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Dissertation

"The transition to the Green Economy: Renewable energy systems as innovation for development"

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ABSTRACT

This dissertation examines the role of the renewable energy sources in supporting sustainable development. It explores the paths that four different countries have taken to develop renewable energy systems and their transition process from one sociotechnical configuration to another. This is done through a cross-country comparison of the policy support mechanisms that have been employed for the promotion of renewable energy. It views their technological transitions through the lens of three the most important sociotechnical approaches: the Large technological systems theory by Thomas Huge, the Actor network theory by M. Callon and B. Latour and the most recent sociotecnical systems approach. It finds that technological transitions do not include just a technology substitution, but there are social factors too, which have a significant role to the diffusion of knowledge. It ends up by identifying the particular patterns and mechanisms in each country's transition process that contributed in a more or less successful way to their sustainable development.

Keywords: Technological transitions, sustainable development, sociotechnical approaches, renewable energy policy, Denmark, the Netherlands, Spain, Germany

ΠΕΡΙΛΗΨΗ

Αυτή η διπλωματική εργασία ερευνα τον ρόλο των ανανεώσιμων πηγών ενέργειας στην αειφόρο ανάπτυξη. Πιο συγκεκριμένα εξετάζει τα μονοπάτια που ακολούθησαν τέσσερεις συγκεκριμένες χώρες προκειμένου να αναπτύξουν το ενεργειακό τους σύστημα με την τεχνολογία των ανανεώσιμων πηγών, καθώς και την διαδικασία μετάβασής τους από το ένα κοινωνικο-τεχνολογικό καθεστώς στο άλλο. Αυτό πραγματοποιείται μέσω μιας σύγκρισης των πολιτικών που ακολούθησαν οι χώρες αυτές για την προώθηση της χρήσης των ανανεώσιμων πηγών ενέργειας. Παρατηρούμε τις τεχνολογικές μεταβάσεις των χωρών αυτών από την οπτική τριων εκ των πιο σημαντικών κοινωνικο-τεχνολογικών προσεγγίσεων: της θεωρίας των μεγάλων τεχνολογικών συστημάτων του Thomas Huge, της θεωρίας των δρώντων δικτύων των M. Callon and B. Latour και της πιο πρόσφατης κοινωνιο-τεχνολογικής συστημικής προσέγγισης. Βρίσκουμε ότι οι τεχνολογικές μεταβάσεις δεν περιορίζονται μόνο στην υποκατάσταση της τεχνολογίας που ήδη χρησιμοποιείται από μία άλλη, αλλά υπάρχουν και κοινωνικοί παράγοντες οι οποίοι έχουν αξιοσημείωτο ρόλο στην διάχυση της γνώσης. Καταλήγουμε εντοπίζοντας τους συγκεκριμένους μηχανισμούς της διαδικασίας μετάβασης κάθε χώρας , οι οποίοιοι συνέβαλλαν, άλλοτε περισσότερο και άλλοτε λιγότερο επιτυχημένα στην αειφόρο ανάπτυξή τους.

Λέξεις κλειδιά: τεχνολογική μετάβαση, αειφόρος ανάπτυξη, κοινωνικο-τεχνολογικές προσεγγίσεις, πολιτικές ανανεώσιμων πηγών ενέργειας, Δανία, Ολλανδία, Ισπανία, Γερμανία

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ABBREVIATIONS

ANT: Actor network theory

APPA: Association of small renewable energy producers

BWE: German wind energy association

CNC: National energy Commission

DWTS: Danish wind turbine test station

EEG: Renewable energy Act

FIT: Feed in tariffs

GCS: Green certificate systems

GLS: Green label scheme

LTS: Large technological systems

MEP: Environmental quality of electricity production

NOW: National research programme of wind energy

PEN: National energy plans

PPPs: Public-private partnerships

RES-E: Renewable energy sources-electricity

RES: Renewable energy systems

RnD: Research and development

SNM: Strategic niche management

StrEG: The act on supplying electricity from renewables

TGC: Tradable green certificates

TSIS: Technology specific innovation system

TT: Technological transitions

1. INTRODUCTION

The aim of this dissertation is to study the transition to a new technological paradigm in the context of renewable energy sources. More specifically, the dissertation addresses the question of how technological transitions (TT) come about and which are the particular patterns and mechanisms in transition processes.

The TT process is being approached by a socio-technical perspective, as it doesn’t involve only a substitution of technology, but it also brings changes in user practices, regulation, industrial networks, infrastructure and culture.

