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Wind power success in Brazil

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Method:	Qualitative Case study	

Summery: This study seeks the explanation behind the Brazilian wind power success.

Since the beginning the industry have turned out to be a success by becoming the cheapest source of electricity. This study discusses three different explanations (hypotheses) to the success: Technological explanation (hypothesis 1), market explanation (hypothesis 2) or governmental explanation (hypothesis 3). The study has been conducted as a triangulated qualitative case study by combining interviews and written data.

The explanations were not supported as one-factor explanations. The technological - and the market explanation were concluded to be necessary but not sufficient. The governmental explanation was both necessary and sufficient to create the success.

Keywords for library: PROINFA, Brazil, Wind Power, Path-dependence, Path-creation, Innovation, Technology, Lock-in, Entrepreneur, innovation models, demand, supply, government regulations,

Preface

This thesis marks the end of my MSc Innovation and Entrepreneurship at Bergen University College. The work on this thesis has been exciting, instructive but at times also demanding.

I want to thank everyone who made this thesis possible.

I would like to thank my talented supervisor, Tom Skauge for his patience and guidance with my thesis. He has always taken the time and given me good and constructive feedback that has been a great help to me throughout this thesis.

I will also thanks the researchers: Tom Skauge, Einar Braathen, Jan Froestad and Antonio José Junqueira Botelho from the research program: Transition to sustainable energy systems in emerging economies – A South African focused comparative project (comparing China, India, South Africa and Brazil, the southern BRICS) for collecting interviews and let me use their data material in this study.

Thanks to Antonio José Junqueira Botelho for taking time for interview when you was visiting Bergen spring 2015.

Thanks to Ricky Röntsch for transcription of one of my interview.

Thanks to Paula DeWitte for review this thesis.

Glossery

GWEC	Global Wind Energy Council
PROINFA	Program of Incentives for Renewable Energy
BRICS	Brazil, Russia, India, China, South-Africa
WBG	World Bank Group
BNDES	Brazilian National Development Bank
CO_2	Carbon dioxide
SOE	State Owned Enterprise
PPA	Power Purchase Agreement
ABEEólica	Brazilian Wind Power Association
RETs	Renewable Energy Technologies
CAPEX	Capital Expenses
IRENA	International Renewable Energy Agency
R&D	Research and Development

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1 Introduction

> *"Wind is becoming the cheapest source of energy in Brazil, beating natural gas and hydroelectric power." Nielsen (2011)*

Autumn 2014 Brazil managed through energy auctions to sell energy produced by wind turbines at competitive prices to hydropower and non-renewable energy sources. I will in this study call this a success in the Brazilian energy matrix, where they have been able to produce economical sustainable wind power that is competitive with well-established power sources. Brazil has a tradition for energy from renewable sources. Between 70-90 % of the Brazilian electricity have been covered from hydropower. The last decade the country has been facing major blackouts. It is believed this is a result of several factors such as energy theft, draughts and growing demand for energy.

Brazil is one of the countries in the industrial world with largest share of clean energy. 44.1 %[1] of the energy in Brazil comes from renewable energy sources. Hydropower, which is the main source, contributes with as much as 81.7 % of all the electricity. Despite of this other renewable energy technologies have an annual growth rate at 10.01 % (Hsiao-Tien Pao and Hsin-Chia Fu 2013: 382),

> *"Energy drives human life and is extremely crucial for continued human development. Throughout the course of history, with the evolution of civilizations, the human demand for energy has continuously risen." M. Asif and T. Muneer (2007: 1389).*

Energy is crucial for the economical development of a country, secure and stabile access to energy is necessary for economic growth, and MacKay (2009: 5) have asked the question *"why are we discussing energy policy?".* He suggests three different motivations that drive the energy discussion today. Fossil fuel is a finite resource, energy security when it comes to supply and the truth that fossil fuels are changing the climate.

[1] Numbers from 2013

We live in a historical period where green energy is getting more important. The world is changing and the growing demand for energy worldwide puts energy supply under pressure. My motivation to study the wind power industry in Brazil is connected to its success. In a short period of time Brazil has manage to create a new industry. By studying this phenomenon I hope to create value and insight into the emergence of an industry and how it evolve to become sustainable. Several communities are today facing a critical juncture where they face a negative lock-in, by understanding how industries emerge I will gain better insight about turning a negative lock-in to be unlocked.

I was presented the thematic of this study from my supervisor that is part of the research group studying energy transitions in BRICS countries. BRICS countries are defined as Brazil, Russia, India, China and South - Africa. The group of BRICS countries is emerging markets in the global economy.

1.1 Problem definition

The case of this study is wind power industry in Brazil. The wind industry is one of three technologies that is part of the Program of Incentives for Renewable Energy, called the PROINFA program. Beside wind power technology in the PROINFA program there is biomass technology and small hydro technology. The goal of the program was to initiate 3,300 MW of renewable energy into the energy matrix of Brazil. Of these 3,300 MW, there was supposed to be 1,100 MW from each of the three technologies (Peter Meier, Maria Vagliasindi et al. 2015: 222). Biomass and hydropower was already presented in Brazil and especially hydropower was well known and highly represented in the energy matrix.

Wind power is the one that have been most successful through the PROINFA program. I will discuss three different hypotheses as possible explanations. The three hypotheses are all suggested to have played a central role for the success.

Hypothesis 1 (H1): *Wind turbine technology was mature and the technological risk was low.*

I shall call this the *technological explanation.*
Wind power technology has been on the market for decades and has been going through radical and incremental innovations. The technology could easily be implemented and there is low technological risk.

Hypothesis 2 (H2): *Entrepreneurs linked a demand for energy with a supply from wind technology.*

I shall call this the *market explanation*.
Brazil have been facing economic growth, greater share of the population have been lifted out of poverty. It is anticipated that all this led to an increasing demand for energy. There was low risk in order for entrepreneurs to create a market and both a demand and supply were present in Brazil.

Hypothesis 3 (H3): *The success is a result of government market creation by changing the energy path.*

I shall call this the *governmental explanation.*

The combination of government regulation and the creation of a path is the answer of the success. A government market creation to meet energy demand and affected of historical contingent factors. The fast growing industry was stabilized by regulations, founding and government market-push that all led up to a success within wind industry.

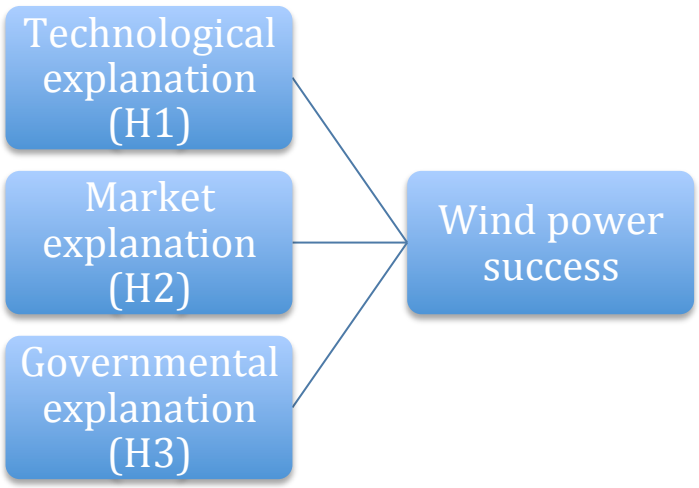

Figure 1.1 – Three different explanations that will be discussed in relation to the Brazilian wind power success.

I do not expect these three explanations to be mutually exclusive. I rather believe they have contributed to the success in various ways. This implies there will be no one-factor explanation where there is one hypothesis that explains the success and that others will be disconfirmed or not supported.

1.2 Outline

In my study I will start with presenting theory that I will use in my discussions. Theory I´m going to use is put in different section, one for each hypothesis. Theory will be presented in chapter 2.

I will then discuss methods and research design for my study in chapter 3. In this chapter sources of data applied will be elaborated, choice of research design and how the quality of the research is taking into account, I then refer to the validity and reliability of this study.

Chapter 4 is my chapter for analysis and is where I will be discussing the different hypothesis. I will present evidence and concluded whether or not there is sufficient evidence and if my anticipation to find support for the different hypothesis is met. The three different explanations will be discussed in separate subsections.

Chapter 5 summarize my conclusions from the different discussions.

2 Theory

Theories that are anticipated to highlight factors behind the success of the wind power industry will be presented in this chapter. I have decided to divide it into different parts.

In section 2.1 I will present different models of innovations and how a market adoption for technology is undertaken. Then in section 2.2 I will be looking at the demand for energy in Brazil and theory of entrepreneurial recognition and risks associated by undertake entrepreneurship. Further I will present difficulties with renewable energy technologies (RETs) penetration.

Theory to be applied in my main discussion will be presented as two parts, section 2.3 and 2.4.

In Section 2.3 theories regarding path-creation, path-dependence and path-constitution will be presented. It will also describe the term ”lock-in” and what lies behind a positive or negative ”lock-in”.

In section 2.4 I will go through government regulations. This will be regulation regarding privatization/quasi-market and regulations to promote development of RETs.

2.1 Technology development and innovation

It is argued that there is three phases in an innovation process (Trott 2012: 210). These three phases are divided into *fluid phase, transitional phase* and *specific phase.* Trott referring to a model presented by Utterback (1996: 17-18).

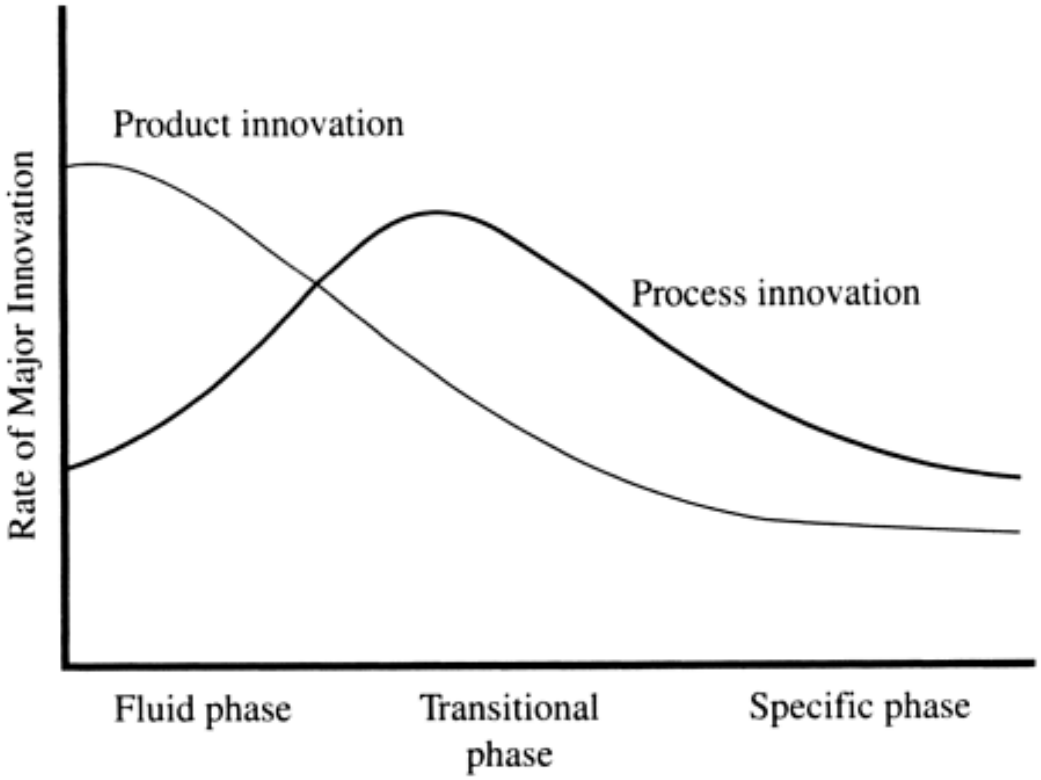

Figure 2.1.1 – Phases of innovation. Source: Utterback (1996: 17)

Trott (2012: 210-211) presenting the three phases in figure 2.1.1 in a simple way: *Fluid phase* consist of an explosion of different designs and it is an era of radical product innovation. In the *transitional phase* the dominant design is established and there is an emergence of process innovation. The *specific phase* is characterized by contraction of competitors and an era of incremental innovation. In the fluid phase the goal is to establish a dominant design. This occurs at the point where the two curves meets (between the fluid and transitional phase). The specific phase is characterized by focus on lowering cost of the product and create more efficient production processes.

In the beginning of the dominant design innovation model (figure 2.1.1) focus is on catching customers with the product and design. This is why product innovation is high in the fluid phase and not much attention is given to the processes to produce the products (Utterback 1996: 18). When going into the transitional phase, product innovation slows down and the rate of process innovation increases. The dominant design is at this stage established and focus is towards efficient and reliable production processes. When the technology goes into the specific phase the focus is towards cost, volume and capacity. In this phase process innovations will occur as incremental steps.

Between 1950-1970 I was a perception that innovation and technological development emerged as a linear sequence according to (Trott 2012: 26). 1950´s were characterized by technological push while it in the 1970´s shifted towards a process of meeting demand or specific needs in the society. This led technological development being the result of market pull. In a market-push model it starts with basic research where R&D activity is aimed to achieve greater understanding and knowledge. Discoveries from this activity are then pushed into the market. Market-pull is the opposite where new technology is the result of close interaction with customers through marketing that initiate new ides and demand (Trott 2012: 23). These ideas are then taken into R&D before they are manufactured and commercialized.

Technology push

Market pull

Figure 2.1.2 – Linear innovation models (Trott 2012: 22)

Presented in figure 2.1.2 are the linear models of innovation. These was the classic models presented between 1950 – 1970 (Trott 2012: 26). In the 80´s there was perception where innovation occur as a model that combined both technology push and market pull. This was called the interactive innovation model. This model combined the

two linear models into one so that the R&D process could get feedback along the process, and thereby adjusting the commercial product throughout the R&D process. By applying this innovation model the latest technology, science, needs and demand in the society could be feed into the process. Trott (2012: 24) describing this model of being simplified but still present the innovation process comprehensive.

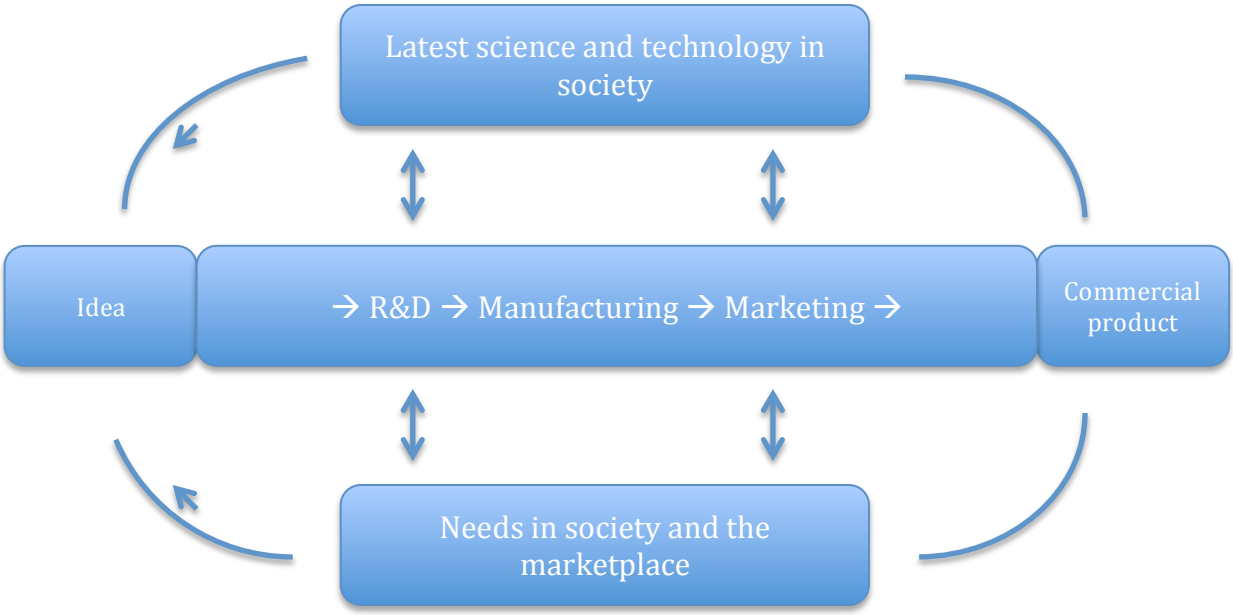

Figure 2.1.3 – Dynamic innovation model (Trott 2012: 24).

I have now presented three different perceptions of the technological innovations process and how it is believed innovations has occurred through time. When the commercial product is launched into a market it has to go through a process where it will be accepted or rejected. A theory explaining how the technological adoption process undergoes is the technology adoption life cycle.

2.1.1 Technology adoption life cycle

Innovation diffusion process is the process where technology are going from market introduction, a stage where it is only accepted from a minority of the market to become an established standard. It all start with a group of actors, which Trott (2012: 68) describes as the innovators and early adopters. These two groups are not a large share of the total addressable market, but counts approximately 16 % of it. The critical phase of every technological innovation is to be embraced by these two groups, in order to achieve acceptance of the early majority of the total addressable market.

Moore (2014), present his model of the technology adoption life cycle.

