**37**	**23**	**28 (since 1991)**	

Notes: n.a.= not available. Figures in parenthesis give the share of country's wind power to World's wind power. Since installed capacity for all the selected countries was together available from 1995 only– cumulative global share is given from 1995.

Source: Roney, 2013

4.4 Results and Discussion

This section discusses the results for each of the countries separately. First we estimate each of the three models - Logistic, Gompertz, and Bass - for each country and then using AIC, BIC, and adjusted R^2 criteria to pick the model that best explains their diffusion.

4.4.1 China

Table 4.2 shows the estimated parameters for each of the models and corresponding AIC, BIC, and Adjusted R^2 values, which have been used for comparison. As can be seen, the statistically superior model for China is the Bass model as AIC and BIC values are smallest. Figure 4.1 shows the fitted curve versus actual values using Bass model.

Table 4.2: Diffusion Model Estimations for China

Parameter/ Model	**Logistic**	**Gompertz**	**Bass**
α	90434***	126724***	90434***
β	1.24×10^{8}***	3367.85**	
γ	0.8853***	0.384***	
p			7.16×10^{-9}***
q			0.8853***
AIC	331.71	373.07	**329.71**
BIC	335.11	376.48	**331.98**
Adjusted R^2	0.9998	0.999	**0.9998**
No. of observations = 17			

Note: Significance codes – '***' 0.01, '**' 0.05

Source: own computation

Based on inflection point estimated by Bass model, diffusion of WPT can be divided in two phases in China: Phase I up to 2005 when growth was slow and Phase II from 2005 to 2012 where WPT diffusion in China observed a CAGR of 85 per cent.

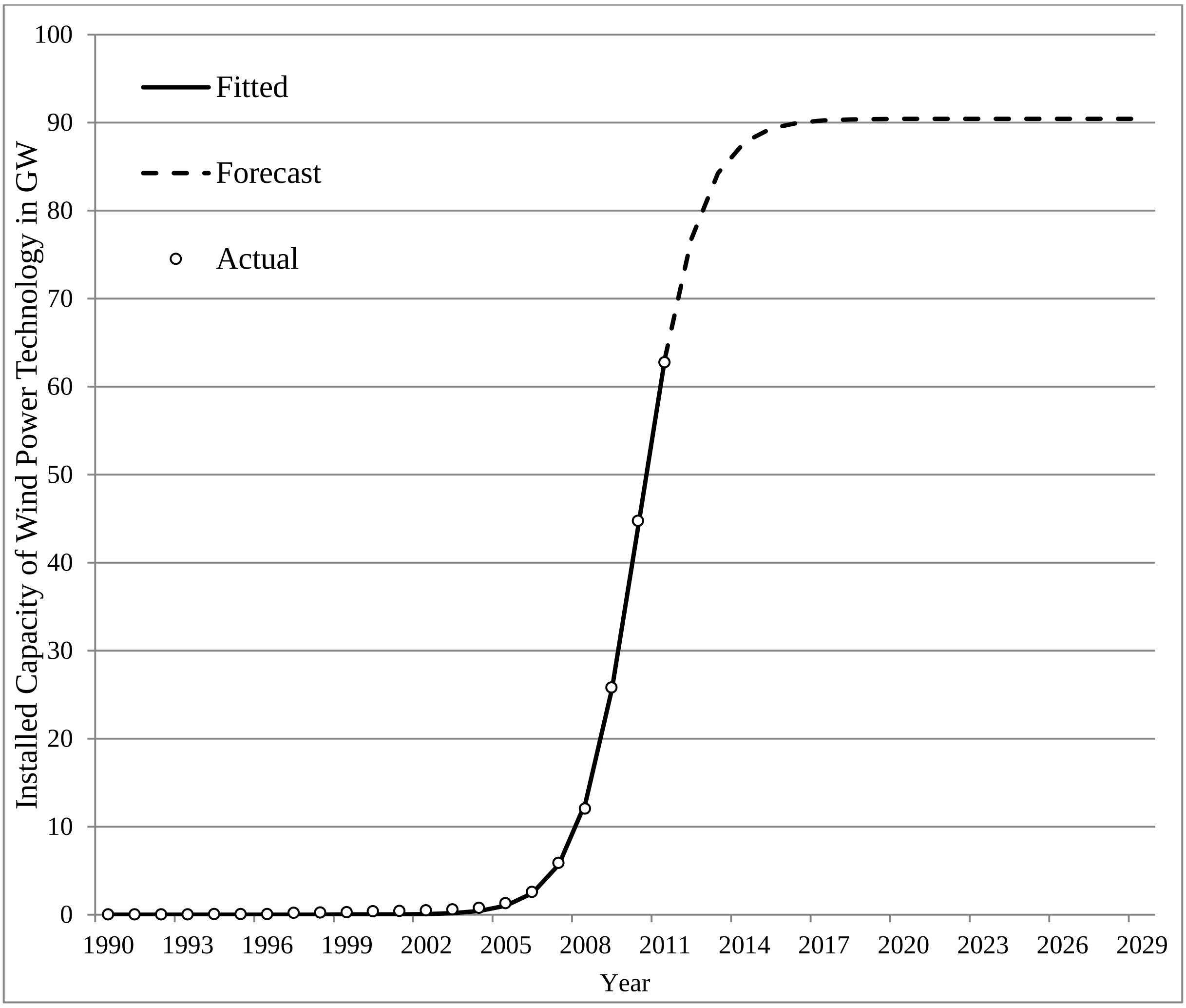


Figure 4.1: Actual versus Fitted Installed Capacity of Wind Power Technology for China

Phase I (1990 – 2005): Though the inception of WPT in China dates back in 1986, the policies enacted up to late 1990's were not directly aimed at supporting installed capacity of WPT. Some of the policy initiatives in this period include - Science and Technology Law in 1993, guidelines for wind farm development in 1994, Innovation fund in 1999 where small and medium sized enterprises were given grants and preferential loans for technology innovation.[14] Also in 1999, the National Development and Reform Commission (NDRC) released an official statement setting wind power pricing 'at a level that would repay capital costs with interest plus a reasonable profit' (Wang, 2010). This was followed by a series of government investments into the construction of wind farms including the first specific target

[14] The budget for innovation was around 1 billion RMB and around 1000 projects were supported with this fund (ALCS, 2013).

by the 10^{th} five year plan of 1500 MW of capacity using WPT that was to be reached by 2005 (Govt. of China, 2006). The actual installed capacity, however, by the end of 2005 was 1272 MW – a shortfall of nearly 18 per cent. This low growth in the early period is reflected by very low coefficient of innovation (p) in fitted Bass model.[15]

A very low coefficient of innovation for China indicates failure of policies to attract large, Utility-scale deployment of wind potential in the early years. The process of securing project approvals from the regional and national government, Power Purchase Agreement (PPA) from the Utility, and project financing was difficult, time-consuming and confusing (Lew, 2000). Foreign investment was also hindered by China's unstated policy to generally limit Returns on Investments (ROI) for foreign companies to 15 per cent (Vaupen, 1999). Consequently, despite the efforts of several provinces to issue favourable power purchase prices, both domestic and foreign investors were cautious because the prices wouldn't escalate with inflation, thus increasing investment risk. Another barrier could be that many windy sites in Inner Mongolia Autonomous Region (IMAR) and Xinjiang Autonomous Regions were far from demand centers making transmission of power from WPT difficult and uneconomical. For example, Beijing is located about 500 km and Harbin about 1400 km from a high wind resource at Huitengxile, IMAR (Lew, 2000). While coal resources could be transported over ships or rails and coal power too can be transmitted over large distances; wind resource cannot be transported and power using WPT couldn't be transmitted without the use of expensive energy storage. Besides, intermittency of such power implied inefficient use of long distance transmission lines.

On the other hand, China has been highly successful in dissemination of small scale wind turbines through minimal subsidies, a decentralized network infrastructure, and extensive training and marketing. The reason could be a large, and mature small scale wind turbine industry was customized for domestic needs[16] while most of the large-scale technology, in the

[15] The force of innovation acts predominantly during the initial years of diffusion (Bass, 1969).

[16] By 1987, 38 types of wind turbines had been imported for technology transfer and cooperation - nearly all of which were micro and small turbines. Technical cooperation between the Chinese and the Swedish, Dutch, German, and Italian governments led to joint design, development, and testing of small wind turbines and wind pumps (Shi, 1988). As a result, by 1999, China had over 40 local manufacturers producing more number of turbines than any other country (Lew, 2000).

form of turbines as well as operations and maintenance, was being imported from Europe till late 1990s. By 1995, there were around 150,000 small turbines were installed in rural China (out of which over 90 per cent were in IMAR) (Celik, 2003). These small scale turbines served to half a million people and contributed to 17 MW of installed capacity (Lew, 2000). Perhaps, because of merely 17 MW capacity contributed by these turbines, it has not been captured in the estimation of coefficient of innovation (p).

Phase II (2005-2012): In 2003, the Wind Power Concession Program was implemented with the aim to acquire investors for wind farms over 50 MW through concession bidding (Wang, 2010).[17] The requirements of local content law passed in 2005 increased the percentage of parts that have to be locally sourced to be eligible for the wind concession program from 50 per cent to 70 per cent (Urban *et al*., 2009). Such an initiative encouraged indigenous manufacturing and by 2012 China was having four wind turbine manufacturers among the World's top ten (Dvorak, 2013). In 2005, Renewable Energy Law[18] (RNE Law) was passed which guaranteed the Feed-in-Tariff (FIT) based on historical project and bidding experience. Shortly after the RNE Law was passed NDRC issued the Provisional Administrative Measure on Pricing and Cost sharing for RNE Power Generation. The regulation created the legal framework enabling the Government to set the price at which power from WPT has to be bought by grid companies (Chunchun *et al.*, 2008). In June 2006, China's Ministry of Finance issued the Tentative Management Method for RNE Development Special Fund, offering "additional measures to enhance support for RNE development". The policy includes making guidelines, assistance in application procedures, their screening and approval, financial management, tests and control. Importantly, the policy has empowered the central government to provide financial assistance for the development of RNE resources including wind (Wang, 2010). The Medium and Long-Term Development Plan for Renewable Energy

[17] Whilst at first the provision was that bidder who agreed to build a wind farm with the lowest concession credit would be selected but this was later revised and electricity price was given 40 per cent of the total weight in deciding the winning bids. Under the wind power concession program the provincial grid company (Utility) must sign a power purchase agreement with the winners of the concession auctions. This was the first time that Utilities were mandated to buy power generated using WPT. This obligation later became part of the Renewable Energy Law in 2005 (Wang, 2010).

[18] The objectives of the law were - a) establish the importance of RNE in China's national energy strategy; b) remove market barriers; c) create markets for RNE; d) establish a financial guarantee system; and e) create awareness, skills, and understanding (Martinot, 2010).

in 2007 had established 5,000 MW target for WPT. Due to these policies, from 2006 till 2011, China has increased its capacity of WPT 25 times (from 2.5 GW to 62 GW - column 1 of Table 4.1) reaching to approximately 35 per cent of installed global capacity (GWEC, 2012).

As per the forecast, China is expected to reach 90 per cent of the WPT diffusion (around 85 GW) in 2014-15, after which further growth would be very slow. The forecast seems to be in line with the current situation in the country where the deployment of turbines has outpaced the growth of corresponding infrastructure to support it. For example, in 2011 an estimated 30 per cent of wind turbines were not producing power because of grid problems (ALCS, 2013). These limitations are caused by both the intermittent nature of power generated using WPT and the lack of transmission lines connecting the areas rich with wind resources. Sometimes, even when interconnection is technologically feasible, politics between local governments have made inter-province interconnection difficult (Li, 2010). Unless the supporting infrastructure is developed to absorb the power generated by wind, the growth of installed capacity would not be feasible.

4.4.2 United States of America

As could be seen from column 2 of Table 4.1, installed capacity of WPT in USA in 1980 was only 8 MW. According to some researchers (Dodge, 2006), it was the year in which the WPT began penetrating wholesale electricity markets, so 1980 could be taken as approximately the beginning point of diffusion of WPT in USA. Table 4.3 shows the estimated parameters from the three models for the USA and corresponding AIC, BIC and adjusted R^2 values.

Based on AIC, BIC, and adjusted R^2, the statistically superior model for USA is also the Bass model. Figure 4.2 shows fitted and actual values of installed capacity over years using Bass model. Based on inflection point, the diffusion of WPT in USA can be divided into two phases: Phase I from 1980 till 2003 and Phase II from 2004 onwards.

Table 4.3: Diffusion Model Estimations for USA

Parameter/ Model	Logistic	Gompertz	Bass
α	129025.5***	6448593	127572.6***
β	51944.84*	20.37***	
γ	0.3242***	0.0446***	
p			6.09^{-6}**
q			0.3257***
AIC	573.9807	579.79	**573.29**
BIC	578.4702	584.28	**577.78**
Adjusted R^2	0.9936	0.9924	**0.9938**
No. of observations = 32			

Note: Significance codes – '***' 0.01, '**' 0.05
Source: own computation

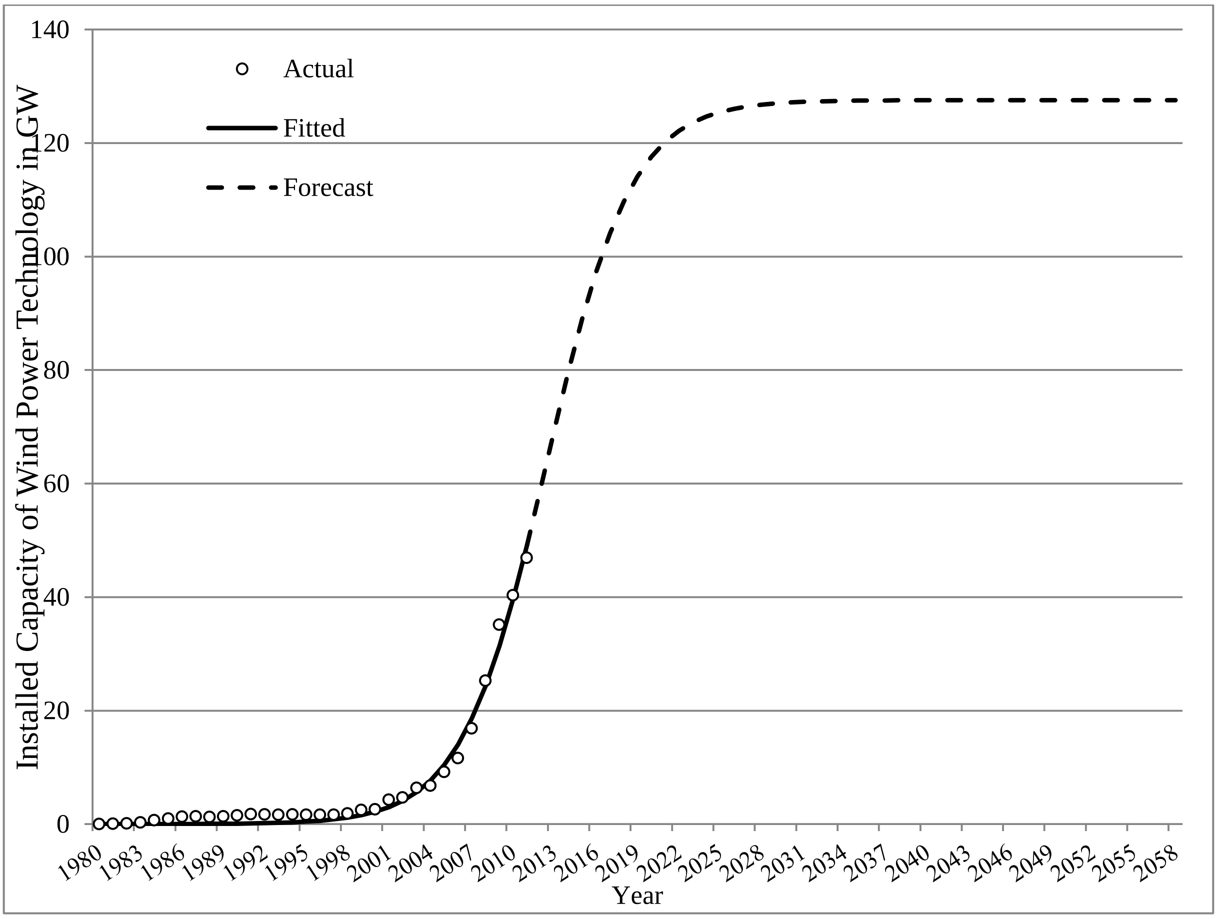


Figure 4.2: Actual versus Fitted Installed Capacity of Wind Power Technology for Unites States of America

Phase I (1980-2003): The period from 1980 to early 2000's witnessed conflicting policies leading to irregular trend of capacity addition of WPT in USA, which is also reflected in the low coefficient of innovation (p) in the model. The first policy initiative during this period was the Energy Policy and Conservation Act of 1975.[19] Also, the federal government introduced market-based incentives, such as 15 per cent energy credit and 10 per cent investment credit, and created a market for non-Utility-produced electric power through the Public Utility Regulatory Policies Act (PURPA) in 1978. It was first implemented in California in 1981. California also introduced 50 per cent energy credit for power from WPT which, combined with PURPA and federal tax credit, helped in the development of country's first Utility-scale wind farms (Dodge, 2006).[20] However, it is to be noted that these incentives were based on energy output (kWh) and not on installed capacity basis. As a result, it did not directly encourage the installation of wind turbines in the country. The only policy aimed at encouraging the installation would have been the five year Accelerated Depreciation (AD) provision by Economic Recovery Tax Act in 1981. The major setback, however, to WPT was received during the same period when President Reagan decided to cancel the funding for Research and Development (R&D) for RNE[21] in favour to conventional power, also federal energy credits were ended in 1984. Increase in military research funding also reduced interest of aerospace firms in developing wind turbines. Another issue with the development of turbines was its cycle was compressed to 2-4 years instead of a more prudent 4-6 years which resulted in inefficient turbines (Dodge, 2006).

After several years of relatively neutral tax treatment in 1980s, government reintroduced several tax incentives in early 1990s. A Production Tax Credit (PTC)[22] of 1.5 cents per kWh was established in the Energy Policy Act of 1992 for WPT (Govt. of USA, 1992). The PTC

---

[19] It was envisioned under this Act that 20 per cent of USA's energy needs should be from solar, wind, and other RNE resources by the year 2000.

[20] Other States followed California's pattern and as a consequence 1478 MW (around 12 per cent of total RNE deployed by then) of WPT was deployed in the country by 1990.

[21] R&D fell by more than half from US$ 6.64 billion in 1981 to 3.15 billion in 1988 (adjusted for inflation in 2005 dollars) and only 4 new wind turbines were developed (Dodge, 2006). Perhaps this is the reason for decline in installed capacity of WPT from 1987 to 1988 (Column 2 of Table 4.1).

[22] The PTC provided an inflation-adjusted cent per kilowatt-hour income tax credit for the first 10 years of a power plant using WPT.

benefit was available for 10 years beginning from October 1993 till September 2003 duly adjusted for inflation using 1993 as base year (Govt. of USA, 1992). For government and non-profit entities that could not use the PTC, the Secretary of Energy was authorized to make "incentive payments" of 1.5 cents per kWh (also adjusted for inflation)). Further, a conservative estimate of the total U.S. government subsidy to WPT totalled over $1,200 per installed kilowatt, which was greater than the direct capital cost of WPT under advanced technology of around $860 per kilowatt and more than double the installed capacity cost of gas-fired combined-cycle plants of approximately $580 per kilowatt (Bradley, 1997). Despite PTC and huge subsidies, moderate capacity of approx. 600 MW was added during the period 1989-1997 (Column 2 of Table 4.1).

The reasons for this low capacity addition could be unstable policies in particular PTC, lower oil prices, and emergence of natural gas as an alternate fuel for power generation. PTC was extended in one and two year intervals and was even allowed to expire in 1999. This uncertainty is clearly manifested in the year 2000 when mere 88 MW capacity of WPT was added (92 per cent drop compared to previous year). Further, though the estimates on cost of WPT declined from around 25 cents per kWh in the early 1980s to around 6-7 cents per kWh[23] when the PTC and other subtle cost items were factored in; the all-inclusive price in the mid-1990s was approximately *double that* of the cost of new gas-fired electricity generation and *three times* that of the cost of existing under-utilized generation (Bradley, 1997). Also technical issues in integrating wind turbines into power system made Utilities wary of power from WPT. For example, though power from WPT is primarily used for peak load demand, peak demand for electricity and peak wind speed do not always coincide. For example, a study by San Diego Gas & Electric (1992) concluded on-peak capacity to be only 7.5 MW per 50 MW of nameplate capacity (a 15 percent factor) and California Energy Commission estimated total on-peak WPT capacity to be 333 MW out of 1812 MW, an 18 percent dependable capacity ratio (California Energy Commission, 1994). Consequently, USA companies were attracted to abroad markets where electricity was scarcer and cost of

[23] Initial estimates for cost of power from WPT in early 1990s were around 5-7 cents per kWh (constant dollars) in prime wind farms (Secretary of Energy Advisory Board, 1995). Department of Energy also estimated around 4.5 cents per kWh at ideal sites (Romm and Curtis, 1996). However, the total cost was really around 6-7 cents per kWh when production tax credit and factors like underutilization of large transmission lines due to poor wind, intermittency of wind resources are taken into account (Bradley, 1997).

new power was higher. This could be one of the reasons that share of USA in World total fell from around 80 per cent in late 1980s to less than 50 per cent by 1997 (Column 2 of Table 4.1). Interestingly, this could be correlated to the lead market model proposed by Beise and Rennings (2005) where technology is developed in one country, but other countries subsequently benefit from it.

It can be seen that in the period from 1980s till early 2000s, the USA government did initiate encouraging policies but failed to sustain them. This discontinuous nature of policies in the critical evolving stage of WPT has resulted in a very low coefficient of innovation.

Phase II (2004 to 2012): From 2004 WPT capacity grew at around CAGR of 39 per cent till 2008. The most important piece of federal legislation during this period was the Energy Policy Act of 2005 (EPACT05) which, among a variety of other provisions, extended and expanded coverage of Section 45 (production) and Section 48 (investment) tax credits (Govt. of USA, 2005). EPACT05 also directed Federal Electricity Regulatory Commission (FERC) to establish incentive rules to encourage greater investment in the national transmission infrastructure, promote electric power reliability, and lower costs for consumers by reducing transmission congestion. . Further in 2008, Dept. of Energy of USA in its study claimed that cost impact of power from WPT could be as little as 10 per cent (DOE, 2008). The DOE study focuses on the initial capital cost of installing the capacity of WPT and upgrading the transmission network and compares these costs to the lower operating costs when wind energy displaces fossil fuels. In 2008, 30 new manufacturing facilities were announced in the country. An additional measure was the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010 (Govt. of USA, 2010). Under this Act, projects (including those of WPT) in service or under construction by 2011 became eligible to the USA Treasury grant programme. By 2011, U.S. manufacturing capabilities grew to nearly 500 manufacturing facilities, producing 60 per cent of the domestic market, thus lowering equipment transportation costs (ALCS, 2013). It can be seen that the problems faced in earlier period like hidden costs in grid integration or movement of USA companies away from domestic market were reduced to a considerable extent.

Forecasts created using Bass model suggest that installed capacity would reach 90 per cent of WPT diffusion in 2021 (114 GW) after which further growth would be very slow.

4.4.3 Germany

Until late 1980s, Germany's electricity supply system was dominated by very large Utilities relying on coal and nuclear generation. However in 1986, the Chernobyl accident had a profound impact on public opinion regarding alternate energy sources and subsequently on energy policies (IRENA, 2012). Between 1987 and 1990, a series of proposals for institutional change were formulated, which included a feed-in law for the electricity produced from RNE. These proposals were supported by several government funded R&D projects (IRENA, 2012). We have data available from 1987 when installed capacity of WPT was merely 5 MW and thus could be treated as beginning point of WPT diffusion in Germany. Table 4.4 shows the estimation results from the three models.

Table 4.4: Diffusion Model Estimations for Germany

Parameter/ Model	Logistic	Gompertz	Bass
α	31386***	37292.38***	31554.75***
β	428.35**	19.54***	
γ	0.3379***	0.175***	
p			0.0008***
q			0.3317***
AIC	422.31	**398.75**	421.32
BIC	426.08	**402.52**	425.09
Adjusted R^2	0.9974	**0.9989**	0.9975
No. of observations =25			

Note: Significance codes – '***' 0.01, '**' 0.05
Source: own computation

It can be inferred (from the values of AIC, BIC and R^2) that Gomeprtz model is statistically superior among all. Figure 4.3 plots actual versus fitted values of installed capacity of WPT for Germany. Computation of inflection point for Gomeprtz curve for Germany indicates 2003 as year when rate of adoption reached its maximum value. Accordingly, diffusion of WPT in Germany could be divided in two phases: phase I from 1987 till 2003 and phase II from 2003 onwards.

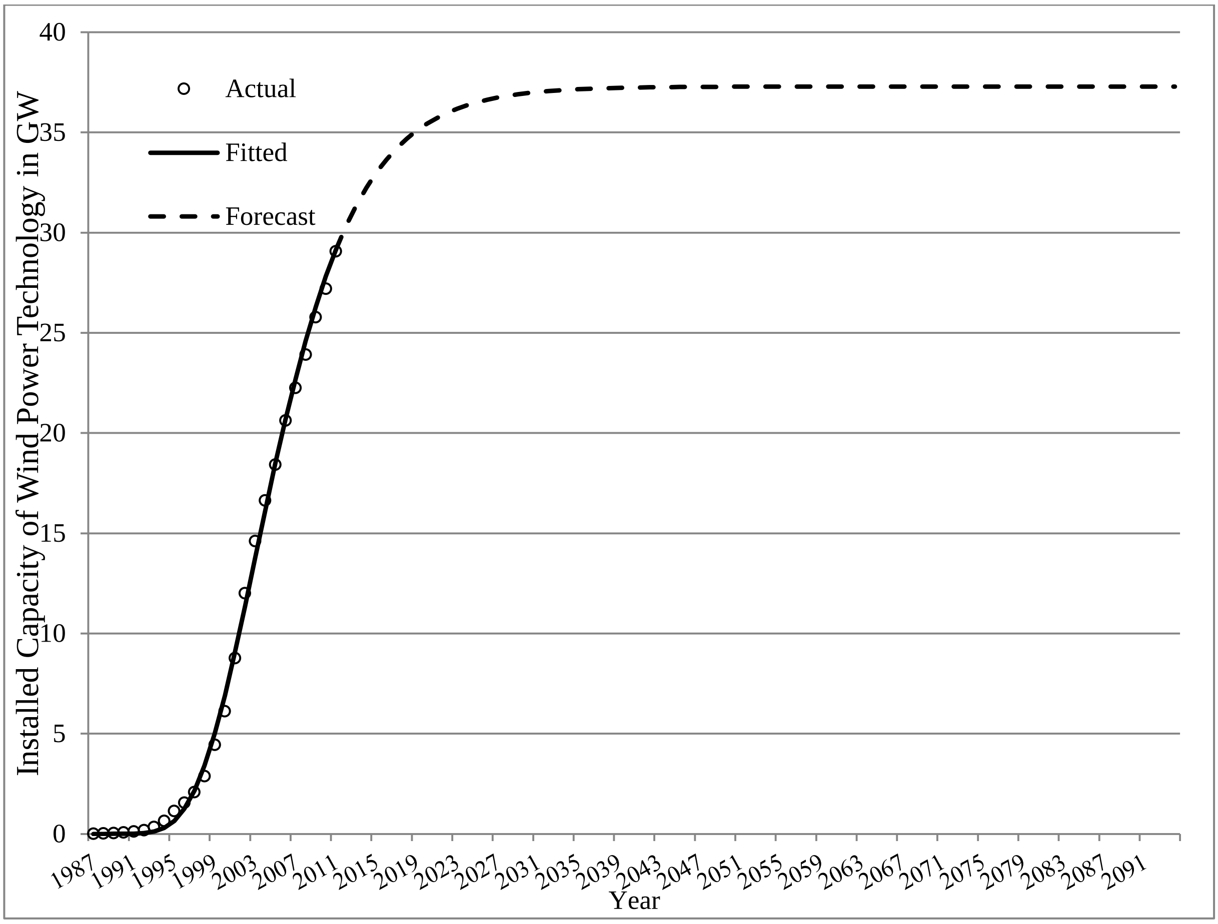


Figure 4.3: Actual versus Fitted Installed Capacity of Wind Power Technology for Germany

Phase I (1987-2003): As could be seen from the graph, the capacity addition of WPT has phenomenally increased since 1994 onwards. The driving forces for it could be the Renewable Energy Supply Act enacted in December 1990 and the first Electricity Feed-In Act (EFL), which came into effect in 1991. The Act regulated the purchase and price of electricity generated by WPT among other RNE sources. The FIT was set at 90 per cent of the average electricity Utility rate per kWh. Together with the 100/250 MW programme[24] and subsidies from various State programmes, the EFL provided secured financial incentives to investors in RNE projects (Sijm, 2002). In 1997, the EFL was incorporated into the Act on the Reform of the Energy Sector, which transposed the European Renewable Energy Directive into national

[24] The aim of the 100/250 MW programme, which ran from June 1990 to December 1995, was to test the use of WPT on a major economic scale, gain experience over the long term and to provide a stimulus for the installation of a large number of wind turbines by different companies at suitable locations (Hemmelskamp, 1998).

law (IRENA, 2012). In 1999, when EFL reform started, Germany's national wind turbine industry already became the second-largest in the World (*ibid.*). The seminal RNE Sources Act (Das Erneuerbare-Energien-Gesetz or EEG) came into force in 2000.[25] A two-component tariff was designed for power from WPT, with an initial fixed tariff for a period of five years, and remaining period of 15 years with a tariff level modulated by the local wind conditions. The effectiveness of market instruments, in particular FIT, is also confirmed in Delaportas (2012) which argues that implementation of FIT increases probability of adoption of WPT in the country by 17 per cent.