Consequently, the broad deployment of renewable energy sources constitutes a new technological transition, because their use differs not only in terms of source and technical characteristics, but also in their structural, organizational, economic and social elements. And due to the fact that renewable energy sources can support the prudent management of the environment for the survival and future development of humanity, they are closely connected to the concept of sustainable development.

As it was mentioned above, the dissertation focuses on the study of the transition from one sociotechnical paradigm to another. This leaded us to the first methodological step, which was to examine the most important sociotechnical theories that have been developed in this field and which explain how the transition process takes places. All of these theories take into consideration the social construction of technological systems and emphasize on the importance not only of the technical, but also of the social, political and economic aspects. At this point it was also thought to be necessary to provide the clarification of the concepts of sustainability and renewable energy sources as well as the most common European policies on the field of renewables which were shaped by the European regulatory framework.

The next step was to select certain case-studies which had a research interest from the aspect of the deployment of renewable energy sources. Thus, four countries were selected, Denmark, the Netherlands, Spain and Germany, which are considered to be the most interesting and successful stories in the energy field, (especially in wind energy). Indeed, these countries have established distinguished local wind power industries, and some of them achieved not only to construct but also to export wind turbines.

Furthermore, having identified the key policy instruments in the above mentioned countries – case studies, we used the sociotechnical theories as methodological tools in order to approach and explain how the technological transitions took place in each case. Every energy system was seen as technological regime with different production process technologies, product characteristics, skills and procedures which emerged through a transition management model.

This analysis provided us with crucial information and enabled us to make a cross-country comparison. Our findings indicated the differences and the similarities among the selected countries with regards the management of the technological transitions. Additionally, we were able to find out to what degree the sociotechnical theories were verified and how adequately they explained the TT.

As far as it concerns the structure, this dissertation consists from four chapters. Chapter one reveals the research field, provides clarifications of the key concepts of the dissertation and includes the methodological tools which are the sociotechnical theories. Chapter two includes four selected case studies: the case of Denmark, the case of the Netherlands, the case of Spain and the case of Germany with regards to the policies towards the deployment of renewable energy. Chapter three examines the above case studies under the lens of the sociotechnical approach, and makes a cross-country comparison trying to identify the similarities and differences. Finally, the last part of the dissertation summarizes the conclusions that derived from the previous analysis.

2. KEY CONCEPTS AND SOCIOTECHNICAL APPROACHES

2.1 THE CONCEPT OF SUSTAINABILITY

The world Commission in its 1987 report titled "Our Common Future" warned of the growing threat to the Earth from pervasive world poverty, environmental degradation, disease and pollution, calling the scientific community to pay increasing attention to the subjects related to these problems. Five years later, in 1992, the United Nations Organization Conference on Environment and Development was held in Rio de Janeiro to discuss and map the road to sustainable development. The Rio conference adopted the Agenda No 21, a blueprint of how to make development socially, economically and environmentally sustainable. Agenda 21 calls on governments to adopt national strategies for sustainable development

It is a fact that sustainability has become a buzz word in the discussion of the resources management and environment policy. There have been various definitions of this term: For the world commission on Environment and Development sustainability is "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Report of the world commission, 1987). According to the Agenda 21 of the Rio conference sustainable is "the development that requires taking long term perspectives, integrating local and regional effects of global change into the development process, and using the best scientific and traditional knowledge available" (Agenda 21 of the Rio Declaration, 1992). Finally, for the Council of Academies of Engineering and Technological Sciences, it means the balancing of economic, social, environmental and technological considerations, as well as the incorporation of a set of ethical values (The earth chapter, 1995).

Furthermore, sustainable development focuses on the role and the use of science in supporting the prudent management of the environment for the survival and future development of humanity (Afgan et. al., 1998). Loorbach (2007) defined sustainable development as redirection of social development in ways that combine economic wealth, environmental protection with social cohesion.

We are able to identify some basic characteristics that are attributed to the concept of sustainable development which occur in almost all definitions. The first is that sustainability is an intergenerational issue. This means that a longtime horizon, at least one or two generations ahead has to be considered. The second characteristic is the importance of scale. Sustainability occurs at different levels. Local or regional sustainability does not necessarily mean national or global sustainability and vice versa. Sustainability analysis thus requires a multitude of scale levels. The third commonality is the different domains that have to be considered in sustainability. Sustainability encompasses a certain context-specific balance between ecological, economic and socio-cultural values and stakes (Rotmans, 1994).