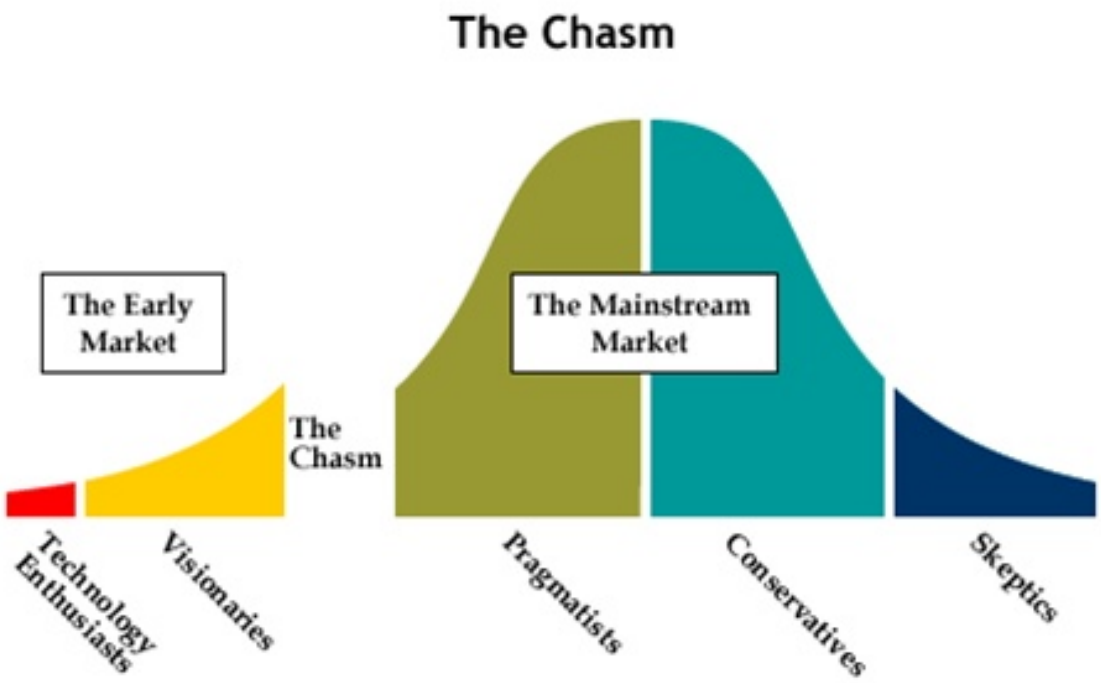

Figure 2.2.1 – Technology adoption life cycle [2]

Innovators and some of the early adaptors often buying products and seek new technologies because of their interest. When acquire new technology these two groups of customer is not concerned with proof of concept (Moore 2014: 15-17). They are willing to take the risk even before the product is ready for a commercial market. Innovators are rare, but for many technological products they are an important group of customers to convince in order to start a technological adaption. Innovators are in many cases followed by early adopters; these buy or seek technology that they could benefit from. Equal to innovators these are willing to take the risk with new technology. Adoption of technology from these groups is not because of references but rather on intuitions and visions.

[2] Source: https://randomwalls.files.wordpress.com/2012/03/crossing-the-chas.jpg

Until now the group of customer has been strictly limited and risk of a market failure is still imminent. The most challenging part of the technological adoption process is yet to come in order to enable an adoption by the mainstream market. To reach early majority of the market the technology has to cross *the chasm*. In order to cross the chasm the technology must complete proof of concept.

Majority of a market is often characterized by sceptics. Early majority of a market often waits until technology is established and not just a passing fad, they further seek references before making their decision to buy or not. Late majority of a market are quite similar to the early majority. Difference is that they need an established standard and to see lot of support to consider adopting technology. The last group of customers in the market is described as laggards. Laggards are the group of customers that is not worth pursuing. This customer group don't want anything to do with new technology.

Trott emphasis consumers' reactions on innovations to the benefit they expect to get out of it.

> *"Consumers´ reactions to innovative new products and their willingness to embrace them are also, of course, driven by the benefit they expect to derive from the products." Trott (2012: 69)*

When new and disruptive or discontinues innovations happens, these will acts as game changers and require more from the customers. Sometimes they require the customer to change in their pattern of behaviour. These kinds of innovations are therefore exposed for high degree of risk, where market failure is an imminent danger.

My technological explanation (H1) anticipates that the success of the Brazilian wind power industry is the result of a mature technology with low technological risk. To find support for this hypothesis I expect to find that wind power technology is the result of long development process. I also expect to find Brazil to be somewhere between early and late majority in the technology adoption life cycle.

2.2 Market and the entrepreneur

Stern (2011: 45) concluded in his study that energy is important for growth since production is the function of capital, labour and energy.

Pursuing a new market, establishing ventures and exploiting technological innovation is linked to high degree of risk and uncertainty. Trott (2012: 95):

> *"Accepting risks does not mean a willingness to gamble. It means the willingness to consider carefully risky opportunities."*

Brian Wu and Anne Marie Knott (2006: 1315) emphasis uncertaintes regarding market demand to be a source of uncertainty in entrepreneurial ventures. Painuly (2001) have been looking at barriers to RET penetration. The potential of renewable energy is large and some RETs are largely competitive with non-renewable energy sources. To be able to realise the potential of RETs their adoptions barriers need to be identified and overcome. Painuly (2001: 79-81) presenting barriers for a RET penetration to occur:

Market failure/imperfection – If there is restricted access to technology and lack of competition it could lead to lack of investment in RET. Lack of competition my increase cost of technology, if it is available. If not available technology has to be imported which further increase the cost. This could lead to uncertainty of supply. *Market distortions* – If the government favour conventional energy by subsidies it will affect the competitiveness of RETs. By don't calculate externalities into the price of conventional energy the price end up being less then it should be and RETs could probably not compete on price. *Economic and financial* – High up-front capital costs on RETs increase the risk of projects not being completed. The technology also need to be economical viable in order to limit financial and economical barriers. *Institutional* – If there is lack of institutions/mechanisms to disseminate information there is none that can promote the technology above the government. A critical barrier is lack of R&D culture. If this is lacking a technological adoption process could be difficult. It is also important to have private sector participation. If it is lacking it could result in insufficient competition and ineffectiveness. *Technical* – Lack of standard, codes and certification could result in poor

quality and thereby affecting the product acceptability and increase technological risk. Skilled personnel are also important in order to create manufacturing of RETs. *Social, Cultural and Behavioural* - Lack of consumer acceptance of the product could affect the market size. Other barriers that Painuly (2001) presenting are environmental barriers and lack of infrastructure. Environmental focus in the country, environmental damage or pollution may lead to public resistance and then increase the barrier of RETs penetration, or it could be favourable and then lowering the barriers. Infrastructure is especially important when it comes to wind technology. Roads for transportation and grid connectivity are essential when using this technology.

2.2.1 The Entrepreneur

Robert Wiltbank, Nicholaas Dew et al. (2006) have been discussing the situation of non - predictive strategy within firms and entrepreneurial activity. It is refer to two different fundamental prescriptions they could follow to make the choice of *what to do next*. Either the firms might *try harder to predict better*, or they could *move faster to adapt better.*

> *"Which prescription a firm is to follow depends upon how confident the firm is in its ability to predict changes in its environment." Robert Wiltbank, Nicholaas Dew et al. (2006: 983)*

Try harder to predict better refers to the strategy of planning where the emphasis of prediction is high while the emphasis of control is low, it is about trying to predict and position more accurately. M*ove faster to adapt better* refers to the strategy of adaptive where the emphasis of prediction is low and so is the emphasis of control, it is about moving faster to a rapidly changing environment (Robert Wiltbank, Nicholaas Dew et al. 2006: 983)

Jeffery S. McMullen and Dimo Dimov (2013) emphasize human capital in entrepreneurial activity. The term entrepreneur are defined in different ways, some define it as risk taking, other as new ventures in the response of identified opportunities. One definition that cover the activity of being a entrepreneur, entrepreneurship are:

> *"The process by which people recognize opportunities to satisfy needs and then gather and use resources to meet those needs." Jones (2013: 24)*

The entrepreneurial process is not a linear sequence, the journey and time line is as understand through the work of Jeffery S. McMullen and Dimo Dimov (2013: 1487) depended of the entrepreneurs ability to observe and process new information. Sometimes information needed in the start of a sequence of events where given or observed to late. By perform entrepreneurial activity the individuals taking a great portion of risk when going the path by exploit market opportunity technical or organizational with innovation.

Information is acquired over time and is then combined with existing information that is possessed. As Jeffery S. McMullen and Dimo Dimov (2013: 1491) put it, new information is added on existing if this information is consistent with the prior knowledge. Other times the existing knowledge base have to be reorganized to get the full benefit or understanding of new information.

Saras D. Sarasvathy, Nicholas Dew et al. (2010: 81) presenting three views of entrepreneurial opportunity: *opportunity recognition, opportunity discovery* and *opportunity creation.*

With *Opportunity recognition* there is an obviously supply and demand. The opportunity is to bring these two together and this has to be recognized. Bringing supply and demand together could be done through existing or a new firm.

> *"This notion of opportunity has to do with the exploitation of existing markets." Saras D. Sarasvathy, Nicholas Dew et al. (2010: 81)*

When only one side exist, either supply or demand, there will be a non-existing side. There is one side that have to be *discovered* to be able to create a match between supply and demand. *Opportunity discovery "has to do with the exploration of existing and latent markets."* (Saras D. Sarasvathy, Nicholas Dew et al. 2010: 81).

With both *opportunity recognition* and *opportunity discovery* either one or both side of the market is known. It is about to making a match so the supply will meet the demand and vice versa. When it comes to *opportunity creation* neither supply or demand exist in an obvious manner. One or both have to be *created*. *"This notion of opportunity has to do with the creation of new markets"* (Saras D. Sarasvathy, Nicholas Dew et al. 2010: 81-82).

The contrast to this is the *expert entrepreneurs*, they do not necessarily start with an opportunity or market research (Saras D. Sarasvathy and Nicholas Dew 2013: 289). Instead it starts with three basic questions; *who I am, what I know, whom I know*. Expert entrepreneurs are likely to perform entrepreneurship as an instrument to achieve non-economic goals. This could be to achieve a preferred lifestyle or to solve societal problems such as environmental issues. But in the same whey they might perform entrepreneurship to make money and get an entrepreneurial career. When expert entrepreneurs trying to turn their means into new ends they interact with potential stakeholders.

There is a common perception that entrepreneurs are risk takers. They create new ventures and thereby undertake high degree of uncertainty that is associated with risk. When starting a new business the risk acceptance need to be relatively high in order for the entrepreneur to create the venture (Baron 2012: 101). The failure rate of new ventures is between 80-85 % during the first three years. As Baron (2012: 101) conclude on the question whether entrepreneurs are risk takers or not, is that it depends on the how and when risk are measured. He further emphasise that the risk acceptance changes in different phases of the business creation. Entrepreneurs are anticipated to take higher risk in early phases but not necessarily later in the process (Baron 2012: 104).

Entrepreneur faces a set of risk and has to manage these in order to succeed with its company. Entrepreneurs share their risk with investors that often finance their projects. Risk is dynamic and by considering the risk entrepreneurs could plan for the future. Risk

in entrepreneurial activity is both internal and external. There are risk of not getting skilled personnel and technological risk of the product or solution. Other risks are connected to the market and opportunity, competitive risk, financial risk, political and economic risk (McKinsey&Company 2007).

My hypothesis 2 (The market explanation), searching for evidences that could explain the success of the wind power industry as the result entrepreneurial market creation. Entrepreneurs created the link between supply and demand. To find support from my data I expect to find evidence of a demand and supply side that entrepreneurs could recognize and create the link between. At the same time I anticipate to find barriers of RETs penetration to be low enough so a demand and supply side could be matched.

2.3 Path-dependence and government regulations (2.4)

Theory that I will use to discuss hypothesis 3 is based on two different theories. I will first present theory about path-dependence/path-creation and then regulation policy.

2.3.1 Path-dependence/Path-Creation

> *"The message of path dependency appears to be simple: once you´re on you probably can´t get off." Uli Meyer and Cornelius Schubert (2007: 24)*

Within the theory of path-dependence there is different theories and suggestions how the path actually occur and evolve through time. Theories addresses the field of path-dependence are believed to be central for this study.

I will here present different theories referring the emerging of paths, where it begins and how it evolves. In this study the fact that "history matters" will be central, but also the ability to shape and create the path from different actors. These actors could be the government, industry or public groups. With other words: powerful actors.

2.3.2 Defining the term "Path-Dependence" and "Path-Creation"

"Path-dependence" is through theory described in many different ways. Some says "path-dependence" refer to the case where history matters (Mahoney 2000: 507, Editors 2010: 734), other claim an adequate definition is rarely or hard to find (Pierson 2000: 252). Path-depending process is used increasingly to explain emergence of novelty (Raghu Garud and Karnøe 2012: 5). Social Scientist do distinguishes between the two terms "path-dependence" and "path-creation". As *Raghu Garud and Karnøe (2012)* refers to the term path-dependence it is:

> *"…a sequence of events constituting a self-reinforcing process…" (Raghu Garud and Karnøe 2012: 4)*

In a path-dependence process it is claimed that early stages of the path will be most critical for the development of the path. This is shown by Arthur (1994: 6-8) and his example with Polya´s Urn. In his example there is an urn filled with balls that have different colours. One random ball is picked without watching. The colour is registered and two balls of that colour are added to the urn. After a while equilibrium of balls with different colours will occur. The colours picked at an early stage will heavily affect the equilibrium at the end. The probability of picking a specific colour will change with every ball picked.

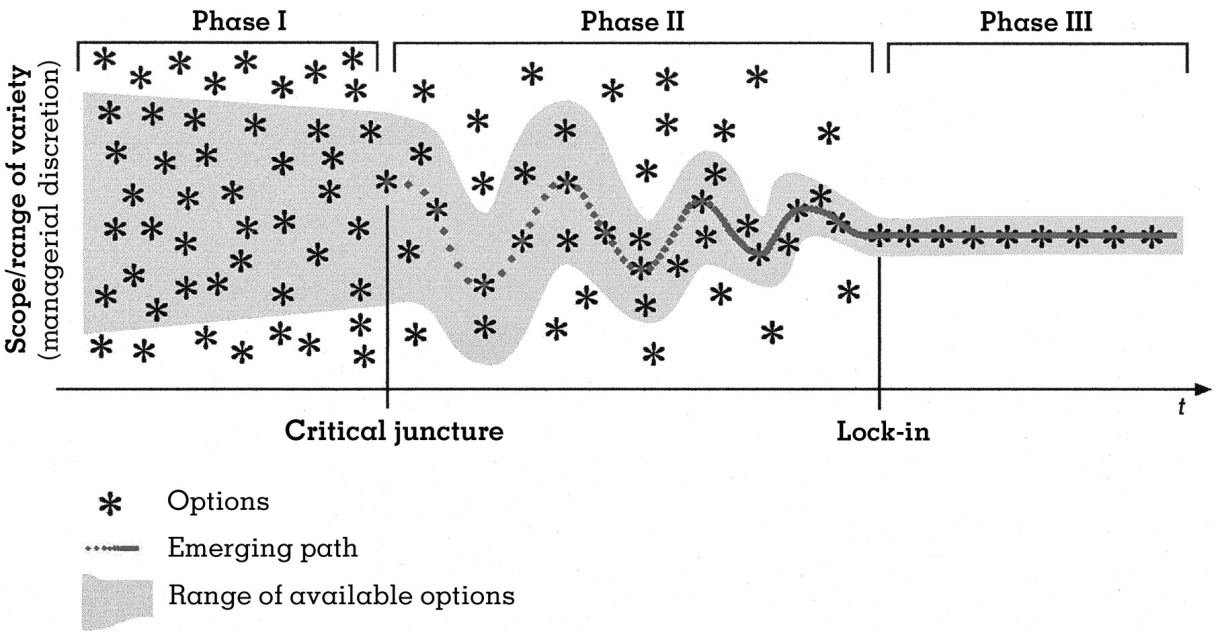

Figure 2.3.1 – constitution of an organizational path (Jörg Sydow and Schreyögg 2009: 692)

The figure presented above showing three phases. These three phases are (1) from the start of a path-dependence process, (2) emergent of the path and (3) the lock-in phase. It all starts with lots of different possibilities. By making some choices in phase 1 the range of available options narrow. In the beginning of phase 2 the emerging of the path could be seen, and at the end of this phase the path will be more and more clear. When phase 3 is entered the availability to select other options is gone. As Jörg Sydow and Schreyögg (2009: 692) explain the flexibility is gone and businesses or regions are locked to certain choices or action patterns. At this point the "lock-in" occurs.