The average capacity per turbine grew from 175 kW in 1991 to 380 kW in 1994 and to 510 kW in 1996 (Michaelowa, 2004). Most of the German manufacturers initially were small engineering outfits that profited from the availability of highly skilled but unemployed engineers because of collapse of shipbuilding industry in Germany in late 1980s (Fornahl, 2011). Political support in these locations, particularly northern Germany, was extremely strong, as WPT enabled to diversify the economy. Power plants using WPT were planned and financed predominantly by small associations formed by farmers. The farmers dominated the local policymaking and thus were able to get WPT projects approved quickly. By 2003, 95 per cent of power plants from WPT in Germany had Utility-independent private ownership (Scheer, 1998). It must be noted that costs of power from WPT was as uneconomical in Germany as was in the USA resulting in frequent opposition for EFL by some politicians, Utilities and business analysts. European Wind Energy Association (EWEA) also criticized BWE for fixed prices and advocated need to lay out level playing field. Morthorst and Chandler (2004) argue that EFL didn't promote efficiency and actually resulted in high cost when MW barrier was reached in late 1990s. However, the formation of strong wind lobby consisting of German Wind Energy Association (Bundesverband Windenergie, BWE), trade unions, and agricultural associations resulted in the continuation of EFL. In fact, German wind lobby also intervened in EU's proposed directive of doubling the RNE production in member countries by 2010 based on quota system.

[25] The EEG was amended in January 2009. It included an increased initial tariff for both onshore and offshore WPT. The tariff system was designed to respond to market dynamics and the level of technology maturity. The EEG was again amended in January 2012. The main amendments included an increase in the tariff degression rate from 1 per cent to 1.5 per cent for onshore implementation and a "repowering bonus", which improves the economic conditions of the repowering WPT projects (Sijm, 2002).

Phase II (2004-2011): As can be seen, the growth of WPT has slowed down in phase II. Laird and Stefes (2009) report that, since early 2000's, political resistance to WPT grew stronger in both industrial and consumer constituencies. In early 2000s, Economics Minister Muller and his successor Clement argued for reduction in EFL and demanding for quota system, supported by the Ministry of Environment. BWE, continuing its aggressive stand, produced a study indicating average cost to be 0.1 cent/kWh with expected rise to 0.2 cent/kWh (Krzikalla, 2001). Utilities also raised their concerns of keeping around 7 per cent of "buffer energy" to cover short term variability of WPT (Michaelowa, 2004). The wind lobby claimed about creation of jobs in economically weak regions and becoming the second largest customer of German steel industry. It was inexplicable to the Utilities that actual costs were about 0.5 cents/kWh while estimates were in the range of 0.1-0.2 cents/kWh. Interestingly, wind lobbyists seldom claimed about environmental benignity of WPT and this could be attributed to numerous studies by institutes like the Bremen Energy Institute wherein issues like bird killing or avian mortality by wind turbines were highlighted (Michaelowa, 2004). Earlier, the communities especially farmers who had vigorously supported installation of wind turbines now in early 2000s adopted so called Not In My Back Yard (NIMBY) attitude and refused to participate or support WPT projects (Scheer, 1998). Media too became critical of WPT (Augstein, 2004). As a result, tariff is reduced to 5.5 cents/kWh for certain yield and subsidies were withdrawn for plants less than 44 per cent of that certain yield (von Hammerstein, 2004). Also, post 2003, changes in tax law and introduction of emissions trading made WPT funds less attractive for investors.

On the other hand, capacity based on solar PV has considerably increased post 2004. The share of installed capacity from solar PV in total RNE grew from around five per cent in 2004 to around 40 per cent by 2011 (reaching to more than 85 per cent of WPT capacity) (Fraunhofer Institute of Solar Energy (ISE), 2015). Correspondingly, share of power generation from solar PV in total power grew from near zero per cent in 2004 to around 3 per cent by 2011 (reaching to almost 40 per cent of the power supplied by WPT) (*ibid*). Another factor dis-incentivising WPT could be that increasing number of industrial consumers being exempted from paying the RNE surcharge - this number increased more than three-fold between 2005 and 2011 than earlier period[26]. Also notably wholesale power prices have

[26] *Source*: http://energytransition.de/2014/03/germans-face-high-fossil-fuel-costs/

overall shown a downward trend in this period. Though initially wholesale power prices nearly doubled between 2004 and 2006; there has been sharp decline afterwards. The peak load (for which RNE technologies are primarily used) prices which were more than 80 €/MWh at the beginning of 2007 fell to almost 60 €/MWh by the end of 2011 (Bayer, 2014).

Forecasts created using Gompertz curve suggest that beyond 2014 (where 95 per cent of diffusion would be reached i.e., 35 GW) the growth of WPT would further slowdown.

4.4.4 India

Table 4.5 shows the estimation results from the three models and corresponding AIC, BIC and adjusted R^2 values for India. As could be seen, the superior model is the logistic model.

Table 4.5: Diffusion Model Estimations for India

Parameter/ Model	Logistic	Gompertz	Bass
α	36590***	425438	37160***
β	699***	10.6***	
γ	0.2879***	0.0534***	
p			0.0042***
q			0.2839***
AIC	**349.84**	354.48	350.63
BIC	**353.25**	357.89	354.03
Adjusted R^2	**0.9964**	0.995	0.9958
No. of observations = 21			

Note: Significance codes – '***' 0.01, '**' 0.05
Source: Own Computation

Figure 4.4 plots the actual and forecasted installed capacity of WPT in India using logistic curve.[27] Subject to the data available for installed capacity, we analyse the linkage between WPT diffusion and policies from 1991 onwards only. Guided by inflection point, the growth

[27] It is to be noted that we have data available 1991 onwards when installed capacity of WPT had already reached 39 MW. Hence, there is a possibility that the diffusion may have begun before 1991.

of WPT for India can be divided into two phases: phase I from 1991 till 2002 and phase II from 2003 onwards.

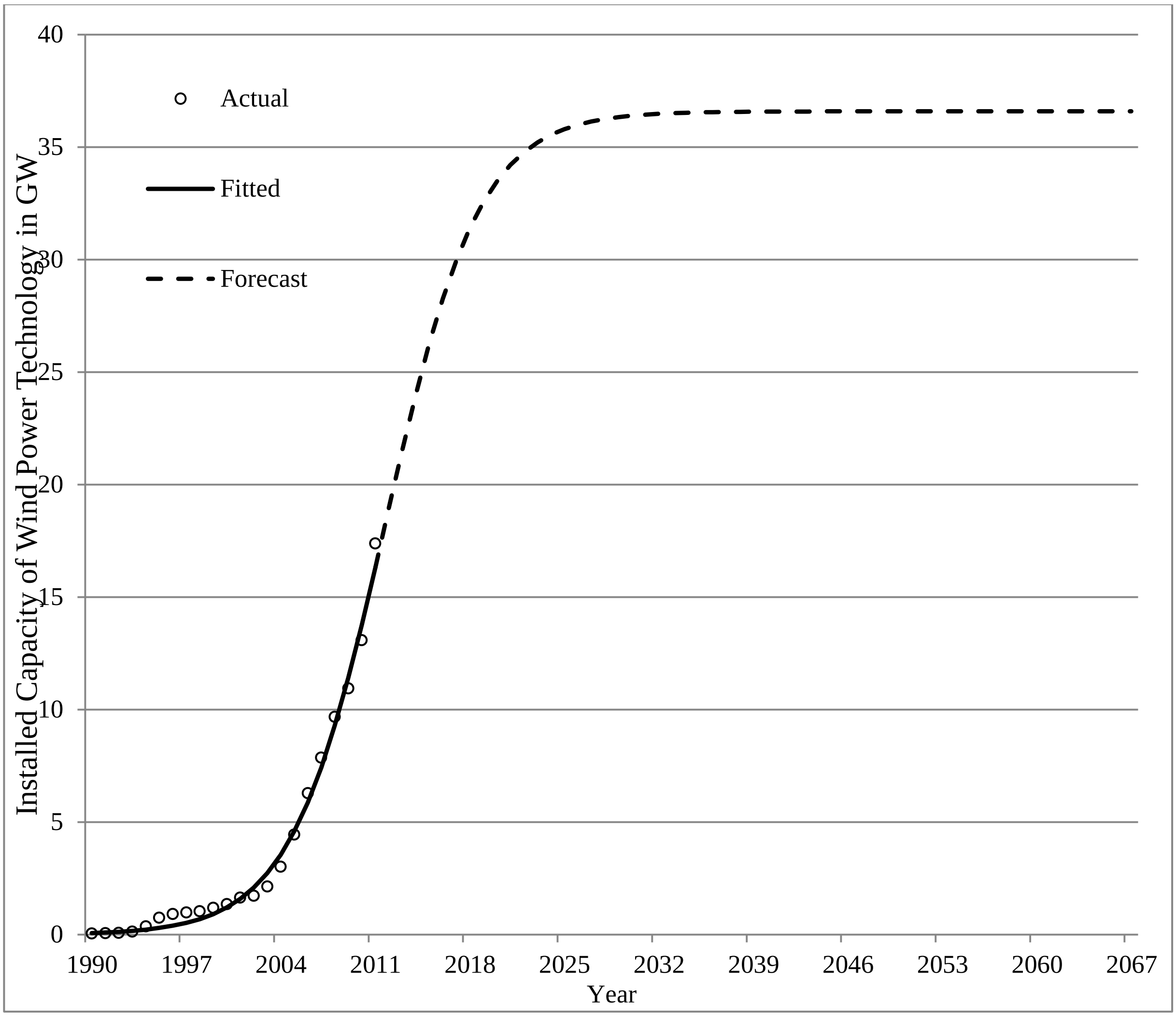


Figure 4.4: Actual versus Fitted Installed Capacity of Wind Power Technology for India

Phase I (1991–2002): In 1991, Indian electricity market was opened to private investors - both domestic and foreign. Import duties and taxes were reduced for Independent Power Producers (IPPs) and secured rates of return were offered to foreign investors through cost-based tariffs. Further, India is perhaps the only country in the World that has a dedicated ministry created in 1992 to support and develop RNE power (Sharma *et al*., 2012). These changes were all enacted as part of the broader national economic liberalisation strategy in 1991. Among other incentives was the provision of 100 per cent AD which has been the most attractive incentive for private sector to adopt WPT (Jagadeesh, 2000). In 1994, the Ministry with support from Indian Renewable Energy Development Agency (IREDA), worked on identifying sites of high wind potential to provide plots for the installation of wind turbines by individual investors as a joint public-private partnership (IRENA, 2012). Similar to USA, the objective behind the promotion of RNE in India was to attain energy self-sufficiency (Carolinmabel and Fernandez, 2008). Suzlon, an Indian multinational turbine manufacturing company, came into being in 1995 as a response to high electricity prices (Rajsekhar *et al*., 1999). By 1997, India had around 900 MW installed capacity of WPT with 51 MW as demonstration projects. It is interesting to note that all the wind turbines installed were being imported from four leading countries like Denmark (60 per cent), Germany (20 per cent), USA (10 per cent), Netherlands (5 per cent), and remaining (5 per cent) from other countries. Virtually all components of Utility-scale energy systems using WPT were manufactured or assembled in India by 22 companies. Lead-lag market model as proposed by Beise and Rennings (2005) seems to have been quite successful in case of India.

However, problems with inaccurate wind resource data and poor installation practices led to poor power plant performance (Rajsekhar *et al*., 1999). Acknowledging that wind turbines were being deployed solely for tax exemption, the benefit of five year tax holiday as declared in 1992 was nullified with the introduction Minimum Alternate Tax (MAT) in 1997. The impact was immediately visible in the following years when capacity addition reduced dramatically (column 5, Table 4.1).

Phase II (2003-2012): Post economic liberalization, the growth was accentuated with the introduction of Electricity Act in 2003 (EA’03) which upheld the need to promote of efficient and environmentally benign policies. Some of the provisions of the Act related to RNE included determination of preferential tariffs by State Electricity Regulatory Commissions (SERC) for RNE generated power, ensure connectivity to the grid for project sites that are generally in remote locations and away from major load centres, specification of purchase of electricity from RNE as percentage of total purchase of electricity by distribution Utility and prepare National Electricity Policy and Tariff Policy to ensure inclusion of RNE in total energy mix (Ministry of Law and Justice, 2003). As a result of successful implementation of most of these provisions, around 14,000 MW capacity of WPT was installed between 2003 and 2012. In 2009, the Government of India (GoI) implemented a Generation Based Incentive (GBI) scheme for grid-connected projects using WPT. GBI was introduced to promote efficiency for power plants using WPT. The GBI is over and above the tariff approved by the

Electricity Regulatory Commissions and disbursed on a half-yearly basis through Indian Renewable Energy Development Agency, IREDA (IREDA, 2013).[28]

To accommodate the variation in resource endowment across different States, in 2010 the Central Electricity Regulatory Commission (CERC) proposed a complementary mechanism to allow less-endowed states to meet their obligations through tradable Renewable Energy Certificates (REC) (Global Wind Energy Council *et al.*, 2011). All RNE projects commissioned after March 2010 became eligible to register under the REC framework. WPT made up over half of the projects registered for the certificates. However, it is to be noted that these incentives are given on electricity generation which is dependent on many external factors like continuous availability of resource and grid. As a consequence, it is beyond the control of operator to adjust for these issues. This could be the reason that post 2010 the growth seems to have slow down. WPT development received another setback in FY 2012 when AD was removed. The capacity addition of WPT, having grown at annual compounded growth rate of 22 per cent since 1992, fell by 39 per cent between April'12 and September'12 (IWTMA, 2013). Forecasts suggest that 95 per cent of the diffusion of WPT (around 35 GW) would be achieved by 2021. Given the same set of policies, the growth would be very slow after this.

Forecasts suggest that 95 per cent of the WPT diffusion (around 35 GW) would be achieved by 2021. Given the same set of policies, the growth of WPT would be very slow after this.

4.4.5 Spain

For Spain, data on installed capacity of WPT is available from 1991. Even though initial WPT development dates back to mid-1980s, those projects were deployed in an unregulated environment and mostly were experimental projects co-participated by the regional

[28] One can clearly see a shift in installed capacity of WPT with introduction of this policy (Figure 4.5 and column 5 of Table 4.1)

governments. As indicated in Table 4.6, Spain, like USA and China, has its diffusion best described by Bass model.

Table 4.6: Diffusion Model Estimations for Spain

Parameter/ Model	Logistic	Gompertz	Bass
α	25260***	32957***	25400***
β	415.39***	15.29***	
γ	0.3747***	0.1723***	
p			0.0009***
q			0.3682***
AIC	315.84	325.72	**314**
BIC	319.12	328.99	**317.27**
Adjusted R^2	0.9993	0.9989	**0.9993**
No. of observations = 21			

Note: Significance codes – '***' 0.01, '**' 0.05
Source: own computation

Figure 4.5 depicts the actual and forecast installed capacity of WPT using Bass model. The diffusion of WPT in Spain could be divided into two phases based on the inflection point.

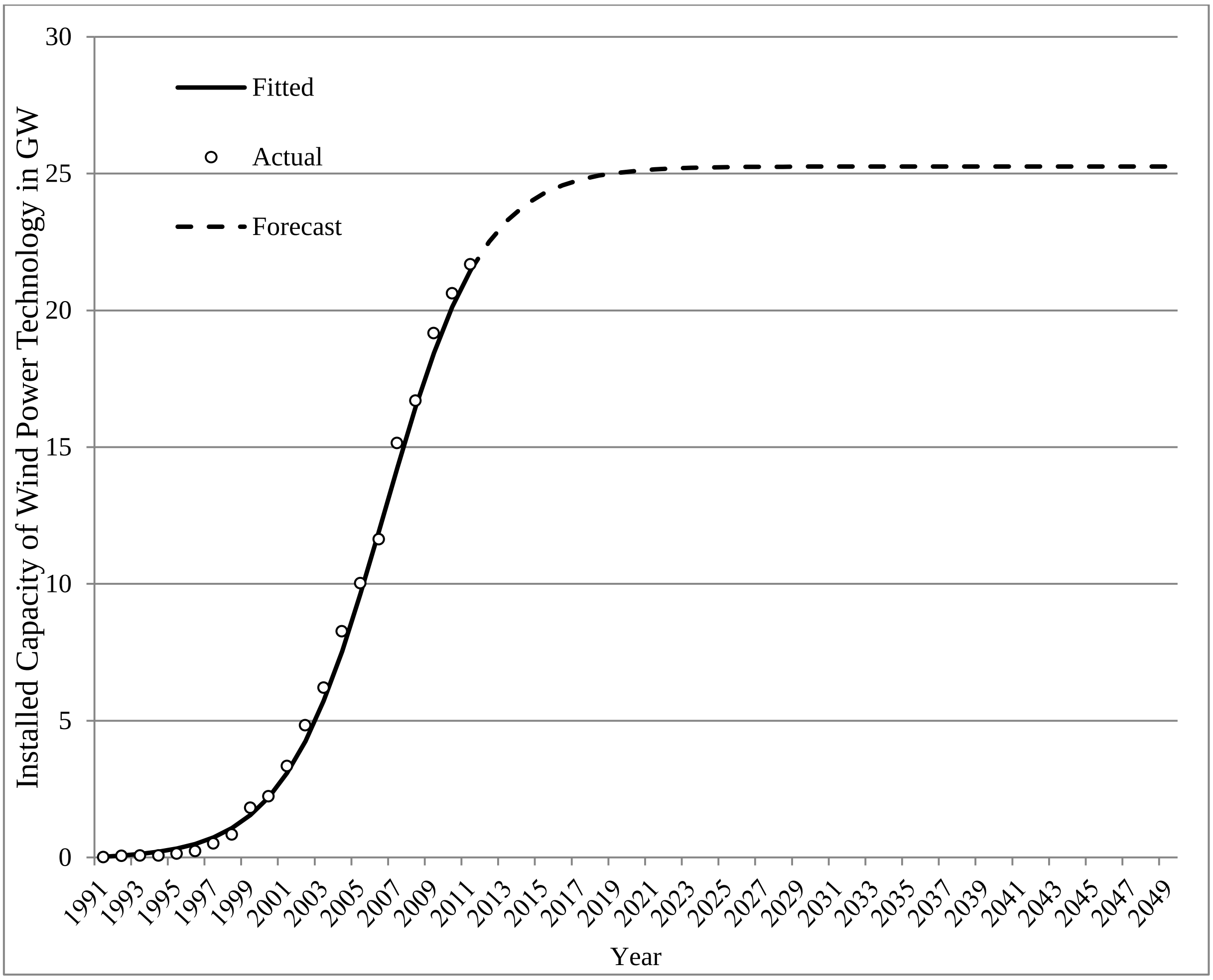


Figure 4.5: Actual versus Fitted Installed Capacity of Wind Power Technology in Spain

Phase I (1991-2005): The national Energy Saving and Efficiency Plan (PAEE), 1991–2000, aimed to increase the overall use of RNE by 1.1 million tons of oil equivalent (Mtoe)[29] by the year 2000, including an increase in the contribution of non-hydro RNE in electricity generation from 0.5 per cent in 1990 to 1.4 per cent in 2000. The PAEE provided subsidies in the form of capital grants, up to 30 per cent of eligible costs of project. As a result, installed capacity of WPT grew from 5 MW in 1991 to over 377 MW in November 1997 (at CAGR of around 105 per cent). This was more than double the government's target of 168 MW by 2000. Lewis and Wiser (2005) argue that Spain was able to increase its installed wind

[29] The toe (tonne of oil equivalent) is a defined unit, which corresponds to 7.33 barrels of oil (BP, 2009) and measures primary energy use of other energy sources than oil. It is useful for a country like Spain (which is part of EU) to set targets in 1991in terms of primary energy use since emission reduction targets were already set in 1990.

capacity of WPT and simultaneously develop a local wind industry by actively supporting local manufacturing with policies. The take-off was triggered by federal requirement that Utilities pay a guaranteed premium price for electricity from WPT over the first five years of the project —an incentive similar to the one that facilitated the growth of market in Germany for power from WPT. State (or "province") governments eager to capitalize on the benefits of WPT have also sought to boost such development locally and required that a large share of the investments (such as manufacturing and construction) remain in the local economy (*ibid*). Perhaps this has encouraged foreign companies to establish manufacturing bases in Spain in return for access to the domestic market.

Unlike USA where initial policies were based on output (kWh) or China where early policies were directed towards R&D in RNE, Spain provided incentives on capital costs (aimed at deployment of wind potential) which is reflected in higher value of coefficient of innovation compared to USA (0.0009 for Spain *vis-à-vis* 0.000006 for USA). The FIT system was fully developed through the Electric Power Act of 1997. The Royal Decree (2818/1998) established the right of RNE producers to sell their entire electricity production to the grid, and to be paid the wholesale market price plus a premium (IRENA, 2012).

Phase II (2006-2012): Along with the other policy initiatives to support RNE sector, the 2007 modification to the Spanish FIT system (Royal Decree 661/2007) introduced two alternative remuneration options for power from WPT – FIT (which guaranteed 7 per cent internal rate of return) and feed-in-premium (which was paid as a complement to the electricity market price with a minimum and maximum overall remuneration level on an hourly basis) (IRENA, 2012). About 80 per cent of the wind farms have opted for market price plus premium till 2012(*ibid*).

In 2012, however, the new government decided that there would be no more incentives for installations using WPT after 2012. Further, towards the end of the year, 7 per cent tax on all existing power generating installations of WPT was also approved. Recently, in February 2013, a new royal decree was passed cancelling the market price plus premium option; so all the wind farms that already had it were automatically pushed to the fixed tariff from 1 January 2013 onwards. These developments are expected to hamper the growth the sector using WPT overall. Interestingly, as per the Bass model also, Spain is expected to reach 95 per cent of its diffusion (around 24 GW) in 2013. After which, further growth is expected to be very slow.

4.5 Diffusion parameters and Policies – A comparison

To summarize, diffusion of WPT in five leading countries has been studied by employing three diffusion models for each. Subsequently one model was chosen for each country based on AIC, BIC, and adjusted R^2. Causal relationship between model parameters and policy mechanisms is proposed which further strengthens the choice of model for each country. Table 4.7 summarizes different policies that have been enacted in these five countries. Column 1 gives the list of policies that were identical in nature, whereas column 2 lists specific policies for each country.

Table 4.7: Policies/ Acts Enacted by Selected Countries - Similar and Different

Similar Policies	Different Policies
• **R&D fund, grants, preferential loans –** China (1993), USA (1975), Germany (1990), India (1994), Spain (1991) • **FIT–** China (2005), USA (1978), Germany (1990) , India (1994), Spain (1991) • **Obligation to absorb specified quantum of wind power –** China (2003), USA (1981), India (2006) • **Capital subsidy as per cent of total cost –** China (1999), USA (1978), Germany (1990), India (1994), Spain (1991) • **Accelerated Depreciation –** India (1994), Germany (1990)	• **Local content law in China (2005) –** 70 per cent of wind turbine parts to be locally sourced • **Energy Policy and Conservation Act in USA (1975) –** 15 per cent energy credit + 10 per cent investment credit, 20 per cent of total energy through RE • **Tax relief, Unemployment Insurance Reauthorization and Job Creation Act in USA (2010)–** wind power included under USA Treasury Grant Program • **100/250 MW program in Germany (1990)-** test the use of wind energy on a major economic scale • **Dedicated Ministry to develop RE in India (1992) –** Resource assessment, demonstration projects, policy design • **Feed-in-Premium in Spain (2007) –** complement to electricity price with minimum and maximum remuneration level on hourly basis

Note: Figure in parenthesis gives year when a policy or Act was implemented or passed in a country.
Source: own compilation

Table 4.8 indicates the estimated inflection point as per fitted model and actual inflection point for each country. Inflection point is the characteristic of diffusion models that captures behaviour of core variables. Our models have been able to capture these inflection points for Spain, India, and Germany. Further our model predicts inflection point for USA as 2012 whereas the actual inflection point for the data from 1981 to 2013 is 2012 (13, 200 MW). For China, inflection point would be reaching in year 2015.

Table 4.8: Comparison of Inflection Point for Selected Countries

Inflection Point (Model)	Spain (Bass)	India (Logistic)	Germany (Gompertz)	USA (Bass)	China (Bass)
Predicted year	2006	2012	2003	2013	2015
Actual year	2007	2011	2002	2012	--

Source: own computation

The parameter β of the logistic and Gompertz and parameter q of Bass model which indicate the growth rates of diffusion of WPT for different countries are summarized in Table 4.9.

Table 4.9: Growth Rate Parameters for Selected Countries

Country	**China**	**USA**	**Germany**	**India**	**Spain**
Model	Bass	Bass	Gompertz	Logistic	Bass
Growth Rate Parameter (β or q)	0.8853	0.3257	0.175	0.2873	0.3682

Source: own computation

This parameter defines the rate of growth with respect to time in diffusion process. It could be seen that China has highest growth parameter among all the five high growth countries. Despite great differences in absolute capacity and policies pursued, USA and Spain were found to have nearly equal growth parameters. On the other hand, growth parameter is lowest for Germany even though RNE's share in Germany's energy mix grew tremendously in recent years.[30]

4.6 Conclusions

The chapter is an attempt to model diffusion of WPT in five selected countries, namely, China, USA, India, Germany, and Spain. Together these five countries account for nearly three-fourth of World's installed capacity of WPT. Three models, namely Logistic, Gompertz, and Bass, were employed and finally selected based on AIC, BIC, and adjusted R^2 criteria. Our analysis yields that China, USA, and Spain follow Bass model, whereas Germany and India follow Gompertz and Logistic model, respectively. Our analysis also shows that policies like Wind Power Concession Programme in China in 2003, Energy Policy Act in USA in

[30] This parameter however cannot be viewed in isolation to compare growth since models underlying the diffusion process are different. For example- both China, having highest b value, and Germany, having lowest b value, are predicted to reach 95 per cent of their ultimate potential by 2013.

2005, Renewable Energy Supply Act in Germany in 1990, and Electricity Act in India in 2003 acted as catalyst to propel diffusion of WPT in these countries. In particular, successful policies are: quantity based instruments like significant R&D grants in Germany and USA, capital subsidies in per cent of project cost in Spain and China, obligation on Utilities to buy RNE power in USA, Germany, and India and price based instrument like FIT in all five countries.

Surprisingly the policies based on generation (kWh) could not result in significant diffusion, but they could trigger high growth in Germany.[31] The answer lies in the motive behind promoting RNE in Germany. While in USA or in India, RNE was promoted as a response to rising oil prices and energy shortages; the principal aim of RNE policy in Germany has been the reduction of greenhouse gas emissions through the replacement of fossil fuel based power systems which came as an obligation from EU level legislation and directives. Being one of the most influential countries in EU, Germany's compliance with EU policies is important to the legitimacy and prestige of both EU and Germany (Runci, 2005). Hence, resources devoted to deployment of RNE technologies far exceed than those directed towards RNE R&D. For example, by 2006, the difference was of the order of 400 per cent (Runci, 2005). Such a finding confirms that same set of policies may work differently for different countries.

During forecasting, it is observed that once the capacity reaches the 95 per cent of the ultimate potential predicted by the respective models, further growth is very slow. It is observed that 95 per cent diffusion (i.e., saturation point) for India and USA would be achieved in the year 2019 and 2021, respectively. For Germany, Spain, and China the corresponding year is 2013. Table 4.10 compares the saturation points for the selected countries along with respective capacity targets set by them.

[31] Between 1990 and 2003, RNE's share in Germany's electric power generation fuel mix grew from less than three per cent to almost nine per cent. Over the same period, net electricity consumption in Germany grew by approximately five per cent, while CO_2 emissions from power production declined by roughly 13 per cent (Runci, 2005).

Table 4.10: Comparison of Saturation Point for Selected Countries

Country	**India**	**Spain**	**USA**	**China**	**Germany**
Selected Model	Logistic	Bass	Bass	Bass	Gompertz
Year (to reach 95 per cent of diffusion)	2019	2013	2021	2013	2013
95 per cent of ultimate potential as predicted by model in GW	35	24	121	85	35
Capacity target (year)	29 (2017)	35 (2020)	293 (2030)	100 (2015)	45 (2020)

Data sources for capacity targets: GoI, 2012; Dept. of Energy U.S., 2008; McDermott, 2012; EWEA, 2013.

Our computation of saturation points based on selected models accurately coincides with the political shift and sectorial challenges hampering WPT growth in these countries. In India and Spain, for example, tax incentives were removed in 2012 after being perceived by the governments as a tool of merely promoting tax benefits and not performance. Further in India particularly, due to increased tariffs and high variability due to increased connected wind load, several State Utilities have started facing load management issues and often refuse to accept power from WPT. In Germany (post 2003) and USA (mid-1990s), for example, there has been a dip in the growth after actual cost was found to be much higher than the stated cost and hence Utilities objected to maintain buffer capacity, sometimes as high as seven per cent. China too is lacking infrastructure to support large WPT capacity. Every country is facing resistance at local level. To summarize, large scale deployment of WPT, as of today, is hindered by issues in managing reserve capacity, underutilization of networks, and controversial NIMBY attitude.

Chapter 5

Diffusion at Macro Level: Analysis across States of India

5.1 Introduction

The previous chapter has identified successful policy initiatives that have propelled the diffusion of Wind Power Technology (WPT) in leading countries including China, United States of America (USA), Germany, India, and Spain. Among these, India and China are developing countries. India has accumulated a long experience of more than 30 years of implementing policy mechanisms to support Renewable Energy (RNE) technologies. Further, it is perhaps the only country in the World to have a dedicated ministry (Ministry of New and Renewable Energy known as MNRE) to promote and develop RNE technologies. The Indian RNE development program was launched primarily as a response to the perceived rural energy crisis in the 1970s. The initial strategy for promotion of RNE included wind resource assessment, demonstration, awareness creation, and providing useful operating experience to industry and Utilities. Following the initial phase of government-sponsored demonstration projects, this sector was liberalized for private sector participation in 1992 supported by appropriate policy initiatives, fiscal incentives and institutional arrangements.