2.2 RENEWABLE ENERGY SOURCES AND SUSTAINABLE DEVELOPMENT

It is worth pointing out that many authors argue that renewable energy resources can contribute to sustainable development. The challenge is not only to commit enough resources to satisfy energy requirements, but also to select options consistent with sustainable development and cost competitiveness.

At the moment we should mention that the use of renewable energy sources includes solar energy resources, geothermal energy resources, biomass energy resources, wind energy resources and hydro-energy resources.

Such energy strategy consistent with sustainable development entails:

a) Reliable, timely and cost-effective supply. If these requirements are not fulfilled, economic growth, competitiveness, quality of life and equity will be adversely affected.
b) Reducing system vulnerability. Even though an insufficient availability of energy resources normally can be related to greater vulnerability, in the context of sustainable development energy dependency should be interpreted as a reduced capability to design and implement an independent energy policy.
c) Minimum environmental impacts. Energy production and use cause important environmental impacts. Their severity will depend upon the technology employed, the fuel quality and the maintenance of the equipment.
d) Equity oriented energy supply. Lack of adequate supply seriously affects the quality of life, reducing the ability of certain services presently considered essential. This situation may reduce productivity of the economic agents, as well as income obtained from their labour. (Maldonado and Marquez, 1996).

The broad deployment of renewables constitutes a new "technological transition", because their use differs not only in terms of source and technical characteristics, but also in their structural, organizational, economic and social elements.

At this point we should make a few clarifications on the concept of "technological transitions". Technological Transitions (TT) are defined as major technological transformations in the way societal functions such as transportation, communication, housing, feeding, are fulfilled. TT do not only involve technological changes, but also changes in elements such as user practices, regulation, industrial networks, infrastructure, and symbolic meaning (Geels 2002).

Freeman and Perez (1988) suggest that TT include a change from one sociotechnical configuration to another, involving substitution of technology, as well as changes in other elements. Such processes cannot occur easily, because the elements in a sociotechnical configuration are linked and aligned to each other. Consequently, new technologies have a hard time to break through, because regulations, infrastructure, user practices, maintenance networks are aligned to the existing technology. New technologies often face a mis-match with the established socio-institutional framework.

More specifically, for the use of renewable energy sources there are no established markets and no fixed preferences. The use of these new technologies and the emergence of their markets co-evolve. As far as it concerns the users, as Lie and Sorensen (1996) note, they have to integrate new technologies in their practices, organizations and routines, something which involves both learning and adjustments.

In fact, the sustainable diffusion of renewable energy resources implies a new technological regime shift, which is though to be a more complicated process than a simple substitution of technology. Thus the evolution of this technological paradigm is socially embedded through the interaction with the socio-political structure of a system.

The definition of the term "Socio-technical regimes" indicates linkages between technical and social elements of the system. So, according to Rip and Kemp (1998) socio-technical regimes are relatively stable configurations of institutions, techniques and artefacts, as well as rules, practices and networks that determine the 'normal' development and use of technologies. Regimes fulfil socially valued functions, which they also help to constitute (Geels, 2002).

The emerging niche for renewable generated electricity is facing a rather slow diffusion in the wider social and economic system. Some of the reasons renewable technology is not diffusing rapidly through firms, relate to overarching structures of markets, patterns of final consumer demand, institutional and regulatory systems and inadequate infrastructures for change (Smith et. al., 2005).

Kemp et al. (1998) identified seven types of barriers to the shift to more sustainable technologies:

- technological factors
- government policy and regulatory framework
- cultural and psychological factors
- demand factors
- production factors
- infrastructure and maintenance
- Undesirable social and environmental effects of new technologies

2.3 THREE APPROACHES FOR SUSTAINABLE INNOVATION POLICIES

In recent years, three relatively well-developed evolutionary sustainable innovation policy approaches have been proposed which attempt to integrate the insights gained in innovation policy practice.

Strategic niche management

The basic idea of the strategic niche management approach (SNM) is to use niches for creating a transition path to a new technological regime. SNM is an evolutionary approach aiming at fostering innovations with sustainability benefits and the securing the sustainability of those innovations.

Specifically, SNM is the creation and management of protected spaces (niches) for promising technologies by means of experimentation with the aim of learning about the performance, effects, economic viability and social desirability of the technology and to use this knowledge to inform private and public policies that are needed for the further development and rate of application of new technologies and technology systems (Nill and Kemp, 2009).

Nevertheless, this approach has been criticized for being too much of a bottom-up strategy. The criticism is also supported by the fact that some good niche strategies were not enough to reach a successful technological transition, causing doubt about the potential of SNM as a standalone tool for transition (Berkhout et al. 2004).