It is anticipated that path-creation is not that unlike a path-dependence process. Both are based on the same assumptions that the technological development is embedded historically, the path might stabilize and if it does it is difficult to reverse it (Uli Meyer and Cornelius Schubert 2007: 26). Uli Meyer and Cornelius Schubert (2007: 27) argue that there is a problematic simplification with the classical path dependency concepts. The simplification could be addressed by highlighting the deliberated aspects in path creation:

1. *Powerful actors can strategically influence the development of a path. They can shape the path, while over time they are themselves shaped by the path.*
2. *Increasing returns and lock-in are subject to deliberate actions and tied in with broader social dynamics.*
3. *The creation, but also the ending of a path may be caused by deliberated actions which do not necessarily have to be external.*

Path-creation is insufficient to describe how a path evolve after it is created (Uli Meyer and Cornelius Schubert 2007: 27). By entrepreneurs the path-creation processes is set in motion in real time. The attempt is to shape institutional, social and technical facets of an emerging technical field (Raghu Garud and Karnøe 2012: 7). By understanding path creation it could be possible to understand how entrepreneurs escape from technological lock-in (Raghu Garud and Karnøe 2012: 7). As Raghu Garud and Karnøe (2012: 6) argue the path creation process could be described as a mindful deviation from well known rules and procedures.

Uli Meyer and Cornelius Schubert (2007: 28) have been looking for a way to integrate the two conceptual approaches into one general understanding. The suggestion is to combine path-creation and path-dependence into one term, *path constitution*. By establishing the term, path-constitution, it will be taken into consideration that a path emerge as a combination of both emergent processes and deliberated actions (Uli Meyer and Cornelius Schubert 2007: 28-29). The path is then no longer a result of just history or random events. More or less it will be the result of planned actions built on coincidence or emergent processes.

The basic properties of path dependency and path creation		
	Concept of constitution	Path properties
Path dependency	Evolutionary-emergent: Paths emerge behind the back of actors, they are not and cannot be controlled by them	- History matters - Increasing returns - Lock-in
Path creation	Strategic-deliberate: Path can be deliberately created by actors, if they are able to mobilise the necessary resources.	- History and social actors matter - Increasing returns and mobilising actors - Lock-in

Table 2.3.1 – Basic properties of path dependence and path creation (Uli Meyer and Cornelius Schubert 2007: 28)

Uli Meyer and Cornelius Schubert (2007: 29) present phases of a path constitution to be divided into three different phases: *generation, continuation and termination*. These three phases is necessary to understand how path creation and path dependence could be combined into path constitution.

The *generation* phase describing the process from the beginning of a path and until it is stabilize. When the path is stabilized the *continuation* phase begin and might end up in the *termination* phase.

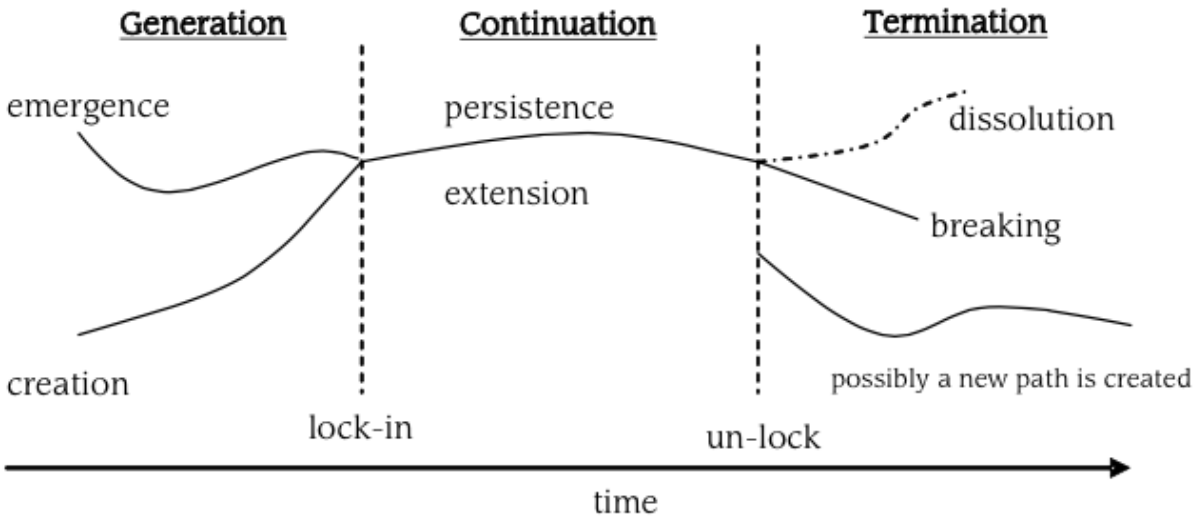

Figure 2.3.2 – phases of path constitution: generation, continuation and termination (Uli Meyer and Cornelius Schubert 2007: 31)

As Uli Meyer and Cornelius Schubert (2007: 30) explains that generation of a new path can have different causes. These causes correspond to different types of processes between emergence and deliberated actions. One thing that is crucial:

> *" Irrespective of how a path has developed, after it has stabilised, and positive feedback has set in, it is very likely to become locked-in" Uli Meyer and Cornelius Schubert (2007: 30)*

Technological options might not get locked-in on it´s own. They then has to be continuously stabilized by deliberated actors (Uli Meyer and Cornelius Schubert 2007: 30). In continuation phase actors are aware of the path and are actively supporting it, at this stage process is path-dependent and shows some sort of self-reinforcement.

Termination phase is the last phase. Uli Meyer and Cornelius Schubert (2007: 31) divide between *path breaking* and *path dissolution.* Path breaking is when an actor mindfully

creates the termination phase. If the termination is the result of emergent processes it is called path dissolution.

2.3.3 Strength and weakness of "lock-in"

A "lock-in" should not just be view as a negative stage within a path-depending process (Ron Martin and Sunley 2006: 415-416). If companies within a region achieve a high degree of technical specialisation it could result as a positive "lock-in". When a positive "lock-in" occurs the region and its companies could be facing economical growth as result of their specialization. The effect of a positive "lock-in" I would say is underestimated, the positive effect this kind of lock-in entails is affecting the entire industry or region where it evolve. An example of this is the Norwegian Subsea industry, which probably have been emerged through a positive lock-in. It is not before the oil industry change that this industry can be locked inside of a negative lock-in. But the industry has created tremendous wealth and jobs for decades before the change from positive to negative lock-in occur.

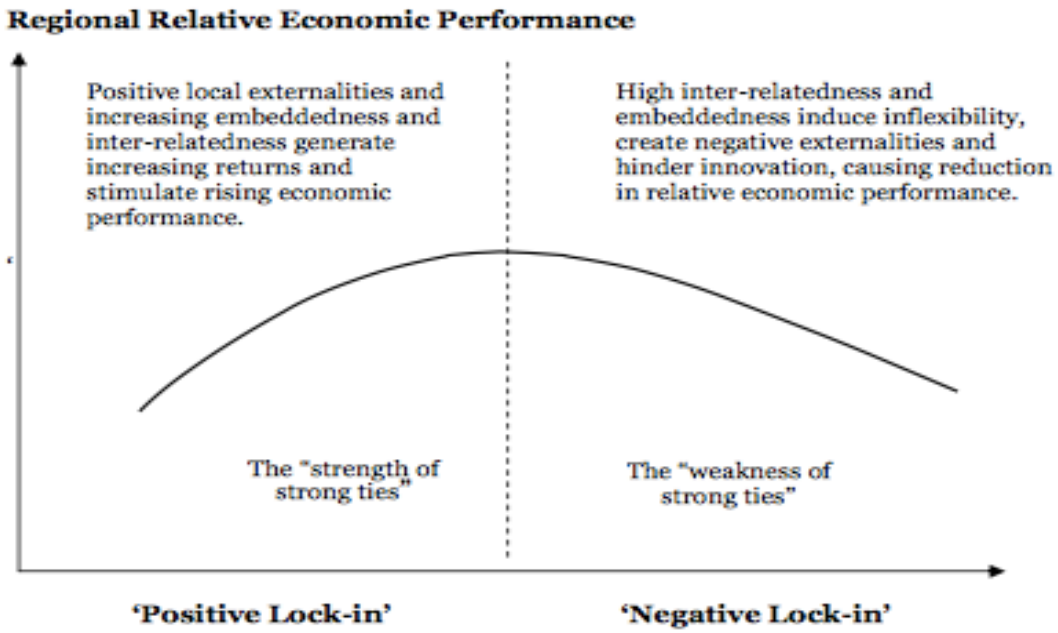

Figure 2.3.3 – Positive lock-in could over time go into a negative lock-in (Ron Martin and Sunley 2006: 416)

Regional growth could in many cases be connected to the growth in an industry or interrelated industries. These stimulate and take advantage of emerging external economies (Ron Martin and Sunley 2006: 415-416). This is what Ron Martin and Sunley (2006) refer to as positive "lock-in". This kind of "lock-in" can be persistent for decades before a technological shift occurs or the market decrease. In worst case the whole market could collapse. Theories of economical history argues that leading technological regions through years will experience a shift, this kind of shift may happen when the industry change from a positive "lock-in" to a negative "lock-in". The negative "lock-in" will not be a problem before the market change and the regional business have locked it self around out-dated, old or slow technology, but also if their success have been on a decreasing market (Asbjørn Karlsen and Isaksen 2008: 52). When the negative "lock-in" phase enters the industry could suffer from economical decline. Ron Martin and Sunley (2006: 417) argue that this regional economical decline is the inability or inertia to adapt with the emergence of competitors or new technologies. Theory of path-dependence present this kind of external shock as driving forces for change. External shocks are explained to bring the industry out from the negative "lock-in" and help it to increase its competitiveness. The major problem that could arise instead is that companies start to layoff employees and cut costs to meet the changes in technology or market demand.

I shall use this as a central concept in my study. The concept of path-creation and path-dependence is considered as central concepts when studying at the emergence of industries and regional development (Asbjørn Karlsen and Isaksen 2008)

2.4 Government regulation

Why do government regulate? One explanation could be to control the market so there will be no monopoles. In this case regulations would be to protect the customers or consumers. Robert Baldwin and Martin Cave (1999: 10) explains that monopoles cause companies to put their prices above marginal costs, which is not beneficial to the consumer. Another explanation to use regulations could be to control environmental harmful discharges from companies, and to control externalities (Carson 2015). A way

to do this is to regulate so that prices of products or services reflecting the total cost. This means price also need to include environmental cost. In Europe the policy to stimulate development of RETs do all focus on the price versus quantity debate (Philippe Menanteau, Dominique Finon et al. 2003: 802). It is three different support schemes that is widely used; feed-in tariffs, bidding processes and green certificates. The different types of support schemes have been used with various results.

2.4.1 Feed-in tariff

By the use of Feed-in tariff (FIT) there is an obligation from the electric utilities to purchase the electricity produced from renewable energy sources. The price for the electricity is determined by a tariff that sets the price for a specific period. FIT is a subsidy to producers of renewable energy. As Philippe Menanteau, Dominique Finon et al. (2003: 802) explain the FIT works in the same way as pollution tax for polluting companies.

The subsidy in FIT-systems is according to Philippe Menanteau, Dominique Finon et al. (2003: 802) financed by cross subsidies of electricity consumers, obligation from utility to buy renewable green electricity, by taxpayer or combination of different types of these.

2.4.2 Competitive bidding process

When applying competitive bidding process the regulator defines a reserved market for a given amount of electricity (Philippe Menanteau, Dominique Finon et al. 2003: 802). It is then organised competition between different renewable energy producers to allocate the given amount. The electric utilities are then obliged to purchase the electricity produced from the companies that have been selected.

Focus in competitions is the price per kWh that is proposed during the bidding process. The proposals are then organized in increasing order of price until the amount to be contracted is reached (Philippe Menanteau, Dominique Finon et al. 2003: 802). Producers of renewable energy that is selected through the competition is awarded with long term contracts of supplying electricity. The price is pay-as-bid.

2.4.3 Green certificate

By using green certificate as mechanism a fixed quota of the electricity sold by operators need to be generated from renewable energy sources (Philippe Menanteau, Dominique Finon et al. 2003: 803). Green certificate takes into consideration that operators have different opportunities to develop renewable energy sources, this lead to different marginal production costs.

Producers of renewable energy issue the Green Certificates. Green Certificate let the producers of renewable energy benefit in two different ways: selling the renewable energy at market price and by selling Green Certificates. When applying Green Certificate it is often done as for bidding schemes; the amount of green electricity to be produced are predetermine and then divided among the different operators (Philippe Menanteau, Dominique Finon et al. 2003: 803).

Philippe Menanteau, Dominique Finon et al. (2003) have been looking at price versus quantity as policy to promote development of renewable energy. They concluded that quantity-based approach was most efficient to control cost of the government incentive policy (Philippe Menanteau, Dominique Finon et al. 2003: 810). Installed capacity where much greater when applying a price-based approach (Philippe Menanteau, Dominique Finon et al. 2003: 811), while incentives to reduce costs of RETs are strongest when competitive bidding is used. Competitive bidding put pressure on producers to reflect lower cost to win the subsidies (Philippe Menanteau, Dominique Finon et al. 2003: 811).

The ability to limit risk is important for investors (Peter Meier, Maria Vagliasindi et al. 2015: 2), and government regulations can be efficient to do it. Government have the benefit that they in certain ways will be able control the technological development in a country. Through regulations and policy governments will be able to affect development by sending signals of accepted and non-accepted ways of technological development (Patrick van Zwanenberg, Adrian Ely et al. 2011: 13). By doing so, government regulations could be path-creating factors. Like innovation policy where the aim is to stimulate and encourage private and public actors to do R&D at areas where the government have political goals or ambitions (Patrick van Zwanenberg, Adrian Ely et al. 2011: 13). Patrick van Zwanenberg, Adrian Ely et al. (2011: 15) state that to be

successful with regulations it is important that get acceptance by the majority of those the regulations affect.

Governments have the ability to affect entrance barriers to an industry by the use of regulations. This might by through regulations specifying production methods, toxic waste or harmful discharges, but also the amount of energy or quantity produced. Limited agreements, auctions, or other kinds of regulations create high entrance barriers to an industry and will therefore affect the competition. Regulations can also limit the cost from the government and in some cases give increased profit from taxes (Patrick van Zwanenberg, Adrian Ely et al. 2011: 16).

Hepburn (2006: 226) states that new regulatory framework has to make incentives so there will be large private investment in energy industry. The goal of these investments should be to secure the excess to energy but also to reduce discharges of greenhouse gasses. The energy industry in several countries is probably at a crossroad where different countries have to choose; renewable, non-renewable or hybrid solution[3].

Environmental economical theories focus mainly on regulations with the aim to internalize negative externalities. Intervention in other sectors is often to control the market forces and to internalize positive externalities (Hepburn 2006: 227). Carson (2015: 176) explains externalities as a socioeconomically problem that could be solved through regulations, taxes and surcharges. It is also important to have penalty for those that don't follow the regulations or attempting to evade various forms of reporting requirements. Hepburn (2006) has been looking at different policy to achieve a specific target. One policy that was found was that economical instrument was particular useful when there was asymmetric information regarding the companies costs. This mean that some companies could do changes very easily with low cost and modifications, others had to do large investments and modifications. Further Hepburn (2006) presenting the hybrid instrument as being efficient where it is possible to combine both price and quantity. When circumstances are uncertain, price as instrument will not be able to give a desired amount. In a corresponding manner will a desired price not be achieved when quantity is used as instrument, if the circumstances are unpredictable.

[3] Hybrid solution is a combination of renewable and non-renewable

Hybrid instruments will be preferred above a clear price or quantity instruments. A hybrid instrument will be much more complex and advance than using single instruments, as the hybrid combines these two. Hepburn (2006: 230) point out that it is important to put an upper and lower limit of price when using hybrid instruments.

Another important aspect of the theory regarding political and governmental regulation policy for this study is the creation of a market. There is different ways this could be done; some of these are through a private market, combination of public and private or quasi market.

Robertsen (1999) refers to competitive tendering of public services or businesses as the purpose to create cheaper manufacturing of goods and services. He differs the concept of quasi competition and privatization. Quasi competition occurs if public businesses are being exposed to competition among themselves. While privatization refers to the action when public sector sets out the production of goods or delivery of services to a private market. It could then be a public/private corporation or competition. In some cases it might end up with private/private competition for delivery of goods and services to the public sector.

Competition tendering by privatization could potentially give increased efficiency compared with public services or production of goods. One reason for this is the constant pressure on private actors to deliver good results and be profitable. If they don't deliver as expected there might be lay offs or the company getting sold, in worst case it will go bankrupt (Robertsen 1999). For public companies, or companies where the government owning shares, the government have the option to reinvest if the companies present low or bad results. But as Robertsen (1999) argue; it is difficult to draw a conclusion whether protected public business or competitive tendering in private sector will operate most efficient.

2.4.4 Quasi markets

Quasi markets are often the result of bad or non-existing private competition in the market. By establish quasi markets there is a risk that the market could get inefficient and don't have any incentives to develop itself or to keep costs down. Quasi markets need incentives or mechanisms that make the companies believe they are operating in a competitive market. Even this is done they might end up with better quality and not cheaper services and products or to be more efficient. The other alternative is to privatize the market, but then there could be high transactions costs from the government to monitor the market, to acquire information, by doing auctions and tenders.

Robertsen (1999) point out that length of contracts is crucial when it comes to projects that require large investment. Contracts that extend over a long period of time will be essential in order to limit risk and uncertainty for investors and entrepreneurs. If the length of contracts is short and there is no guarantee that these will be extended they will be unattractive and increase the risk.