Accordingly in 1993, MNRE provided a package of incentives to WPT project developers which included tax concessions (such as Accelerated Depreciation (AD), tax holidays, customs and excise duty reliefs), soft loans, and liberalized foreign investment procedures. By 1998, the country observed the development of the World's fourth largest WPT program (Ghosh *et al*., 2001). Figure 5.1 giving the installed capacity of WPT since 1992 indicates that the installed capacity has grown from 52 MW in 1992 to around 19,000 MW by 2012 at Compound Annual Growth Rate (CAGR) of 34 per cent (IWTMA, 2013). Further, in twelfth plan Government of India (GoI) has envisaged a total of 18.5 GW of capacity addition in RNE, of which more than 60 per cent (≈11 GW) is expected to come from WPT (GoI, 2012).

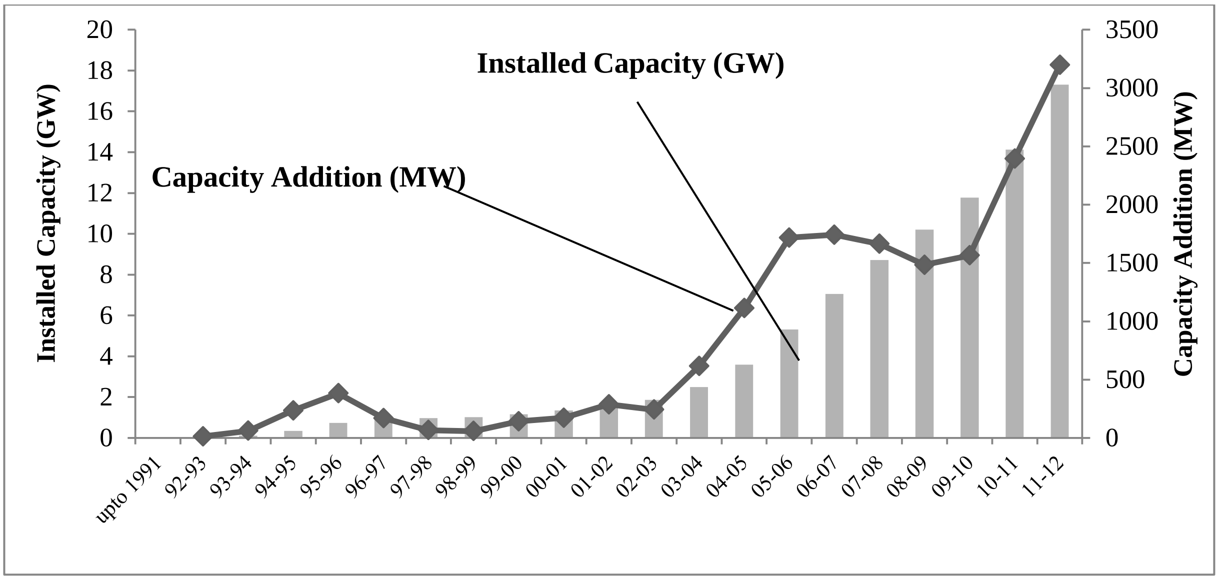
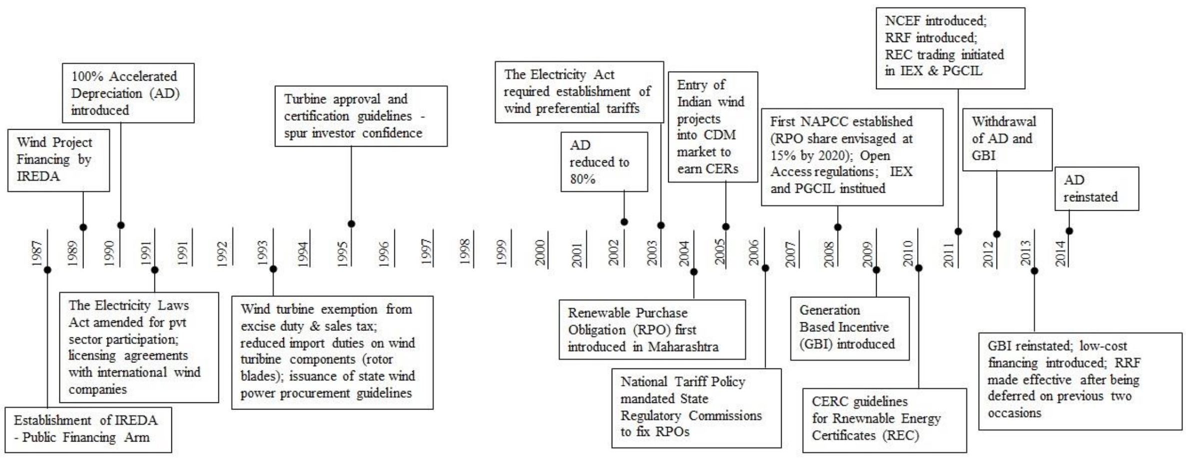


Figure 5.1: Growth in Installed Capacity in Wind Power Technology in India

Since power (electricity) in India is a concurrent subject under constitution of India, the most important milestone of all the Central government initiatives has been institutional arrangement that MNRE evolved through discussion with the State governments for allowing their Utilities to incorporate WPT generated power. In addition, to ensure orderly growth, MNRE issued Guidelines for Clearance of WPT Projects in July 1995 (amended in June, 1996). As a result, it became mandatory for all Utilities and nodal agencies – the State implementing bodies for WPT development – to make guidelines, facilitate infrastructure, provide financial incentives to support WPT projects in the States (Parthan, 1998).

The focus on RNE was sharpened in the Electricity Act 2003 (EA'03). Following EA'03, RNE generation, transmission, distribution, trading and use of power is regulated by Central and State Electricity Regulatory Commissions (SERC). In concordance with the EA'03, National Electricity Policy 2005 was framed and can be viewed as key in providing guidelines to the functioning of SERC in designing policy framework. Subsequently, Tariff Policy, 2006 was framed which focused on reliability and competitive price, financial viability of the projects, attracting investment into the project, minimizing of regulatory hassles, promotion of completion and improve the quality of the power supply. In order to encourage efficiency, Generation Based Incentive (GBI) was enacted in 2009 which provided price over above FIT for more than expected power generation from WPT. Figure 5.2 gives the key policies undertaken to promote WPT in India from till 2014.



Notes: NAPCC – National Action Plan on Climate Change, NCEF – National Clean Energy Fund, RRF – Renewable Regulatory Fund, IEX – Indian Energy Exchange, PGCIL – Power Grid Corporation of India Ltd., CDM – Clean Development Mechanism, CERs – Certified Emission Reduction.

Source: Adapted from Natural Resource Defense Council, 2014

Figure 5.2: Timeline of Policies for Wind Power Technology in India

With all these common set of policies in place, installed capacity of WPT in different States of India show a varied picture. Table 5.1 shows the wind potential and corresponding installed capacity of WPT in the States of India. As can be seen, more than 85 per cent of the potential is concentrated in seven States. Among these, where Tamil Nadu (TN) has exploited more than 100 per cent of its wind potential, States like Andhra Pradesh (AP), Karnataka (K), Gujarat (GJ), have not been able to exploit even 50 per cent of their respective wind potential.

Table 5.1: Installed Capacity of Wind Power Technology in the States of India

Sl. No.	State	Potential @ 50m[32]	Potential @ 80m	Installed Capacity (per cent of potential @ 50m)
1	Andhra Pradesh (AP)	5394	14497	447.65 (8.3)
2	Gujarat (GJ)	10609	35071	3,174.66 (29.92)
3	Karnataka (KN)	8591	13593	2,135.30 (24.86)
4	Madhya Pradesh (MP)	920	2931	385.99 (41.96)
5	Maharashtra (MH)	5439	5961	3,021.85 (55.56)
6	Rajasthan (RJ)	5005	5050	2,684.25 (53.63)
7	Tamil Nadu (TN)	5374	14152	7,162.27 (>100)
8	Others	6866	9280	3.2
	Total	**49130**	**102778**	**19,050.37**

Data Source: MNRE, 2012

This differential exploitation of wind potential leads to our second research question – *What role policies play in diffusion of WPT across States of India*?

Given that power is a concurrent subject in India which implies that both Centre and State governments can formulate their own policies to promote RNE technologies. In particular, State governments can choose specific values to some of the policy parameters based on resource availability and prevalent energy sector situation in their respective jurisdiction. Further, they can also offer additional financial incentives to attract WPT projects. Nonetheless, it is usually expected that State governments will align their policies based on guidelines laid out by the centre. As identified in previous chapter, the major policies that have attracted investment in WPT are Accelerated Depreciation (AD), Feed-In-Tariff (FIT), and Renewable Purchase Obligation (RPO). Among these, while AD is equally applicable to all the States, the remaining two including FIT and RPO are implemented by respective State governments. Further States can also choose whether to have banking facility (as explained

[32] The National Institute of Wind Energy (NIWE), an autonomous institution established under the aegis of the MNRE has estimated wind potential at two heights - 50 meters and 80 meters. The share of these States grows to around 88 per cent (of total 102 GW) when installable height of 80m is considered instead of 50m.

later) and magnitude of charges to be paid for the grid usage. Because of this, investors may perceive some States more attractive than others.

From the literature review given in section 3.3, it can be concluded that in the Indian context there are only handful of studies that have attempted to see the role of States' policies on RNE development. It can be seen from the Table 3.3 that while crucial role of policies and proactive attitude of government has been appreciated in diffusion of WPT in India, most of the studies follow either the case study approach or correlation to find link. Moreover, while studies have been carried out to compare diffusion of WPT across few States of India, there is a lack of a comprehensive study examining impact of policies of all major States together except Kathuria *et al*. However, they study the impact of policies on foreign investment only (which forms less than 5 per cent of total investment[33]) and not at the overall investment which includes domestic investment as well. Accordingly, this chapter fills the gap by studying whether State level policies have impacted diffusion of WPT across States of India.

In order to make a fine grained analysis and uncover the role of institutional differences between and spatial dimensions of State level incentives systems, we create an index for these chosen policies and then deploy a multivariate statistical weighting approach, principal components analysis (PCA) to obtain independent aggregate indices. Panel data techniques are then employed to investigate the impact of policy differences on installed capacity of WPT for seven selected States over the 19 years period, after controlling for several State specific factors. The controlling factors include per capita income of the State, ratio of installed capacity to geographic potential, and power deficit.

The remaining chapter is organized as follows. Next section gives the methodology to see the impact of policy on installed capacity in WPT. Since different States have pursued different policies to attract investment, we build a composite policy index for the policies in this section. Section 5.3 gives the estimation results. Section 5.4 discusses the results and the chapter concludes in section 5.5.

---

[33] FDI Investment in RNE sector in India is around 3.5 per cent of the total investment in RNE sector in India (Narayanan and Hamsalakshmi, 2014).

5.2 Model and Methodology

As most natural resources fall under the Con current List, the respective State governments can formulate their own energy policies. Given the varied resource availability, and different energy scarcity situation prevailing in different States, there would be heterogeneity in various policy parameters. This heterogeneity could mean that certain States could be adopting more developer attractive policy. The chapter explores the possible influence of State level policies on the installed capacity of WPT in the State.

As discussed later, an aggregate index for State level energy policy are computed. Using these indices and controlling for other factors that could affect installed capacity to a particular State, following model is estimated:

$$IC_{s,t} = \alpha + \sum_{i=1}^{n} \beta_i PC_i + +\gamma X_{s,t} + \varepsilon_{s,t} \tag{1}$$

Where,

$IC_{s,t}$ = Installed capacity of WPT in a State

PC_i = ith Principal component of State's policies for WPT

$X_{s,t}$ = Vector of State's other characteristics affecting $IC_{s,t}$

$\varepsilon_{s,t} =$ Error term comprising of two parts: a time invariant State effect (μ_s) and an independent and identically distributed (iid) random State-year term $(v_{s,t})$.

β_i is the estimated parameter ith principal component of State's policies and is predicted to have positive influence on the deployment of wind potential. γ's are the coefficients of control variables. Some of the control variables include peak power deficit in the State (in MW), per capita net State domestic product. The likely effect of these control variables is given later in the chapter.

For the given objective, there exist a variety of estimation models. A simple pooled Ordinary Least Squares (OLS) model would yield biased and inconsistent parameters if time invariant covariates are omitted. A Fixed Effect (FE) model will provide a consistent and unbiased estimate of the parameters while simultaneously controlling for unobserved unit heterogeneity if omitted time-invariant variables are correlated with the policy incentive variables. On the other hand, if these omitted time-invariant variables are uncorrelated with the policy variable, a Random Effect (RE) model would provide a more efficient estimate than FE model. Hausman test validates these assumptions.

5.3.1. Attractiveness of a State for deployment

To compare various policy measures across seven States in India, which have high wind potential, four policy parameters as discussed earlier- namely, FIT, wheeling charges, energy banking facility, and RPO - are used to compute a policy index for a State. These policy measures are designed by SNAs and are implemented by the SERC of respective States. It is to be noted that we do not include policies like AD, GBI, tax-holidays, etc. which are common across all States.

It was observed that policy variables were not entirely independent of each other. Further, policies may have unequal influence over the deployment resulting in different weights to different policies. Considering this, a multivariate statistical weighting approach, principal components analysis (PCA) was employed to extract uncorrelated components using individual policy indices. We assume the policy enacted would impact deployment in the next year; hence accordingly lagged values of principal components were used.

5.3.2. Methodology in computing policy indices

In order to represent attractiveness of each State for WPT, a composite index for four different policies for WPT is computed for a State. Methodological choices for associated with construction of composite indices are various. As the unit of measurement of parameters is different, normalization is done to aggregate them. Among the various techniques of normalization, the current study employs min-max criterion for normalization. Min-max method is based on the distance approach from the ideal. Often index calculated based on distance approach works better in comparison to others (Nathan *et al.*, 2010).

Each policy variable is first individually considered and normalized. Each normalized parameter value is then aggregated across time t for each State. Final scores received by each

State across time is normalized further to create the final index values. The normalization is done by min-max criteria.

$$A_{is} = \frac{B_{is,actual} - B_{is,min}}{B_{is,max} - B_{is,min}} \quad (2)$$

Where, B_{is} = Value of parameter i for State s, and A_{is}= Score received by each parameter i for State s at time t.

The parameters (B_{is}) considered are: FIT, wheeling charges, banking period, and RPO. Table 5.2 and Table 5.3 give the summary of these policies in respective States for two time period – one in early 1990s and another in 2012. Following sub-sections explain in detail how each of these policies work and how an index has been computed for each.

5.3.2.1. Feed in Tariff - Tariff for Wind Power Technology

Tariff rate is the rate at which an operator can sell power if produced using WPT. Two methods of tariff setting could be observed in the States of India. First, where tariffs are fixed for initial few years of the plant and then per unit escalation in price over remaining period is provided. This method was practiced in 1990s. And second which is currently practiced by SERCs, where a levelized tariff is computed by considering annual escalation for the entire plant life. Over the years, States have moved from allowing escalation in tariff to adopting a levelized tariff over the plant life for WPT.

Since investment decision for the year is governed by current policy, the year itself is considered crucial in the current study. The tariff rate is then normalized using min-max criterion. The State which offered high tariff rate reflects a pro-investor policy, and is assigned a value of one and vice versa. MH received highest index since it offered highest tariff, in thirteen out of nineteen years. Among the States having lowest tariffs are TN, MP, and GJ. RJ had allowed rates to be decided between buyer and seller up to 2006. Corresponding index for RJ was lowest from 1993 to 1998 and more than 0.85 from 1999 to 2003. However from 2007 to 2013, State Electricity Regulatory Commission (SERC) of RJ issued six tariff orders for WPT. Corresponding index of RJ increased from 0.49 (in 2007) to 1 (in 2011) dropping to 0.16 (in 2012).

Table 5.2: Summary of Selected Policies for Wind Power Technology in States of India in 1990s

Items	**AP (1997)**	**TN(1995)**	**KN(1993)**	**MH(1998)**	**GJ(1993)***	**MP(1998)**
Wheeling charges** (% of energy)	2	2	5	2	2	2
Banking facility (months)	12	12	12	12	6	---
FIT** (Rs./kWh)	2.25 (5% escalation, 97-98)	2.25 (5% escalation, 95-96)	2.25 (5% escalation, 94-95)	2.25 (5% escalation, 94-95)	1.75 (no escalation)	2.25 (no escalation)

Notes: * - Policy expired in 1998. ** - FIT and Wheeling charges have been revised several times by respective SERCs.

Table 5.3: Summary of Selected Policies for States of India for Wind Power Technology in States of India in 2012

Items	**AP**			**TN**			**KN**			**MH**			**GJ**			**MP**			**RJ**		
Wheeling Charges (%)	At par with conventional			5% of energy			5% of energy + Rs.1.15/kWh as cross subsidy for 3rd party sale.			2% of Energy as wheeling + 5% as T&D loss.			7% of energy for investor having one Turbine & 10% for others			2% of energy + transmission charges as per ERC			1% of energy @ 33kV and 4% of energy @ 132/220 kV system		
Banking facility (months)				5% (12months, FY)			Allowed @ 2% energy input			12 months			Not allowed			Not allowed			6 months		
Renewable Purchase Obligation (RPO, % of total procurement of power from a Utility)	5% since 2005 (with no escalation), reduced to 4.75% in 2012			10% since 2006 (with no escalation), reduced to 8.95% in 2012			2% since 2007 (with no escalation), increased to 12% in 2012			3% from 2006 (with annual 1% escalation till 2009), 5.75% from 2010 (with annual 1% escalation till 2012)			1% from 2006, 10% in 2009, 4.5% in 2010 (with annual 0.5% escalation till 2012)			10% from 2008 (with annual 1% escalation till 2009), reduced to 0.8% in 2010, 2.5% in 2011, 4% in 2012.			2% from 2006, 4% from 2007 with annual 1% annual escalation till 2009, 6.75% from 2010, reduced to 5.5 in 2012.		
FIT(Rs./kWh)	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
	2.25	4.7	2.81	2.25	3.57	2.65	2.25	5.01	2.79	2.25	4.65	2.93	2.25	4.23	2.68	2.25	4.35	2.3	2.75	4.78	3.47

Source: Jagadessh, 2000; MNRE, 1993

Table 5.4: State-wise Index for Feed-in-Tariff in India

Year	MH	GJ	TN	AP	KN	MP	RJ
1993	0	1	0	0	0	0	0
1994	1	0.7778	0	0	1	0	0
1995	1	0.7407	0	0	1	0	0
1996	1	0.7055	0.9070	0	1	0	0
1997	1	0	0.9070	0.8638	1	0	0
1998	1	0.6398	0.9070	0.8638	1	0.8227	0
1999	1	0	0.762	0.6514	1	0.4458	0.8916
2000	0.9885	0	0.7695	0.6677	0.9884	0.3906	1
2001	0.9624	0	0.6636	0.9892	0.9892	0.3493	1
2002	0.908	0.3209	0.4126	0.9851	0.9851	0	1
2003	1	0.32	0.36	0.9924	0.74	0	0.856
2004	1	0	0	0.6091	0.4896	0.1536	0.1909
2005	1	0.0357	0	0.5989	0.5	0.1207	0.1857
2006	1	0.346	0	0.56	0.3651	0.3543	0.1175
2007	1	0.2907	0	0.5603	0.3067	0.2976	0.4907
2008	1	0.2506	0	0.3103	0.2644	0.2841	0.423
2009	1	0	0.0104	0.0674	0.0155	0.0378	0.5285
2010	0.7943	0.1771	0	0.1146	0.3229	1	0.5625
2011	0.8502	0.1435	0	0.0928	0.2616	0.8101	1
2012	0.9538	0.605	0	1	0.1597	0.7059	0.1597

Source: Own Computation

5.3.2.2. Wheeling charges

Wheeling Charge is the cost incurred by the producer to transfer energy produced to the designated Utility. These costs are expressed in terms of percentage to the total energy transmitted. Some States in addition also charge for transmission losses incurred in the process of energy transmission. Broadly States have adopted wheeling charges in the range of 2 per cent to 12 per cent of the total energy transmitted.

Most of the States adopted a more producer friendly policies over the years by reducing wheeling charges as high as 10 per cent of the total transmitted energy to less than equal to five per cent of the total energy transmitted. For the year 2010-11 drastic changes in the score is observed. This change is due to the amendments in wind power policy in several States. Discriminatory wheeling charges are also practiced in GJ and TN with lower wheeling charges imposed for transmission above 66 kV and higher wheeling charges for transmission at less than 66 kV. On the other hand, MP also charges for transmission losses. Due to the varied nature of practices adopted in imposing an additional charge, the current study has considered only wheeling charges.

To create an index for wheeling charges, the absolute wheeling percentage was considered. The total score was then normalized using max-min criterion. A score of one is assigned to the State with the least wheeling charge thereby indicating it being most attractive. TN has begun to charge in Rs./MW and Rs./MWh since 2012. Our methodology to convert these to charges in terms of energy is given in Appendix I.

. Table 5.5 shows the state-wise index computed for wheeling charges.

Table 5.5: State-wise Index for Wheeling Charges for India

Year	MH	GJ	TN	AP	KN	MP	RJ
1993	0.00	1.00	0.00	0.00	0.00	0.00	0.00
1994	1.00	1.00	0.00	0.00	0.00	0.00	0.00
1995	1.00	1.00	0.00	0.00	1.00	0.00	0.00
1996	1.00	1.00	0.00	0.00	1.00	0.00	0.00
1997	1.00	1.00	1.00	0.00	1.00	0.00	0.00
1998	1.00	0.00	1.00	1.00	1.00	1.00	0.00
1999	1.00	0.00	1.00	1.00	1.00	1.00	0.00
2000	1.00	0.00	1.00	1.00	1.00	1.00	1.00
2001	1.00	0.00	1.00	1.00	1.00	1.00	1.00
2002	1.00	0.00	1.00	1.00	1.00	1.00	1.00
2003	0.67	0.89	0.83	1.00	0.00	1.00	1.00
2004	0.90	0.80	0.75	0.90	0.00	1.00	0.50
2005	0.90	0.80	0.75	0.90	0.00	1.00	0.50
2006	1.00	0.75	0.63	1.00	0.63	1.00	0.00
2007	1.00	0.75	0.63	1.00	0.63	1.00	0.00
2008	1.00	0.75	0.63	1.00	0.63	1.00	0.00
2009	1.00	0.75	0.63	0.63	0.63	1.00	0.00
2010	1.00	0.75	0.47	0.63	0.63	1.00	0.00
2011	1.00	0.19	0.47	0.63	0.63	1.00	0.00
2012	1.00	0.19	0.25	0.63	0.63	1.00	0.00

Source: Own computation

5.3.2.3. Banking of energy

With respect to energy banking policies, there is a huge variation with some States allow banking throughout the year without restriction on the quantity of power that can be banked while others place a restriction on the quantity and the duration for which the energy can be banked. Some States do not allow energy banking.

To factor these three parameters, share of banking period is obtained by dividing allowed banking months by 12 i.e., the total possible months. This ratio is then normalized using min-max criterion. Table 5.6 shows the state-wise index for banking facility. AP varied between full year banking to no banking while MP shifted from no banking to full year banking. However, post 2010-11 most States have relaxed their policy towards banking.

Table 5.6: State-wise Index for Banking of Wind Power Technology for India

Year	MH	GJ	TN	AP	KN	MP	RJ
1993	0	0.5	0	0	0	0	0
1994	1	0.5	0	0	0	0	0
1995	1	0.5	0	0	1	0	0
1996	1	0.5	0	0	1	0	0
1997	1	0	1	1	1	0	0
1998	1	0	1	1	1	0	0
1999	1	0	1	1	1	0	1
2000	1	0	1	1	1	0	1
2001	1	0	1	1	1	0	1
2002	1	0.5	1	1	1	0	1
2003	1	0.5	1	1	1	0	1
2004	1	1	1	1	1	1	1
2005	1	0.5	1	1	1	1	1
2006	1	0.5	1	1	1	1	1
2007	1	0.5	1	1	1	1	1
2008	1	0.5	1	0	1	1	1
2009	1	0.083333	1	0	1	1	1
2010	1	0.083333	1	0	1	1	1
2011	1	0.083333	1	0	1	1	1
2012	1	0.083333	1	0	1	1	1
2013	1	0.083333	1	0	1	1	1

Source: Own Computation

5.3.2.4.Renewable Purchase Obligation – Obligation to accept wind power

Under Section 86(1)(e) of the EA'03, the SERCs are empowered to specify the percentage of electricity to be procured by the obligated entities from RNE. Most SERCs have put significant emphasis on this provision and have issued Orders specifying such percentages. This percentage is referred to as Renewable Purchase Obligation (RPO).

In order to compute an index, per cent RPO levied by SERC was considered. The total score was then normalized using max-min criterion. A score of one is assigned to the State with highest RPO thereby indicating the most attractiveness. Table 5.7 shows the State-wise index for RPO for selected States of India. As can be seen, TN has highest index since enactment of RPO there in 2006. On the other hand, MP has received high scores for first years of RPO enactment (2008 and 2009) where RPO was near or equal to highest. Thereafter RPO level was reduced by more than half resulting in lowest index value.

Table 5.7: State-wise Index for Renewable Purchase Obligation for India

Year	MH	GJ	TN	AP	KN	MP	RJ
2005	0	0	0	1	0	0.1	0
2006	0.263158	0.052632	1	0.473684	0.157895	0	0.157895
2007	0.368421	0.052632	1	0.473684	0.368421	0	0.368421
2008	0.375	0	1	0.375	0.375	1	0.375
2009	0.125	0.625	1	0	0.125	0.75	0.125
2010	0.538043	0.402174	1	0.456522	0.646739	0	0.646739
2011	0.566667	0.333333	1	0.333333	0.666667	0	0.666667
2012	0.757576	0.30303	1	0.20202	0.30303	0	0.30303

Source: Own Computation

5.3.3. Methodology for Computing Aggregate Indicator – Principal Component Analysis

After computation of policy indices, the correlation matrix revealed that they were not entirely independent of each other. Further, a policy may exert different influence at different stage of project. For example, FIT is paid by Utility to a generator upon injection of wind power to the grid whereas wheeling charges are paid for network usage by generator. RPO is obligation on Utility and banking is offered to store and withdraw power later. These policies may offer different degree of attractiveness to an investor and hence could be given different weights while computing aggregate index. This study makes use of multivariate statistical weighting approach, principal component analysis (PCA) to compute weights. PCA facilitates a relatively objective approach to setting weights that is dictated by data rather than the analyst (Jollands *et al.*, 2004).

PCA is relevant for its ability to extract a small number of sub-indices (called principal components) from a given set of indices (Marcoulides and Hershberger, 1997). The first principal component is the linear combination of the original variables that exhibits the greatest possible variance. In our specific case, we expect the first component to account for the maximum amount of variation of information in the original set of policy proxies. With sequential application of the technique it is possible to identify a second linear combination of the original variables that explain the greater share of the residual variance, and so on. It is to be noted that every component is orthogonal to all the others, and consequently is expected to reflect a different dimension of the original set of variables (*ibid*). To build aggregate indices, the general rule of thumb is to use only those components that account for a sufficient amount of variance (generally those associated with an eigenvalue greater than 1) (Grossman *et al.*, 1991).

Accordingly PCA was performed on four policy indices. Table 5.8 gives the selected two principal components with eigen value greater than 1. Further, Table 5.9 gives the explained variance by these components. It can be seen that together the two components explain around 80 per cent of the variance among policy indices.

Table 5.8: Principal Components' Computation using Selected Policies for Wind Power Technology in the States of India

Principal components/ correlation — Number of observations = 140

Number of components = 2

Trace = 4

Rho = 0.793

SEs assume multivariate normality — SE(Rho) = 0.020

	Coefficient
Eigenvalues	
comp 1	2.04***
comp 2	1.13***
comp 1	
FIT	0.57***
RPO	-0.001
Wheeling	0.58***
Banking	0.58***
comp 2	
FIT	-0.30***
RPO	0.91***
Wheeling	0.01
Banking	0.29***

Significance code: '***' – 0.01

Source: Own computation

Table 5.9: Explained Variance by Principal Components for State Policies in India

Components	Eigen value	Proportion	SE_Prop	Cumulative	SE_cum	Bias
comp1	2.04	0.51	0.036	0.51	0.036	0.026
comp2	1.13	0.28	0.030	0.79	0.020	-0.009
comp3	0.46	0.12	0.015	0.91	0.012	0.024
comp4	0.36	0.09	0.012	1.00	0.000	-0.019

Source: Own Computation

5.3.4. Data and Variables

The data set used for the study is annual data of installed capacity for 19 years (from 1993 to 2012) of WPT in seven States of India. Table 5.10 gives the initial and final year values of growth rate of WPT in selected States. As can be seen, average rate of growth is highest for RJ (67.27 per cent) followed by KN (51.17 per cent), MH (48.57).[34] MP and AP have nearly equal growth rates, 38.29 and 39.81 respectively. Though GJ has lowest average growth rate (30.22 per cent) among all States, it has observed tremendous growth in recent years (500 per cent since 2006).

Table 5.10: Initial and Final year values with average growth rate for wind power capacity (MW) in selected States of India

States	MH	GJ	TN	AP	KN	MP	RJ*
1992-93	1.10	16.15	33.38	0.55	0.55	0.59	0.00
2012-13	3021.85	3174.66	7162.27	447.65	2135.30	385.99	2684.25
Average Rate of Growth	48.57	30.22	32.65	39.81	51.17	38.29	67.27

Note: *- First year of available installed capacity for RJ is 1999 (2 MW). Hence, growth rate is computed that year onwards.
Data Source: Jagadessh (2000), MNRE (2012)

Table 5.11 gives the description and data source for policy variables. The data source includes various central and State government reports. Figure 5.3 and Figure 5.4 give scatter plots between policy components (as obtained from PCA) of these States and installed capacity of

[34] The average rates of growth are not strictly comparable since base values of States are different.