Transition management

Transition management is a model for fostering sustainability transitions to deal with persistent problems that require system innovation. The basic philosophy is that of goal-oriented modulation: the utilisation of ongoing developments for societal goals, with the aim to achieve a societally desirable transition (Nill and Kemp, 2009). The very idea of the management of transitions has been criticized because transitions (as processes of co-evolution) cannot be managed.

Time strategies

The time-strategic evolutionary policy approach starts from the diagnosis of a possible lock-in problem that hinders the market introduction and diffusion of environmental technologies. In addition it takes into account that the extent of lock-in and path dependence may vary over time, and stable and unstable phases of technological competition alternate. Correspondingly, political opportunities for environmental innovation policies depend on the underlying techno-economic dynamics (Nill and Kemp, 2009).

It also includes three corresponding policy strategies: window preparation (this policy is appropriate when the situation is characterized by a stable old path, but there is at least one promising solution), window creation (government will apply this policy when there is strong social or political pressure to act) and window utilisation (it is applied when the old path is unstable or at least a techno-economic window can be anticipated and at least one new solution becomes competitive to some extent), (Nill and Kemp, 2009).

However, the critique here is that elements of a substantive assessment of the sustainability of different competing technologies have only been partly conducted as part of the time-strategic framework while the concept is still mainly qualitative (Sartorius 2006).

2.4 EUROPEAN POLICIES FOR RENEWABLE ENERGY

As the EU’s long term energy policy is mainly fostering the use of renewable energy, all member states have set up ambitious installations targets for alternative energy sources. For this purpose they have adopted certain policy instruments. Policy instruments are defined as any concrete activity initiated by the government in order to enlarge the market implementation of renewables (Harmelink et. al., 2006). Those policy instruments, aim at increasing the implementation of renewables on the short to medium–short term, and include investment support schemes, feed-in tariffs, renewable energy obligations and regulations.

Ringel (2006) suggests that in most European member – countries, the energy policy is formulated in a triad: 'security of energy supply', 'competitive energy costs and prices' and the 'environmentally benign use of energy'.

In this perspective, the security of supply rests to a reduced dependency on imported primary energy sources in order to safeguard a domestic supply, while competitive energy costs and prices lead to the transition from state-owned monopolies to liberalised energy markets in many countries, which reached the aim of cost-orientation far better than the regularised systems. Finally, the 'environmentally benign use of energy' is mainly seen in the perspective of avoiding greenhouse gas emissions, under the obligations set by the Kyoto-Protocol (Ringel, 2006).

So, there is a significant support for renewable energy by the EU and most of its member states. The development is supported by the Europe-wide targets for renewables and by mostly national policies. The national supporting policies do one or more of the following:

1. Shift some of the investment costs away from the investor, e.g., to the public sector.
2. Guarantee access to a market.
3. Guarantee a certain market size.
4. Guarantee a certain price on any quantity delivered (Johansson and Turkenburg, 2004).

Furthermore, at present we are able to identify two major different political support mechanisms applied in EU Member States, the feed-in tariff (FiT) systems and the tradable green certificate (TGC) systems.

- Feed-in tariff schemes

In the FiT systems the basic principle is that any national generator of renewable electricity (RES) can sell its electricity at a fixed tariff for a specified time period under specific conditions depending on location, technology, etc (Fouquet and Johansson, 2008). The tariffs are set either as fixed tariffs (above market price) or as bonus tariffs adding to the present market price, while they cover the cost disadvantage of the renewable energy sources (Ringel, 2006). The costs of FiT payments are in general passed on to the electricity consumers. Feed-in tariffs, used in particular in Denmark, Germany, Spain and Italy, constitute the oldest and most widely used support system (Menanteau et. al., 2003).

- Tradable green certificates

In the tradable green certificates schemes, electricity suppliers are obliged to produce or distribute a certain quota of renewable energy (Menanteau et. al., 2003). The principle behind the quota mechanism is that a RE producer may receive additional financial benefit from the selling of certificates on the market (Fouquet and Johansson, 2008). This means that the target of RE under the TGC system is set by the government and the certificate price is determined by the market. TGC mechanisms are established in Belgium, Poland, Romania, Sweden and in the United Kingdom (Fouquet and Johansson, 2008).

These two support schemes differ with regard to their compatibility with the principles of the internal market. Fouquet and Johansson (2008) provided a comparison of the two schemes. They suggest that in TGC schemes, renewable electricity is normally traded in the electricity market and is subject to market prices and conditions. And since the electricity is sold in the market, the producers participate on the regular electricity market in competition with other producers and this supply will have an influence on the price.