Barber (2007: 21) presenting that quasi-market could be an option to full-scale privatization. There are areas governments hesitate to fully privatise. The option could then be to use elements of private sector but still keep public control of commissioning services and let the private actors deliver them. In a quasi-market the state pays a service provider for the item provided on the on behalf of the user (Grand 2011: 81). Providers in a quasi-market could be private profit-making organizations as well as non-profit organizations or organizations in the public sector.

My governmental explanation (H3) states that the success is a result of market creation by changing the energy path. For this explanation I will be using both theory of path-dependence and governmental regulation. To find support for this explanation I expect to find that the framework of the wind power market was deliberate created by governmental regulation. I also expect to find that regulations have been used to actively support the emergence of a new path by the use of path-creation actions that has resulted or could result in path-dependence.

3 Method and research design

This study will be conducted as a triangulated qualitative research by single case study. I have decided to do qualitative research since the study is using data that is not quantifiable. The research design will be based on a combination of positivistic and constructionist research design. By using only a positivistic design I would believe there are true answers or correct answer. The study would then have started with a hypothesis and looking for answer to confirm or disconfirm it (Mark Easterby-Smith, Richard Thorpe et al. 2012: 39). Positivism is generally associated in that sense that it is looking for patterns and casual relations. Positivistic research design clearly distinguish it selves from constructionist research design by assuming there is true answer. Constructionist research design assume there is no absolute truth (Mark Easterby-Smith, Richard Thorpe et al. 2012: 48). By changing between the two different research designs I will keep a more critical view and it is less likely that causes will be overlooked.

One key assumption with positivism is that the researcher should be completely independent of the object that it is studying. If applying a constructionist research design the researcher could take part in the setting or case being studied. In this study I will not be able to take part of the case, neither will I be able to affect the case that is being studied. I will therefore say that the collection of data and data material is connected to positivism and the analysis of the data is a combination of both research designs.

This study is based on a combination of inductive and deductive research approach. My data collection and hypotheses formation is based on inductive approach while the study is presented as a deductive approach. Inductive approach makes it possible to create new data based on data collection. By first making observations of the case and then looking for pattern and theory to cover this is normal to do when applying inductive research approach. An inductive research approach is also described as a bottom-up approach since theory to explain the observations and patterns are not

looked at before in the end. Inductive research approach is also described as being more open-ended and more exploratory in the beginning.

When applying deductive approach hypothesis is created from theory and than tested to be confirmed or disconfirmed. Theories are narrowed into more specific hypotheses and get further narrowed down when collecting data material to address the hypothesis.

Inductive approach was chosen for data collection and hypothesis collection since it starts with an observation. Then I was looking for pattern to explain this observation. It was then made three hypotheses that were anticipated to play to describe the observation. After this I where looking for theory to explain the three hypothesis.

3.1 Collection of data

In my study data material will be divided by different sources. It is used written data from reports, news articles, different case study of the Brazilian energy sector, scientific journals regarding wind industry in other countries and interviews conducted by myself and researcher from the BRICS study.

Interview

Interview that is done by other then myself are conducted as part of a larger study, which is financed by the Norwegian Research Council. The case of that study is to explain sources of energy in BRICS countries. These interviews where collected at various locations in Brazil autumn 2014, with representatives from central actors in the Brazilian power sector.

List of interview:

Interviewee	Interviews	Organization	Transcription	Place	Date
Roberto Veiga (R1), President, Wind Energy Council	Einar Braathen Tom Skauge	ABIMAQ	Ricky Röntsch	Sao Paulo, Brazil	25.11.2014
Marcio Drummond (R2), Head of Department, Energy Trading Department	Tom Skauge Antonio J. J. Botelho	Eletrobras	Andreas N. Persson	Rio de Janeiro, Brazil	03.12.2014
Antonio Botelho (R3), Ph.D., Researcher BRICS study	Andreas N. Persson	Expert interview Professor	Andreas N. Persson	Bergen, Norway	27.03.2015

Table 3.1.1 – List of interviews. R1, R2 and R3 refers to respondent 1, 2 and 3.

About ABIMAQ – The Brazilian Association of Machinery and Equipment. Founded in 1975 with the aim of acting in the favour of strengthen national industry (ABIMAQ).

About Eletrobras – The largest company in the Latin American power sector. Is the leader of several subsidiaries, distribution companies, research centres and shareholder of large hydro electric dams (Eletrobras). Eletrobras was choose to run the PROINFA program (Requejo 2009: 15).

Interviews where conducted as semi-structured interview, it was through the interview used laddering technique to reveal new and unknown information. Some interviews was also in-depth interview to reveal information about certain areas that where unclear in existing written data. Example of this are the area of actors, demand for energy in Brazil and happenings in the industrial history.

Written data

Literature used in this study is divided between several sources such as books, scientific journals, reports and news articles.

Written data from books have been from books covering areas of governance, environmental policy, sustainable growth, innovation theory and organizational theory. Books applied in this study are listed in the reference list.

Reports on wind power development, support mechanisms and the Brazilian energy sector are from different sources. Mainly these have been from reports published by The Global Wind Energy Council (GWEC), The World Bank and The International Renewable Energy Agency (IRENA). Reports published by GWEC are characterized as important for this study. These are published every year, both as *global wind energy outlook* and *global wind report: annual market update.* These are important to information regarding the development world wide, but also to retrieve data regarding the Brazilian wind energy market. These reports are divided into different sections with case study of several countries that have or developing a wind industry. Reports published by The World Bank are considered as being important since these reports have been studying renewable energy policy in various countries. They have also been studying regulations to implement these.

Electronic news articles have been used to understand the current situation in the Brazilian wind industry. There is a wide range of renewable energy webpages, wind association and news articles regarding the Brazilian wind industry and energy market in Brazil. These are all listed in the reference list.

Scientific journals have been important to establish theories and relevant concepts for this study, but also to understand the Brazilian wind industry in a better way. I have been studying through journals covering technology of wind turbines, theory connected to path-dependence and case studies of wind energy market in other countries. There is also a wide range of research articles written about the PROINFA and different support mechanisms used in Brazil and elsewhere

3.2 Quality requirements

Yin (2014: 45) refers to different tests to secure the quality on research designs. I will in this subsection present how the research design of this study is looked after in terms of internal validity, external validity and reliability.

Internal validity

To secure that the findings that are uncovered through this study is valid for this particular study it is important to be sure that what is said in interviews, what is written in articles, journals and books are based on facts and not constructed material of data. In some cases this could not be done easily. One way this could be done is to crosscheck the data material that is used. Interviews with people that have a controversial sight of the Brazilian wind industry, the PROINFA program or other related cases to this study have to be crosschecked in order to secure that it is based on facts.

Interviews are also collected from different persons with different roles within the power sector. My expert interview was conducted with one of the researchers, Antonio Botelho (R3 2015), that is part of the study of energy sources in BRICS countries. He where also present when interviews where collected in Brazil. Answer and findings from the interview with him could then be affected by the interviews he was present at in Brazil. On the other hand he is a knowledgeable and wise man that are able to reflect upon answers. My interview where conducted at English which is not the native language of the neither the interviewer or interview object. Since the interview is not conducted at the native language this could give rise to bias in the interview due to miss perception.

Interview that where collected by researchers in BRICS country was collected for another propose then this study. I where not present when the interviews where carried out, which means I did not had the possibility to ask follow up questions or be sure that the questions where perceived equal to the interviewer and the interview object. Since the interviews are recorded it has been possible to listen to them and data revealed from them has been crosschecked.

Yin (2014: 47) describes one of the challenges when studying a special phenomenon or case. When studying the wind power industry in Brazil I´m trying to understand and describe the success behind the wind power industry. I will call this incident *B*. The success might be a result of incident or event *A* that caused the success in the industry. By implying that *A* caused B, the study limit it self and leave out possible explanations. There could be incidents or events C, D, E and further that played a central role to achieved the success. By using different hypothesis my study does not limit itself to one explanation, but rather look at it from different perspectives.

External validity

When doing case study it is sometimes difficult to secure the external validity, or generalizability of the study. The reason for this and the reason why this could be difficult for my study are because it is looking at a special case. The study is looking at the success for the wind power industry in Brazil, and what has been the contribution to the success. This is a special case connected to one specific region and country. The success could be the result of several factors such as policy, government, global position, workmanship, production, wind systems and other factors. Brazil is one of few countries in the world along with Canada and Norway where hydropower is the main source of energy. To transfer the results from this case study will because of this be difficult.

On the other hand policy instruments, techniques and methods used to achieve the success could most likely be transferred. Geographic conditions are not possible to do anything about, but discoveries in this study could most likely be transferred to places with comparable conditions. Generalizability of some findings from this study may be possible.

Reliability

There are several threats against the reliability of this study. I have not conducted all interviews myself which means that essential things could be overlooked. At the same time I´m dependent on others transcription of the interviews. Ideally there should have been more interviews and ideally I should have been in Brazil to conduct them myself. This mean that I need to thrust the work of the researchers.

The amount of written data available is massive in scope. This means that there could be important factors or explanations that are overlooked or excluded. Since the available amount of data is massive I could not be sure that I have found the best available data for my study.

To increase the reliability of my study I will highlight how this is done. Actors that have been interviewed in Brazil are chosen by an extremely professional and serious work by contacts to researchers in the BRICS study. The person who has transcribed the interview is an extremely skilled person. At the same time I have had the opportunity to investigate what has been unclear in the interview conducted in Brazil through my expert interview. The interviewee in this case where conducted with one that know the conditions in Brazil very well. He was also present at several of the interview conducted by the BRICS study research group.

By using a triangulated method it has the strength that it use data from different sources to study cases. A triangulated method gives me the possibility to combine written texts, interviews and other data into one case. Important evidence revealed through interviews could then be further explained or discusses by the use of written data. At the same time my study have a starting point that is defined by year and time, autumn 2014. The study uses mainly data published between 2000-2014 in the discussions of the hypotheses. There are also some data used to present the history of the Brazilian energy sector, this could be found in the book "The Political Economy of Power Sector Reform" Edited by David Victor and Thomas C. Heller. This book contains a chapter[4] that describing the development of the Brazilian power sector (Oliveira 2007).

[4] Chapter 2: Political economy of the Brazilian power industry reform

4 Discussion

I proposed three different hypotheses that I wanted to use for my study of the Brazilian wind power success. I have so far been going through theory that I´m going to use in my discussion of the different explanations. The three different hypotheses I presented were:

Technological explanation.
Hypothesis 1 (H1): *The wind turbine technology has been mature and competitive.*

Market explanation.
Hypothesis 2 (H2): *Entrepreneurs linked a demand for energy with a supply from wind technology.*

Governmental explanation.
Hypothesis 3 (H3): *The success is a result of government market creation by changing the energy path.*

I will first start with the technology explanation. In this I will be going through the technological development of wind turbines. In the market explanation the market before the PROINFA program will be examined to understand if entrepreneurs could create the market. In the governmental explanation I will search for a market creation. Then I will use theory of path dependence to understand if it is emergence of a new path.

4.1 Technology explanation

The basic behind a wind turbine is to convert wind energy into electricity. A more complex explanation is that electricity is generated from wind turbines by converting kinetic energy to electricity by using an electric generator attached to a shaft with aerodynamic blades on. The kinetic energy in the wind creates lift force on the blades when passing, this lift turns the shaft around that makes the generators able to generate electricity.

The development of wind turbines has been going on for decades. Increasing efficiency in turbine components has followed the technological development. Efficiency and quality of components have increased as the result of new production processes and the use of new materials. All components have most likely been going through some sort of incremental or radical innovation. For the overall efficiency of wind turbines there are some components that is anticipated to contribute more then others, these are believed to be tower, blades and transmissions systems. These are also some of the most expensive components that the turbines consist of (Blanco 2009: 1375). I will here go through the technological development and which obstacle these vital parts are facing.

Rotor

The widely accepted configuration of wind turbines today are the "upwind" turbine with three-bladed rotor (Tangler 2000: 2). Three blades seem to be the optimal choice with respect to aerodynamic efficiency and rotor-noise. Rotor blades have been manufactured in many different materials such as wood, steel, aluminium, fiberglass and carbon fibres.

> *"For a given blade strength and stiffness, the blade should be as light as possible to minimize inertial and gyroscopic loads, which contribute to blade fatigue. Blades made from steel and aluminium suffer from excessive weight and low fatigue life relative to modern composites." Tangler (2000: 5).*

Major achievements of turbine blades that have carried out through the last 20 years are production technology that allows making better and more reliable turbine blades. The technique of manufacturing wind turbine blades came from the boat building industry (James C. Watson and Serrano 2010). These processes demanded high labour and exposed the blades for defects. Later vacuum infusion process was introduced that created higher quality on the components and removed some of the earlier problems with defects.

Today the technology is going towards automated production systems to manufacture turbine blades. High demand for wind turbines put pressure on blade producers to create new and more efficient production methods (Black 2009), but input materials for blade production have not evolved rapidly. The first turbine blade made of fibre-glass was applied in 1979 (Raghu Garud and Peter Karnøe 2003: 282).

Tower

Another vital part of wind turbines is the tower that keeps the turbine up in the air. Towers of wind turbines have increased from approximately 15 meter in 1998 and are anticipated to exceed 178 meter in 2015 (Søren Krohn, Paul-Erik Morthorst et al. 2009: 39). The higher above ground the wind turbine is placed the stronger the wind is and wind flows are more laminar then close to ground where they are turbulent. Conditions to generate electricity will then be better.

Wind turbine towers have been made of a various types of materials. Today the most common material is steel and some places concrete or even hybrid. In hybrid towers steel and concrete are combined.

To exploit better wind conditions wind turbine towers has increase in heights, this make the blades to be longer and the rotor swept area to be larger which give it the ability to produce more electricity. One of the challenges today is the size of wind turbines parts. The standard for wind turbines today are that they routinely are designed to be 80 meter. This height is the limit of highway systems for transport of these parts (Crawford 2013). It is anticipated that steel tower to use for wind turbines have reached its high limit. For tower to exceed the height of 100 meters and still be able to use existing

infrastructure new methods of building and assembling towers need to be develop, so far reinforced concrete with the ability to be assembled from sections at the foundation on the wind farms seems to be a solution. Wind turbine towers made of concrete solve several of the challenges with regular steel tower. Manufacturing of concrete towers have 55-65 % less CO_2 emission compared to manufacturing of steel towers (Jimeno 2012). Towers made of concrete do also contribute to reduce noise because of the damping effect of concrete.

Drive system

> *"A turbine drive system includes the shaft turned by the rotor, sometimes a gearbox, and at least one generator to convert the mechanical power in the turning shaft to electrical power for the grid system." Vries (2012).*

The most widely applied drive systems in wind turbines today are high-speed gear systems. This type of systems represent a market share at around 80 % (Vries 2012). Gear systems have been necessary in turbines because generators are designed to run at 1200-1800 rpm, while wind turbines operate between 10-60 rpm depending on their size (P. W. Carlin, A. S. Laxson et al. 2003: 135). The alternative to high-speed gear system is direct drive turbines. When applying this design the generator is design to run at low rpm. This type of generator has not achieved such high market share as high-speed gear system because of its size. Technological development has been large on both of the technologies, *gear* systems and *direct drive* system. When applying a *gear* system all components suffer high stress as the result of variable wind speed and turbulence (Morris 2011). When using direct drive instead of gear system the most critical part of the wind turbine is removed.

By placing the wind turbine in the dominant design innovation model (figure 2.2.1) by Utterback (1996) I will say it is in the middle of the transitional phase. This does not apply for all of the components but for wind turbine as one unit. For some of the parts a wind turbines consist of there is still not a dominant design but rather rival technologies that fight to become the established standard. It is also anticipated that the towers have reach the stage of process innovation and that the dominant design is conical tubes made of either steel or in some cases concrete. Often these two materials are combined

and there is used concrete at the bottom and conical steel tower above this (IRENA 2012: 7). For other parts such as blades and the wind turbine as one unit, the dominant design is established. It is going towards process innovations to speed up the manufacturing process and lower cost. This is essential to be able to meet the growing demand for wind turbines world wide (IRENA 2012: 13-14). Theory of innovation describes the specific phase as being characterized with focus on cost, volume and capacity. I believe that wind turbine as a technology is at this stage. But, the potential of the technology is probably higher than we see today. The technology will be going through a series of incremental innovations to increase the efficiency, reliability and cost of wind turbines. As more and more countries adopting the technology as it goes further into a late majority of the market it will be learning by doing.

When more countries adopt the technology, it will be more feedback, more input and changing demand and preferences from customers. This will put pressure on the suppliers to change their products in order to meet these new customers and their demand. By looking at the dynamic innovation model (figure 2.1.3) where both technology push and market pull models (figure 2.1.2) are combined this could be explained. The dynamic model gets feedback from the market and experienced with the commercial product. Along the development process it also adopting and integrate the latest technology and market needs into the process.

The linear innovation model (figure 2.1.2) where it is either the results of a technology push or market pull could be describing of the wind turbines development start. The development of wind turbines seems to have started both in Denmark 1950 and in USA around 1920. Both of these seem to be the result of a technology push. This changed to a market pull of wind turbines in response of the energy crisis in the 70´s. The market pull model could then be viewed both in Denmark and USA (Raghu Garud and Peter Karnøe 2003: 382-383). The modern wind turbine has been traced back to 1950 in Denmark (Raghu Garud and Peter Karnøe 2003: 282).