WPT. Interestingly, despite high index in MH and GJ, installed capacity has not increased and rather it is inversely proportional. On the other hand, in AP there seems neutral relationship between composite index and WPT installed capacity.

Table 5.11: Brief Description of Policies Selected for Analysis

Variables	Description	Data Source	Remarks
FIT	Per unit tariff for energy fed to the grid	MNRE, 1993; Tariff Orders by SERCs	Increasing trend of adopting levelized per unit cost
RPO	Mandating distribution Utilities to purchase a fix quantum of power generated using RNE	Tariff orders by SERCs	Obligation has been increased on annual basis regularly
Wheeling Charges	Charges imposed on generator for transfer of energy across grid	Same as for FIT	Wheeling charges have reduced with discriminatory charges imposed on transmission lines
Banking Charges	Allows withdrawal of energy in future for energy fed earlier	Same as for FIT	Allowed in all States. Few impose restriction on the months.

Figure 5.3: State-wise Policy Index (Component 1) versus Installed Capacity of Wind Power Technology in India

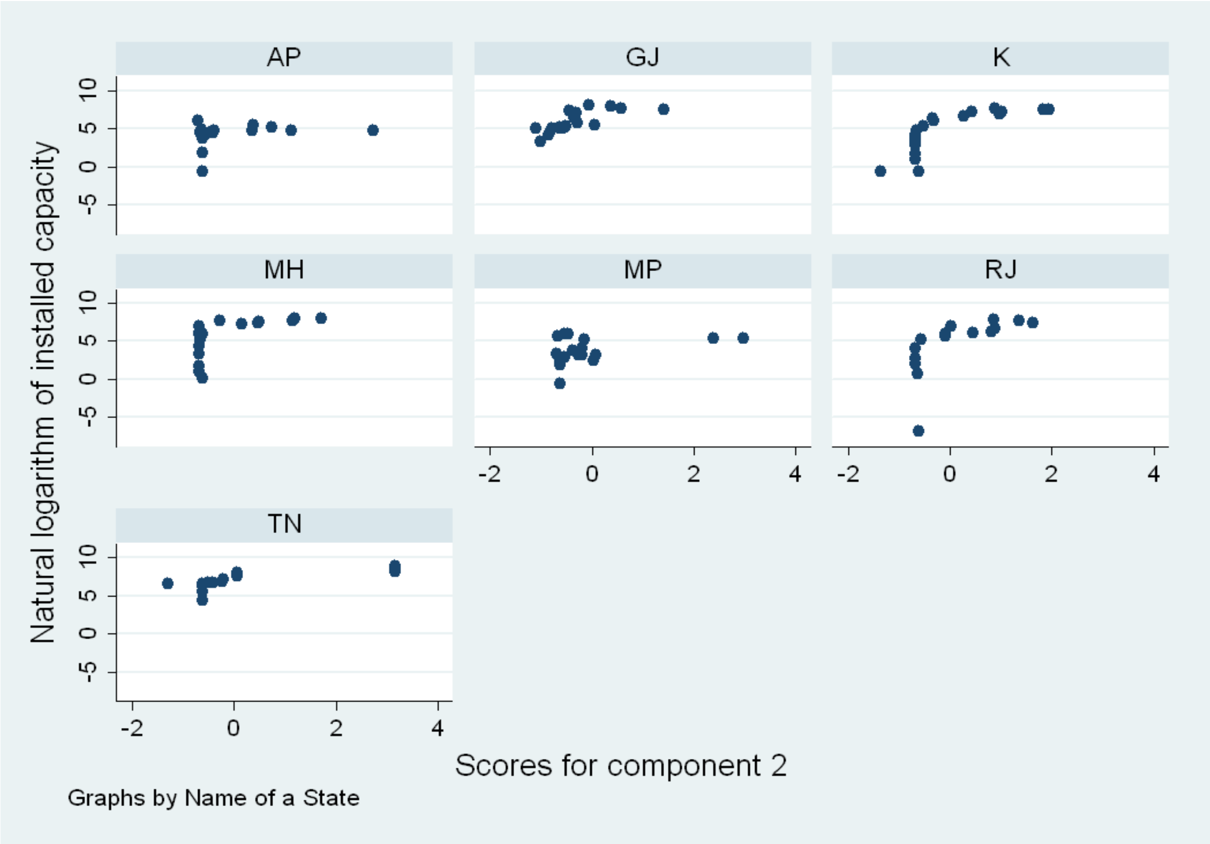


Figure 5.4: State-wise Policy Index (Component 2) versus Installed Capacity of Wind Power Technology in India

While the literature suggests towards necessity of policies in causing diffusion of WPT, figures 5.3 and 5.4 indicate that they alone are not sufficient. Accordingly, it could be observed that there are other factors, apart from policy, that have influenced deployment of wind potential across States of India. Interestingly, this result also reinforces the relevance of forecasts obtained in previous chapter where all leading countries under current policy initiatives are set to reach their saturation limits within a decade. Accordingly, in order to examine the impact of policies on diffusion of WPT, we need to control for these factors in the analysis as explained in sub-section 5.3.5.

5.3.5. Control Variables

The literature has used variables like per capita income of the State, peak power deficit, geographic potential etc. as control variables. We have also used them in our study as control variables.

- **Market size**: A bigger market attracts wind power developers and thus, capacity addition. This is due to large potential demand and thereby economies of scale (Walsh and Yu, 2010). The market size is measured by per capita net State domestic product (PCNDP). A bigger market size is expected to have a positive sign.

- **Demand for power**: Higher power deficit in a State is expected to attract more investment in WPT. Fluctuation in power deficits runs across all the States. Maharashtra (a State with the highest PCNDP) and the MP (a State with low PCNDP) suffer from on an average 18 per cent deficit in energy. TN despite pioneering in WPT installed capacity suffers from energy deficits of over 6.5 per cent in last four years.

- **Resource Endowment**: Geographic potential is one of the crucial factors which attract WPT capacity in a State. A State with higher wind potential is expected to have more installed capacity. However, as it receives more installed capacity, scope for future installations reduces. Hence, in our computation, we used ratio of installed capacity to geographic potential on yearly basis (Rpot) to reflect unmet potential. This variable is expected to have negative sign. Table 5.12 gives the data sources and expected sign of these control variables.

Table 5.12: Expected Relation of Variables with Dependent Variable

Variables	Description	Data Source	Expected Sign
Aggregate Indicators	Two components selected by applying PCA to policy variables	Policy variables as shown in Table 6	+
Control Variables			
PCNDP		Reserve bank of India	+
Power Deficit	Annual average Peak power deficit faced by States	CEA Annual Reports; Socioeconomic Review reports for each State	+
Geographic Potential	Ratio of geographic potential to installed capacity for States	MNRE, 1993; MNRE, 2005	-

5.3.6. Descriptive Statistics

Table 5.13 gives the mean value of control variables used in the analysis. The mean of PCNDP is higher than the sample mean for GJ, MH, and TN. Hence, these States are likely to have higher installed capacity. However, installed capacity in these States have varied greatly from around 3000 MW in GJ and MH to around 7000 MW in TN. AP and MP have received much below the overall mean installed capacity; whereas AP has PCNDP and deficit approaching sample mean, MP is relatively poorer State in terms of PCNDP.

GJ, despite having highest geographic potential for wind, has exploited only 30 per cent of its potential whereas TN, being endowed with only around half the potential of GJ, has exploited more than 100 per cent of its potential. Power deficit is highest in MP followed GJ and KN, respectively. However, corresponding order of installed capacity of WPT is GJ followed by KN and MP, respectively.

Table 5.13: Descriptive Statistics of the Control Variables

State	Installed Capacity of Wind Power Technology (MW)	PCNDP (Rs.)	Deficit (%)	Ratio of installed capacity to potential as of 2012
MH	915.36	31728.85	15.18	0.56
GJ	786.72	27193.65	16.74	0.3
TN	2465.23	27040.5	11.70	1.33
AP	117.18	21193.25	13.89	0.08
KN	595.88	22486.2	16.49	0.25
MP	97.68	13313	19.39	0.38
RJ	501.05	15605.7	4.93	0.54
Mean	**782.73**	**22651.6**	**14.04**	**0.49**

Source: Own Computation

5.3 Results

Before estimating the model, we first study correlation between different control variables. Appendix II gives the correlation matrix and also gives significance of the correlation coefficient at minimum 10 per cent level. We find that a State with higher per capita income (ln PCNDP) is having higher peak power deficit (deficit), and also high ratio of installed capacity to potential (Rpot). Consequently we could not use all the controlled variables together.

Table 5.14 gives the econometric results. We first estimated equation (1) by pooling the data for all the States (pooled OLS). However, if there are time invariant omitted variables, the OLS results would be biased. Thus we need to use panel data techniques. Subsequently we ran both – fixed effect (FE) and random effect (RE) models. First we do F-test to see whether individual fixed effect exists or not. Since F value (12.78) is greater than the tabulated value, this implies we reject the null hypothesis (i.e., model is pooled OLS) and we need to run FE and RE models. Columns 2 and 3 of Table 5.14 give FE and RE estimates.

Table 5.14: Does Policy Influence Installed Capacity of Wind Power Technology?
Dependent variable – Natural Logarithm of Installed Capacity of Wind power

Variable	**Pooled OLS (1)**	**FE (2)**	**RE (3)**	**FGLS (4)**
$PC1_{t-1}$	0.273* (1.81)	0.392 (1.21)	0.374 (1.17)	0.149** (2.06)
$PC2_{t-1}$	-0.103 (0.84)	0.000 (0.00)	-0.018 (0.17)	0.0276 (0.29)
ln PCNDP	2.512*** (8.74)	2.267** (3.42)	2.300*** (3.60)	1.183*** (5.85)
Rpot	3.218*** (5.38)	3.007 (1.23)	3.087** (1.98)	2.81*** (4.56)
Constant	-20.499*** (6.91)	-18.045** (2.80)	-18.387*** (2.80)	-7.14*** (-3.59)
R^2	0.60	0.55		
N	133	133	133	133
F test/ wald chi square		**12.78 (0.004)**	9.49 (0.00)	90.87(0.00)
Hausman test		**0.49 (0.9743)**		

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$
Source: Own Computation

Whether these omitted variables (State-specific differences) are fixed or random are tested using Hausman Test as given in the last row. Since the tests statistic 0.49 is less than the critical value of a Chi-squared (1df, 5 per cent) (3.84), we accept the null of RE being more efficient. However, as could be seen, principal components (row 1 and 2) are not significant which means policy does not impact installed capacity, whereas per capita income of the State is statistically significant. As we are using panel data with different variables showing change over time, the autocorrelation cannot be ruled out. Given the problems of heteroskedasticity and autocorrelation, we use Feasible Generalized Least Squares (FGLS) procedure to estimate the parameters (Column 4 of Table 5.14). Results indicate that lagged value of policy (as measured by principal component 1) has statistically positive influence on installed capacity of WPT. Among control variables, both per capita income and unmet capacity also induce firms to invest on WPT.

In order to see whether results are robust, we reestimate RE(FGLS) model with different combinations of control variables. Table 5.15 gives the results where some of the variables are dropped or alterante control variables are used. Model 1 reports the results when only policy components are used whereas Model 2 depicts results when ln PCNDP is introduced. Model 3 reports the results when ln PCNDP and deficit are used together. Model 4 reports the results when deficit and Rpot are used whereas Model 5 shows the results when deficit, Rpot and square of rpot are used.

Table 5.15: Robustness Testing: Influence of Policy on Installed Capacity of Wind Power Technology in Selected States of India

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
$PC1_{t-1}$	0.173 (2.02)**	0.174 (2.22)**	0.168 (2.15)**	0.146 (1.87)*	0.121 (1.70)*
$PC2_{t-1}$	0.195 (1.99)**	0.088 (0.86)	0.101 (0.98)	0.132 (1.45)	0.122 (1.43)
lnPCNDP		1.490 (7.09)***	1.453 (6.87)***		
deficit			-0.014 (1.15)	-0.014 (1.19)	-0.006 (0.53)
Rpot				2.686 (4.65)***	10.291 (6.94)***
$rpot^2$					-6.445 (5.40)***
constant	5.181	-9.656	-9.082	4.754	3.945
	(19.04)***	(4.62)***	(4.26)***	(14.03)***	(11.63)***
N	133	133	133	133	133

Note: * p<0.1; ** p<0.05; *** p<0.01
Source: Own Computation

As can be seen, the sign and significance of policy index variable is always above the acceptable level of confidence (90 per cent). The results are thus observed to be robust to non-inclusion of control variables. Based on the results, we can conclude that favourable policy facilitates deployment of wind potential in the State irrespective of whether control variables are included or not.

5.4 Discussion

The results of this analysis confirm the significant role of States in formulating policies to promote WPT within their jurisdiction. Further, the results demonstrate that States having higher policy index would have higher diffusion of WPT. Based on the coefficient value, the results indicate that at the mean values of per capita income and wind potential, 10 per cent increase in major component of policy index from 1.57 to 1.73 would result in additional 3505 MW of WPT installed capacity.

The unmet capacity and PCNDP have positive association with the diffusion of WPT. In particular, influence of unmet capacity is in line with others' findings (see for example, Menz and Vachon, 2006; Lewis and Wiser, 2005) and also the conventional logic that unexplored regions with high wind potential would be more attractive for investors. Evidently, this also shows that States having high unmet capacity would have high diffusion rate if they have mean level of policy support. Based on the coefficient value, the results indicate that at the mean values of other variables, 10 per cent decrease in unmet capacity from 0.56 to 0.504 would decrease additional WPT installed capacity by 596 MW.

On the other hand, positive sign of PCNDP indicates the influence of overall development of a State on the WPT diffusion. States with higher PCNDP indicate higher industrialization and development and consequently high demand for power. Because of this perhaps, investors in these States choose WPT to meet their power requirement. For example, many WPT projects in India have been set up by investors in the business of cement and textile industry to meet their demand (Jagadeesh, 2000).

However, results also indicate that power deficit doesn't have any impact on the diffusion of WPT. This means that while investors seem to choose WPT as a means to meet their power demand (as indicated by PCNDP); the reason behind this is not shortage of power. It could be because wind offers them a captive and cheaper source of power compared to conventional power. In fact, in recent years cost of generation from WPT is around 3.5 Rs./kWh, which is lower than that from conventional power (around 4 Rs./kWh)[35](Narasimhan, 2012).

5.5 Conclusions

Last few decades has seen significant capacity addition in WPT in India. However, despite having high potential some States have not received much investment in WPT. On the other hand, some States with relatively low wind potential could muster enough installed capacity. This chapter is an enquiry into the role of State policy in influencing WPT installed capacity. The chapter studies the impact of policies on deployment of wind potential across the States of India over two decades. Aggregate indices are computed for each of the seven wind resourceful States of India indicating attractiveness for installed capacity of WPT. For computing the indices, four policies, FIT, RPO, banking facility, and wheeling charges are considered. Panel data techniques are then employed to investigate the impact of the policy differences on wind potential deployment over the 19 year period (1993 to 2012) after controlling for three State-specific factors. The controlling factors include per-capita income of the State, power deficit, and ratio of installed capacity of WPT to geographic potential.

Based on the results, we can conclude that policy index positively impacts diffusion of WPT whether control variables are included or not. The analysis thus confirms the influential role of States in promoting deployment of wind potential. Given the huge unexploited wind potential in different States of India, (for example, 1260 MW in Uttar Pradesh or 5685 MW in Jammu and Kashmir as per the estimates by CWET), such an analysis encourages implementation of these policies to initiate diffusion of WPT.

[35] On the one hand, the coal price is India is around 4000-5000 Rs./tonne (approx. 62-77 US$), while the price of imported coal is five times of that. On the other hand, the technological advancement - in terms of larger wind turbines, gearless machines, and better mapping of sites - has reduced cost of WPT making it economically viable over conventional power (Narasimhan, 2012).

Further, our model has been able to capture certain preferences of investors while investing in WPT. Since the index has been computed using policies that reward actual generation than mere installation, this indicates that investors are looking at WPT as a source for generating power rather than mere tax benefits based on installation.

Apart from State policy index, from the positive influence of unmet capacity, it can be concluded that unexplored State with higher wind potential would attract investment in wind even with moderately attractive policies. Positive influence of PCNDP implies that with more development, energy portfolio of a State tends to get diversified towards environment friendly technologies like wind power. Further, the driving factor for this is not shortage of power but economic viability of these technologies over conventional power technologies.

Chapter 6

Diffusion at Micro Level: Identification of Factors

6.1 Introduction

As seen in previous chapter, the index computed using selected policies' parameters – namely, Feed-in-Tariff (FIT), Renewable Purchase Obligation (RPO), banking facility, and wheeling charge - positively impacts the diffusion of Wind Power Technology (WPT) across selected seven States of India. Among these States, Maharashtra ranks second in terms of installed capacity of WPT after Tamil Nadu. Also, Maharashtra has been at the forefront in setting aggressive policy parameters for WPT. For example, the State has offered highest FIT for WPT among all the States of India for 13 out of 19 years (refer to page 92). Also, it is the first State of India to introduce RPO policy in 2006.

Despite pioneer in enacting wind policies and having significant wind potential, Maharashtra has not been able to exploit its available wind potential fully. Figure 6.1 shows the geography of Maharashtra including the districts having significant wind potential as identified by National Institute of Wind Energy (NIWE). Table 6.1 shows wind potential vis-à-vis installed capacity of WPT in Maharashtra for nine districts for which significant wind potential exists. As can be seen, the State has been able to exploit only around 60 per cent of its wind potential. On the other hand, without very favourable policy (as seen from the aggregate index of policy computed in last chapter), Tamil Nadu has been able to harness more than 100 per cent of its wind potential.

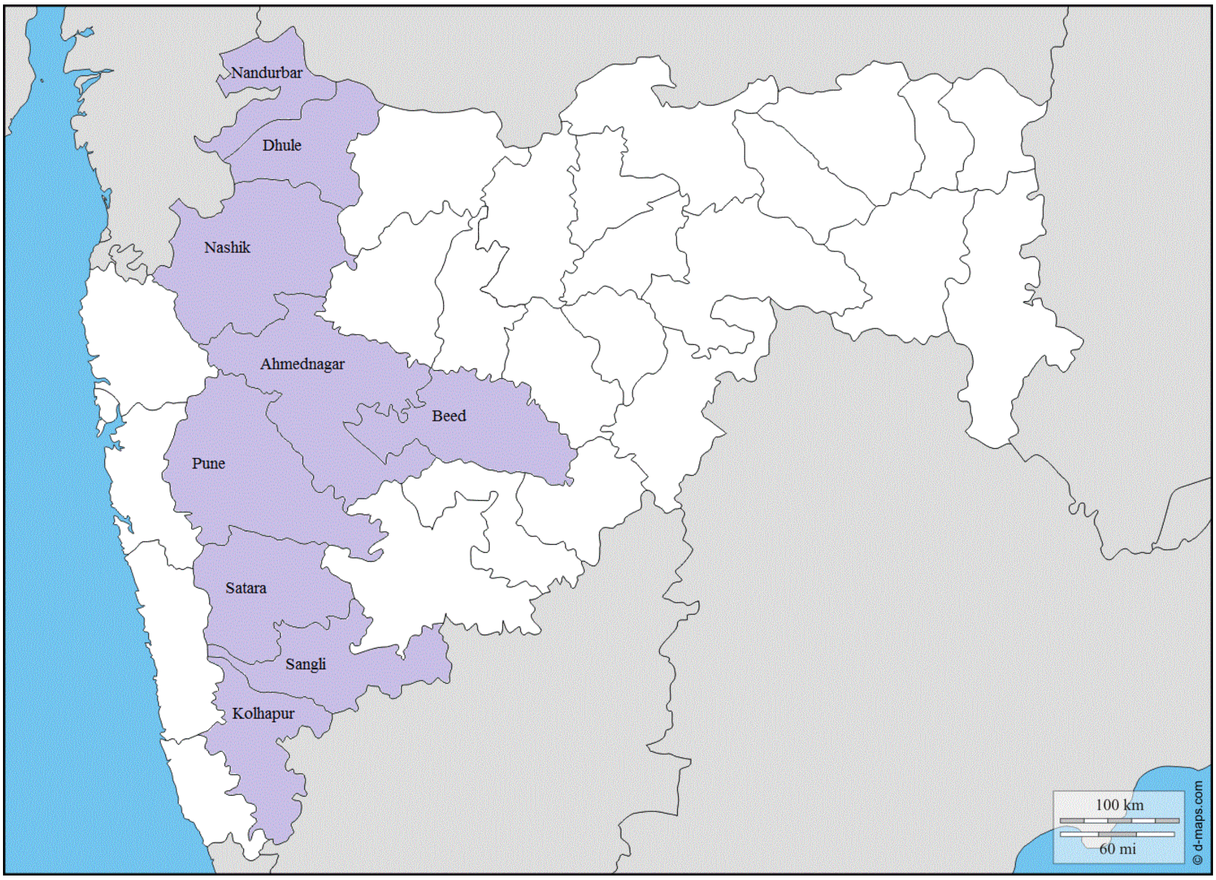


Figure 6.1: Location of Districts of Maharashtra with Significant Wind Potential

From the table, one can see the skewed utilization of wind potential among districts of Maharashtra. Nashik having highest wind potential has received installed capacity a little over 10 per cent of its potential. Similarly, Pune which is the third ranked district in terms of wind potential has received installed capacity only around 13 per cent of its wind potential. Interestingly, five districts (namely Satara, Ahmednagar, Dhule, Nandurbar, and Sangli) accounting for around 45 per cent of total wind potential contribute over 90 per cent of the total installed capacity of WPT in Maharashtra. Except Ahmednagar, remaining four leading districts have received installed capacity more than their respective wind potential (column 4 of Table 6.1). Interestingly, Sangli having lowest wind potential ranks second in terms of installed capacity of WPT.

As four out of nine districts have exceeded their potential limit, NIWE was contacted again to understand the procedure of wind potential assessment across States of India. The institute informed that assessment of wind potential in performed periodically (three programs have taken place till now – first in 1995, then in 2005, and third one is underway). Initially, models and satellite information are used to locate windy sites and accordingly dedicated masts with multilevel instrumentation are used for further investigation.

Table 6.1: District-wise Installed Capacity of Wind Power Technology in MW in Maharashtra

Sl. No	District	Wind potential in MW	Installed Capacity in MW	Installed Capacity as % of potential
1	Nashik	954.65	101	10.58
2	Satara	931.23	1176.24	126.31
3	Pune	843.10	106.4	12.62
4	Ahmednagar	794.15	233.85	29.45
5	Beed	616.65	56.95	9.24
6	Kolhapur	430.72	4.25	0.99
7	Dhule	229.54	535.25	233.18
8	Nandurbar	210.00	313.75	149.4
9	Sangli	155.66	813.97	522.92
10	Total	5165.7	3386	62.25

Data Source: MEDA, 2013; Personal Communication with NIWE on January 24, 2015 for wind potential data

Given the highly skewed utilization of wind potential as shown in Table 6.1, as expected, there is no correlation between wind potential and installed capacity of WPT in Maharashtra (correlation coefficient being -0.0952). This suggests that there can be factors along with wind potential that are influencing the location choices of firms in Maharashtra for adopting WPT. Literature (kindly see section 6.2) has highlighted some of the factors which influence the location choices of investors for WPT projects around the World.

Identification of factors governing the location choices of firms for adoption of WPT in a leading State like Maharashtra would help in addressing the barriers which hinder the exploitation of available wind potential in the State. This is turn would contribute in diffusion of WPT at macro (country) level which is necessary because international comparative analysis conducted in Chapter 4 reveals that WPT diffusion in India would be reaching its saturation limit (MW) in 2019. This saturation limit is lower than the capacity target set by India (GoI, 2012) and far less than the actual wind potential available (49 MW) in India (MNRE, 2015). Hence, micro level study of factors impacting the location choices of firms would help in achieving the wide spread diffusion of WPT in Maharashtra and elsewhere too contributing to growth of WPT in India.

Thus the present chapter looks into: whether *local differences have any influence on the decision of firms to adopt WPT?*

To address the above questions, a case study methodology was adopted and semi-structured interviews were conducted with firms investing in WPT projects in Maharashtra to identify the factors influencing the decision of firms to invest in WPT at a location within the State. A literature review as given in section 3.4 is carried out in order to understand the basic factors influencing location choices of firms in many regions across the World. To summarize, wind potential as indicated by wind speed has an influence in terms of power generation from WPT project and land requirement. Societal opposition to WPT projects is driven by NIMBY attitude where actual motivation for resistance is often not clear and also by damage to surrounding area during transportation of wind turbine components. The transportation in-turn is affected by limitations in existing infrastructure particularly in hilly areas and approach of local authorities in facilitating traffic across different administrative areas.

In order to find out whether the same factors also explain the skewed distribution of WPT in Maharashtra, a questionnaire was administered. Kindly refer to Appendix III for the questionnaire used in the study.

The remaining chapter is divided into four sections. Section 6.2 discusses about sample of firms interviewed for the study. Section 6.3 gives the procedure followed for data collection.

Section 6.4 describes the factors as pointed by firms during discussions. Section 6.5 concludes.

6.2 Sample Selection

Data available with the State Nodal Agency termed as Maharashtra Energy Development Agency (MEDA) shows that there are 31 developers (who actually have built or are building WPT project) and around 860 investors (who finance a WPT project) for WPT projects in Maharashtra as of 2013. From these, 15 developers were approached out of which three agreed for the interviews whereas 10 investors were approached out of which three agreed for the interviews (kindly refer to Appendix IV for list of developers and investors approached).

Table 6.2 gives the general information about the sample firms. Two out of these six firms are engaged in the business of WPT projects only whereas remaining four are diversified. From out of six, three firms have entered into business of WPT in Maharashtra since or before 2000 indicating an experience of more than a decade. Remaining three firms are relatively new having entered the business post 2005. Four out of six firms have invested in WPT projects in several other States of India including Gujarat, Madhya Pradesh, Tamil Nadu, Karnataka, Rajasthan, and Andhra Pradesh. The share of WPT projects in Maharashtra by these four firms varies from 20 per cent to 38 per cent. This makes it interesting to understand as to what factors they are looking into Maharashtra while developing a WPT project. Cumulatively, these six firms contribute to over 50 per cent of the installed capacity of WPT in Maharashtra thus the preferences crucial for the present study.

Table 6.3 shows the district level contribution of the sample firms in WPT capacity in Maharashtra. Interestingly, four firms have chosen Satara to install more than 50 per cent of their total power capacity of WPT. Five out of six firms have shown preferences for more than one district and have installed more than 90 per cent of the installed capacity in the leading five districts, namely – Satara, Sangli, Dhule, Nandurbar, and Ahmednagar. Hence, it would be interesting to understand what factors have influenced their choices of selecting a particular district to install a WPT project.

Table 6.2: General Information about the Sample Firms as of 2014

Firm	Inc. Year	Diversified	Year of Entry into Wind Sector in Maharashtra	Active in Wind Sector Other States (No.)	Installed Capacity of Wind in Maharashtra in MW (% share of Total Wind Capacity in India)
A[2,3]	1995	No	1997	Yes (7)	1690 (20)
B[1]	1911	Yes	1999	Yes (5)	176 (38)
C	1930	Yes	2000	No	65 (100)
D	2007	No	2011	Yes (3)	272 (25)
E[2]	1987	Yes	2012	Yes (3)	106 (33)
F	2008	Yes	2012	No	10 (100)

Notes: [1] - Firm is also engaged in the business of generating power using conventional energy sources and other RNE sources in five other States of India and three other developing countries.
[2]- Firm is engaged in manufacturing of wind turbines as well.
[3] - Firm has WPT projects in over 30 countries across five continents.
Data Source: Firms' interviews; their annual reports; MEDA, 2013

Table 6.3: District-wise Contribution of Sample Firms in Wind Power Technology

Firm	No. of Districts having WPT projects	Chosen Districts (≈ % Share of WPT installed capacity of firm's total WPT capacity in Maharashtra)
A	2	Satara (69), Ahmednagar (31)
B	3	Satara (55), Ahmednagar (39), Dhule (6)
C	9	Dhule (28), Satara (25), Nandurbar (20), Sangli (18), Nashik (5), Ahmednagar (4)
D	2	Sangli (70), Satara(30)
E*	1	Beed (100)
F	2	Satara (97), Sangli (3)

Note: Firm E is currently developing another WPT project near Bhimashakar in Pune district.
Data Source: MEDA, 2013; interviews with firms

6.3 Data Collection Procedure

The discussions were carried using semi-structured interviews with these six firms between February 2014 and November 2014. In person interviews were conducted with firms having major share in the WPT projects in the State and with firms located in Mumbai. All the interviewees were guaranteed anonymity so as to obtain frank opinions during discussions. Based on the inputs, additional data (both of qualitative and quantitative nature) was gathered from multiple sources including: personal communication with government agencies at State and central levels administering the energy sector of the State, secondary sources like regulatory orders enacted by regulatory body, study reports by government appointment committees and environmental activists, socio-economic review reports for districts, and local newspaper articles.

6.4 Results and Discussion

Five factors – namely, geographical, technological, infrastructural, societal, and bureaucratic – have emerged as a result of semi structured interviews with these sample firms. These factors seem to have influenced location choices of firms for adoption of WPT in a district of Maharashtra. Each factor is discussed in detail as follows.