As Trott (2012: 69) puts forward; the willingness to embrace new technology and consumers reactions to innovative new products is driven by the benefit expected from the technology or product.

Brazil didn´t had any tradition or widely developed wind industry in the beginning of the 21th-century. They were not aware of their potential until the Brazilian wind atlas was published in 2001.The wind atlas presenting the total estimated wind potential in Brazil. The potential was estimated for locations with annual wind speed above 6 m/s and by using performance curves from modern midsize turbines installed on 50 meter high towers (Odilon A. Camargo do Amarante, Michael Brower E John Zack et al. 2001: 43). The total potential was then estimated to 143,5 GW, where north-east and south-east region of Brazil where the two regions with highest potential (Odilon A. Camargo do Amarante, Michael Brower E John Zack et al. 2001: 44). Later around, 2009-2010, the potential was again examine. This time it was examined for turbines installed at higher tower, 80-100 meters. This revealed an even higher wind potential then previously estimated, the result showed potential above 350 GW (GWEC 2010: 22).

Before 2001 the wind potential in Brazil had been the case of many studies since 1970 (Odilon A. Camargo do Amarante, Michael Brower E John Zack et al. 2001: 9). If we go back to the statement by Trott, Brazil where before 2001 not known of their wind potential, they must have known that there where something, but the total size was most likely unknown. Their willingness to adopt wind power technology probably increased with the publication of the wind atlas because of high-expected benefits from this technology, prior of this Brazil had experienced weaknesses in their energy matrix.

4.1.1 Brazil in the technology adoption life cycle

By looking at the technology adoption process presented by Moore (2014), it could be claim that Brazil is not among the innovator or early adaptors of wind turbine technology. This could be claimed since the wind turbine technology is an already established technology. It has made its proof of concept many years ago and countries throughout Europe, USA, Africa and Asia have been adopting the technology and performed outstanding R&D with the technology. Since the start of the wind power industry wind generators have grown in both size and capacity. In the beginning wind turbines had a capacity at approximately 0.5 MW and 30 years of R&D have made the industry capable of manufacture turbines with the capacity of 8 MW (IRENA 2012: 6). In

the 80´s Denmark was the industry leader and it was a period of trial-and-error (Raghu Garud and Peter Karnøe 2003: 282). Denmark also launched the first offshore wind farm in 1991 (South Baltic Offshore).

In the product life cycle adoption I will place Brazil somewhere between the early and late majority in the technology adoption life cycle. The success with wind power in Brazil would probably not be achieved in this limited time, one decade, without the technology already being at a mature stage.

Producers and suppliers of wind turbines in Brazil are mainly foreign companies. In Brazil there is only one Brazilian company, this purchased the technology from an American company and started to produce the equipment and sell it in Brazil (Veiga R1 2014: 2). Today the supply chain in Brazil for components of wind turbines parts produce a wide range of components. Brazil have industry that manufacture both steel and concrete tower, with the ability to meet the annual demand of 2 GW, which sums up to 1000 wind turbines tower.

The bottleneck in the supply chain are claimed to be forged goods. Forged items on wind turbines are used in bearings and flanges for the towers. A problem by producing turbines components in Brazil is that it is anticipated to be 34 % more expensive then to produce it in countries in Europe (Veiga R1 2014: 3).

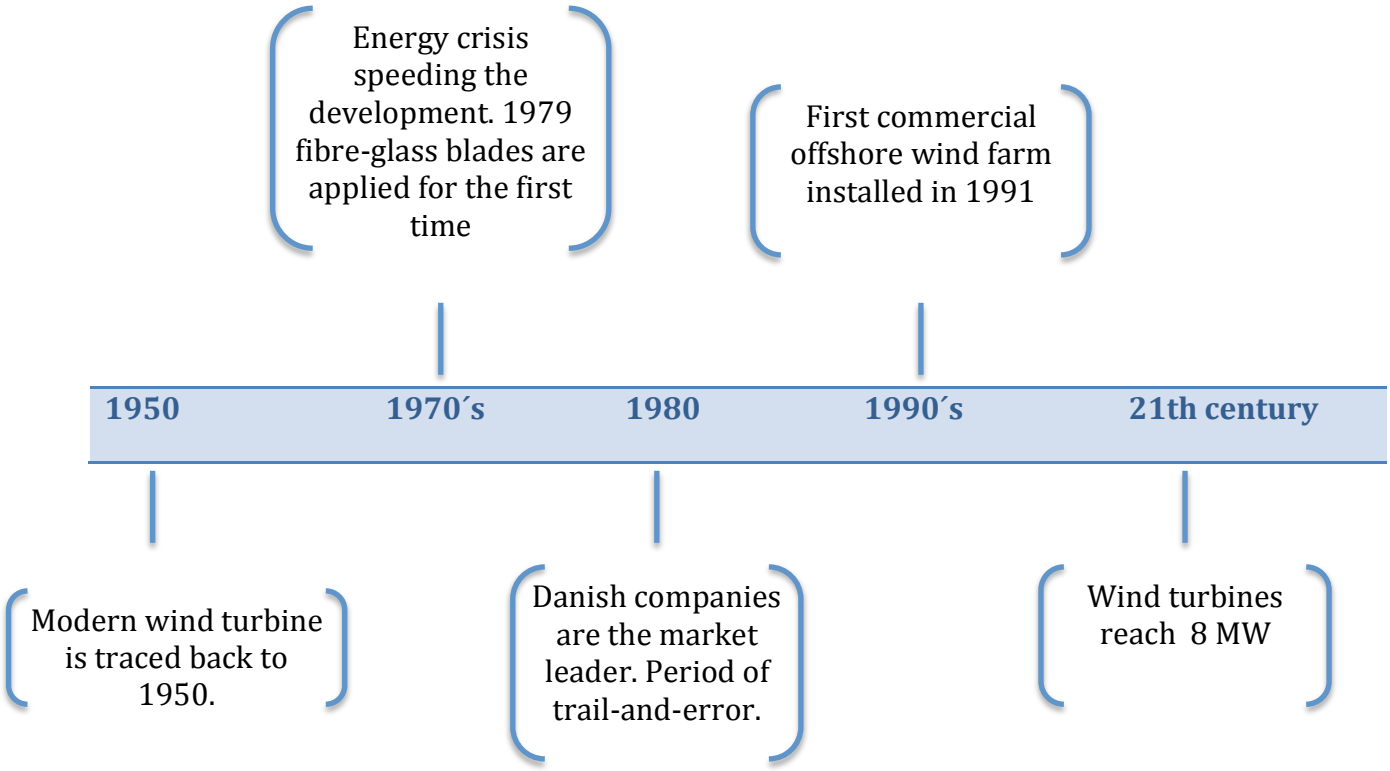

Figure 4.1.1 – Timeline of wind turbine development global

4.1.2 Wind turbines meet wind

As Blanco (2009: 1376) explain, the local wind conditions are the most important factor that's affect the profitability of wind projects.

Even the production costs are anticipated to be 34 % higher than in Europe the electricity from wind turbines are cheaper. Veiga (R1 2014: 3) ask the question how this could generate revenue and at the same time presenting the answer; the capacity factor of the wind farms in Brazil compared to those in Europe. Capacity factor is the measure of the produced electricity over a given time, divided by the hypothetical maximum energy that could be produced over the same period.

$$\frac{MWh}{(24 * 7 * 365) * turbine\ capacity} = capacity\ factor\ \%$$

The capacity factor in Brazil are almost 2,5 times higher then in Europe. This have made it possible to sell wind energy in Brazil at 30-40 euro per MWh, while in Germany they charge almost 90 euro per MWh.

> *"It is because the capacity factor in Brazil is 2,5 times the capacity factor that you have in Europe. The capacity factor in Brazil is around 50-60%, some places in Brazil for instance 70%, against 30-35 that you have in Germany." Veiga (R1 2014: 3)*

Capacity factor on wind farms could be increased by optimizing the wind turbines (Blanco 2009: 1380). By changing the size of the blades, using new advanced materials and by improving forecasting and siting techniques capacity factor could be increased, but the most important factor for the capacity is the local wind conditions (Blanco 2009: 1379).

> *"One-third of the time during the year you have the wind generator running (in Germany), and here you have the wind generator running more than half the time in the year And then you can produce more. Then in despite of the high cost of production and the low cost of tariff you can earn money in your investments." Veiga (R1 2014: 3)*

The typical Brazilian configuration of turbines have been to secure that generators are running at optimal capacity a great portion of the time (Melo 2013). This has been necessary to give low enough bids to win PPA in energy auctions. Another important measure of wind turbines is the "swept area" of the blades. The "swept area" is given by:

$$Swept\ area = \pi * r^2$$

Where r = length of the individual blade on the turbine.

By doubling the diameter of the rotor the swept area and therefore the power output is increased by a factor of four (IRENA 2012: 5).

The conditions for generating electricity by using wind turbines seem to be very favourable in Brazil. Not all areas are suitable and the most competitive wind farms are located in north-east of Brazil (Veiga R1 2014: 4). The fact that wind technology was a mature technology have helped reducing the risk, and made the implementation of systems easier and faster. The technology could just be transferred from countries that were part of the early majority and had widely developed wind industry.

> *"It is pretty much stabilised (the technology), they had a lot of wind farms in US and Europe so people knew how to build it, it was a mature technology in terms of technological system." Botelho (R3 2015: 10)*

A large competitive advantage lies in the geography of Brazil, North - east have wind from only one direction and there is less turbulence in the wind. Low turbulence give better conditions for the wind turbines to generate electricity.

My technological explanation (H1) anticipated that the success of the Brazilian wind power industry is the result of a mature technology with low technological risk. If this explanation should get support from my data I expect to find that wind power technology was a result of long development process. I also expected to find Brazil to be somewhere between early and late majority in the technology adoption life cycle.

I found that wind power technology has been going through a long development process. The modern wind turbine, as we know it today, have been traced back to 1950. The technology has since the beginning been the subject for a series of technological innovations. This is both as product innovation but also in terms of process innovation.

I placed Brazil between early and late majority of the market by using the technological adoption life cycle. I also expected to find this in order to conclude that it is a technology with low technological risk.

I will conclude that the technology was mature and ready. The technological risk was low and implementation could be done from countries that had been using the technology for decades. This means that a supply side of a wind power market where

ready. Interview also revealed that conditions in Brazil in terms of metrology and geography were very beneficial in terms of exploiting the technological potential of wind turbines. The conditions were much better then what had been present elsewhere. My data therefore largely support hypothesis 1, but it I concluded that it was a necessary and not sufficient explanation to describe the success of the Brazilian wind industry. The technology explanation is not a one-factor explanation to the success. The technology has been efficient enough to generate electricity at competitive prices.

To create a market there need to be a supply and demand side. The technology explanation support that the technology was ready but how was the demand side? This leads to a discussion of my market explanation.

4.2 Market explanation

Brazil is expected to see an increase in energy consumption at almost 60 % growth (Yapp 2011). Despite of this the Brazilian government has made a commitment to reduce their CO_2 emission between 36-39 % by 2020. Unlike many other industrial countries Brazil´s emission of CO_2 is not mainly related to energy production. The largest CO_2 emission in Brazil is related to deforestation of the Amazon forest (Roberto A. Ferdman and Lily Kuo 2013). The last decades Brazil has been able to cut back on CO_2 emission. This cut backs are not the result of decreasing energy production, but rather decreasing deforestation of the Amazon and other land-use changes in Brazil. At the same time emissions from energy production have increased in the last two years according to Gallucci (2014). The increase of emission from energy production is tied to draughts, which affect the electricity generation from hydropower. This was critical since hydropower have been the major source of energy in Brazil. Hydropower covers as much as 70-90 %[5] of the total electricity production. A combination of draughts and constantly growing demand for energy forced the government to find a fast solution to prevent blackouts in the grid system. This led to increasingly use of thermal power plants run by fossil fuel in order to keep the lights on in Brazil.

Where does the demand for energy comes from? The demand seems to be a result of increase in prosperity combined with energy theft, economic growth and challenges at the supply side. In my interview it where revealed that losses in transmission lines is somewhere between 30-40 % (Botelho R3 2015: 5). This loss is mainly the result of energy theft from the slums and favelas in major cities throughout Brazil. At the same time energy security has been a central theme for Brazil the last years. A series of draughts the last decade has led to blackouts and questioned the reliability of the energy matrix.

In Brazil there have been large inequality and poverty. The poorest 60 % of the population had 4 % of the wealth and the richest 20 % held 58 % (Wetzel 2013). Bolsa Família was a program initiated by president Lula with the goal to help poor families by

[5] The number depending on sources of data but also time of year

making small cash transfer. This cash transfer where given to those that did keep their children in school and vent to preventive health care visits. The program ended up successfully and have helped almost 50 million people out of poverty (Wetzel 2013). Established in 2003, the program has been going on for more than 10 years. By lifting the population out of poverty there will be more consumers to buying goods using electricity, that further increasing demand for energy and energy consumption increase.

> *"But mostly now it has been growing in the residential market, I believe is growing faster because of rising income no… they brought condition of employment, and they took a lot of people out of poverty with all these social programs. So the middleclass in Brazil increase considerably, so they consume more good, and the electricity consumption went up." Botelho (R3 2015: 4)*

It all indicates that there was increasing demand for electricity at the same time as the supply side had problems of meeting the demand. Brazil also made volunteer commitments to extend the Kyoto Protocol to still cut emissions of green house gasses (Morales 2011).

By going through some of the barriers to RET penetration, presented by Painuly (2001), with the conditions in Brazil pre 2002, it will be possible to understand if entrepreneurs could established the linked between supply and demand and thereby create the market for wind power technology.

First of all there were, known to me, only one production facility for wind turbines or wind turbine equipment in Brazil. Wobben Windpower where established in Brazil in 1995 as a subsidiary of German Enercon. Wobben Windpower manufactured components to be used locally, but also to be exported (Wind power monthly 2006). Since only one manufacture of wind turbines where present in Brazil access to wind turbines technology where strictly limited the. According to Painuly (2001) this is a barrier to RET penetration, the technology will in this case be difficult to access and result in increased cost since more need to be imported.

A beneficial condition for a RET penetration to take place where that the Brazilian government did not favoured conventional energy, like fossil fuel. Their main source was hydropower that is characterized as RET. When Brazil was ending a political crisis in 1999 they where facing draught. The question of building thermal energy plant where then raised, but they where not give PPA and environmentalists was afraid fossil fuel then would take over for hydro power (Oliveira 2007: 66).

Blanco (2009: 1381) concluded that wind turbine as characterized as capital-intensive technology; Fixed assets counted as much as 80 % of the total investment cost of turbines. Painuly (2001) emphasised that high cost of capital will be an economic barrier to RET penetration. It was also important that the technology where economically viable in order to carry out a RET penetration. Most likely the technology was not economically viable in Brazil. The reason for this where that almost all wind turbines needed to be imported and to be competitive the wind power technology was competing with hydropower and natural gas on price. It is anticipated that it was lack of capital. High capital costs entail the need for investments. RETs projects have been considered as risky projects. Especially those having changing supply throughout the year. Investors are more willing to invest in project that give high rate of retur. For investors it is also important that gains are realized relatively quickly. Investors and entrepreneurs are not willing to take risk for any price. At the same time projects that provide the highest rates of return are those being most attractive to private lenders. They are risk averse and thereby require returns on their investment within a relatively short period of time (Gregory C. Unruh and Carrillo-Hermonsilla 2006: 1188).

The Brazilian wind association, ABEEólica was not established before 2002 (ABEEólica). ABEEólica represent members from the entire wind industry and act on behalf of these. Before this it does not seems to be any wind association that could organize and disseminate information or to promote the wind power above key players. Private actors were highly represented in the energy sector as the result of a governmental privatization program. The only problem was that risk had been transferred from the government to private actors, since these were anticipated to handle it better than state

owned companies (Oliveira 2007: 62). This meant it was no guarantee rate of returns for the generators and no fixed tariff for the consumer.

Painuly (2001: 80) describe that lack of R&D culture could make technological adaption difficult. In Brazil it is claimed that the initiatives to create energy efficiency and R&D activity was unlikely to happened unless regulators enforced it (Jannuzzi 2005: 1761). The public sector created research centres to the power sector and established an electricity conservation program. These were run by large state-owned companies When the privatization of the energy sector took place the R&D activity also changed (Jannuzzi 2005: 1754). When the privatization started the contracts contained clauses were the utilities were obligated to invest in energy efficiency and R&D (Jannuzzi 2005: 1755).

Technologically wind turbines are at a stage where the technology is widely accepted and the technology is considered as being mature. This entails that the technological risk is low and the implementation of wind turbines is done relatively easy. There is also standards regarding design requirements of wind turbines, IEC 61400 (IEC). Standards will increase the quality of wind turbines since there is requirements need to be fulfilled.

Before 2002, wind turbines were almost non-existence in Brazil. Because of this I believe there was lack of skilled personnel both for the manufactures and for operation and maintenance (O&M). Interview revealed that there had been some R&D activity around wind turbines on an academic level. This may have given some experience on wind turbines and wind turbine equipment in Brazil.

> *"So it had for sometime been pushed for renewables and few people had, academics had been studying for quite a while. Developing wind technology at lab level." Botelho (R3 2015: 13)*

Painuly (2001: 80) also presented the barrier where there is lack of acceptance from the consumer in order to succeed with RET penetration. In Brazil the consumers are divided in two main groups depending on the amount of energy they require. If the customer consumes more then 3 MW they are allowed to go on the "free" market and make individual agreements. If the consumer consumes less then 3 MW they are considered as

captive consumer. They have then no choice to decide where to get their electricity and it need to come from the local distribution company where the electricity is regulated through auction market (Castalia 2013: 15). This means that consumers, equal to 75% of the electricity consumption, can´t chose where to get the electricity from.

Other barriers to succeed with renewable energy penetration is lack of infrastructure, where Painuly (2001: 81) remark that wind technology need strong infrastructure such as rods and grid connectivity.

> *"Another is the logistic costs in Brazil because we have no … in the coastline that you have in Brazil. We have not efficient road transportation. We have no rail transportation in Brazil. So we have a little number of companies that can comply with the assembly of these wind fields in Brazil. Then you need to pay high amount to the owner of the freight companies because they can chose which product they will attend." Veiga (R1 2014: 3)*

This indicated that the infrastructure has been missing or was not well developed in Brazil. Lack of infrastructure make transportation of equipment difficult and often increase the CAPEX costs of the projects. Environmental resistance in Brazil have been directed against building of hydroelectric dams since these deforest the Amazon, but also against thermal power plants run on fossil fuel.

It also looks like there was high risk of entering the market with new technology, especially if the entrepreneurs or wind farm developer did not know if they got long-term contract with the purchaser of electricity. In Brazil most of the distribution and transmissions have been privatized after 1990 (U. Wachsmann and M. T. Tolmasquim 2003: 1033). This mean there would be risk of not getting agreements with companies running the distribution and transmission.

In hypothesis 2 I suggested a market explanation could describe the success. The success was a result of entrepreneurial activity to create the link between a supply and demand. In order to find support for my hypothesis I expected to find a supply and demand side that entrepreneurs could create the link between and thereby establish the

market. In addition to this I expected that the barriers of a RET penetration to occur was low enough,

I found that there is increasing demand for energy in Brazil. This increasing demand is the result of several factors where the combination probably has provided a reinforcing effect. Draught, theft, increased middle class and commitments to reduce emission of green house gasses. This support that there was a demand for energy.

My technology explanation largely confirmed that the technology was at a mature stage and that it was low technological risk. At the same time it found that conditions in Brazil in terms of metrology and geography were excellent in order to exploit the potential of this technology.

This indicates that both the demand side was present and the technology was mature and ready. At the other hand the supply chain of wind turbines were not present in Brazil. In order to create the link between the Brazilian demand for energy and a supply from wind turbines a RET penetration was needed. I will conclude that the barriers of a RET penetration to occur where to high, resulting that entrepreneurs could not start the process. The risk of failure was high and even entrepreneurs are considered as risk takers there were conditions that the entrepreneur could not change or affect in order to mitigate or manage the risk. The infrastructure in Brazil for wind power technology was not sufficient. There was lack of installed capacity so there was lack of skilled personnel. There was also financial risk since the CAPEX costs of wind turbines are high which is know to be unattractive to investors. At the same time it was uncertainty of consumer since 75 % of electricity consumption is captive consumers the entrepreneurs were depending on grid connection.

Trott (2012: 95) put that risk is not about gamble, but to consider carefully risky opportunities. If the risk is too high, projects are not attractive.

My conclusion for the market explanation is that it is a necessary but not sufficient to explain the success. In order to create a market there need to be a demand and a supply side. In my discussion of the market explanation I found support for a demand being

present in Brazil. This demand could not be supplied by wind power even the technology was mature and ready because of to high risk for entrepreneur. The market explanation is not a one-factor explanation of the success. The increasing demand could might as well been supplied by more hydropower or fossil fuel.

The demand side asking for energy but the supply side for wind turbines were not present in Brazil. In order to create the link between these the risk was to high for entrepreneurs to do. This indicates that there was a large actor that could handle mitigate the risk and facilitate the conditions for a RET penetration to occur. Mainly the actor had three objectives that it needed conduct in order to start a RET penetration of wind power technology:

- Create framework for a market where demand of energy could be supplied from wind power technology
- Attract investors and entrepreneurs to explore the market
- Attract wind power technology to create a supply chain in Brazil

This leads to the discussion of my government explanation.

4.3 Governmental explanation

4.3.1 From private, to Public and private again

How has the Brazilian industry sector evolved, and what have this to du with wind energy? To answer this question it is necessary to go back almost one century to pre 1934. At this time the Brazilian energy industry was dominated by private actors (Oliveira 2007: 35). In 1934 the federal government in Brazil adapted the *Water Code, which* marked the start for development of the hydroelectric power in Brazil. The *Water Code* assigned the property rights of the hydropower potential of the rivers, but also the authority to regulate the power service to the government. *The Water Code* was a result of nationalization campaign against foreign investors and world depression affecting the Brazilian economy (Edmund Amann and Baer 2011: 26).

The water code discouraged private investors (mainly foreign) in the energy industry. This was mainly due to changes in tariff scheme (Oliveira 2007: 35, Edmund Amann and Baer 2011: 26). The changes in the tariff scheme created higher risk for the private investors. All of this resulted in unwillingness for private investors to invest more in the growing industry and led up to creation and expansion of government companies. By 1970 most of the power generation, transmission and distribution was controlled by the state companies in Brazil (Edmund Amann and Baer 2011: 26).

The Brazilian government got financial support from the World Bank to develop their hydropower resources. A consortium among international engineering companies designed a plan of how to develop the power systems in Brazil. Their suggestion were that hydro power was the cheapest option at that time, and concluded that thermal power plants were to costly. The oil shocks in the 1970´s made hydro power plants more competitive and made power policy makers to get a perception of Brazil as a hydropower country (Oliveira 2007: 37).

In the 1960´s political instability resulted in military control in Brazil. Even the military supported the right wing parties they upheld ambitions of government control over the

energy sector. The aim of the government was to create a federally controlled enterprise that controlled both the generation and transmission of power. The federally controlled enterprise then transmitted the power to state-owned regional distributers (Oliveira 2007: 40).

In 1970 the Brazilian economy was growing rapidly and 80 % of the country´s oil consumption was imported. The oil shock made the military launch an industrialization program with the aim to accelerate an import substitution process.

In 1985 the military rulers stepped aside, new constitution in 1988 and President election in 1989. In the end of the 80´s and beginning of the 90´s Brazil was in a pretty bad debt crisis. This resulted in a National Privatization Program where Law 8031 of 12. April 1990 created the framework for this program (Macedo 2000: 2).

4.3.2 Building a new industry

I concluded in both hypothesis 1 and hypothesis 2 that they where necessary but not sufficient to explain the success as a one-factor explanation. In H1 I found that the technology was mature and the conditions in Brazil was very beneficial to exploit the potential of the technology. In H2 I found evidence of a growing demand for energy. I concluded that the risk were too high for entrepreneurs to create the link between demand for energy in Brazil with wind power technology.

This implies that there might be a governmental explanation behind the success. Trott (2012: 48) presenting the process of converting a basic discovery into a commercial product as a difficult process, it is a:

> *".. Long-term, high-risk, complex, interactive and non-linear sequence". Trott (2012: 48)*

When the Brazilian wind atlas was published in 2001 (chapter 4.1) this could be viewed as a basic discovery for them. This basic discovery needed to be converted into electricity to get into a commercial product. A market explanation (H2) to do this was

not fully supported and Trott refer to the role of the state to be extremely important in technological development. As a major financier and purchaser of R&D the state have significant impact on the direction of the R&D activity, but also to encourage entrepreneurial behaviour and innovation activity in the society (Trott 2012: 51). The state also covers other aspect in the society to facilitate and stimulate for these kinds of activities, but also to limit the risk for the innovator and entrepreneur. The state are in many cases the purchaser and financer. They facilitate education, regulate competition, establish environmental and safety regulations, building infrastructure, keep political stability and take care of macroeconomic conditions.

If the success is the result of a governmental created market how was this done, and how was the arena for wind energy in Brazil created? Theory of *entrepreneurial opportunity* by Saras D. Sarasvathy, Nicholas Dew et al. (2010) refer to *opportunity creation* when there is neither supply nor demand. In Brazil there was neither demand for wind turbines nor demand for the electricity they produced. Interview with Eletrobras explained that there was only a small amount of installed capacity in terms of a few machines (Drummond R2 2014: 1). My question is then if the process was *opportunity discovery*, *opportunity recognition* or *opportunity creation*? I will refer to it as an *opportunity creation*. This is because the demand for energy was a demand for energy in general, there was no specification of where this energy should be produced or how. The demand for energy produced by wind turbines then had to be created. At the same time supply of wind turbines were present in Brazil through a small company. Despite of this I will claim the supply side needed to be created since the single company that existed could not accommodate a growing demand alone.

4.3.3 Creation of renewable energy market

The PROINFA program was established by the Cardoso presidency and Hochstetler (2015: 14) describe it as a response to the 2001 blackouts. But for researchers the exact reason is unclear. Why the program was established is unclear to researchers studying energy sources in the BRICS countries as well (Botelho R3 2015: 3), and they seek to find the answer to this. The simple solution that the casual factor to establish a billion dollar government project with the aim to change the entire power sector in Brazil was a

draught does not seems to be entirely correct. I will not claim that the draughts don't have been one of several factors to the establishment. I think rather the establishment of the PROINFA program could be explained through these factors:

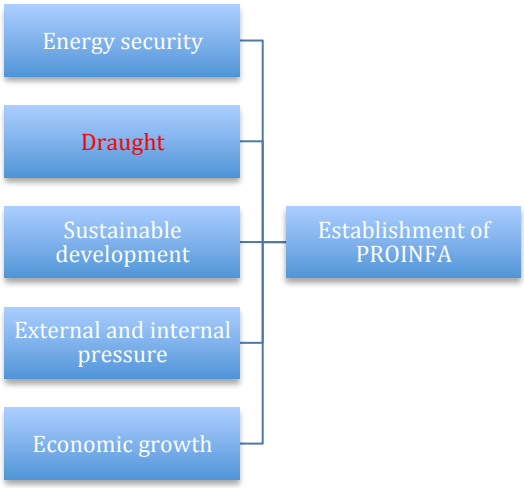

Figure 4.3.1 – Reasons for establishing PROINFA. Draught seems to be *the* trigger

The draughts might have been the triggering factor or the *external shock* to question the energy security and economic growth. From organizational theory we know that crisis leads to organizational changes. When the critical point of a crisis has arrived a major reorganizations is sufficient to get the organization back on track, the changes might change the culture of the organization forever (Jones 2013: 349). Other factors could be linked to political choices and strategy. This will not be covered or discussed in this study.

Since my data revealed that the risk for entrepreneurs to create a market was too high in hypothesis 2 I anticipated there was need of a large actor to mitigate the risk. This led to a discussion of hypothesis 3, my governmental explanation .The demand side of the wind market was created under the PROINFA program that was established by Law 10.438 in 2002 (Requejo 2009: 8). This was later updat by Law 10.762 in 2003. The program also established incentives to make the energy technology economically competitive to other energy technologies in Brazil (Xavier 2008: 408). The program was an opportunity for Brazil to create jobs in economical sustainable way.

The PROINFA program was planned as being implemented in two different stages. The goal of the first stage was to initiate 3,300 MW of renewable energy divided equally among three different RETs wind, small hydro and biomass (ANEEL 2002). In the second stage, that was never implemented, the goal was to get renewable energy at a level corresponding 10 % of the total electricity consumption in Brazil by 2022. Despite of the second stage was never implemented the market was created through the PROINFA program first stage.

> *"Now we have the market. The market began warm up in 2009. The first auction with wind energy with this low tariff was in November 2009. From 2009 on we don't need more incentive program." Drummond (R2 2014: 9)*

The PROINFA program was an incentive program to establish the market with both a supply and demand side for wind power technology, which it did successfully. How did the government managed to attract private firms to invest in wind power technology through PROINFA? Hochstetler (2015: 18) suggest the answer lies in the FIT that where used. These were high enough to attracting both private firms and investors to exploiting wind power technology. FIT is widely used mechanism to promote renewable energy and one of the key advantage by using FIT is that it offering a guarantee price and thereby reduces risk for the investors (Peter Meier, Maria Vagliasindi et al. 2015: 2).

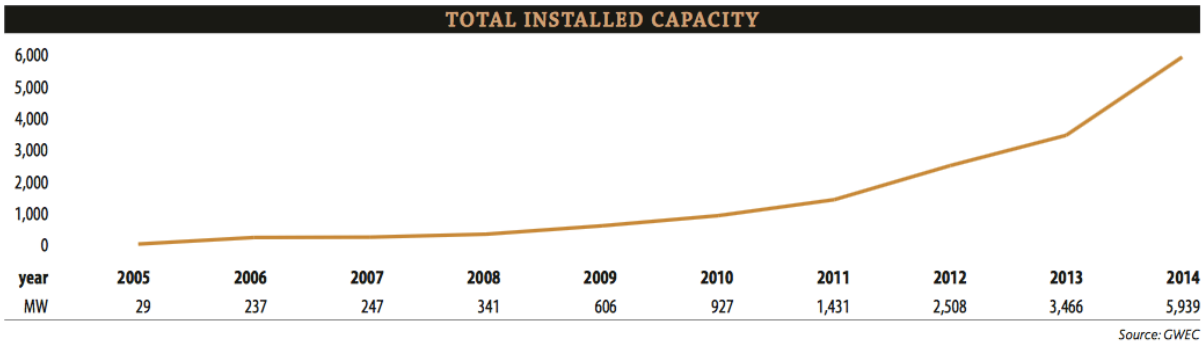

Figure 4.3.2 – Total installed capacity of wind power 2003-2014. (GWEC 2015: 33)

Since PROINFA had the goal to contract 1100 MW of wind power, the largest growth of installed capacity seems to have started after the PROINFA program and by the use of energy auctions. As shown in the figure 4.3.3 the annual growth in the Brazilian wind

industry in terms of total installed capacity have been growing steadily since 2005. The growth seems to be largest under the auctions that started in 2009.

By starting the first wind auctions in 2009 seems to be good planning. The financial crisis in 2008 had reduced demand for wind equipment. This increased competition among suppliers, resulting in large price drops (Luiz T. A. Maurer and Barroso 2011: 87).

To better understand how the auctions have contributed to the growth it is necessary to understand how they work and are executed.

4.3.4 PROINFA goes into Auctions

Today Brazil is using auctions to contract wind power. The World Bank study describes it as *quantity* based auction where there is "direct auctions for price" (Peter Meier, Maria Vagliasindi et al. 2015: 6). It is also said to be a hybrid auction consisting of two phases. Phase one is *descending clock auction* and phase two is a *sealed-bid auction* (Hugo Lucas, Rabia Ferroukhi et al. 2013: 43). Descending clock auction is described as followed:

> *"The descending clock uses multi-round bids where the auctioneer announces a price for acquiring the RE electricity generated. Bidders bid for the right to provide the quantity of the product they wish to supply at the going price announced. The auctioneer progressively lowers the price (which results in a lower quantity offered from bidders) until the quantity offered matches the quantity to be procured. This is a more dynamic auction system where participants know each other's bids and adapt their price and quantities accordingly in subsequent rounds." Hugo Lucas, Rabia Ferroukhi et al. (2013: 12)*

While sealed-bid auctions is described as:

> *"In the sealed-bid auction, bidders simultaneously submit their bids with an offer of price and quantity, and no bidder knows the offered price of the other participants.*

Bids that meet all of the mandatory requirements outlined in the call for tenders are ranked from the lowest to the highest price if the evaluation is based on the price only. Starting from the lowest price, projects are awarded until the sum of the quantities that they offer covers the volume auctioned.“ Hugo Lucas, Rabia Ferroukhi et al. (2013: 11)

Roberto Veiga (R1 2014: 4-5) described the auction process in my interview: It all starts with pre-approving the projects that will be allowed to bid in the auctions. A ceiling price is then being launched. The ceiling price is the maximum price the government is willing to pay for the amount of energy they demanding. The demand is not official to the bidders pre of the auctions, and will not be revealed before the lowest possible price is achieved. The price is reduced by lower the ceiling price. Bidders that can´t meet this new low prices leaving the auction. The ceiling price is lowered until enough bidders have left the auctions so that the remaining ones correspond to the demand. The government now buys projects that are left.

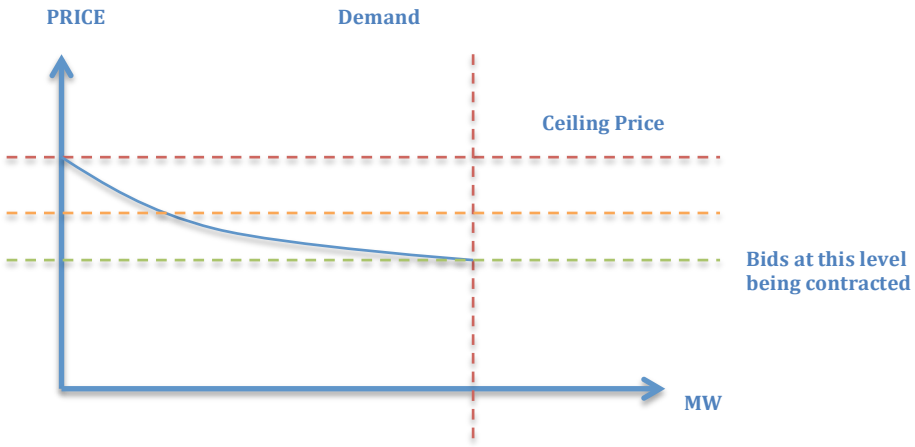

Figure 4.3.3 – Presenting how the ceiling price is being reduced to push prices down.