6.4.1 Geographical

Firms opined that districts with high wind potential are preferred. NIWE has published a map indicating 49 potential locations (sites) suitable for WPT projects in nine districts of Maharashtra (Appendix V). Accordingly, most of the developers have chosen to use locations as declared by NIWE. However, some of the sample firms had identified new locations based on improvement in wind resource mapping techniques. These firms suggested that more of such new windy sites have been identified in districts like Satara, Sangli, and Dhule. In fact, telephonic discussions with a policy maker revealed that there are around as many new sites discovered by firms as those declared by NIWE. Unfortunately, these windy sites are not incorporated by NIWE while estimating the wind potential. Accordingly, as seen earlier, there is a huge disparity between installed capacity and wind potential for districts like Sangli, Dhule, and Satara (Table 6.1).

Further a firm opined that due to increasing difficulties in getting land, investors prefer large size turbine to install maximum MW on minimum land

Table 6.4 shows the district-wise average size of wind turbines installed in Maharashtra. Also, data from CECL (2013) shows that in Satara district when WPT diffusion started since 1997, almost 50 per cent of the turbines deployed are of sizes less than or equal to 500 kW. On the other hand, in Ahmednagar, where deployment began post 2006, more than 85 per cent of the turbines deployed are of size greater than or equal to 800 kW. Dhule, where 90 per cent of the turbines have been deployed post 2005, has more than 85 per cent of the turbines of size greater than or equal to 1250 kW. A firm argued that, along with land availability, lower land prices in districts like Beed, Ahmednagar, and Latur have also played a crucial role in attracting WPT installed capacity in those districts[36].

Table 6.4: District-wise Average Size of Wind Turbine Installed in Maharashtra

District	Average Size of Wind Turbine (Std. Deviation)	No. of Wind Turbines
Satara	0.750 (0.53)	1666
Sangli	1.3 (0.52)	648
Dhule	1.2 (0.27)	429
Nandurbar	0.8(0.2)	213
Ahmednagar	1.4(0.16)	285
Pune	0.8(0)	133
Nashik	1.4(0.35)	72
Beed	0.7(0.66)	71
Kolhapur	0.85(0)	5

Data Source: MEDA, 2013

6.4.2 Technological

All the firms pointed out that they carried out micro-siting exercise to forecast the power output in terms of Plant Load Factor (PLF) from a WPT project. PLF is an important variable contributing to Internal Rate of Return (IRR) of a WPT project. This is because the revenue from a WPT project is generated based on tariff which is in turn is offered on PLF. Table 6.5 shows that the power sector regulator of Maharashtra too has mandated on maintaining a certain minimum PLF and tariff based on wind power density since 2010 (MERC, 2010).

[36] In fact, to substantiate that less land less land availability is forcing firms to opt for high rating turbine – one needs to compare turbine rating installations per sq. km of poor vs. rich districts – rich districts means land prices are more and poor districts means land prices are less. However, data on land prices couldn’t be obtained at district level.

Firms stated that sites having more expected PLF are preferred considering the variability of wind resource.

Table 6.5: Norms for Plant Load Factor for Wind Power Technology in Maharashtra

Annual Wind Power Density (Watts/m^2)	**Minimum Plant Load Factor (%)**	**Tariff* (Rs./kWh)**
200-250	20	5.52
250-300	23	4.85
300-400	27	4.05
> 400	30	3.8

Note: Figures for tariff are average of tariff offered with and without accelerated depreciation benefit.
Source: MERC, 2010

Interestingly, PLF at aggregate level too offers interesting insights. Data from BP Statistical Review shows that there is a considerable variation in PLFs across various countries. As can be seen from Table 6.6, USA has maximum average PLF whereas India and China have lowest average PLFs. Accordingly, it can be implied that perhaps PLF is an important factor of decision making at country level too.

Table 6.6: Variation in PLF across Top Five Leading Countries

Country	**Minimum PLF**	**Maximum PLF**	**Average PLF**	**Std. Deviation**
USA	16.3	31.5	24.2	3.8
China	10.6	20.6	16.4	3.5
Germany	13.7	20.4	16.8	2
India	12	19.9	16.5	2.5
Spain	16	27.8	22.7	2.4

Data Source: BP, 2015

6.4.3 Infrastructural

All firms opined that locations which have substations, nearby dedicated for WPT, are convenient to evacuate the power generated using WPT. In case of absence of substation in one of the districts, a developer had to erect as long as 170 km long EHV lines from pooling substation which not only increases risk of technical losses but also increases project cost drastically. Table 6.7 gives the data obtained from Maharashtra State Load Dispatch Centre (MSLDC) on substations dedicated for WPT within Maharashtra. The data thus obtained shows that leading districts in terms of WPT installed capacity are also leading in number of substations also. For example, Satara has maximum (17) substations followed by Sangli (12) and Dhule (6). Whereas Beed which has hardly received any WPT projects doesn't have any substation dedicated for WPT.

Table 6.7: District-wise Number of Substations for Wind Power Projects in Maharashtra

Sl. No.	District	No. of Substations	Installed Capacity (MW)
1	Satara	16	1176.24
2	Sangli	12	813.97
3	Dhule	6	535.25
4	Ahmednagar	4	233.85
5	Nandurbar	1	313.75
6	Kolhapur	1	4.25
7	Pune	1	106.4
8	Nashik	0	101
9	Beed	0	56.95

Data Source: Personal Communication with State Load Dispatch Centre of Maharashtra

Prominent developers like Suzlon, Vestas, and Wind World have their manufacturing facilities in other States including Tamil Nadu, Diu Daman, Gujarat. The preferred mode of transportation of wind turbine components to a location in Maharashtra is by road. The longest pieces to be transported are rotor blades and tower which are transported in trailer. Blades in particular being delicate and very long require wide and straight road. Firms opined that considering the high costs involved in inter-State transport, remote locations of windy sites, and nature of wind turbine components; locations in the vicinity of the highways (State and national) are preferred.

6.4.4 Societal

Firms claimed that often the time spent on negotiations with communities in land acquisition is lesser compared to time and efforts required to deal with resistance from the same communities. It is evident from the fact that Asia's largest wind farm (of capacity 1000 MW) is embroiled in a raging controversy in Sakhri Taluka of Dhule district in Maharashtra, on the issue of forcible private land acquisition by the administration.[37] The issue began when Maharashtra State government enacted Renewable Energy Comprehensive Policy which has allowed diversion of forest land for establishment of WPT projects. However, while creating the above favourable policy for WPT, an important land related policy termed as Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act 2006 was overlooked which was meant to regularize the said land in tribal people's name.[38] Accordingly, tribals in Dhule aggressively opposed construction and operation of the wind farm.

Local opposition due to transport of wind turbine components causing damage in surrounding area is relevant for Maharashtra as well. Firms revealed that many WPT projects have been shifted from one district to another because of Right-of-Way (ROW) issue put forward by local communities[39]. Some of the firms suggested that ROW issues arise because of damage caused to village area during transportation and construction of WPT projects. During our field trips also, considerable damage to the surrounding area of WPT projects and to the approach roads was observed.

In this regard, Madhav Gadgil and others of the Indian Institute of Science, Bengaluru, have studied WPT projects in Maharashtra for the Western Ghats Ecology Expert Panel (WGEEP). The roads running at the crest line of the mountain cause huge amounts of erosions. To get these 70-80 meter high wind towers up you need the same kind of cranes used for constructing high-rises. Because of this the roads are built 13-16 meters wide using bulldozers and blasting, in an ecologically sensitive area. There has been no effort to fix hill-sides that were cut to make the road. This has led to heavy erosion and land-slides during and after the monsoon with the rubble ending up in rivers and farmland below (Gadgil *et al*., 2011).

---

[37] *Source*: http://docs.wind-watch.org/downtoearth.html [accessed on April 30, 2015]

[38] *Source*: http://www.thehindu.com/todays-paper/tp-national/forest-land-diverted-for-wind-energy-projects / article1812465.ece [accessed on October 25, 2014]

[39] A right-of-way is a right to make a way over a piece of land, usually to and from another piece of land. A right of way is a type of easement granted or reserved over the land for transportation purposes, this can be for a highway, public footpath, rail transport, canal, as well as electrical transmission lines, oil and gas pipelines (Black, 2014).

Interestingly, eight out of nine districts with wind potential (except Beed) are located along Western Ghats.[40] In light of such studies, there is a growing demand for strict green norms including Environmental Impact Assessment (EIA) for WPT projects in India (CSE, 2013).

Apart from local residents, there is an increasing opposition to WPT projects in Maharashtra from environment activists too. For example, Ela Foundation, a Pune-based organisation working on nature conservation, undertook a two-year study to assess the impact of WPT projects on birds. The study also documents the avian diversity at Bhambarwadi Plateau in the northern Western Ghats. The study found that out of 89 avian species were found on the plateau, 27 flew in the risk area swept by the rotor blades, and hence are potentially at risk of collision (CSE, 2013).

6.4.5 Bureaucratic

All firms indicated that bureaucratic procedure has played an important role in facilitation of forest land for WPT projects in Maharashtra. Table 6.8 shows that currently around 1330 hectare of forest land in Maharashtra has been allocated for WPT projects[41] which contribute around 38 per cent of installed capacity of WPT in Maharashtra.

Table 6.8: Status of Forest Land Diverted for Wind Power Technology in Maharashtra

Total Forest Land Diverted in Hectares	**Wind Installed Capacity on Forest Land in MW**	**Total Wind Installed Capacity in MW**	**≈ % of Total Wind Capacity on Forest Land**
1331.7	1323.9	3386	38

Source: CSE, 2013

[40] *Source*: http://westernghats-paimohan.blogspot.in/2008/07/geopolitical-profile.html [accessed on June 2, 2015]

[41] Ministry of environment and forests (MoEF) data since 1980 reveals that 3,932 hectares of forestland have been diverted for WPT — this is excluding the forestland diverted for roads and transmission lines to and from WPT project sites. About 88 per cent of total forestland diverted for wind projects has taken place in Karnataka (57 per cent) and Maharashtra (31 per cent) (CSE, 2013).

A firm suggested that networking with local politicians is essential to get the forest land license quickly. This is because the license to use the forest land for WPT projects is granted either by State government or Central government depending on the size of land proposed by firm (CSE, 2013). Some firms opined that due to increase in societal issues on private land, forest land is increasingly being preferred. This is because once the licence for forest land is granted; it can be used for 30 years with legal protection from State. The favourable approach of government is evident from the study by CSE (2013) which shows that forest land throughout India - particularly in Karnataka and Maharashtra – diverted for WPT projects from 2006 to 2013 is nine times than that diverted from 1980-2006. Further their analysis shows that in-principle approvals took less than one month and the average time for final clearance was 7.5 months[42].

Increasing preference for forest land is not only manifested from bureaucratic support but also from the increasing issues on private land. All firms stated that private land acquisition takes minimum 6 months and involves more complications such as identification of land owners, land demarcation, and negotiations with land owners followed by legal formalities. Figure 6.2 gives the summary of the procedures followed by the top six firms engaged in developing WPT projects in Maharashtra.

Though the procedure may look straightforward, it has led to severe complications in certain WPT projects. For example, local villagers in Kadve Khurd village in Satara launched a strong opposition to WPT project by Bharat Forge Ltd. of 4.2 MW around 2006 claiming forcible land acquisition by the company. The project occupies largely devottar or temple properties and privately held farmland. The deal for these lands was struck with a village headman whose family has been traditionally holding the land on behalf of the villagers. The villagers had old colonial-era documents dating back to the 19th century but no ‘official’ and ‘new’ title to the land. Accordingly, the company did not compensate them. The local administration refused to hear the villagers’ case, and in vain they sought justice from the Collector’s Court in Pune.

---

[42] The forest clearance process is a two-stage process with an in-principal approval first, followed by a final approval given after funds for reforestation have been submitted by the project proponent (CSE, 2013).

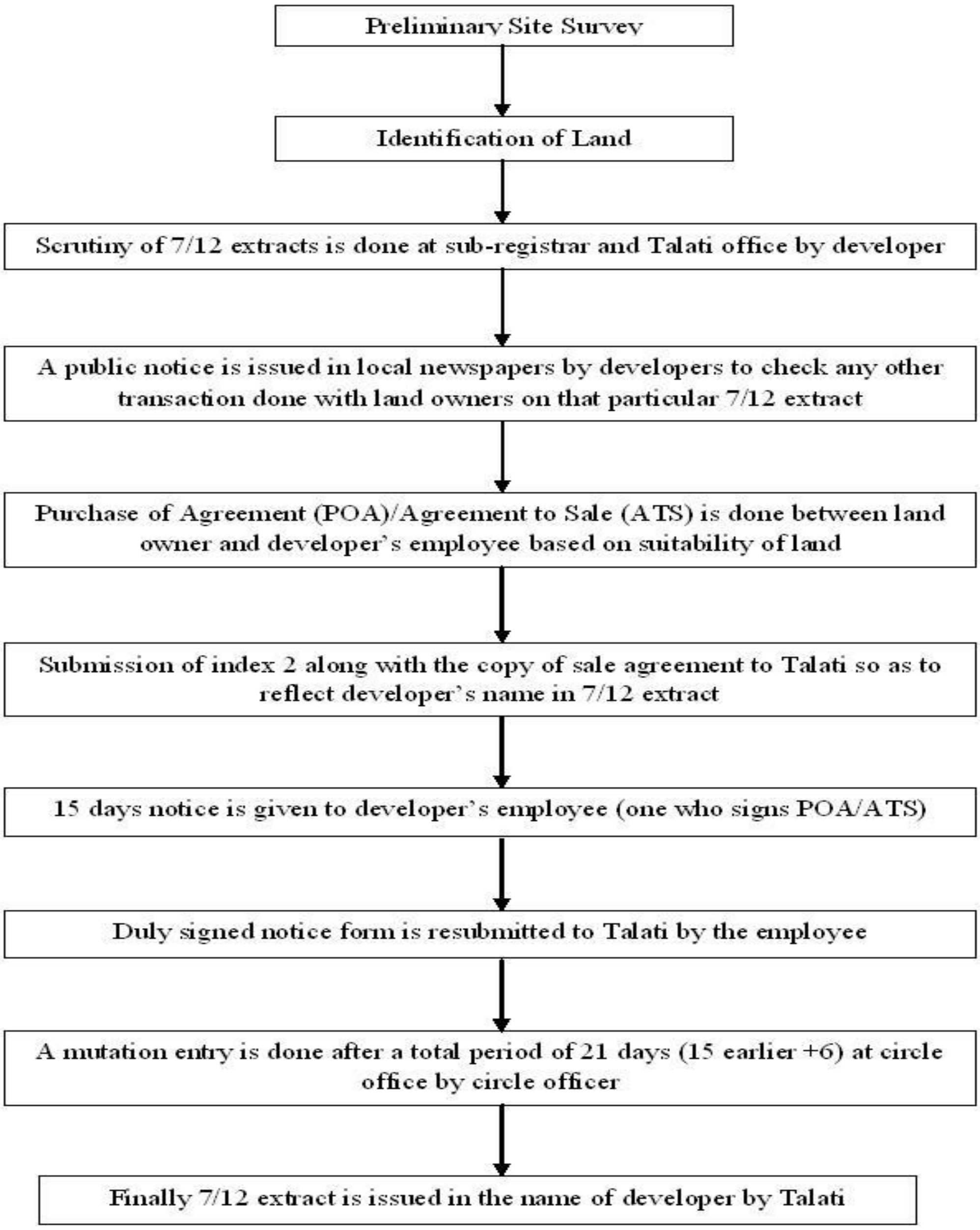


Figure 6.2: Process Flowchart for Acquisition of Private Land for Wind Power Projects in Districts of Maharashtra

The Collector refused to stop construction of the wind turbines and annulled a motion to that effect that had been passed by a lower court.[43]

Another issue with respect to private land arose in 2010 when the gram-panchayats of Satara passed an order demanding a property/ building tax on wind farms under the Bombay Village Panchayats Act, 1958 and the Maharashtra Village Panchayats Taxes and Fees Rules, 1960[44]. The cost is of the magnitude of around 76,000 Rs. /turbine. Suzlon and 29 other developers have filed petitions claiming that Act doesn't envisage any such tax payable on a wind turbine per se.[45]

Apart from the opposition from local administration discussed above, the MNRE and State government have acted favourably in dealing with societal opposition to WPT projects. For example in 2013, MNRE officials visited six sites in India including three sites located in Satara, Ahmednagar, and Pune to investigate the ecological impacts of WPT projects as claimed by environmental activists. Though it was found that ecological impacts including soil erosion, tree cover loss for farm, tree loss for building of access roads, and natural habitat loss are evident in all three sites located in Maharashtra, overall the report concluded that these changes are reversible and can be mitigated by proper environment management programme. Further the report concluded that since WPT projects are established far from habitations, impact on local resources is minimal and local economy in fact can experience growth due to project linked activities (MNRE, 2013). The report stressed that development of RNE projects must be continued and existing conflicts regarding environmental or social impacts can be addressed by appropriate policy changes (*ibid*).

---

[43] *Source*: http://www.carbontradewatch.org/multimedia/en/category/photo-essays/carbon-market-crimes / blown – away -wind-energy-projects-in-satara-maharashtra-india [accessed on March 21, 2014]

[44] Gram panchayats have raised exorbitant property tax demands ranging from Rs. 5,03,895 in one village to Rs. 1,40,25280 in another village within the same district (http://www.dnaindia.com/india/report-wind-power-giant-petitions-bombay-high-court-against-panchayat-order-1392426) [accessed on March 20, 2014].

[45] *Source*: http://www.dnaindia.com/india/report-wind-power-giant-petitions-bombay-high-court-against-panchayat-order-1392426 [accessed on March 20, 2014]

6.5 Conclusions

To summarize, a case study methodology was adopted to identify the factors influencing the location choices of firms while adopting WPT in a district of Maharashtra. A literature review was performed to identify the initial factors for initiating the research. These initial factors included wind potential, societal attitude, quality of transport infrastructure, and approach of local administration. Interestingly, our analysis has found relevance of all the above factors and additionally some new factors have emerged to be influencing location choices of firms. For example, evacuation infrastructure in terms of number of substations and peer influence in terms of installed capacity in a district have been found to influence the firms' decisions. Ultimately, five broad factors – namely geographical, technological, infrastructure, societal, and bureaucratic – have been proposed from the semi-structured interviews with six firms contributing to over 50 per cent of the installed capacity of WPT in Maharashtra[46].

In order to validate the identified factors and measure their influence on diffusion of WPT in districts of Maharashtra, next chapter carries out an econometric analysis conducted using quantification of the identified factors.

[46] The sample size of six firms is certainly a limitation given the large population of 860 investors and more than 40 developers investing in WPT in Maharashtra. However, as discussed in section 6.2, the selected firms do represent location choices of overall population and hence their preferences are relevant for the current study.

Chapter 7

Diffusion at Micro Level: Validation of Factors

7.1 Introduction

The previous chapter using semi-structured interviews of firms using wind power technology (WPT) has identified five factors - namely, geographical, technological, infrastructure, societal, and bureaucratic - to be influencing location choices of firms to adopt WPT in Maharashtra. This chapter follows from the earlier chapter and deals with empirical validation of these factors. The purpose of the chapter is to test and measure the influence of the identified factors using quantitative techniques, in particular econometric techniques. Such an analysis would facilitate in generalizing the claims made in the previous chapter.

In order to perform the econometric analysis, indicators are constructed for each of these five factors. For example, number of substations and length of highway for transportation comprised infrastructure factor for WPT projects. Also, wind potential indicates geographic factor. Under technological factor, expected Plant Load Factor (PLF) is the indicator. Capacity addition in a district is chosen as an indicator of location choices of firms. Indicators for remaining factors – namely, societal and bureaucratic - have been constructed as discussed later. Using these indicators, panel data techniques were deployed to test and measure the influence of indicators.

The remaining chapter is divided into five sections. Section 7.2 describes the modelling framework and hypotheses formulation. Section 7.3 describes data and variables used in this study. Section 7.4 shows with the descriptive statistics of the proposed indicators. Section 7.5 gives the results followed by discussion in the section 7.6. Section 7.7 concludes.

7.2 Modelling Framework and Hypotheses

Using the identified factors with corresponding indicators for each of them and controlling for Per Capita net District Domestic Product (PCNDDP), a framework is developed in the form of a fish bone diagram (also termed as cause-and-effect diagram) as shown in the Figure 7.1. As can be seen, five factors represent the bones (causes) and indicators represent smaller bones (sub-causes). We argue that these indicators lead to location choices of firms (effect) indicated by capacity addition of WPT in a district of Maharashtra.

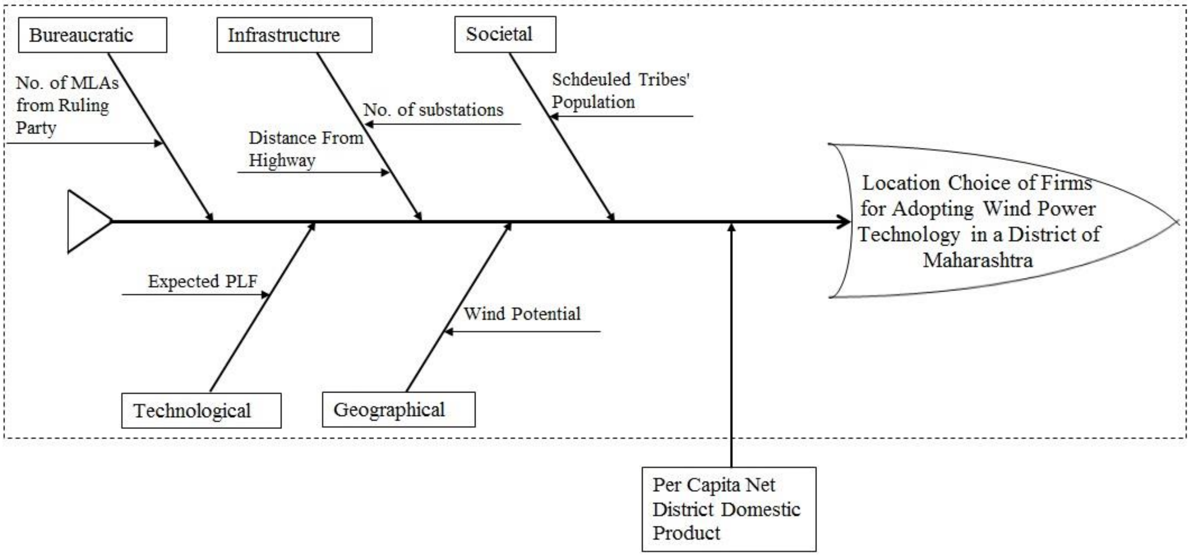


Figure 7.1: Fishbone Diagram for Location Choices of Firms to Adopt Wind Power Technology in a District of Maharashtra

Regarding geographical factor, an interesting contrast was observed between firm's said preferences for locations with high wind potential and actual WPT capacity installed. Whereas, firms suggested that several new windy sites have been discovered in the leading districts, the interesting question is why districts with existing high wind potential (already declared by NIWE) have not received significant WPT capacity. In order to capture firms' tendency of repeatedly investing in few districts, a variable is constructed as difference between wind potential and installed capacity of WPT. A priori, this variable is expected to have a negative influence on capacity addition. Accordingly, we propose following hypothesis:

Hypothesis 1: Districts with more difference between wind potential and installed capacity are likely to receive less capacity addition than those with less difference.

Technological factor is indicated by expected PLF. Regarding expected PLF, as discussed in previous chapter, higher value of expected PLF at a location would incentivise the firms to build WPT projects. Hence, we propose following hypothesis:

Hypothesis 2: Districts with more expected PLF are likely to receive more capacity addition.

Infrastructure factor is indicated by number of substations dedicated for evacuation of power from WPT and distance of a site from highway. Of these, number of substations is expected to have a positive influence on capacity addition whereas distance from highway is expected to have a negative influence. Accordingly, we propose following hypotheses:

Hypothesis 3a: Districts with more number of substations are likely to receive more capacity addition.

Hypothesis 3b: Districts with less length of highways are likely to receive less capacity addition.

Societal factor is indicated by Scheduled Tribes' (ST) population (kindly see section 7.3). A priori, this factor is expected to have a negative influence on the capacity addition. Accordingly, the hypothesis is:

Hypothesis 4: Districts with more ST population are likely to receive less capacity addition.

Lastly for the bureaucratic approach, number of Members of Legislative Assembly (MLAs) of ruling party is chosen (kindly see section 7.3). A priori, this indicator is expected to have a positive influence on the capacity addition. Hence, the hypothesis is:

Hypothesis 5: Districts with more number of MLAs from ruling party are likely to receive more capacity addition.

In order to test the above hypotheses, quantitative approach using econometric analysis is followed. Data against each of the indicators is collected using various sources (kindly see section 7.3). Using these indicators and controlling for PCNDDP, following model is estimated.

$$CA_{i,t} = \alpha + \beta_1 x_{1,i} + \beta_2 x_{2,i} + \sum_j \beta_3 \, x_{3,j} + \beta_4 x_{4,i} + \beta_5 x_{5,i} + \beta_6 control_i + \varepsilon_{i,t}$$

Where, $CA_{i,t}$ is the capacity addition of WPT in a district, x_1 the wind potential – installed capacity, x_2 the expected PLF, x_3 the infrastructure factor indicated by number of substations and length of highway, x_4 the ST population, x_5 the number of MLAs from ruling party, control the PCNDDP, and $\varepsilon_{i,t}$ the error term comprising of two parts: a time invariant district effect (μ_s) and an independent and identically distributed (iid) random district-year term ($v_{i,t}$). β_i is the estimated parameter of i^{th} indicator and is predicted to have an influence on the capacity addition as per the hypotheses stated above.

For the given objective, there exist a variety of estimation models. A simple pooled Ordinary Least Squares (OLS) model would yield biased and inconsistent parameters if time invariant covariates are omitted. A Fixed Effect (FE) model will provide a consistent and unbiased estimate of the parameters while simultaneously controlling for unobserved unit heterogeneity if omitted time-invariant variables are correlated with the indicator variables. On the other hand, if these omitted time-invariant variables are uncorrelated with the indicator variables, a Random Effect (RE) model would provide a more efficient estimate than FE model. Hausman test validates these assumptions.

7.3 Data and Variables

This section describes the quantification of the factors in terms of indicator variables for the purpose of econometric testing. Some of the quantitative indicators of the three factors were obtained during discussions with firms. These factors include technological perceptions indicated by expected PLF and installed capacity of WPT, and infrastructure quality indicated by number of substations and length of highways. In order to indicate location choices made by firms for adoption of WPT, capacity addition of WPT is chosen.

For bureaucratic approach, the previous chapter discussed that WPT projects have received a favourable support from both State and central government. Particularly, the State has powers and responsibility to implement policies and ensure growth of RNE technologies. The State government in turn has chosen local MLAs to implement RNE projects under Renewable

Energy Policy 2005[47]. On the other hand, interest of MLAs in the WPT projects in Maharashtra has become evident from some cases particularly in Dhule, Nandurbar, and Satara. In Dhule and Nandurbar, for example, the State committee was formed in 2009 after complaint was filed by MLAs from opposition party. On the other hand in Satara, MLAs have been alleged to have a substantial share in one of the WPT projects.[48] Accordingly, in view of the favourable support of State in promoting WPT and involvement of MLAs as discussed above, MLAs from ruling party can be considered to indicate the positive support to WPT projects in a district. A priori, this indicator is expected to have a positive influence on capacity addition of WPT.

In order to capture societal attitude towards WPT, population of Scheduled Tribes' (ST) population has been chosen. ST population is expected to capture the opposition to WPT projects particularly on forest land. As discussed in previous chapter, there had been instances where a legal provision regarding land ownership of ST has been overlooked resulting into strong opposition to WPT projects in some districts. For example in 2005, Satyashodhak Gramin Kashtakari Sabha took out a morcha in Sakri Taluka in Dhule to protest against land allocation to WPT projects. They demanded the land be regularized in STs' name under Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act 2006.[49]

Regarding transport infrastructure, since firms preferred to locate a WPT project near highways; length of State plus national highway has been taken as an indicator. A priori, this variable is expected to have a positive influence on capacity addition.

---

[47] Members of Parliaments (MPs) and Members of Legislative Assembly (MLAs) in Maharashtra as elsewhere can implement various small scale RNE projects in their constituencies (both urban and rural areas) through active utilization of MP and MLA Local Area Development (LAD) funds. Besides, they can also demonstrate suitable examples in provision of lighting, cooking, water and other services through RNE in line with the recent initiatives like the Sansad Adarsh Gram Yojana (SAGY) and other national and State level schemes. The success of such RNE led integrated community projects will help with scaling up efforts throughout the rural districts and eventually across the State (Rao *et al*., 2014).