Hugo Lucas, Rabia Ferroukhi et al. (2013: 12) emphasise some strengths by the use of auctions. By using auctions project developers know there is a market for the electricity they producing. This limits their risk when making the investment. At the same time it is a fixed price and connection to the grid. PPA signed in RE auctions normally has a timeframe between 15 and 20 years. This further reducing the risk for investors that again could contribute so the investor could lower cost per MWh. By letting the

entrepreneurs and investors knowing that there is a market and secured payment for their service or product in a given timeframe make the projects less uncertain and increase the willingness to pursue these opportunities. It will also be easier for the investor to know the rate of return on their investment.

Auctions have the effect that they put downward pressure on prices. Putting a ceiling price could also control the prices and overall costs in auctions. Analysis also uncovered that auctions could be useful to lower price at RE and at the same time establish competitive prices (Hugo Lucas, Rabia Ferroukhi et al. 2013: 13). Auctions will also make it easy to control capacity installed since a target or capped volume is part of the auction design, while ceiling price help keeping budgets.

But, there is also some weaknesses by using auctions. Auctions need to be put on a fixed schedule or regular intervals. This factor affect the development of local manufactures (Hugo Lucas, Rabia Ferroukhi et al. 2013: 13). This is what ABEEólica lobbying the government to do in Brazil, contract at least 2 GW of wind power annually (Spatuzza 2012). ABEEólica is the Brazilian Wind Association, it is a private non-profit organization bringing together companies in the supply chain and wind farms developers in Brazil (ABEEólica). Joanna I. Lewisa and Ryan H. Wiser (2007: 1848-1849) emphasis the importance of a stable, sizable annual demand for wind turbines in their study. This is important in order to attract local manufacturing in particular locations.

There is also high risk of not winning the auctions. At the same time there might be high transactions cost, especially when bidders need to present feasibility studies and land use permit. Transaction costs are defined by Jones (2013: 101): *"The cost of negotiating, monitoring, and governing exchanges between people."*. It is argued that auctions for this reason often is best suited to large and well established developers that can afford these up-front costs (Hugo Lucas, Rabia Ferroukhi et al. 2013: 13). Drummond (R2 2014: 5) explain that these kinds of transaction costs is presented in the Brazilian auctions:

> *"… before they apply to the program they have to present some documents, like authorization of our electricity agents, regulations agents annual… Then they had to be authorized to build the plant in specifically place. They had to present*

environmental license for that place. They had to present …any document that prove the availability of land use for 20 years and authorization for connection."

Participants in the wind power auctions in Brazil are becoming more specialized and the developers winning the auctions have grown steadily larger (Hochstetler 2015: 19). This is consistent with prior findings as weaknesses in auctions as described by Hugo Lucas, Rabia Ferroukhi et al. (2013). If this evolves further in the direction where wind farms developers are growing larger they could end up with a monopoly situation. This is not beneficial for the wind industry since monopolists do not have incentives to pursue marginal costs and competition disappears. It could also affect quality and price.

There is a risk that developers underbidding since lowest bids win in auctions. Rate of return in the projects will then be too low to get finance for the project. Government might end up paying a higher price then the winning bid to let the wind farm be built.

In Brazil there is running different types of auctions, these are primary divided into new projects, and renew of existing ones.

- Reserve auction: this type of auction is used to contract supplementary energy to increase the reserve margin in the energy system. The demand for reserve energy is decided by the government and linked to security of supply and energy policy (G. Cunha, L. A. Barosso et al. 2012: 26). Reserve energy auctions could be exclusive for one specific type of energy technology. The first reserve energy auction exclusive for wind where held in 2009 (Hugo Lucas, Rabia Ferroukhi et al. 2013: 18).

If it is not a reserve auctions, procurement for new generation projects are contracted in two ways (Luiz T. A. Maurer and Barroso 2011: 34):

- A-3 auctions: Contracts on generations' projects ready do deliver electricity within 3 years.
- A-5 auctions: Contracts on generations' projects ready do deliver electricity within 5 years.

- There is also used technology-specific auction. By using this type one specific technology is promoted (Hugo Lucas, Rabia Ferroukhi et al. 2013: 6). Technology specific auctions are important, and probably *the* single most important decision to achieve the success. Technology specific auctions that was exclusive for wind power was introduced in 2009. This is visual in figure 4.3.3.

There are separate auctions for contract new energy and to renew existing contracts. This is done to take into account the there is risk in new projects. For new projects it is critical to get long term contracts to ensure project financing (Luiz T. A. Maurer and Barroso 2011: 33). Luiz T. A. Maurer and Barroso (2011: 35) claim that auctions have helped create competition for "the market", where investors now compete for long-term contracts and in this way enter the market.

In Brazil FIT scheme was used between 2002-2006, before technology-specific auctions where introduced in 2007 (Hugo Lucas, Rabia Ferroukhi et al. 2013: 16) FIT have been proved to give higher investment in RETs then other types of support mechanisms, and a study conducted by The World Bank found that developing countries that used FIT had better chance of attracting private investments (Peter Meier, Maria Vagliasindi et al. 2015: 2). In Brazil FIT was only used for wind farm projects being contracted under the PROINFA program. Projects being contracted through auctions don't getting FIT. To still attract entrepreneurs and investors to further develop the industry there have been used some regulations to mitigate the risk.

4.3.5 Handling the risk

We know from Trott (2012) that the process of being an entrepreneur, or investor, is associated with high degree of risk. Exploiting new markets and taking a basic discovery to become a commercial product is not easy.

When establishing a new market there is high degree of risks that a market failure will occur. By limiting the risk the market will be much more attracting to entrepreneurs and investors. By reducing the uncertainty there will be less chance for entrepreneurs and investors to lose their investment and when the rate of return for projects is known from the start risk could most likely be managed.

In Brazil it has actually been different actors that all have affected the risk in different ways. I will highlight some of the risk mitigations that have been applied in Brazil. Some of them have been reducing risk for investors, some for the entrepreneurs and some for public organizations operating in the power sector.

I the auctions PPA are signed with a length of 20 years. This limit the risk by knowing that there is a market for the electricity produced for at least 20 years. 20 years is the same time as the estimated lifetime of an wind turbine (Blanco 2009: 1378). Another factor that is extremely important is that the owner of the wind farms are getting paid for owning the wind farm, this mean that they are getting paid even they produce electricity or not.

> *"Eletrobras is the buyer of the energy of all these projects, so we gave them purchase power agreement, PPA, for 20 years.*
>
> *This is, lets say, the expected annual income. Then in the first year they receive it 1/12 of this amount per month, independent if they generate or not. If they generate more or less, it will be a compensation for the subsequent year.*
> *If they (entrepreneurs) have a loan … Eletrobras guarantee the payment, 70% of this amount, independent on the generation, to face with the loan. So it was used for all entrepreneurs as a guarantee to get the loan." Drummond (R2 2014: 4)*

By paying developers even their wind farm is not connected to the grid is seen as important risk mitigation. Especially since the developers of the wind farms are depending on others to transfer the electricity they produce into the grid. Development of the grid system and transmission lines is Eletrobras job. Botelho (R3 2015: 6) explain:

> *"There are several wind farms who generate power but is not connected to the grid because there where delays in the transmission lines.*
>
> *Delays, because of Eletrobras…, where in charge of building transmission lines and they screw it up. They had budget cuts and did not do it."*

Another mechanism that has been used to limit the risk for entrepreneurs and investors are to give access to cheap and secure financing for the projects. This is done through BNDES. But there is commitment with the financing, which does not affect the borrower but the supplier of wind turbines that the borrowers choose for their wind farms. To receive financing in terms of loans from BNDES there is a local content requirement that is put on equipment used in wind turbines.

Continuing auctions for wind power showing an on-going demand for this type energy technology in Brazil. This has made firms seeing great opportunities with their new manufactures for wind turbine equipment. These manufactures are also critical to further expansion of wind generation capacity (Hochstetler 2015: 19). By creating an on-going demand through auctions there is less risk of investment when establishing manufacturing facilities for equipment. The local content requirement is beneficial both suppliers and workers in the manufacture of equipment. To create incentives to develop a local manufacturing industry that could supply a growing demand for wind turbines will be important, both to get experience to facilitate R&D and to reduce cost of production.

Local content requirement is view as a support mechanism that could be used to create local wind manufacturing industry. Regulations will then require a percentage of some or all wind farm projects that are being installed to have equipment or components manufactured locally (Joanna I. Lewisa and Ryan H. Wiser 2007: 1851). It is also critical

for economical development and to create jobs. As Joanna I. Lewisa and Ryan H. Wiser (2007: 1846) explain:

> *"direct jobs are typically created in three areas: manufacturing of wind power equipment, constructing and installing the projects, and operating and maintaining the projects over their lifetime."*

A local content requirement secure that subsidies that are used to mitigate risk and to attract wind farms developers are being re-invested to further growth in the Brazilian industry and economy.

4.3.6 Local content requirement

A local content requirement usually refer to a number or percentage of components needed to be manufactured in a country or region to meet commitments or laws (OECD 2001).

When the PROINFA program was established a local content requirement was initiated. It was then a requirement of 60 % needed to be locally or domestic manufactured. Since the PROINFA program was planned as a two stages program the local content requirement was planned to be increase up to 90 % when the second stage was launched. PROINFA unofficial ended in 2008 (Hochstetler 2015: 18), and the local content requirement was then continued through BNDES. It is important to be aware that the local content requirement is not a protected rule to bid in the energy auctions:

> *"It´s not a protection rule in the bid. The protection rule is on the money from the bank. If you want to get money from our bank, that came from my pocket, because we contribute every month with part of our salary to this bank, then if you want to use our money then you have to manufacture part of the wind turbine here. If you don´t want, no problem. You can bring the money from outside and also the machine. We have no restriction about that."- Veiga (R1 2014: 8)*

As (Hochstetler 2015: 18) also put forward the local content requirement is not formally required in the auctions, *"the bids that where low enough to win the auctions were those with financing from BNDES.."*. Interview with Antonio Botelho (R3 2015) also explain the BNDES loan, and why wind farm developers want to have these loans:

> *"…they all get the loans from BNDES, because BNDES conditions are much cheaper, the interest rates are so much cheaper that it made it feasible for them to meet the prices. It is heavily subsidised industry." Botelho (R3 2015: 11)*

By further asking what is meant by *"heavily subsidised industry"* it was referred to CAPEX of wind farms. It is anticipated that the subsidies are the loans given by BNDES, especially since these are connected to production of equipment and wind turbines.

> *"It is not subsidising the consumer, but it subsidising the producers." Botelho (R3 2015: 11)*

Often local content requirements gradual increase in percentage of locally produced equipment (Jan-Christoph Kuntze and Tom Moerenhout 2013: 5). The overall objectives of these requirements are anticipated to be either to develop competitive local industry or to increase employment. The mission of BNDES is:

> "*To foster sustainable and competitive development in the Brazilian economy, generating employment while reducing social and regional inequalities." BNDES (2008)*

This is consistent with anticipation of the overall objectives when creating a local content requirement.

Jan-Christoph Kuntze and Tom Moerenhout (2013: 6) explain support mechanisms as a way to fostering infant industries by protecting them from competition from foreign companies. The support mechanisms often persist until the industry is aware of their competitive advantage compared to foreign competition. If the regulatory actor preparing local content requirements in cooperative with local manufactures this will

increase information and certainty among both of them. The regulator will get information about what the industry is capable of handle in terms of requirements and the manufactures will be able to prepare cooperation, to prevent foreign companies to threat their growth.

Entrance barriers to become supplier of wind turbine in Brazil is anticipated to be high as the result of BNDES regulations of local content requirement (GWEC 2010: 23).

The benefit of using local content requirement is that jobs are created and industrial growth that induces economic development. This creates legitimacy and support among citizen. I will say this is important when spending public financial resources.

Because of the local content requirement the supply side in Brazil has become 10-20 times the demand for wind energy (Veiga R1 2014: 6). Large companies are also buying more then the supply chain is anticipated to handle. This will put pressure on manufacturing and logistics in the supply chain. Veiga (R1 2014: 8-9) emphasise the importance of stable annual demand to create a market that don't will act as a "bubble". As Veiga (R1 2014: 8-9) explain it would be better to have stable annual demand, then one year with large demand and 10 years without. This is also what Joanna I. Lewisa and Ryan H. Wiser (2007: 1848-1849) emphasis as the importance to be able to attract local manufacturing in particular locations stable and sizable annual demand for wind turbines.

In subsection 4.3.3 I referred to Drummond (R2 2014) that explain that the market where created. Government could create markets by the use of different mechanisms. In the theory chapter 2.5 I presented both quasi-market and privatization.

4.3.7 Quasi-market, privatization, or both?

Robertsen (1999) presenting the quasi-market as being established when there is a non-existing private competitive market. In the case of the Brazilian power sector it is most likely a public-private market, where the public sector is the purchaser of a product from the private sector. The Brazilian power sector went through a large privatization

process in the beginning of the 1990. Some parts of the sector where then to be covered by private actors and the state kept some of the main activities of the power sector to be covered by the public (Oliveira 2007).

Grand (2011) present the quasi-market to also consist of private profit making actors. The question is then if the development of the wind power industry in Brazil should be characterized as a quasi-market. If we look at the way it is presented in chapter 2.4 it could for some reasons be characterized as a quasi-market. But there are also elements of a privatization, these could be found in by looking at the developers of the wind farms, which are almost only private actors. At the same time the main financier, the purchaser and the consumer of the electricity are all a mix of public and private actors.

Most of the utilities and power stations are privatized today. This was the result of a large privatizations program in the 90´s. Today only 15-20 % of the utility companies are remaining in the public sector (Veiga R1 2014: 6). I will characterize the creation of the wind power market as a quasi-market. The purchaser of all the electricity is by a public actor. PPA is signed with a public actors and the public actor is responsible for the transmission of the purchased electricity. The government is also taking the financial risk by paying the developers for building and to be able to deliver electricity from their wind farms.

4.3.8 What has been achieved?

Since the beginning of this study the wind power industry in Brazil has been presented as a great success. The prices of wind power started at $150 USD/MWh with FIT system under PROINFA. The auctions in 2009 started at $84 USD/MWh (Hugo Lucas, Rabia Ferroukhi et al. 2013), and the last auctions in fall 2014 contracted wind power at a price as low as $ 44,9 USD/MWh[6] (CCEE 2014: 4). Prices for electricity produced by wind turbines are therefor brought to almost half the price since 2009 when the auctions started.

[6] R$ 135,49 = $ 44,92 USD 23.04.2015

BNDES have by the use of local content requirements provided jobs, economic growth and tax income to Brazil. It is claimed that the PROINFA program have created 150 000 jobs, generated R$ 5 Billion[7] in equipment and contribute to a reduction of CO_2 emission at 2,8 million tons annually[8].

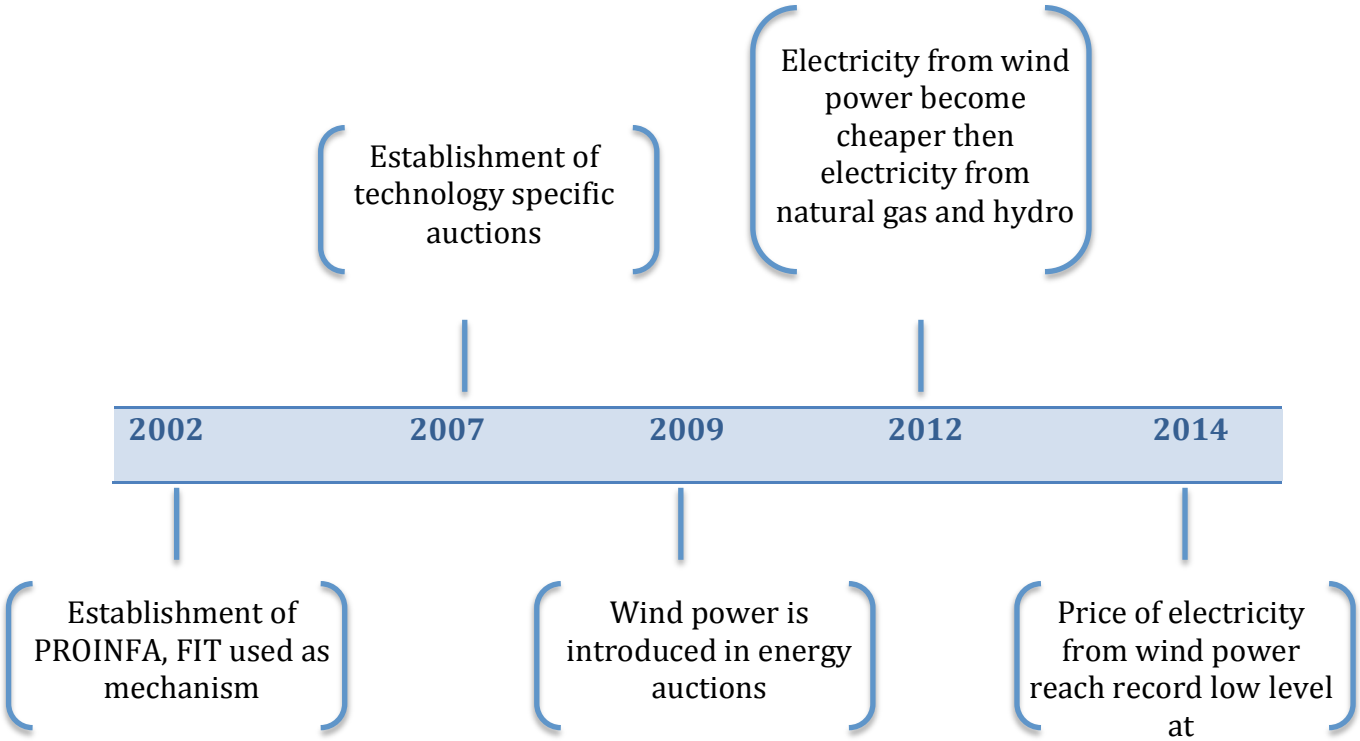

Figure 4.3.6 – Development of the Brazilian wind industry

4.3.9 Energy path of Brazil

Geert Verbong and Geels (2012: 208) presenting *the transformation pathway*. *The transformation pathway* is the one where it could be drawn parallels to the Brazilian pathway. Transformation pathway is characterized by situations where regime actors perceive moderate external pressure. The pressure create problem with on-going practices and create "windows of opportunity". Changes are enacted by regime actors and reorganise existing development trajectories.