[48] *Source*: http://www.thehindu.com/news/national/other-states/congress-mlas-brothers-booked-in-satara-blast-case/article6775551.ece [accessed on May 20, 2015]

[49] *Source*: http://www.thehindu.com/todays-paper/tp-national/forest-land-diverted-for-wind-energy-projects / article1812465.ece [accessed on September 23, 2014]

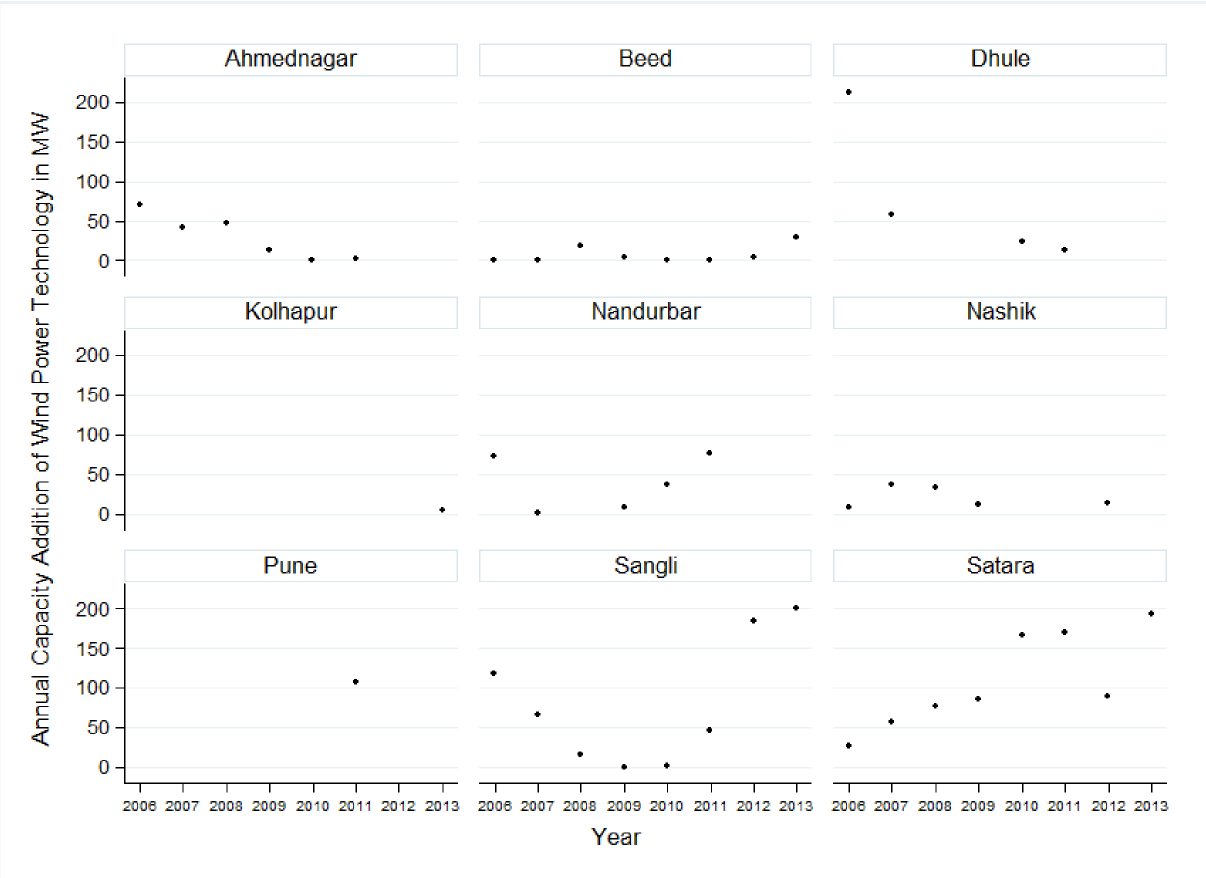
Data against each of the indicators is gathered at district level using secondary data sources. The data sources include government agencies at State and central levels including MEDA (for number of locations with wind speeds to compute expected PLF for a district – kindly refer to Appendix VI for procedure followed for computation), State Load Dispatch Centre (SLDC) (for number of substations), and NIWE (for district level potential estimates). Secondary data sources include like statistical report on general election of Maharashtra legislative assembly (for number of MLAs form ruling party), socio-economic review reports for districts (for ST population, and length of highway). In order to control for district specific differences, per capita net district domestic product has been taken. Table 7.1 shows the data source for each of the factors along with its expected sign. Data for all the factors has been collected for the period 2006-2013 and organized at district level for nine districts with significant wind potential.

Table 7.1: Summary of the Selected Indicators with the Data Sources and Expected Sign

Factor	Indicator	Data Source	Expected Sign
Location Choice	Capacity Addition in a District (MW)	MEDA	
Geographical	Wind Potential	MEDA, Personal communication with NIWE	+
Technological	Expected PLF (%)	MEDA	+
	Installed Capacity (MW)	MEDA	+
Infrastructure	Number of Substations (No.)	Personal communication with Maharashtra State Load Dispatch Centre	+
	Length of Highway/ Total Road Length	District socio-economic review reports	+
Societal	Scheduled Tribes Population/ Rural Area	District socio-economic review reports	-
Bureaucratic	MLAs from Ruling Party/ Total No. of MLAs	Statistical report on general election to the legislative assembly of Maharashtra	+

7.4 Descriptive Statistics

The data obtained through various sources as discussed above shows that districts vary significantly in terms of the selected indicator variables. Figure 7.2 gives trend of dependent variable - capacity addition - in nine districts selected for the study. Dhule received highest capacity addition of WPT of 212 MW in 2006 among all districts in all years. However since then, it received capacity addition in only three years including 2007 (58.6 MW), 2010 (23.1 MW), and 2011 (12.6 MW) which is relatively quite low compared to that in 2006. Nandurbar received significant capacity addition in three years including 2006 (72.5 MW), 2010 (37.15 MW), and 2011 (76.65 MW); whereas Nashik has received significant capacity addition in four years including 2007 (35.9 MW), 2008 (33.3 MW), and 2012 (12.6 MW).



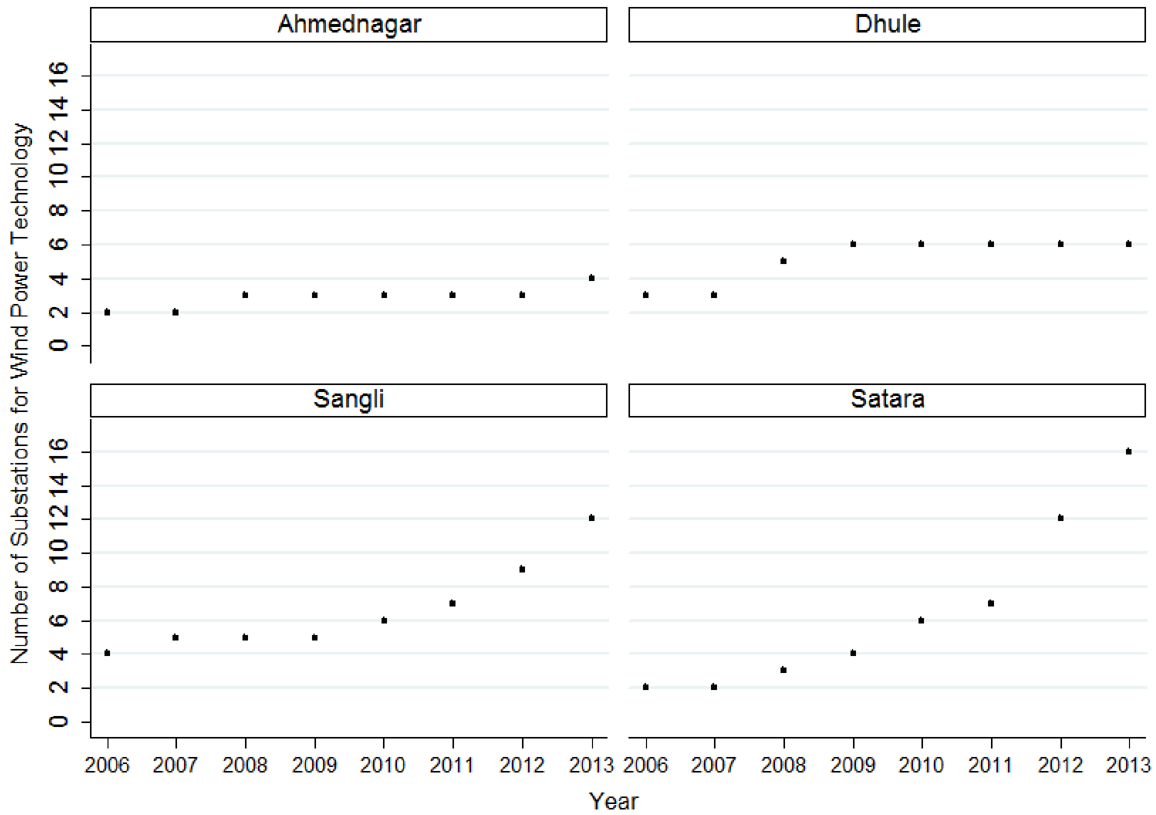
Note: * - The district received capacity addition for the first time in the period.

Data Source: MEDA, 2013

Figure 7.2: District-wise Capacity Addition of Wind Power Technology in Maharashtra

Figure 7.3 gives the trend of number in substations in four districts – namely, Ahmednagar, Dhule, Sangli, and Satara dedicated for evacuation of power from WPT. Among all these, Satara observed highest increase from two in 2006 to 17 by 2013 followed by Sangli from four in 2006 to 12 by 2013. Among remaining districts – Pune, Kolhapur and Nandurbar have one substation each built in 2011, 1990, and 2012, respectively. Beed and Nashik do not have substation for WPT.

Table **7.2** gives descriptive statistics of above variables along with the other variables. Among other variables, gap variable shows that installed capacity has exceeded corresponding estimated potential in four leading districts including Satara (126 per cent), Sangli (523 per cent), Dhule (233 per cent), and Nandurbar (149 per cent). On the other hand, expected PLF ranges from around 8 per cent (Pune) to around 23 per cent (Nandurbar). Rest of the districts have expected PLF between 16 per cent and 18 per cent.



Data Source: Personal Communication with Maharashtra State Load Dispatch Centre

Figure 7.3: District-wise Number of Substations for Wind Power Projects in Maharashtra

Table 7.2: Descriptive Statistics of the Selected Indicators

Variable Name	Description (unit)	Mean	Std. Deviation	Min	Max
CA	Capacity Addition in a District (MW)	33.83	55.14	0	212
GAP	Wind Potential - Installed Capacity (MW)	323.58	437.58	-658.31	947.45
PLF_EXP	Expected PLF (%)	17	4	8	23
NO_SUBSTA	No. of Substations (No.)	2.53	3.28	0	16
HIGHWAY	Length of Highway/ Total Length	0.13	0.02	0.1	0.17
ST_DENSITY	Population of Scheduled Tribes'/ Rural Area (Sq km)	51.61	71.47	1.99	252.28
MLA_GOVT	No. of MLAs from Ruling Party / Total No. of MLAs	0.49	0.2	0.17	0.88
PCNDDP	Per Capita Net District Domestic Product (in Rs. Crore)	42811.5	15185.81	23401.4	88585.4

Data Source: Own computation

7.5 Results

Before estimating the model, we study the correlation table as shown in Appendix VII. Correlation table reveals significant correlation between factors. Interestingly, gap between installed capacity and potential is correlated with the number of substations. Consequently, all the variables could not be used together in the analysis.

Table 7.3 gives econometric results of the selected model including variables representing maximum branches of the fish bone diagram. First we estimate the model by pooling the data for all the States (pooled Ordinary Least Squares - OLS). However, if there are time invariant omitted variables, the OLS results would be biased. Subsequently, both – FE and RE models were estimated. First, F test is performed to see whether individual fixed effects exist or not. Since F value (1.57) is greater than tabulated value at significance around 10 per cent level (13 per cent), null hypothesis was rejected (i.e. model is pooled OLS) and panel data techniques are needed. Columns 2 and 3 of Table 7.3 give FE and RE estimates. Whether these omitted variables (district specific differences) are fixed or random is tested using Hausman test as given in the last row. Since the Hausman statistic is not significant at 10 per cent level, RE model is preferred. To further confirm whether RE exists, we use additional test i.e. Breusch – Pagan Lagrange – Multiplier test. As Lagrange Multiplier (LM) value (3.42) is greater than critical value, we reject the null; hence there exists individual random effect.

Table 7.3: Variables Influecing Location Choices of Firms for Adopting Wind Power Technology in a District of Maharahstra (Dependent Variable = ln(CA))

Variable	**Pooled OLS (1)**	**FE (2)**	**RE (3)**	**RE (FGLS) (4)**
ST_DENSITY (per 100 Sq./km)	-1.923** (0.935)	-7.635 (11.95)	-2.398 (1.849)	-2.689** (1.062)
MLA_GOVT	9.967*** (2.825)	9.618** (4.369)	8.089** (3.496)	8.012*** (2.861)
GAP (‘00MW)	-0.217 (0.145)	-1.312* (0.658)	-0.430* (0.257)	-0.381** (0.162)
PLF_EXP	0.492* (1.450)	71.84 (395.0)	0.775 (2.606)	0.650* (1.708)
LN_PCNDDP	2.571 (3.586)	13.41 (10.64)	6.710 (5.482)	4.411 (3.957)
Year dummies	Yes	Yes	Yes	Yes
Observations	72	72	72	72
R-squared	0.316	0.27		
F –test/ Wald χ^2		0.13		
Number of Observations	72	72	72	72
Hausman test		**7.06 (0.854)**		

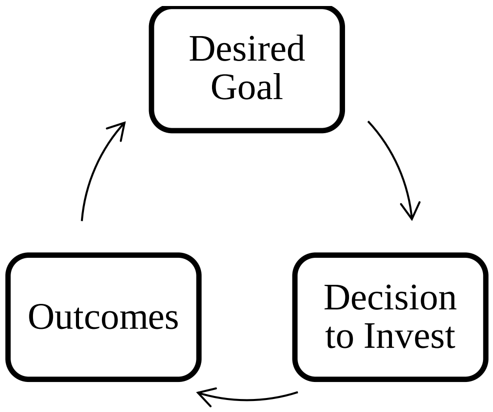
Note: * p<0.1; ** p<0.05; *** p<0.01
Data Source: Own computation

However, the use of panel data with different variables showing change over time, and consequently possibility of autocorrelation, necessitated the Wooldridge test for autocorrelation (where null is no first-order autocorrelation), which gives value 6.532 with probability less than 5 per cent level. This indicates that there exists autocorrelation and standard errors of coefficients to be smaller than they actually are, and corresponding high R^2. Cross-sectional dependence (also called contemporaneous correlation) can lead to bias in tests results. The null hypothesis is that residuals are not correlated and is verified by the test results. Also, modified Wald test is carried out in order to test for group wise heteroskedasticity. The chi-square value of 19.88 indicates the null of homoscedasticity (or constant variance) is rejected. Given the problems of heteroskedasticity and autocorrelation, we subsequently correct for it using Feasible Generalized Least Squares (FGLS) procedure (column 4 of Table 7.3).

7.6 Discussion

As can be seen from Table 7.3, four variables, namely – unmet capacity, ST population density, proportion of MLAs from ruling party, and expected PLF are statistically significant on their impact on capacity addition of WPT. All the variables have expected signs as per the hypotheses formulated earlier.

Based on the coefficient value, at the mean values of other variables, a 1 MW increase in difference in unmet capacity (difference between wind potential and installed capacity) from 559.7 to 560.7 would reduce capacity addition by around 3.5 MW. The negative influence of the coefficient demonstrates the tendency of investors to repeatedly invest in same locations irrespective of availability of other potential locations. This can be explained as follows. Initially some locations receive investment out of which few provide favourable outcomes. The outcomes may not only include technological success but also accumulation of local and technical knowledge of these locations by existing firms followed by its spread among next adopter firms. This in turn perhaps reduces the risk (as perceived by firms) associated with adoption of WPT at these locations and they are again preferred over alternate and new locations. As a result, a positive feedback loop where investment at a location brings returns and higher returns brings more investments at the location; a virtuous cycle is established as shown in Figure 7.4.



Source: Adapted from Qudrat-Ullah, 2014

Figure 7.4: A Feedback Loop Diagram for Investment Decisions

Such a finding also helps in establishing commonalities between investors in WPT sector and those in many other sectors, say real estate, automobile, jewellery, leather, or Information Technology (IT) where agglomeration of firms is quite common a phenomenon (Ramachandran and Ray, 2003; Patel, 2013). In Indian IT sector for example, Ramachandran and Ray (2003) analyse how Bangalore, Hyderabad, and Kolkata have emerged as software centres in India. Further, the large accumulation of WPT projects in few of the selected districts has resulted in increased local opposition. Table 7.4 and Table 7.5 present the summary of complaints filed by landowners and violations of land related laws in various districts of Maharashtra from 2006 to 2009, respectively[50].

The types of complaints made by land owners include cheating into sale of land, fewer prices than market prices, encroachment, damage to land, erection of electric poles, no consent of all co-holders, and damage to public roads As can be seen, most of the complaints (more than 99 per cent) are registered in leading districts including Satara and Sangli. On the other hand,

[50] The data shown is obtained during discussion with a policy maker. He revealed that post 2005 there has been a multi-fold rise in local disturbances to WPT projects in various projects. Owing to this, State government constituted a special committee including authorities from MEDA and Revenue and Forest Department. The committee in turn directed district collectors of various districts having WPT installed capacity to investigate the unrest regarding WPT projects in a twofold manner. First, details were gathered at district level regarding the cases of violations of various lands related Acts for WPT projects and second, details regarding the various complaints made by land owners with regards to land used for projects in WPT. The policy maker added that investigations regarding genuineness of these complaints are being investigated by the government and hence those details can't be divulged.

Satara and Ahmednagar comprise of around 75 per cent of the total cases of violations of laws related to land. This growing resistance and legal violations may have made further installations increasingly difficult in these districts causing diseconomies of scale.

Table 7.4: Summary of Complaints Recieved by District Collectors for Wind Power Projects in Maharashtra (2006-2009)

Sr. No.	District	Cheated farmers into sale of land	Received fewer prices for the land in the transfer transaction or less than the annual Market value Table (Ready Recknoer)	Encroached on lands of farmers and erected the plants	Damage to farmers land	Erection of electric poles in farmers land without his permission	Consent at all co-holders of the land is not obtained	Damaged public roads while erecting the project	Total
1	Satara	654	226	226	63	105	44	0	1318
2	Sangli	166	804	126	679	775	639	41	3230
3	Nandurbar	0	10	0	0	0	0	0	10
4	Nashik	8	0	0	0	0	0	0	8
5	Solapur	1	0	0	0	0	0	0	1
6	**Total**	**829**	**1040**	**362**	**742**	**880**	**683**	**41**	**4567**

Data Source: Personal Communication with Government of Maharashtra in 2014

Table 7.5: Summary of Violation of Rules Detected upon Investigating All Types of Land Transfers in Wind Power Projects in Maharashtra (2006-2009)

Sr. No.	District	Bombay Tenancy And Agricultural Lands Act 1948				Maharashtra Agricultural Land (LAND CEILING) Act 1961		Maharashtra Land Revenue Act 1966		Regarding inheritance (vatan)/ reward		Forest Conservation Act 1960 and Indian Forest Act 1927		Maharashtra Land Revenue Act (disposing of Government lands) 1971		Total No.	Total Area
		No.			Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area		
		Total	43 (A)	63(1)(A)													
1	Satara	4	4	0	15.46	0	0	207	517.8	0	0	6	2.99	0	0	217	536.3
2	Sangli	7	7	0	9.15	19	22.82	0	96.03	6	4.55	0	0	1	0.8	33	133.4
3	Ahmednagar	93	0	93	280.9	2	3.46	51	138.4	0	0	0	0	19	73.92	165	496.7
4	Dhule	0	0	0	0	0	0	0	0	0	0	13	64.56	0	0	13	64.56
5	Nandurbar	25	25	0	66.44	0	0	0	0	0	0	0	0	1	0.81	25	67.25
6	Nashik	35	0	35	49.14	0	0	19	41.63	0	0	0	0	0	0	54	90.77
7	**Total**	**164**	**36**	**128**	**421.1**	**21**	**26.28**	**277**	**793.8**	**6**	**4.55**	**19**	**67.55**	**21**	**75.53**	**507**	**1388.9**

Data Source: Personal Communication with Government of Maharashtra in 2014

Interestingly, our analysis too supports this theory as the density of ST population has a negative influence on capacity addition of WPT. Our results indicate that based on the coefficient value, at the mean values of other variables, a decrease of 10 per cent in ST population density from 3.71 to 3.34 would increase capacity addition by 10 MW.

Among other variables, proportion of MLAs from ruling party has a positive influence on the capacity addition of WPT. Based on coefficient value, at the mean values of other variables, based on coefficient value an increase of 10 per cent in proportion of MLAs rom ruling party from 0.83 to 0.91 would increase capacity addition by around 57 MW. Positive influence of MLAs of ruling party corroborates our hypothesis that districts under more control of the State have been preferred by firms. This support offered by State through MLAs can be in terms of faster processing of files, facilitation of clearances at various levels, and in dealing with local opposition for land acquisition as discussed in earlier chapter. For example, in 2010, it was alleged that a local MLA promised villagers a share of power generated from WPT project situated in Pune district.[51] In 2012, An MLA in Devgad village in Sindhudurg district claimed that wind turbines will contribute towards energy security and boost tourism.[52]

Lastly, expected PLF has a positive influence on capacity addition of WPT. Based on the coefficient value, at the mean values of other variables, a one percent increase in expected PLF from 17.92 to 18.92 would increase capacity addition by around 19 MW. Positive influence of PLF confirms the hypothesis that districts with more expected output as perceived by firms receive higher capacity addition.

7.7 Conclusions

The purpose of the chapter was to empirically validate the factors identified in earlier chapter regarding influence of local level differences on the decision of firms to adopt WPT in a district of Maharashtra. The factors identified using a case study methodology included geographical, technological, societal, and bureaucratic. In order to perform validation, quantitative indicators are used some of which were obtained during discussions with firms. These include wind potential for geographic factor, expected PLF for technological factor, and number of substations and length of highway for infrastructure factor. The present chapter constructs the indicators for remaining factors including societal and bureaucratic and describes the econometric analysis performed for validation. Scheduled Tribes' population is

[51] *Source*: http://www.downtoearth.org.in/content/wind-farm-threat-forests [accessed on June 2, 2015]

[52] *Source*: http://www.thegoan.net/story.php?id=621 [accessed on June 2, 2015]

chosen to indicate societal factor, number of MLAs from ruling party is chosen to indicate bureaucratic factor, and length of highways is chosen to indicate transport infrastructure.

Data for each of the indicators from 2006 to 2013 is collected using various secondary sources for nine districts with significant wind potential. These nine districts include Satara, Sangli, Dhule, Nandurbar, Ahmednagar, Pune, Nashik, Beed, and Kolhapur. Our analysis using panel data techniques shows that four factors, namely – geographical, technological, social, and bureaucratic influence the decision of firms to adopt WPT at a location in a district of Maharashtra. Among these, geographical, technological, and bureaucratic have positive influence whereas societal factor has negative influence. Interestingly, a positive feedback loop (where investment at a location fetches better returns which in turn leads to higher investment at the same location) or agglomeration effect is dominant in development of WPT in Maharashtra. At the same time, diseconomies of scale because of agglomeration become evident from the data obtained from the State government with respect to the local opposition and illegal land acquisition.

Chapter 8

Conclusions and Future Work

8.1 Introduction

Growth of Wind Power Technology (WPT) across the World is phenomenal in the last few decades. Several policy mechanisms have been introduced by many countries. A developing country like India despite being faced with dual challenge of energy security and carbon footprint has made its mark in WPT adoption. Given the importance of promoting Renewable Energy (RNE) deployment in general, and the high financial costs often associated with policy support, it is essential for the governments to know how policies are contributing to diffusion of WPT in actual vis-à-vis the expectations. Also, an understanding of underlying factors responsible for adoption of WPT by firms is essential to design and implement policy mechanisms. Accordingly, present thesis is an effort to see the impact of policies causing diffusion at macro (aggregate) level and identify factors driving choice of adoption at micro (firm) level using theories of diffusion of innovations.

In order to achieve the objective, the study had formulated three research questions –

1. *Is WPT diffusion pattern same across countries?*

2. *What role policies play for diffusion of WPT across States of India?* and lastly,

3. *Whether local differences have any influence on the decision of firms to adopt WPT?*

8.2 Conclusions from Different Chapters

This section gives in brief the conclusions from different chapters of the thesis. At macro level, study involved modelling impact of policies on diffusion of WPT in two stages as stated by the first two research questions. Whereas for micro level analysis stated by third research question, a primary survey of key developers was carried out in the State of Maharashtra in India to understand the preferences of firms while choosing a location to install a WPT project.

8.2.1 Diffusion at Marco Level: International Comparative Analysis

For the first research question, comparative analysis of impact of policies on diffusion of WPT across five leading countries - namely China, USA, Germany, India, and Spain - was performed to identify successful policies. Together these countries have consistently contributed to around three-fourth of the World's total WPT capacity for more than 15 years. Accordingly, cumulative data on WPT installations for the period 1980 to 2012 is collected and non-linear regression was performed using three diffusion models - Gompertz, Logistic, and Bass - for each country. Consequently, one specific model for each country was selected using statistical inference and model parameters were justified with corresponding policy initiatives in the respective country. Based on the chosen model, the study also identifies the corresponding saturation point of diffusion for each country.

Our analysis yields that China, USA, and Spain follow Bass model, whereas Germany and India follow Gompertz and Logistic model, respectively. Our analysis also showed that policies like Wind Power Concession Programme in China in 2003, Energy Policy Act in USA in 2005, Renewable Energy Supply Act in Germany in 1990, and Electricity Act in

India in 2003 acted as catalyst to propel diffusion of WPT in these countries. In particular, successful policies that attracted the diffusion of WPT are: quantity based instruments like significant R&D grants in Germany and USA, capital subsidies as a percentage of project cost in Spain and China, obligation on Utilities to buy RNE power in USA, Germany, and India. Interestingly, the analysis found relevance of price based instrument like Feed-in-Tariff (FIT) in all the five countries.

Forecasting based on chosen model indicated that that once the capacity reaches the 95 per cent of the ultimate potential predicted by the respective models, further growth is very slow. Results indicated that 95 per cent diffusion (i.e., saturation point) for India and USA would be achieved in the year 2019 and 2021, respectively. For Germany, Spain, and China the corresponding year was 2013 (Refer Table 4.10 on page 81).

Our computation of saturation points based on selected models accurately coincides with the political shift and several challenges hampering WPT growth in these countries. In India and Spain, for example, tax incentives were removed in 2012 after being perceived by the governments as a tool of merely promoting tax benefits and not performance. Further in India particularly, due to increased tariffs and high variability due to increased connected wind load, several State Utilities have started facing load management issues and often refuse to accept power from WPT. In Germany (post 2003) and USA (mid-1990s), for example, there has been a dip in the growth after actual cost was found to be much higher than the stated cost and hence Utilities objected to maintaining buffer capacity, which sometimes was as high as seven per cent. China too is lacking infrastructure to support large WPT capacity. Every country is facing resistance at the local level. To summarize, large scale deployment of WPT, as of today, is hindered by issues in managing reserve capacity, underutilization of networks, and controversial Not-In-My-Back-Yard (NIMBY) attitude.

8.2.2 Diffusion at Macro Level – Impact of Policies on Diffusion across States of India

For the second research question, impact of successful policies including FIT and RPO (as identified in international comparative analysis) along with other State specific policies (including banking facility and wheeling charges) on their relative attractiveness was modelled using econometric analysis on diffusion of WPT across selected States of India. Seven States of India - namely, Tamil Nadu, Maharashtra, Gujarat, Karnataka, Rajasthan, Andhra Pradesh, and Madhya Pradesh- having significant wind potential were selected for the study. Using these policies' parameters for these States for the period of 19 years (from 1993 to 2012), an aggregate index for each State was built using principal component analysis. Using this index and controlling for other State specific characteristics, econometric analysis using panel data techniques was performed to examine policies' impact on their relative attractiveness on diffusion of WPT. The controlling factors include per-capita income of the State, power deficit, and ratio of installed capacity of WPT to geographic potential.

Of the seven selected States, Maharashtra received highest score on major principal component of aggregate index[53] for 14 out of 19 years. On the other hand, Rajasthan received the lowest score for eight of 19 years. The analysis yielded that a State with high policy index has received high WPT installations. The significance of policy index persists regardless of inclusion or exclusion of control variables. Higher per capita income is an indication of better performing States, thereby encouraging installed capacity of WPT apart from the State-policy index. Results however indicated that the power deficit condition in a State does not guarantee that it will attract WPT. The study thus demonstrated the important role of States in implementing policies for WPT.

8.2.3 Diffusion at Micro Level - Influence of Local Differences on Firms' Decision Making

For the third research question which is a micro level study, State of Maharashtra in India was chosen. This is because despite ranking second in terms of installed capacity of WPT in India after Tamil Nadu, the State has been able to exploit only around 60 per cent of its potential. More interestingly, there is no correlation between wind potential and corresponding installed capacity across districts suggesting that there are other factors which may be influencing the decision of firms to adopt WPT. Study of location choices of firms within Maharashtra

---

[53] This component has captured more than 50 per cent variation among selected policy variables (refer Table 5.9 on page 100).

facilitated identifying the barriers and consequently finding forces that result in widespread adoption of WPT within Maharashtra and thereby contributing to the diffusion in India.

The case study methodology was adopted to identify factors influencing the location choices of firms while adopting WPT in a district of Maharashtra. Five factors – namely, geographical, technological, infrastructure, societal, and bureaucratic - were identified through semi-structured interviews with six firms. These firms have contributed to over 50 per cent of the installed capacity of WPT in Maharashtra. Subsequently, the factors were tested by building quantitative indicators and carrying out econometric analysis using panel data techniques. The analysis was performed for nine districts – namely, Satara, Sangli, Dhule, Nandurbar, Ahmednagar, Pune, Nashik, Beed, and Kolhapur - of Maharashtra for period from 2006 to 2013. The analysis showed that four factors influence the location choices of firms. These include geographical indicated by gap between potential and installed capacity, technological indicated by expected Plant Load Factor (PLF), societal indicated by density of Scheduled Tribes' population, and bureaucratic indicated by proportion of Members of Legislative Assembly of ruling party (MLAs).

The geographical factor captured the firms' tendency of repeatedly choosing same districts thereby giving rise to a virtuous cycle of investment decisions. The bureaucratic factor demonstrated the relevance of government intervention at micro level too, apart from policy making at macro level. The negative influence of societal factor demonstrated the dominance of so called NIMBY attitude in Maharashtra.

8.3 Contributions of the Research

The study contributes to the existing literature in various aspects to study diffusion of WPT. Also, the understanding achieved through this study would help design better policies to harness wind potential.