[7] $1,65 Billion USD 17.04.2015
[8] Information from presentation in meeting with Eletrobras. Data material collected by researchers in the research project: Transition to sustainable energy systems in emerging economies – A South African focused comparative project (comparing China, India, South Africa and Brazil, the southern BRICS)

> *"In the transformation pathway, the existing regime actors adjust to the outside pressure and to the internal regime tension by modifying the direction of development." Geert Verbong and Geels (2012: 210)*

In Brazil there where internal pressure on building large hydropower dams, there was also external pressure on reducing deforestation and there where draughts. It is anticipated that the draughts were the *trigger* or *that* specific trigger that establish the PROINFA program, and created their window of opportunity. It was then a question on how they could create energy security and diversify the energy matrix. It is important to know that the PROINFA program was for renewable energy, not just for wind power technology. One challenge with their primary energy source, large hydropower plants, was that it leads to deforesting of the Amazon forest and thereby contributes to high environmental impact. The external pressure where related to deforestation of the Amazon, and The World Bank had banned large hydropower projects (Botelho R3 2015: 8). The financial support to these projects was by this gone.

The energy path in Brazil has been heavily affected by their large access of hydropower. Since the beginning of the 20th-century this have been the main sources of energy, and could for several reasons be called a *path dependence* of hydropower. The hydropower has for years been the superior source of energy but as economical growth has increased the energy consumption. Further development of this energy source is therefore questioned. Internal resistance to further exploit the hydropower sources as these deforest the amazon, forces the native people to leave and causes high environmental impact in the form of CO_2 and methane emission. Both of these contribute to increase of greenhouse gasses.

Hydropower had had a long period of positive growth. This could be viewed as a positive lock-in that now have turned into a negative lock-in. Theory of path-dependence refers to these kinds of lock-in to persist as positive for decades, before they shift towards a negative lock-in (Ron Martin and Sunley 2006). One major problem with hydropower is the environmental licences to build the hydropower plants, it is anticipated that it takes more then 5 years only to get the licence. Another issue with hydroelectric power plants is their location which is at the big rivers in the Amazon, This

makes difficulties with transmission lines but also with environmental government agency (Veiga R1 2014: 2).

Establishment of the PROINFA program could then be viewed as an "unlocking" program. The PROINFA program was established by deliberated actions (path creation) and three different technologies were organized in the program. Two of them had been present in the Brazilian energy matrix for a long time, wind power was the only new on. It is anticipated that this where the result of narrowed options, and as Jörg Sydow and Schreyögg (2009: 693) describe the "shadow" in phase I of figure 2.3.1. It is the heritage of the organization and means that there are already limit options from the start. Jones (2013: 81) explains that organizational choices and actions is embedded in the organizations routines and practices and thereby define the organizational environment. This works as a set of forces that surrounding the organization. These forces have the ability to change the way organizations operate and access scarce resources. There was problem with hydropower and biomass needed structure. Brazil had found oil and gas, so thermal power plants run by fossil fuel could be an option, but the last thing Eletrobras wanted was fossil fuel. Their history was hydropower, renewable energy.

> *"Brazil has the tradition of clean energy. Now for decades Eletrobras, the last thing we wanted to hear about was fossil. Only if there is no other way. Today there is no other way. "Drummond (R2 2014: 12)*

Fossil-fuel had been a supplement in the energy matrix to cover for shortfalls from hydropower, as the base load (Hochstetler 2015: 13). This means that organisations, and especially public organisations regulating the power sector, had renewable energy and sustainable development embedded in their organizational environment. Power plants in Brazil run on fossil-fuel was not well developed before 1990, and the Brazilian oil reserves where not exploited before this time (Botelho R3 2015: 9). It was not before 1999 that gas fired power plants was attractive to investors, this was the result of government subsidies to rapid attract construction of gas project as response to draught (Oliveira 2007: 61-62). Beside this, thermal power plant projects have been less

attractive in Brazil. This is a result of governmental regulations that has not favoured this energy resource.

The critical juncture seen in figure 2.3.1 was in Brazil to diversify the energy matrix and enhance energy security with RETs. By the use of deliberated actions developers where attracted to explore wind power. The deliberated action where to use FIT that limited risk. At the same time a framework for a wind industry was established and local content requirement used to attracting suppliers to establishing manufactures in Brazil. Deliberated actions had then created both the demand side in Brazil, and used regulations to attracting the supply side.

Deliberated actions created positive feedback, and as Uli Meyer and Cornelius Schubert (2007: 30) describe paths could get lock-in when they are stabilized and given positive feedback. By recap chapter 2.3.2, Uli Meyer and Cornelius Schubert emphasizes that technological options might not get locked-in on it´s own. They need to be continuously stabilized by deliberated actions. For the wind power in Brazil this is believed to be the case. Regular auctions to contract more wind power, increase of local content requirement, PPA for 20 year, mitigation of the financial risks and secure grid connections do all anticipate to be deliberate actions to stabilize the path. It is then assumed that actors are aware of an emerging path and actively support it. I will assume the wind power industry is in the beginning of the *continuation* phase of figure 2.3.2, and in the middle of phase II figure 2.3.1.

The positive feedback given from wind power are such as becoming the cheapest source of electricity in energy auctions and are *opposite correlated* in terms of annual inflow with water. It could thereby secure access of energy in dry periods[9]. Further it´s great potential made it replacing hydropower in the auctions;

> *"What happened was that the wind power took the place of small hydro… the market for them is very low. Because you can build wind in half or 1/3 of the time,*

[9] Information from presentation in meeting with Eletrobras. Data material collected by researchers in the research project: Transition to sustainable energy systems in emerging economies – A South African focused comparative project (comparing China, India, South Africa and Brazil, the southern BRICS)

and cheaper, and with less environmental impacts, problems with licences and so on. It is easy, it is modular." Drummond (R2 2014: 10-11).

Wind power is claimed to have taken the place for small hydropower plants and that this technology does not have a place in Brazil anymore, or at least a small market (Drummond R2 2014: 11). There was also positive feedback from the wind power in 2014 when low rainfall was compensated by electricity produced from wind turbines (GWEC 2015: 32). After the wind power market was created through the PROINFA program the Brazilian government had problems contract more hydropower, since wind power stole the market from it. The government took the choice to excluded wind power from A-5 auctions over a period to prevent them from taking the place of hydropower (Spatuzza 2012).

One actor that was central in stabilizing and to create positive feedback from the wind power industry was BNDES. Interview revealed that loan through BNDES could be viewed as a subsidy to the wind industry. It is anticipated that this has been critical and highly important to achieve success in the wind power industry. Hydropower has been relatively cheap source of energy so far, but because of the favourable conditions given to wind power technology it seems like hydropower has been priced out of the market.

" … BNDES subsidies is critical for the wind but when you look at the PCH, the small hydro, they don't get subsidies. So they are relatively priced out of the market because of that" Botelho (R3 2015: 12)

In order to achieve loan from BNDES the supplier of wind turbines that a wind farm developer choose need to fulfil the local content requirement. At the same time developers need BNDES loan to win the auctions as was uncovered through interviews. For some reasons this could be viewed as a *self-reinforcing sequence*, every time more wind power is contracted more equipment and parts of wind turbines are being produced in Brazil, as further develop the local industry. Mahoney (2000: 508) connecting the term *self-reinforcing sequence* to increasing return where Pierson (2000: 252) further connecting the increasing return to path-dependence:

"In an increasing returns process, the probability of further steps along the same path increases with each move down that path. This is because the relative benefits of the current activity compared with other possible options increase over time."

Jörg Sydow and Schreyögg (2009) emphasis the increasing return which further induce a self-reinforcing process. They explain that a self-reinforcing process and that increasing returns leads to processes that become more and more irreversible. The higher investment the greater is the chance of becoming irreversible. By increasing returns it is understood that the cost of going back to choose another option is larger, then going further in the chosen direction, it is then greater benefit of moving towards the directions that is already emerging. Every time more wind power is contracted the actors goes one further step down the path towards a path dependence of wind power. Since the local content requirement is a commitment for the borrower it will induce regional development.

The deliberate action that created the framework for the wind power market, attracted wind farm developers and limited the financial risk has led to a series of emerging events. Loans that have been offered by BNDES to wind farm developers are now needed to win auctions, since loans from others don't have good enough terms. This has most likely led to a self-reinforcing process and increasing returns. If the government stop contract wind power the industry manufacturing turbines and equipment will probably stagnate and the unemployment is likely to increase. Even though wind turbine equipment could be exported the production costs in Brazil is 34% higher then in Europe (found in my technological explanation).

What we have witnessed in the Brazilian wind power case is consistent with the way Arthur (1994) describing a path dependence by using Polya´s Urn (chapter 2.3.2). This refers to early choices of a path that will heavily affect further development. Wind power was given favourable conditions from the start and has given the best result of the three RETs from the PROINFA program.

Is the hydropower path at a stage of *dissolution*? When a path goes into the termination phase and dissolute it is an emergent process (Uli Meyer and Cornelius Schubert 2007:

31). As described the hydro path might be at a stage of negative lock-in. While more wind power is being contracted it take the place of hydropower, it is also more efficient to build and have less environmental impact. Changing climate also affecting the stability of hydropower.

If there is an emerging wind path in Brazil I will describe this path as a result of path constitution. Created by deliberated (path creation) and incidental (path dependence) actions. Deliberate action has then led to path dependence.

My government explanation, hypothesis 3, suggested that the success was a result of a government market creation by changing the energy path. The theory for this explanation was divided in two; path dependence/path creation theory and government regulation. To find support for this explanation I expected to find that the framework of the wind power market was deliberate created by governmental regulations. I also expected to find that regulations have been used to actively support the emergence of a new path by the use of path-creation actions that has resulted or could result in path-dependence.

I found that the demand side for wind power where created by the PROINFA program. This program established the framework for the market and where deliberate created by the use of government regulation. The program also used regulations in order to attract and create local manufacturing of wind turbine components, by the use of local content requirement. This requirement was continued after the program ended, this time connected to financial risk mitigation. By the use of efficient energy auctions and creation of technology specific auctions it was succeed to achieve competitive prices on electricity generated by wind turbines.

By going through how regulations have actively been used to mitigate risk, create favourable conditions for wind power and created a demand and supply side in Brazil, with theory of path dependence and path creations there is much that could indicate a new path emerges as a response on path creation activities. The game changer was establishment of the PROINFA program that created the market. Where technology

specific auctions for wind power technology in 2009 gave positive feedback and probably started a self-reinforcing process.

I will conclude there is support for my governmental hypothesis. The wind power industry where created by governmental regulations. These regulations enabled to link the demand for energy to be supplied by wind technology. As concluded both in the technology explanation and market explanation neither of them could describe the success as a one-factor explanation. This also applies for my governmental explanation. Even there is support to conclude governmental actors created the link between the supply and demand the governmental explanation is not sufficient to describe the success as a one-factor explanation.

5 Conclusion

In this study I have been studying factors that could explain the success of the wind power industry in Brazil. I formed three hypotheses that could be used to explain the success. I have been discussing a technological explanation (hypothesis 1), market explanation (hypothesis 2) and a governmental explanation (hypothesis 3).

To find support for my technological explanation (H1) I expected to find that wind power technology was a mature technology and that there was low technological risk. I found that wind power technology has been going through a long development process. The technology has since the beginning been the subject for a series of technological innovations. This is both as product innovation but also in terms of process innovation. I further placed Brazil between early and late majority of the market by using the technological adoption life cycle. By doing this I draw the conclusion that it was low technological risk. This hypothesis was largely supported from my data, but the technology where not present in Brazil at time the wind power industry started. I was then looking for entrepreneurs or a demand that created the market that led to discussion of the market explanation.

To find support for my market explanation (H2) I expected that there where both a supply and demand side. Entrepreneurs could recognize and create the link between these two in order to establish a market. I also anticipated that barriers for RETs penetration to occur were low enough. I found that there was a clear demand side, but that the supply of wind turbines were not established in Brazil. This mean that the demand could be served by fossil fuel, more hydro power or any other energy source or technology available in Brazil. In order to start a RETs penetration conditions where not sufficient. The technology was not present in Brazil. Infrastructure was also missing. There was lack of financial resources and skilled personnel. I concluded that the risk of meeting the demand with wind power technology was to high in order for entrepreneurs to do this.

Hypotheses 1 and 2 were successfully to identify that the technology was ready and mature and that there was a demand for energy in Brazil. Entrepreneurs could not create the link because the risk was too high. This led to my governmental explanation since a large actor to mitigate the risk was needed.

My government explanation, hypothesis 3, suggested that the success was a result of a government market creation by changing the energy path. The theory for this explanation was divided in two; path dependence/path creation theory and government regulations. To find support for this explanation I expected to find that the framework of the wind power market was deliberate created by governmental regulation. I also expected to find that regulations have been used to actively support the emergence of a new path by the use of path-creation actions that has resulted or could result in path-dependence. I found that the demand side for wind power was created through the PROINFA program. This program established the framework for the market and was deliberately created by the use of government regulation. Further I linked this to path creation where government by using regulations created beneficial conditions for wind power industry to emerge. I concluded that this hypotheses where largely supported trough my data, but it was neither as a one-factor explanation.

My conclusion is that the success of the Brazilian wind power industry seems to be a combination of all three explanations. None of them where fully supported as a one-factor explanation to the success. On one side there was a mature technology that had become highly competitive, on the other side there was an increasing demand for energy. Condition was not sufficient for entrepreneurs to establish the market because of high risk of failure. The government, as a large actor, then created a demand for specific types of energy and made incentives to establish a supply chain in Brazil. Governmental actors mitigated the risk so entrepreneurs and investors could explore the market. I will also conclude that governmental decisions and path dependence need to be seen in context. Governmental decisions are often historical contingent and choices are often adjacent to this.

Largely this study support Trott (2012: 51) that referring to the role of the state as being important in technological development. This study has showed that government may

start technological development by making the conditions attractive for investors and entrepreneurs. At the same time government could affect the technological development by the use of regulations, but also by favour technology and thereby send signals on desired technological direction.

As argued in the research design section there are many objectives of what could be learn and what kind of transferability results from special cases, like the wind industry in Brazil could create. My contribution is to present the role of governmental organizations. In many cases these could be extremely important to mitigate risk and thereby make a market attractive. This study also shows that government could use regulations to create desired technological development.

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Appendix I

About PROINFA

- Why can we describe the PROINFA program as a success?
    - Why do you think PROINFA have been important for Brazil?
    - Which reasons where behind the establishment of the program?
    - Can you tell me about the energy crisis in 2001, and have there been others later on? Other crisis then droughts.

The market

- How is the demand for energy in Brazil?
    - Is it growing demand from the industry or private household?
    - What is the cause for this demand?

- Is there a demand for renewable-energy or energy in general?
    - Who are the actors that demanding the different types of energy?

External pressure

- How is the external pressure on Brazil to develop more renewable and sustainable energy?
    - How is this related to the wind industry?
    - What about hydropower?

Economy

- Are the wind power industry economic sustainable?
    - Which subsidies are there to support the industry?

- What will you describe as the major happenings for the industry on its way to the success?
    - How is the innovation on wind power technology in Brazil? Development or technology transfer

- Why is it important to develop the local industry in Brazil?
    - Is this national industry a requirement for all the resources, and have it been a requirement since the start?

- Who are the actors that want the industry and who is the one working against it?

- Are there a lot of new established companies that bidding in the auctions or is it marked leaders that establishing subsidiary in Brazil?

- Who are the private investors in the projects?