8.3.1 Contributions to Theory

At macro level, international comparative analysis among five selected leading countries shows that popular traditional approach of "one size fits all" is not followed in diffusion of

WPT. Despite having same policy initiatives each country can indeed have a unique diffusion path owing its economic, social, and political objectives.

Forecasts which have been generated using the selected models show that the leading countries are reaching their diffusion limit within a decade from now despite having various policy initiatives in place. This saturation limit is well below the future targets set by the respective countries and far less than the potential estimates for power generation using WPT. Such a finding additionally justifies the need to study factors - apart from policies - which are dominant at micro level and which determine the choice of adoption of WPT at micro level.

For the seven selected leading States of India, an aggregate index reflecting overall attractiveness of a State for WPT has been computed.

Micro level analysis identifies that geographical characteristics, technology perceptions, societal attitude, and bureaucratic approach in a location determine the choice of adoption of WPT by firms in a district of Maharashtra. Interestingly, while unmet capacity has a positive impact on diffusion at macro level, it has exactly opposite influence on adoption of WPT at micro level. Such a finding suggests towards the positive feedback loop dominant in investment decision in WPT where favourable returns on investments in one location lead to repeated investments in the same location. In other words, our analysis points out risk averseness of firms while investing in WPT.

8.3.2 Contributions to Practice - Policy Recommendations

Our analysis has shown that diffusion of WPT at macro level is primarily driven by policies and has identified successful policies which have led to this diffusion. Our primary survey too has confirmed that policy initiatives like FIT and RPO are encouraging diffusion of WPT. These policy mechanisms can be implemented in other countries with wind potential to initiate diffusion of WPT. Given the huge unexploited wind potential in other States of India, for example, 1260 MW in Uttar Pradesh or 5685 MW in Jammu and Kashmir, such an analysis encourages implementation of these policies to promote growth of WPT.

Nonetheless for the selected countries which are shown to be heading towards their saturation point within a decade from now, these policy initiatives may not able to sustain the further diffusion. Our primary survey in Maharashtra regarding the issues in current policies also confirms inability of current policies to cause further diffusion of WPT. For example, many firms opined that policies like RPO policy may not effective unless it is enforced with stringent penalty. This is because though RPO exists, Utilities in Maharashtra have not been able to fulfil their targets. In fact, power from WPT is sometimes not accepted by Utility. In this regard, an official from a distribution Utility in Maharashtra confirmed that WPT power if generated in night may not be accepted since the demand is low. On the other hand, he argued that buying WPT power has resulted in loss of revenue for Utilities since High Tension (HT) consumers are increasingly opting for WPT power. This is because tariff charged by the Utility for HT consumers is higher compared to cost of power from WPT purchased through third party sale or captive route (MERC, 2010; 2012; 2014).

In this context, a firm suggested that there is a need of governance by subject matter experts to deal with protection of ecosystems surrounding WPT projects. Often, trees with not so big in size are often classified as shrubs and the corresponding area is classified as wasteland not worth protecting. While stunting of any tress or plants on hill ridges is necessary in order to deal with high wind speeds, losses due to misidentification may lead to inadvertent environmental losses leading to societal agitation. Unfortunately, these issues have remained unaddressed in existing policy frameworks in India[54].

Accordingly, there seem to be two broad pathways to ensure continued growth of WPT in leading countries. First is an amendment in existing policy initiatives which is likely to lead to shift in saturation point further. This can clearly be observed in case of China and Germany which have already exceeded their saturation limits by 2014. In 2013, the Chinese government adopted Action Plan of Air Pollution Prevention and Control, regarded as the strictest air pollution control measures ever adopted in China which seems to have encouraged cleaner energy production[55]. Also in 2014, China introduced a separate policy for

---

[54] In this context, there is a growing demand that WPT projects should be brought under Environmental Impact Assessment (EIA) and Environmental Management Programme (EMP) (CSE, 2013).

[55] *Source*: http://newsroom.unfccc.int/clean-energy/policies-drive-wind-energy-growth-in-china-the-us-and-germany/

offshore wind turbines, setting target of 5 GW by 2015 and 30 GW by 2030[56]. Germany also amended its FIT policy (known as EEG) in 2012 and recently in 2014. The amendment not only increased the basic tariff but also provided bonuses for repowering and grid system support services. Also, interestingly, various adaptations in German power system can be observed which have facilitated more power through wind and solar. As stated by Martinot (2015), there are following seven reasons that have allowed German power system to accommodate increasing share of renewables in the grid: (a) the existing strength of its power grids; (2) flexible operation of coal and nuclear plants (and to a lesser extent gas and pumped hydro); (3) better design of the balancing (ancillary) power markets, to make them more effective, faster, and open; (4) better system control software and day-ahead weather forecasting; (5) modest technical improvements to local-level distribution systems; (6) exports of power to neighbouring countries; and (7) solving the "50.2 hertz" inverter problem[57].

For remaining countries, restoring tax incentives for countries like India and Spain or enforcing RPO targets in the States of India could be immediate remedies. In fact, Government of India has restored Accelerated Depreciation (AD) for WPT in 2014.[58] However, this may not be able to propel diffusion in the long term since these would protect interests of investor firms only which results in overlooking of the issues faced by Utilities and local communities as explained earlier.

Accordingly, second pathway may be adopted with an objective to shift diffusion curve to a higher level thereby ensuring long term diffusion of WPT. This would involve designing new policies which would not only protect interests of all stakeholders but also control and regulate the positive feedback loop in operation regarding location choices of firms. Regarding societal issues, an independent support system may be created to facilitate land acquisition, permits, and construction activities. In this context, an alternate successful model especially for rural areas with minimal subsidies is of China's program of small wind turbines

[56] *Source*: http://www.carbontrust.com/news/2014/09/china-offshore-wind

[57] *Source*: http://energytransition.de/2015/02/how-germany-integrates-renewable-energy/

[58] *Source*: http://articles.economictimes.indiatimes.com/2014-07-25/news/52026488_1_accelerated-depreciation-wind-energy-depreciation-scheme [accessed on February, 18, 2015]

in 1990s. This program not only led to development of industry at domestic level but also helped communities attain self-sufficiency. Regarding issues faced by Utility, perhaps greater efforts are required to design cost-effective technical solutions to accommodate RNE power. In this context, lessons could be learned from other countries which have successfully transited through this. For example, training programs and hands on experience could be arranged for Utilities' personnel in collaboration with countries like Denmark and the USA which are already having high share of WPT in their energy portfolio.

In order to tap the wind potential in lagging districts, perhaps frequent wind resource assessment program accompanied by demonstration WPT projects may be undertaken by NIWE. This would provide firms with updated information on wind potential in a district and also instil confidence among them regarding WPT project viability. Alternately, the risk perceived by investors in installing WPT projects at locations in lagging districts could be minimized through public private partnerships (PPP). Spain, for example, has practiced numerous types of partnerships since early 1990s which though reduced profitability of the projects, reduced risk from around 20 per cent to seven per cent (Dinica, 2008). Also, different policy initiatives with seemingly independent objectives, say energy efficiency and renewable energy, could be combined. For example, Perform, Achieve, and Trade (PAT) which is a market mechanism to enhance cost effectiveness in energy intensive large industries and facilities could be combined with RPO to account for reduction in conventional power usage.

The central idea is that WPT was promoted as an environmental good to begin with and accordingly greater cooperation from every stakeholder including public should be sought by policy makers.

8.4 Limitations and Scope for Future Work

The research has certain limitations in terms of frameworks used for the study and the restricted problem statements. The framework is built using installed capacity as the only indicator of diffusion of WPT. This framework, though widely used, has certain limitations. For example, this overlooks the role of small stand-alone WPT systems which may actually lead to wider diffusion of WPT as demonstrated in case of China. Further, there are alternate choices of models which have been used in the literature like generalized bass model. Also, the research does not distinguish between specific technologies of WPT. For example, diffusion of offshore versus onshore WPT or horizontal-axis wind turbines versus vertical-axis wind turbines which are suitable for different environments has not been separately accounted for. For example, a vertical turbine can operate at lower wind speeds making it suitable for urban areas than is possible with horizontal axis wind turbines.

In terms of evaluating policies too, the study has some avenues for further work. This is because recently policies are being separately formulated acknowledging difference in technology used especially for off-shore WPT. The present study ignores these differences. Further, we haven't taken into account influence of Operation and Maintenance (O&M) services' capability of different countries on diffusion.

At micro level, behavioural characteristics of firms due to cultural differences have not been accounted for. For example, one of the simple reasons for investing in a WPT at a location could be availability of land in home town. Besides, many of the firms have acknowledged the convenience of local language in dealing with ground level issues and also at governance level. Also though we have incorporated data on complaints made by landowners, we couldn't directly include their views and opinions through primary survey.

Also regarding technological factor, we haven't taken into account uncertainty in PLF which has considerable impact on IRR achieved in a WPT project. There is a stream of literature dedicated to creation of separate markets for WPT. For example, Messac *et al*. (2012) propose a methodology to characterize the uncertainty in annual production from wind farm. On the other hand, Saebi *et al*. (2015) propose alternate market termed as Demand Response market exclusively meant to allow for sudden and sharp changes in demand. Alternately, there are insurance mechanisms to manage technological risks. For example, Royal Sundaram provides insurance for (1) Transit & Erection cover inclusive cover for hired machinery, (2) Loss of Profits arising out of insurable loss during erection, (3) All Risk cover at the Operational

Stage and subsequent Loss of Profits, if any, and lastly (4) Public Liability Risk[59]. We haven't analysed impact of such factors on investment decisions.

Accordingly, the research could be further extended in several directions as follows. Diffusion of off-shore WPT may be studied independently since polices for off-shore WPT also are being formulated separately. Further actual power generation could be used as an indicator of diffusion since not all installed capacity would be working all the time. In fact, this would also help evaluate the various policies exclusively aimed at encouraging efficiency of WPT systems. At micro level, the further research in terms of relevance of firm level characteristics and portfolio management in diffusion of WPT could be undertaken.

[59] *Source*: http://www.royalsundaram.in/news/windenergyinsurance.aspx [accessed on June 2, 2015]

Appendices

Appendix I

To compute wheeling charges as percent of energy charges for Tamil Nadu for 2012

On July 31 of 2012, the Hon'ble Tamil Nadu Electricity Regulatory Commission (TNERC) issued Comprehensive Tariff Order on power from WPT in Order No.6, dated 31.07.2012 in supersession of the Order No.1, dated 20.03.2009. In the said order, the Hon'ble TNERC ordered to collect charges on cash basis. For wheeling of power from WPT, it was instructed to collect the charges at the generating end, namely, (i) transmission charges of Rs.2593.20 per day per MW (or) Part thereof (40% on Rs.6483 per day per MW); (ii) wheeling charges of 9.31 paise per unit (40% on 23.27 paise per unit) (Venugopal and Nagalsamy, 2012). In order to convert above charges into per cent of energy charges, we employed the following procedure.

Step 1: Calculate the total charges applicable for year 2012-13

(1) Installed capacity of wind power was 7162.7 MW by 2012-13. Assuming wind power connected load as 50 per cent of total and further assuming it is so for 7 months of the year, transmission Charges (X) = 0.5 * 7162.7 * 2593.2 * 240 = 3,259,544,939.73

Step 2: To calculate the actual wheeling charges paid for generated wind power

(2) We calculated the plant load factor as average of last five years as 17.65 per cent and hence the units generated would be equal to 0.1765 * 7162.7 * 24 * 365 * 1000 = 11.07 Billion kWh. As per the same Tariff Order, the tariff offered was 3.51 Rs/kWh. Accordingly, charges paid would be, Energy Charges (E) = 3.51 * 11.07 * 10^9 = 38,861,133,225.70 Rs.

Step 3: Wheeling Charges as % of energy charges

(E + X)/E = 0.08 or 8 per cent.

Appendix II

	$PC1_{t-1}$	$PC2_{t-1}$	ln PCNDP	deficit	Rpot
$PC1_{t-1}$	1.0000				
$PC2_{t-1}$	-0.0000 (1.0000)	1.0000			
ln PCNDP	0.3109* (0.0029)	0.5299* (0.0000)	1.0000		
deficit	-0.0212 (0.6320)	-0.1482* (0.0110)	-0.1654* (0.0508)	1.0000	
Rpot	0.0913 (0.2832)	0.5071* (0.0000)	0.4092* (0.0000)	-0.1315 (0.1214)	1.0000

Note: * - correlation significant at or above 90 per cent confidence level
$PC1_{t-1}$ – Lagged value of Principal component 1
$PC2_{t-1}$ – Lagged value of Principal component 2.
Source: Own computation

Appendix III

Shailesh J. Mehta School of Management

Indian Institute of Technology Bombay (IIT Bombay)

Questionnaire on Role of Policy in Deployment of Wind Power in Maharashtra

Number ____________ **Questionnaire ID**

Interviewer's contact: **Landline - +912225764785, Mobile – 9930351060**

Email – riddhi@som.iitb.ac.in

Date ____________ **Start time _____________** **End time ____________**

Purpose of Questionnaire

This questionnaire is with regard to my PhD study aimed at evaluating the role of policy to promote large scale deployment of renewable energy in India. Considering its cost-effective technical potential across different States in India, wind energy has been receiving more attention. In this view, I am undertaking the study of policy tools that geared up the wind based electricity generation. I have short listed a few progressive States and corresponding project developers to gather some facts in this matter. Considering the quantum of deployed wind potential, I have included Maharashtra in my study. Understanding your preferences while choosing a location in the State will be useful in my study to analyze the impact of contemporary local characteristics on wind power deployment.

I wish to express that my study is meant only for academic purpose and all information provided will be treated confidentially, and included in the analysis without any specific attribution. Your assistance will be useful to correlate the facts and accordingly come up with new guidelines to design the new policy tools for future deployment of renewable energy resources. I would appreciate your assistance in this regard.

Part A: Contact Details

1. Name of the company – ________________________________
2. Interviewee's name – __________________________________
3. Designation –____
4. Address- ____
5. Telephone Number – __________________________________

Email – ____

Part B: General Information about the company

1. Which category you operate in regarding wind power projects in Maharashtra?

Category	Brief Details
Manufacturer	
Developer	
Investor/ Owner	

2. What is total capacity of wind machines installed/owned by the company across India?

   ____

3. What is the share of the State in total installed capacity of wind power by the company?

   ____

4. Please fill out the following table regarding details of wind farms in Maharashtra?

Site	Capacity (MW)	No. of turbines (manufacturer)	PPA with Utility (yes/no)	Captive use (% of total power)

5. Do you operate power plants generating electricity using any other source? If yes, kindly fill out the following table.

Site (State)	Capacity (MW)	Energy source	PPA with Utility (yes/no)	Captive use (% of total power)

6. Are you an obligated company to reduce energy consumption under Performance, Achieve and Trade (PAT) scheme by Bureau of Energy Efficiency (BEE)? **Yes / No**

7. **If yes**, what is target for improvement given to you?

   ____

8. Are any of your projects registered under Carbon Development Mechanism?

   Yes/ No

9. Which of your projects are registered under Carbon Development Mechanism? What is installed capacity of these projects?

____

Part C: Information About Wind Power Development in Maharashtra

10. Why did you choose the State chosen for setting up wind farms?
    - Already a number of wind farms operating in the State make it a credible choice
    - know authorities in govt. and allied institutions, so the intricacies of setting up a wind farm here are better understood
    - recommended by industry peers and/or consultants
    - native of the State
    - Wanted to own a captive power generation
    - No particular reason – just another State.

11. Were following factors regarded in choosing a particular site/ district for setting up wind farms?

District	Number of Sites					Power (kWh)	Road length per 100 sq. km.	number of 33 kV sub-stations	% of forest cover	% of tribal population	Literacy rate	no. of earlier projects	Previous installed capacity
	Zone I	Zone II	Zone III	Zone IV	Total								
Ahmednagar	3	1			4								
Aurangabad	1				1								
Beed	1				1								
Dhule	2		1		3								
Kolhapur	1				1								
Latur	1				1								
Nandurbar			1		1								
Nashik		2			2								
Pune		1			1								
Sangli	2	3			5								
Satara	4	5		1	10								
Sindhudurga		1			1								
Total	**15**	**13**	**2**	**1**	**31**								

12. Was any cost-benefit analysis performed before choosing sites for wind farms in the State?
    - sites were chosen based primarily on the expected IRR
    - sites were selected based primarily on land availability
    - If any other reason, please state.

    ____

13. What is preferred – sites recommended by Ministry or identification of new sites?

Answer	Why?
Ministry recommended sites	
New sites	

14. Is software package used while predicting generation? **Yes/No**

15. If yes, is the software developed in house? **Yes/No**

16. What is approximate breakup of various costs involved in setting up of a wind farm in the State? Does following breakup of costs in percentage look reasonable?

Component	Cost (%)	Lower/Higher
Cost of land	1	
Cost of tower	14	
Cost of WTG	65-70	
Erection and commissioning charges	10-15	
Infrastructure development	3-8	
Processing fee	01-0.2	
Total	100	

Are there any other major expenses?

17. What is the plant load factor of your wind energy projects in the State?

____

18. Are wind turbines in the State generating power as predicted?

Answer	Why?
Yes	
No	

19. MEDA has outlined the application procedure for setting up a wind power projects in the State on June 30, 2005. Please fill out time in months taken for following clearances/ processes.

Clearance/ Process	Approximate time in months
Identifying a potential site	
Agreement for land (sale, lease, etc.)	
NOC from Geology and Mining Dept.	
Detailed Project Report	
Micro-siting Plan	
Technical details of WTG, power curve, etc	
NOC from forest dept. (if applicable)	
Grid connectivity from MSETCL	
Approach roads (built by MEDA)	
Execution of project till commissioning	

20. Have you ever faced opposition by environmental activists/ local communities in Maharashtra?

Type of opposition	Yes/ No
Wind farms reduce rain fall	
Wind farms kill birds	
Forest land – ownership issue	
Compensation for local people/ land owners	
Theft of parts, electricity, etc.	
Accidents during/after installation (fly away/ breakage of blades)	

a. If any other factor, please mention.

21. Kindly rank the top three States as per your ranking for favorable policy as per your experience.

( ) Maharashtra ( ) Gujarat ( ) Tamil Nadu ( ) Karnataka

( ) Rajasthan ( ) Andhra Pradesh ( ) Madhya Pradesh ( ) Kerala

22. Would you like to suggest any change in the existing policies in Maharashtra?
   a. Feed in Tariff is not at par with cost of generation
   b. RPO level is not sufficient
   c. Wheeling and transmission charges are high
   d. Costs and time spent in supporting infrastructure are high
   e. Time consumed in various clearances is too high
   f. No, Maharashtra is doing fine.

23. What are the most common problems faced by wind farms operating in Maharashtra?
    a. Poor estimates of resource availability
    b. Wind power generation at inadequate times (which is during monsoon) which leads to other technical problems regarding power injection.
    c. Poor placement of turbines leading to lower energy output. Lack of technical know-how and optimization of sites to obtain maximum energy output.
    d. If any other factor, please state.

24. Why is the State not able to exploit wind potential till date?

25. What should be done to promote wind power across States of India?

Appendix IV

List of Developers and Investors approached for Interview

Sl. No.	Investor
1	The Tata Power Company Ltd.
2	CLP India Pvt. Ltd.
3	Bajaj Auto Ltd.
4	Ghodawat Industries India Pvt. Ltd.
5	Sarjan Realities Pvt. Ltd.
6	Parle Products Pvt. Ltd.
7	Continuum Wind Energy Pvt. Ltd.
8	Vatsala Wind Farms Ltd.
9	Telesto Comnet Pvt. Ltd.
10	Reliance Innoventures Pvt. Ltd.

Sl. No.	Developer
1	Sri Maruti Wind Park Developers
2	TS Wind Park Developers
3	Suzlon Energy Limited
4	Suyog Urja Pvt. Ltd.
5	Vestas Wind Technology India
6	Bothe Wind Farm Development Pvt. Ltd.
7	Welspun Energy Maharashtra Pvt. Ltd.
8	The Tata Power Co. Ltd.
9	Weizmann Ltd.
10	Panama Wind Energy Pvt. Ltd.
11	Gamesa Wind Turbines Pvt. Ltd.
12	Regen Power Tech Pvt. Ltd.
13	Inox Wind Ltd.
14	RRB Energy Ltd.
15	Shriram EPC Ltd.

Appendix V

List of Windy Sites Declared by National Institute of Wind Energy in Maharashtra

Sr. No.	Name of Site	Taluka	District	Latitude		Longitude		Elevation (m.a.s.l.)	Avg. wind speed in kmph at 20/25 m	Annual wind power density in W/sq.m at 50 m
				º N Deg.	º E Min.	º N Deg.	º E Min.			
1	Alamprabhu Pathar	Hathangale	Kolhapur	16	46	74	22	790	20.5	224
2	Amberi	Khatav	Satara	17	36	74	18	960	23	275
3	Aundhewadi	Sinnar	Nashik	19	46	73	50	876	23.67	>295
4	Bhud	Khanapur	Sangli	17	21	74	42	834	19.73	224
5	Brahmanwel	Sakri	Dhule	21	10	74	11	600	23.1	324
6	Chakla	Nandurbar	Nandurbar	21	19	74	19	380	23.7	323
7	Chalkewadi	Satara	Satara	17	36	73	49	1160	20.2	218
8	Dhalgaon	Kavthemahankal	Sangli	17	8	74	59	810	21.2	260
9	Dongarwadi	Miraj	Sangli	16	55	74	48	820	21.4	284
10	Gavalwadi	Dindori	Nashik	20	6	73	43	740	19	278
11	Gudhepachgani	Shirala	Sangli	17	7	73	59	903	19.8	296
12	Kankora	Aurangabad	Aurangabad	19	59	75	27	920	20.01	204
13	Kas	Jaoli	Satara	17	44	73	49	1240	20.5	277
14	Kavadyadongar	Parner	Ahmadnagar	19	1	74	32	910	23.2	277
15	Khandke	Ahamadnagar	Ahmadnagar	19	8	74	53	920	19.6	250
16	Kolgaon	Srigonda	Ahmadnagar	18	50	74	43	800	20.5	238
17	Lonavla	Maval	Pune	18	47	73	23	560	15.5	285
18	Mandhardeo	Wai	Satara	18	2	73	53	1280	19.4	206
19	Matrewadi	Patan	Satara	17	12	73	56	898	20.8	253
20	Palsi	Patan	Satara	17	20	73	40	970	18.85	254
21	Panchgani	Mahabaleshwar	Satara	17	65	73	48	1372	18.4	205
22	Panchpatta	Akole	Ahmadnagar	19	42	73	55	1080	20.51	236
23	Raipur	Sakri	Dhule	21	2	74	22	500	18.9	214
24	Rohina	Chakur	Latur	18	27	76	57	676	20.05	226
25	Sautada	Patoda	Beed	18	48	75	20	800	21.2	223
26	Takarmouli	Sakri	Dhule	21	3	73	58	600	20.8	224
27	Thoseghar	Satara	Satara	17	35	73	53	1140	21.7	489
28	Vankusavade	Patan	Satara	17	27	73	50	1100	21.2	293
29	Varekarwadi	Patan	Satara	17	13	73	59	920	21.04	216
30	Vaspet	Jat	Sangli	17	6	75	22	681	20.34	225
31	Vijaydurga	Deogad	Sindhudurg	16	30	73	20	100	19.6	253
32	Kosegavhan $	Shrigonda	Ahmednagar	18	43	74	50	732	6.31	215
33	Mirkala $	Gevrai	Beed	19	11	75	43	577	6.09	211
34	Devgad $	Devgad	Sindhudurg	16	22	73	22	40	5.81	218
35	Bhendwade $	Shahuwadi	Kolhapur	17	1	73	52	812	5.88	223
36	Peth Shivapur $	Bhudargad	Kolhapur	16	15	74	9	973	6.44	224
37	Nenewadi $	Sawantwadi	Sindhudurg	15	54	74	0	784	5.62	205
38	Kolde $	Nandurbar	Nandurbar	21	26	74	17	157	5.89	221
39	Mhaismal $	Khultabad	Aurangabad	20	3	75	10	862	6.2	201
40	Kanur $	Chandgad	Kolhapur	16	1	74	5	1021	7.46	368
41	Sukalmala $	Gaganbavda	Kolhapur	16	33	73	49	619	5.48	225
42	Parwattarfe Waghawale $	Mahabaleshwar	Satara	17	45	73	36	1173	6.12	281
43	Mendhegiri $	Jat	Sangli	16	59	75	13	745	6.32	208
44	Vhanali $	Kagal	Kolhapur	16	29	74	13	728	6.18	203.08
45	Sanmadi $	Jat	Sangli	17	8	75	19	650	5.98	200.46

Appendix V(Contd…)

Sr. no.	Name of Site	Taluka	District	Latitude		Longitude		Elevation (m.a.s.l.)	Avg. wind speed in kmph at 20/25 m	Annual wind power density in W/sq.m at 50 m
				º N Deg.	º E Min.	º N Deg.	º E Min.			
46	Jagmin	Satara	Satara	17	37	73	48	1185	7.42	410
47	Isapur	Pusad	Yevatmal	19	43	77	27	439	5.73	246
48	Khokade	Man	Satara	17	48	74	22	1046	6.53	239
49	Motha**	Chikhaldara	Amrawati	21	22	77	21			

Notes: **- As per MNRE / C-WET "on re-examination of the data concerned to Motha it has opined that a few location, which have elevation above 1040 m above sea level (masl) seems to be having wind power density of more than 200 W/m2 could be considered for." Those areas having elevation in excess of 1040 masl only need to be considered in the exercise. These areas are mainly encompassed by the villages, Motha – Bibisonda-Shahpur – Chikhaldara-Aldoha-Lawada-Bhimkund.

$ - 50m mast

Source: Personal communication with MEDA in 2014

Appendix VI

Procedure to Calculate Expected PLF at District Level

Step (1): Calculate average speed of wind (V_m) in a district using wind speed data at all sites in the district listed in Appendix V.

Step (2): Assuming Weibull distribution for wind, determine scale parameter k and shape parameter c. In many of the wind regimes around the World, k is about 2 (Johnson, 1985). Hence using k as 2, calculate c as follows.

$$c = \Gamma \frac{V_m}{1+\frac{1}{k}}$$ *Source*: Johnson, 1985

Step (3): Collect data on cut-in-speed (V_c), rated speed (V_r), and furling speed (V_f) of all turbines installed in Maharashtra.

Turbine Size	V_c	V_r	V_f
225	4	13	25
230	4	13	25
250	4	13	25
350	4	13	25
500	4	13	25
600	4	13	25
750	3	14	25
800	3	14	25
850	3	14	25
1000	3	15	25
1250	3	14	22
1500	4	12	20
1600	3.5	13	20
1650	3.5	13	20
2000	3	12	22
2100	4	14	25
2500	3.5	11.75	25

Source: Own compilation from websites of wind turbine manufacturers

Step (4): Using averages of speeds obtained above, k, and c, calculate expected Plant Load Factor (PLF) for a district as follows.

$$PLF = \frac{exp\left[-\left(\frac{V_c}{c}\right)^k\right] - exp\left[-\left(\frac{V_r}{c}\right)^k\right]}{\left(\frac{V_r}{c}\right)^k - \left(\frac{V_c}{c}\right)^k} - exp\left[-\left(\frac{V_f}{c}\right)^k\right]$$ Source: Johnson (1985)

Appendix VII

	GAP	PLF_EXP	NO_SUBSTA	HIGHWAY	ST_DENSITY	MLA_GOVT	PCNDDP
GAP	1.0000						
PLF_EXP	-0.38* (0.0011)	1.0000					
NO_SUBSTA	-0.70* (0.0000)	0.04 (0.7421)	1.0000				
HIGHWAY	0.7854* (0.0000)	-0.31* (0.0085)	-0.28* (0.0172)	1.0000			
ST_DENSITY	-0.21* (0.0823)	0.58* (0.0000)	-0.20* (0.0871)	-0.3135* (0.0073)	1.0000		
MLA_GOVT	-0.21* (0.0729)	0.28* (0.0154)	0.21* (0.0758)	-0.19 (0.1103)	0.14 (0.2460)	1.0000	
PCNDDP	0.39* (0.0008)	-0.84* (0.0000)	-0.05 (0.6990)	0.32* (0.0066)	-0.35* (0.0028)	-0.27* (0.0224)	1.0000

Note: *- Significant correlation at or above 90 per cent confidence level.

Source: Own computation

References

.

ALCS. (2013). Wind Energy in China. Retrieved from http://www.alcs.ch/wind-energy-in-china.html

Archer, C. L., & Jacobson, M. Z. (2005). Evaluation of global wind power. *Journal of Geophysical Research*, *110*(September 2004), 1–20.

Augstein, R. (2004, March). Der Windmühlen-Wahn: umweltfreundlicher Energie zur hoch subventionerten Landschaftszerstörung. *Der Spiegel*.

Azuela, E. G., & Barroso, A. L. (2011). *Design and Performance of Policy Instruments to Promote the Development of Renewable Energy : Emerging Experience in Selected Developing Countries*. Washington, DC.

Baker, R. W., Walker, S. N., & Wade, J. E. (1990). Annual and seasonal variations in mean wind speed and wind turbine energy production. *Solar Energy*, *45*(5), 285–289.

Barik, P. K., & Murugesha, K. M. (2012). Induced Diffusion of Innovation: A Study on Wind Energy Development in Karnataka. *Journal of Resources Energy and Development*, *9*(2), 79–88.

Bass, F. M. (1969). A new Product Growth for Model Consumer Durables. *Management Science*, *15*(5), 215–227.

Bayer, E. (2014). *Report on the German power system*. Berlin.

Beise, M., & Rennings, K. (2005). Lead markets and regulation: a framework for analyzing the international diffusion of environmental innovations. *Ecological Economics*, *52*(1), 5–17.

Bell, D., Gray, T. I. M., & Haggett, C. (2005). The “ Social Gap ” in Wind Farm Siting Decisions : Explanations and Policy Responses. *Environmental Politics*, *14*(4), 460–477.

Benecke, G. (2008). “CDM – So What?”: Analysing Determinants of Private Sector Participation in Renewable Energy Deployment in India. In *Human Dimensions of Global Environmental Change: Long-Term Policies: Governing Socio-Ecological Change*. Berlin.

Bergek, A., & Jacobsson, S. (2003). The emergence of a growth industry: a comparative analysis of the German, Dutch and Swedish wind turbine industries. In J. S. P. Metcalfe & U. D. P. Cantner (Eds.), *Change, Transformation and Development* (pp. 197–227). Heidelberg: Physica-Verlag HD.

Bikhchandani, S., Hirshleifer, D., & Welch, I. (1992). A Theory of Fads, Fashion, Custom, and Cultural Change as Informational Cascades. *Journal of Political Economy*, *100*(5), 992. doi:10.1086/261849

Bird, L., Bolinger, M., Gagliano, T., Wiser, R., Brown, M., & Parsons, B. (2005). Policies and market factors driving wind power development in the United States. *Energy Policy*, *33*(11), 1397–1407.

Bird, L., Parsons, B., Gagliano, T., Brown, M., Wiser, R., & Bolinger, M. (2003). *Policies* *and Market Factors Driving Wind Power Development in the United States*. Colorado.

Black, H. (2014). *BLACK'S LAW DICTIONARY*. (B. Garner, Ed.) (10th ed.). Minnesota: Thomson West.

Bosely, P., & Bosley, K. (1988). Public acceptability of California's wind energy developments: three studies. *Wind Engineering*, *12*(5), 311–318.

BP. (2009). *BP Statistical Review of World Energy What ' s inside ?* London.

BP. (2015). *BP Statistical Review of World Energy*. Mumbai.

Bradley, R. L. J. (1997). *Renewable Energy : Not Cheap , Not " Green ."* Washington.

Breukers, S., & Wolsink, M. (2007). Wind power implementation in changing institutional landscapes: An international comparison. *Energy Policy*, *35*, 2737–2750.

Calderia, K., Jain, A., & Hoffer, M. (2003). Climate Sensitivity Uncertainty and the Need for Energy Without CO2 Emission. *Science*, *570*, 2052–2054.

California Energy Commission. (1994). *1994 Electricity Report*. California.

Cantono, S., & Silverberg, G. (2009). A percolation model of eco-innovation diffusion: The relationship between diffusion, learning economies and subsidies. *Technological Forecasting and Social Change*, *76*(4), 487–496.

CanWEA. (2006). *Wind Power FAQs - Amherst Island Wind Project*. Amherst.

Carley, S. (2009). State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy*, *37*(8), 3071–3081.

Celik, A. N. (2003). Energy output estimation for small-scale wind power generators using Weibull-representative wind data. *Journal of Wind Engineering and Industrial Aerodynamics*, *91*(5), 693–707.

Chow, G. C. (1967). Technological Change and the Demand for Computers. *The American Economic Review*, *57*(5), 1117–1130.

Chunchun, N., Power, E., & Group, G. I. (2008). *China' s Wind-Power Generation Policy and Market Developments China ' s Wind-Power Generation Policy and Market Developments*. Tokyo.

Cotrell, J., Stehly, T., Johnson, J., Roberts, J. O., Parker, Z., Scott, G., & Heimiller, D. (2014). *Analysis of Transportation and Logistics Challenges Affecting the Deployment of Larger Wind Turbines: Summary of Results*.

CSE. (2013). *EIA GUIDELINES - WIND POWER*. New Delhi.

Dalla Valle, A., & Furlan, C. (2011). Forecasting accuracy of wind power technology diffusion models across countries. *International Journal of Forecasting*, *27*(2), 592–601.

De Vries, F. P. (2003). *Environmental Policy and Technology Diffusion under Imperfect Competition*. University of Groningen.

Delaportas, K. (2012). An Investigation into the determinants of Diffusion of Wind Power. In *Innovation and Competitiveness Dynamics of Organizations, Industries, Systems and Regions*. Copenhagen: DRUID.

Dept. of Energy U.S. (2008). *20% Wind Energy by 2030 - Increasing Wind Energy's Contribution to U.S. Electricity Supply*. Oak Ridge.

Desiraju, R., Nair, H., & Chintagunta, P. (2004). Diffusion of new pharmaceutical drugs in developing and developed nations. *International Journal of Research in Marketing*, *21*(4), 341–357.

Diaz-rainey, I., & Tzavara, D. (2009). *A diffusion model of an induced environmental market: reconciling WTP to actual adoption of green energy tarif* (No. 33). Florence.

Dinica, V. (2003). *Sustained difffusion of renewable energy. Politically defined investment contexts for the diffusion of renewable electricity technologies in Spain, The Netherlands, and the United Kingdom*. University of Twente.

Dinica, V. (2008). Initiating a sustained diffusion of wind power: The role of public–private partnerships in Spain. *Energy Policy*, *36*(9), 3562–3571.

Dodge, D. M. (2006). Part 3 - Government-Sponsored R&D. *Illustrated Histroy of Wind Power Development*. Retrieved from http://telosnet.com/wind/govprog.html

Dvorak, P. (2013, June 5). Top 10 wind turbine manufacturing companies. *Windpower Engineering Development*. Mumbai. Retrieved from http://www.windpowerengineering.com/featured/business-news-projects/top-10-wind-turbine-manufacturing-companies/

Eberhard, A., Leigland, J., & Kolker, J. (2014). *South Africa's Renewable Energy IPP Procurement Program: Success Factors and Lessons*. Washington, DC.

Energy Information Administration (EIA). (2013). *Electric Power Monthly with Data for March 2013*. Washington.

Est, R. van. (1999). *Winds of Change - A Comparative Study of the Politics of Wind Energy Innovation in California and Denmark*. Utrecht: International Books.

European Wind Energy Association (EWEA). (2013). *Wind in power*. Brussels.

Faundez, P. (2008). Renewable energy in a market-based economy : How to estimate its potential and choose the right incentives. *Renewable Energy*, *33*, 1768–1774.

Fisher, J. C., & Pry, R. H. (1971). A Simple Substitution Model of Technological Change. *Technological Forecasting and Social Change*, *88*, 75–88.

Fornahl, D. (2011). From the old path of shipbuilding onto the new path of offshore wind energy ? The case of northern Germany. In *INNOVATION, STRATEGY, and STRUCTURE - Organizations, Institutions, Systems and Regions*. Copenhagen: DRUID Society.

Fourt, L. A., & Woodlock, J. W. (1960). Prediction Market New Grocery Products. *Journal of Marketing*, *25*(2), 31–38.

Fraunhofer Institute of Solar Energy (ISE). (2015). *Photovoltaics Report*. Freiburg.

Gadgil, M., Krishnan, B. J., Vijayan, V. S., Varma, R. V., Sukumar, R., Noronha, L., … Subrahmanyam, G. V. (2011). *Report of the Western Ghats Ecology Expert Panel*. Bangalore. Retrieved from http://www.iphindia.org/archives/7683

Gamboa, L. F., & Otero, J. (2009). An estimation of the pattern of diffusion of mobile phones : The case of Colombia. *Telecommunications Policy*, *33*, 611–620.

Geroski, P. . (2000). Models of technology diffusion. *Research Policy*, *29*(4-5), 603–625.

Ghosh, D., Shukla, P. R., Amit, G., & Ramana, P. V. (2001). *Renewable Energy Strategies for India*. New Delhi.

Global Wind Energy Council (GWEC). (2012). *Global Wind Report Annual Market Update 2012*. Brussels.

Global Wind Energy Council (GWEC), & Greenpeace International. (2006). *Global Wind Energy Outlook 2006*. Brussels.

Global Wind Energy Council (GWEC), World Institute of Sustainable Energy (WISE), & Indian Wind Turbine Manufacturers Association (IWTMA). (2011). *Indian Wind Energy Outlook 2011*.

GoI. (2012). *Report of The Working Group on Power for Twelfth Plan (2012-17)*. New Delhi.

Govt. of China. (2006). The 10th Five-Year Plan (2001-2005). Retrieved from http://english.gov.cn/2006-04/05/content_245624.htm

Govt. of US. Energy policy act of 1992. , Pub. L. No. 2776 (1992). United States.

Govt. of US. (2005). *Energy Policy Act of 2005*. Washington.

Govt. of US. (2010). *Job Creation Act of 2010*. Washington.

Grossman, G., Nickerson, D., & Freeman, M. (1991). Principal Component Analyses of Assemblage Structure Data : Utility of Tests Based on Eigenvalues. *Ecology*, *72*(1), 341–347.

Guérard, S., & Langley, A. (2007). *Shifting Logics of Legitimation in the Diffusion of Complex Innovations*. Lausanne.

Guidolin, M., & Mortarino, C. (2010). Cross-country diffusion of photovoltaic systems: Modelling choices and forecasts for national adoption patterns. *Technological Forecasting and Social Change*, *77*(2), 279–296.

GWEC, & Greenpeace International. (2014). *Global Wind Energy Outlook 2014*. Brussels.

Hemmelskamp, J. (1998). Wind energy policy and their impact on innovation - an international comparison. In *Seventh International Conference of Greening of Industry Network Rome*. Rome: European Commission.

Hirotugu, A. (1974). A New Look at the Statistical Model Identification. *IEEE Transactions on Automatic Control*, *AC-19*(6), 716–723.

Holt, E. H. E., & Bird, L. (2005). *Emerging Markets for Renewable Energy Certificates : Opportunities and Challenges*. Colorado.

Hull, A. (1995). Local strategies for renewable energy- Policy approaches in England and Wales. *Land Use Policy*, *12*(1), 7–16.

Ibenholt, K. (2002). Explaining learning curves for wind power. *Energy Policy*, *30*, 1181–1189.

Indian Renewable Energy Development Association (IREDA). (2013). Wind GBI. *Government Schemes*. Retrieved from http://www.ireda.gov.in/forms/contentpage.aspx?lid=744

Indian Wind Turbine Manufacturers Association (IWTMA). (2013, June 5). Indian Wind Energy & Economy. Mumbai. Retrieved from http://www.indianwindpower.com/news_views.html

International Energy Agency (IEA). (2008). *Energy Technology Perspectives 2008: Scenarios and Strategies to 2050*. Paris.

International Renewable Energy Agency (IRENA). (2012a). *30 Years of Policies for Wind Energy*. Abu Dhabi.

International Renewable Energy Agency (IRENA). (2012b). *Evaluating Policies in Support of the Deployment*. Abu Dhabi. Retrieved from http://www.irena.org/DocumentDownloads/Publications/Evaluating_policies_in_support_of_the_deployment_of_renewable_power.pdf

InWEnt Consulting. (2004). *Wind Regimes of Africa - Comparative Evaluation of Wind Data from Selected Countries*. Bochum.

IWTMA. (2014). Indian Wind Power. *Wind Power Finance Special*, *1*(August).

Jacobsson, S., & Johnson, A. (2000). The diffusion of renewable energy technology : an analytical framework and key issues for research. *Energy Policy*, *28*, 625–640.

Jagadeesh, A. (2000). Wind energy development in Tamil Nadu and Andhra Pradesh , India Institutional dynamics and barriers - A case study. *Energy Policy*, *28*, 157–168.

Johnson, G. L. (1985). *Wind Energy Systems*. London: Prentice Hall.

Johnstone, N., Haščič, I., & Popp, D. (2010). RENEWABLE ENERGY POLICIES AND TECHNOLOGICAL INNOVATION: EVIDENCE BASED ON PATENT COUNTS. *Environmental and Resource Economics*, *45*(1), 133–155.

Kamp, L. M., Smits, R. E. H. M., & Andriesse, C. D. (2004). Notions on learning applied to wind turbine development in the Netherlands and Denmark. *Energy Policy*, *32*, 1625–1637.

Kathuria, V., Ray, P., & Bhangaonkar, R. (2015). FDI (foreign direct investment) in wind energy sector in India : Testing the effectiveness of state policies using panel data. *Energy, 80*(December), 190–202.

Khan, J. (2004). *Local Politics of Renewable Energy - Project Planning, Siting Conflicts and Citizen Participation*. Lund University.

Kooten, C., & Timilsina, G. (2009). *Wind Power Development - Economics and Policies*. Washington, DC.

KPMG. (2010). *Taxes and incentives for renewable energy*. *ENERGY & NATURAL RESOURCES*. New Jersey.

KPMG International. (2013). *Taxes and Incentives for Renewable Energy*. Zurich.

Krzikalla, N. (2001). *Auswirkungen des EEG und des KWKG auf die Endkundenpreise*. Aachen.

Laird, F. N., & Stefes, C. (2009). The diverging paths of German and United States policies for renewable energy: Sources of difference. *Energy Policy, 37*(7), 2619–2629.

Lamberson, P. J. (2008). *The Diffusion of Hybrid Electric Vehicles*. Michigan.

Lauber, V. (2005). REFIT and RPS : options for a harmonised Community framework. *Energy Policy*, *32*(October), 1405–1414.

Lauber, V., & Mez, L. (2004). Three Decades of Renewable Electricity Policies. *Energy and Environment*, *15*(4), 1–23.

Lew, D. J. (2000). Alternatives to coal and candles : wind power in China. *Energy Policy*, *28*(February 1999), 271–286.

Lewis, J., & Wiser, R. (2005). *A Review of International Experience with Policies to Promote Wind Power Industry Development*.

Li, X. (2010). Development of Wind Energy in the US and China : A Comparative Study. *City University of Hong Kong Law Review*, *2*(October), 331–353.

Lund, P. D. (2007). Upfront resource requirements for large-scale exploitation schemes of new renewable technologies. *Renewable Energy*, *32*, 442–458.

Mabel, M. C., & Fernandez, E. (2008). Growth and future trends of wind energy in India. *Renewable and Sustainable Energy Reviews*, *12*(6), 1745–1757.

Mahajan, V., Muller, E., & Wind, W. (2000). *New-Product Diffusion Models (International Series in Quantitative Marketing)*. New York: Springer.

Mansfield, E. (2012). Technical Change and the Rate of Imitation. *Econometric Society Stable*, *29*(4), 741–766.

Marcoulides, G. A., & Hershberger, S. L. (1997). *Multivariate Statistical Methods: A First Course*. New Jersey: Psychology Press.

Marques, A. C., & Fuinhas, J. A. (2012). Are public policies towards renewables successful? Evidence from European countries. *Renewable Energy*, *44*, 109–118.

Marques, A. C., Fuinhas, J. a., & Pires Manso, J. R. (2010). Motivations driving renewable energy in European countries: A panel data approach. *Energy Policy*, *38*(11), 6877–6885.

Martinot, E. (2010). Renewable power for China: Past, present, and future. *Frontiers of Energy and Power Engineering in China*, *4*(3), 287–294.

Martinot, E., & Beck, F. (2004). Renewable Energy Policies and Barriers. *Encycopedia of Energy*, *5*, 365–383.

McDermott, M. (2012, January 9). Energy News Recap: 2.4 GW Seawater Pumped Hydro Project; China Ups Wind Power Target to 1000 GW. *treehugger*. New York. Retrieved January 9, 2015, from http://www.treehugger.com/energy-policy/first-seawater-pumped-hydro-project-china-ups-wind-power-target-1000GW-2050.html

Meade, N., & Islam, T. (1998). Technological Forecasting Model Stability , and Model Selection , Models Combining. *Management Science*, *44*(8), 1115–1130.

Meade, N., & Islam, T. (2006). Modelling and forecasting the diffusion of innovation – A 25-year review. *International Journal of Forecasting*, *22*, 519–545.

Menz, F. C., & Vachon, S. (2006). The effectiveness of different policy regimes for promoting wind power: Experiences from the states. *Energy Policy*, *34*(14), 1786–1796.

MERC. Maharashtra Electricity Regulatory Commission (Terms and Conditions for Determination of RE Tariff) Regulations, 2010 (2010). Mumbai: Maharashtra Electricity Regulatory Commission (MERC).

Messac, A., Chowdhury, S., & Zhang, J. (2012). Characterizing and Mitigating the Wind Resource- based Uncertainty in Farm Performance. *Journal of Turbulence*, *13*(13), 1–26.

Michaelowa, A. (2004). *The German Wind Energy Lobby How to successfully promote costly technological change* (No. 296). Zurich.

Ministry of Law and Justice. The Electricity Act, 2003. , Pub. L. No. 33004/2003 (2003). India.

Mitchell, C., Bauknecht, D., & Connor, P. M. (2006). Effectiveness through risk reduction : a comparison of the renewable obligation in England and Wales and the feed-in system in Germany. *Energy Policy*, *34*, 297–305.

MNRE. (2013). *Developmental Impacts and Sustainable Governance Aspects of Renewable Energy Projects*. New Delhi.

MNRE. (2015). *LIST OF WIND MONITORING STATIONS WITH MAWS & MAWPD*.

Chennai.

Moreno, R., Barroso, L. a., Rudnick, H., Mocarquer, S., & Bezerra, B. (2010). Auction approaches of long-term contracts to ensure generation investment in electricity markets: Lessons from the Brazilian and Chilean experiences. *Energy Policy*, *38*(10), 5758–5769.

Morthorst, P. E., & Chandler, H. (2004). The cost of wind power. The facts within the fiction. *Renewable Energy World*, *7*(4), 126–137.

Mulder, A. (2008). Do economic instruments matter? Wind turbine investments in the EU(15). *Energy Economics*, *30*(6), 2980–2991.

Narasimhan, T. E. (2012, August 21). Affordable wind energy not hot air. *Business Standard*. Chennai. Retrieved from http://www.business-standard.com/article/economy-policy/affordable-wind-energy-not-hot-air-112082100061_1.html

Narayanan, R., & Hamsalakshmi, R. (2014). Management FDI Opportunities in Indian Renewable Energy Sector. *PARIPEX - INDIAN JOURNAL OF RESEARCH*, *3*(April), 38–39.

Nathan, H., Mishra, S., & Reddy, S. (2010). *An Alternative Approach to Measure HDI* (No. WP-2008-001). Mumbai.

National Renewable Energy Laboratory (NREL). (2012). *IEA Wind Task 26 - The Past and Future Cost of Wind Energy*. Colorado.

Natural Resource Defense Council. (2014). *A Second Wind for India ' s Energy Market: Financing Mechanisms to Support India ' s National Wind Energy Mission*. New York.

Neij, L. (1997). Use of experience curves to analyse the prospects for diffusion and adoption of renewable energy technology. *Energy Policy*, *23*(97), 1099–1107.

Palutikof, J. P., Kelly, P. M., & Davies, T. D. (1987). Impact of Spatial and Temporal Windspeed Variability on Wind Energy Output. *Journal of Climate and Applied Meteorology*, *26*, 1124–1133.

Parthan, B. (1998). Testing and certification of wind turbines: The European and the Indian scenarios. *International Journal of Global Energy Issues*, *10*(2/4), 213–219.

Pasqualetti, M. J. (2001). Wind Energy Landscapes : Society and Technology in the California Desert. *Society & Natural Resources : An International Journal*, *14*(8), 689–699.

Popp, D., Hascic, I., & Medhi, N. (2011). Technology and the diffusion of renewable energy. *Energy Economics*, *33*(4), 648–662.

Qudrat-Ullah, H. (2014). *Better Decision Making in Complex, Dynamic Tasks Training with Human-Facilitated Interactive Learning Environments (Understanding Complex Systems)* (First.). Toronto: Springer.

Rajsekhar, B., Hulle, F. Van, & Jansen, J. C. (1999). Indian wind energy programme :

performance and future directions. *Energy Policy*, *27*, 669–678.

Rangarajan. (1995). Wind Energy Potential in India. *Energy Environment Monitor*, *11*(1), 1–12.

Rao, K. U., & Kishore, V. V. N. (2009). Wind power technology diffusion analysis in selected states of India. *Renewable Energy*, *34*(4), 983–988.

Reiche, D., & Bechberger, M. (2004). Policy differences in the promotion of renewable energies in the EU member states. *Energy Policy*, *32*(7), 843–849.

REN21. (2010). *Renewables 2010 Global Status Report*. Paris.

REN21. (2014). *Renewables 2014 Global Status Report*. Milan.

Río, del P., & Unruh, G. (2007). Overcoming the lock-out of renewable energy technologies in Spain: The cases of wind and solar electricity. *Renewable and Sustainable Energy Reviews*, *11*(7), 1498–1513.

Rogers, E. M. (1962). *Diffusion of innovations*. New York: The Free Press.

Romm, J. J., & Curtis, C. B. (1996, April). Mideast Oil Forever? *The Atlantic Monthly*, (April), 1–15.

Roney, M. J. (2013). *Eco-Economy Indicators - Wind Power*. *Cumulative Installed Wind Power Capacity in Top Ten Countries and the World, 1980-2013*. Washington.

Runci, P. (2005). Renewable Energy Policy in Germany. Maryland. Retrieved August 10, 2013, from http://www.globalchange.umd.edu/energytrends/germany/4/

Saebi, J., Javidi, M. H., & Buygi, M. O. (2015). Toward mitigating wind-uncertainty costs in power system operation : A demand response exchange market framework. *Electric Power Systems Research*, *119*, 157–167.

Sawin, J. L. (2001). *The Role of Government in the Development and Diffusion of Renewable Energy Technologies: Wind Power in the United States, California, Denmark and Germany, 1970-2000*. Tufts University.

Schaefer, M. S., Lloyd, B., & Stephenson, J. R. (2012). The suitability of a feed-in tariff for wind energy in New Zealand-A study based on stakeholders' perspectives. *Energy Policy*, *43*, 80–91.

Scheer, H. (1998). *Windiger Protest: Konflikte um das Zukunftspotential der Windkraft*. (F. Alt, J. Claus, & H. Scheer, Eds.). Bochum: Ponte Press.

Schwarz, G. (1978). Estimating the Dimension of a Model. *The Annals of Statistics*, *6*(2), 461–464.

Secretary of Energy Advisory Board. (1995). *Energy R&D: Shaping Our Nation's Future in a Competitive World: Final Report of the Task Force on Strategic Energy Research and Development*. Washington.

Sesto, E., & Ancona, D. F. (1995). Present and prospective role of wind energy in electricity supply. In *Conference on Designing a sustainable electric system for the 21 Century* (pp. 577–583). Paris.

Sharma, A., Srivastava, J., Kar, S. K., & Kumar, A. (2012). Wind energy status in India: A short review. *Renewable and Sustainable Energy Reviews*, *16*(2), 1157–1164.

Shi, P. (1988). International Cooperation on Wind Energy Technology in China. In *Asian and Pacific Area Wind Energy Conference*. Shanghai.

Sijm, J. P. M. (2002). *The Performance of Feed-in Tariffs to Promote Renewable Electricity in European Countries*. Petten.

Söderholm, P., & Klaassen, G. (2006). Wind Power in Europe: A Simultaneous Innovation–Diffusion Model. *Environmental and Resource Economics*, *36*(2), 163–190.

Sovacool, B. (2008). *The Dirty Energy Dilemma: What's Blocking Clean Power in the United States*. Connecticut: Praeger.

Suck, A. (2002). *Renewable Energy Policy in the United Kingdom and in Germany*. Bonn D.

Teng, J. T. C., Grover, V., & Güttler, W. (2002). Information Technology Innovations : General Diffusion Patterns and Its Relationships to Innovation Characteristics. *IEEE Transaction on Engineering Management*, *49*(1), 13–27.

Toke, D. (2005). Are green electricity certificates the way forward for renewable energy ? An evaluation of the United Kingdom' s Renewables Obligation in the context of international comparisons. *Environment and Planning C: Government and Policy*, *23*, 361–374.

UNDP. (2010). *Global Trends in Sustainable Energy Investment 2010*. New York: United Nations Environment Programme.

UNDP. (2014). *Global Trends in Renewable Energy*. Frankfurt.

UNFCCC. (2007). *Investment and financial flows to address climate change*. Bonn.

Urban, F., Benders, R. M. J., & Moll, H. C. (2009). Renewable and low-carbon energies as mitigation options of climate change for China. *Climatic Change*, *94*(1-2), 169–188.

Vaupen, S. B. (1999). *Renewable Energy Markets in China: An Analysis of Renewable Energy Markets in Guangdong, Jiangxi, Jilin, and Yunnan Provinces, with Updated Information from Beijing*. San Francisco.

Venugopal, K., & Nagalsamy, S. (2012). *Comprehensive Tariff Order on Wind Energy*. Chennai: Government of Tamil Nadu.

Vij, A. K., Vrat, P., & Sushil. (1991). Modelling Diffusion of Energy Technologies: A System Dynamics Approach. In K. Saeed, D. Anderson, & J. Muchuca (Eds.), *The 9th International Conference of the System Dynamics Society* (pp. 636–645). Bangkok: System Dynamics Society.

von Hammerstein, C. (2004). Facing the future - what new policy will mean for wind in Germany. *Renewable Energy World*, *7*, 88–97.

Walden, E., & Browne, G. (2002). Information Cascades in the Adoption of New Technology of New Technology. In F. Miralles & J. Valor (Eds.), *Proceedings of the International Conference on Information Systems 2002* (pp. 435–443). Barcelona: Association for Information Systems 2002.

Wang, Q. (2010). Effective policies for renewable energy—the example of China’s wind power—lessons for China's photovoltaic power. *Renewable and Sustainable Energy Reviews*, *14*(2), 702–712.

Wittman, T., & Bruckner, T. (2009). Agent-based Modeling of Urban Energy Supply Systems Facing Climate Protection Constraints. In *Fifth Urban Research Symposium*. Marseille.

Wolsink, M. (1987). Wind power for the electricity supply of houses. *Netherlands Journal of Housing and Environmental Research*, *2*(3), 195–214.

Wolsink, M. (1996). Dutch wind power policy - Stagnating implementation of renewables. *Energy Policy*, *24*(12), 1079–1088.

Yin, H., & Powers, N. (2010). Do state renewable portfolio standards promote in-state renewable generation?. *Energy Policy*, *38*(2), 1140–1149.

Publications by the candidate

Journal Publications

1. Riddhi Panse and Vinish Kathuria. (2015). "Modeling Diffusion of Wind Power across Countries" *International Journal of Innovation Management*, Vol. 19(4).
2. Riddhi Panse and Vinish Kathuria. (2016). Role of Policy in Deployment of Wind Energy – Evidence across States of India. Vol. 53, pp. 422-432. (*forthcoming*)
3. Riddhi Panse and Vinish Kathuria. The influence of local factors in the investment decision in wind power technology – conceptual framework and empirical findings (Under review in *Energy Policy*)

Book Chapter (as Contributing Author)

1. Patwardhan, A., I. Azevedo, T. Foran, M. Patankar, A. Rao, R. Raven, C. Samaras, A. Smith, G. Verbong and R. Walawalkar, 2012: Chapter 16 - Transitions in Energy Systems. In *Global Energy Assessment - Toward a Sustainable Future*, Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 1173-1202.

Conferences

1. Riddhi Panse and Vinish Kathuria. 2014. Role of Policies in Deployment of Wind Energy - Evidence across the Selected States of India, Int. Conf. of Environment, Technology, and Sustainable Development 2014, Gwalior, India, March 2014 (presented).
2. Riddhi Panse and Vinish Kathuria. 2014. Modelling Diffusion of Wind Power across Countries. 5th World Congress of Environment and Resource Economists, Istanbul, Turkey, June 2014 (presented).
3. Riddhi Panse and Vinish Kathuria. 2014. Role of Policies in Deployment of Wind Energy - Evidence across the Selected States of India, 14th Consortium of Students in Management Research, IISc Bangalore, India, Nov. 2014 (presented and **rewarded second best paper award**).

Acknowledgments

My deepest gratitude goes to my advisor, Dr. Vinish Kathuria, for his generous, invaluable, support, guidance, and patience throughout my research. He has been the best advisor I could ever wish for! Next, I would like to thank my research evaluation committee members – Dr. Shireesh Kedare and Dr. Kiran Kumar Momaya – for their critical feedback and interaction during annual progress seminars and otherwise as well. I am extremely thankful to the firms who whole heartedly participated in the primary survey and also to the government organizations which provided me with much needed data without any discretion.

I am very grateful to my fellow researchers and colleagues from various departments for numerous insightful discussions. Particularly, I would like to thank: Rahi Jain, Neeraj Sanghi, Marshal Maskeranj, Sheeba Sekharan, Shiva Muthu Prakash Murugan, Disha Bhanot, Pranoti Pokale, Deepa More, Rahul Bhat, and Sundar Parthasarathy for all the help and feedback over the years.

I will miss the inspiring atmosphere of the PhD lab, thanks to: Namita Shah, Debabrata Das, Rujuta Matapurkar, Preeti Virdi, Harsh Pradhan, Diksha Rohra, Thiagu Ranganathan, Ruchita Gupta, Sheetal Menon, Siddhartha Sarkar, Madhukar Nagare, Gouri Gargate, Abdul Razak Honnutagi, Vinod Pathari, Rashmi Dyondi, Sagari Dey, Kalpak Kulkarni, Mangesh Gharote, Sirus Sharifi, Govind Srivastava, Vijay Singh Shekhavat, Sunny Arora, Arunima Halder, and Sheila Roy. I have been very lucky to know you. I hope to continue to be friends with all of you.

I would like to acknowledge the financial support from my department at IIT Bombay. Also, I am grateful for support and help from office staff: Narendra Rajput, Archana, Joshi, Nandini Vartak, Satyavan, Dnyaneshwar, and Pradeep.

I owe a lot to my parents who have been the continuous source of love and support ever since. Without them, I couldn’t have evolved as the person and couldn’t have accomplished these milestones. I thank my brother who has advised me on critical matters not only during PhD but also throughout my life. Special thanks to my sister-in-law and my two sweet nieces.