On the other hand, with feed-in tariffs, the renewable electricity is not sold directly in the market. This electricity is shared among the customers and paid for through a fee included in the network tariff. Although renewable electricity which receives a feed-in tariff is not sold directly in the market, this additional supply has an indirect impact on the market price (Fouquet and Johansson, 2008).

Although renewable energy policy in the European community is still very much a national matter, the Union has moved towards a common policy, which is mainly consisted of three elements: supporting technology R&D, setting medium and long-term targets and providing boundary conditions (like a system for guarantees of origin) (Blok, 2006).

As far as it concerns technology and R&D, within the European Union, Germany was the largest contributor while other countries with a substantial contribution to European Union renewable energy R&D are Italy, The Netherlands, Spain, Sweden and the United Kingdom (Blok, 2006).

Finally, medium and long-term targets were set by both European Directives and the Kyoto Protocol. More specifically, the EU-Directive on the promotion of electricity produced from renewable energy, gives all EU member States reference values for their development until 2010. On the other hand, according to the Kyoto Protocol, EU members have to reduce their greenhouse gas emissions by 8% of 1990 levels by 2008–2012 (Reiche and Bechberger, 2004).

2.5 THE EUROPEAN REGULATORY FRAMEWORK

It is widely suggested that the European Union had rather underused the potential for the exploitation of renewable energy sources in the past. The first recognition of the need to promote renewable energy sources as a priority measure (given that their exploitation contributes to environmental protection and sustainable development) came in 2001, by publishing the 2001/77 Directive. The Directive recognized the need for the establishment of a legislative framework as far as it concerns the renewable energy market.

More specifically, the purpose of the Directive was mainly to contribute to the increase of the use of renewable energy sources for electricity production in the internal market and to create a basis for a future Community framework.

Another important element of the Directive was that for the first time the European Union provided clear definitions of “renewable energy sources” and of “the electricity that is being produced”. More specifically, according to the Directive: ‘renewable energy sources’ are renewable non-fossil energy sources (wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases) and ‘electricity produced from renewable energy sources’ is electricity produced by plants using only renewable energy sources, as well as the proportion of electricity produced from renewable energy sources in hybrid plants also using conventional energy sources and including renewable electricity used for filling storage systems, and excluding electricity produced as a result of storage systems (Directive 2001/77/EC).

Indeed, the inclusion of the above definitions was a matter of great importance, since the Directive included also an obligation for the Member-states to ensure that the origin of electricity produced from renewable energy sources would be guaranteed as such within the meaning of the Directive. Consequently, the definitions would operate as a context of reference as far as it concerns the specification of the energy source and of the places of production.

Finally, one of the main provisions of the Directive engaged all the Member States to take appropriate steps to encourage greater consumption of electricity produced from renewable energy sources in proportion to the objective they had to attain. The Member-States were also obliged to publish a report every five years setting national indicative targets for future consumption. On the other hand, The Commission would publish its conclusions in a report which would be accompanied, by proposals to the European Parliament and to the Council.

Apart from all the above, Commission continued to face new challenges for the energy future of the Union. It had to enrich its regulatory framework with a package of measures targeting to reduce greenhouse gas emissions, in order to comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change. By publishing the Directive 2009/28/EC, the Union recognized the opportunities for establishing economic growth through innovation and through a sustainable competitive energy policy. The Directive included provisions for the promotion of technological development and innovation which ensure the security of energy supply.

It is worth mentioning that in this Directive the term “decentralized energy” is being introduced for the first time. More specifically, the Directive “supports the demonstration and commercialization phase of decentralized renewable energy technologies” (2009/28/EC). Decentralized energy means the same as ‘distributed energy’, which is defined as the local supply of electricity and heat which is generated on or near the site where it is used (Woodman and Baker, 2008). But a more completed definition which recognizes that the main purpose of a distributed energy scheme can be to export electricity rather than providing it to a specific locality, is the following: “distributed energy is the renewable electricity generation which is connected directly into the local distribution network, as opposed to connecting to the transmission network, as well as combined heat and power schemes of any scale’ (Ofgem/BERR, 2008).

Furthermore, although national targets for each Member-State are being set and different schemes of support for energy from renewable sources are operated according to the various renewable energy potentials of each country, the Directive introduces optional cooperation mechanisms between Member-States which allow them to agree on the extent to which one Member State supports the energy production in another and on the extent to which the energy production from renewable sources should count towards the national overall target of one or the other.

There are three intra-European cooperation mechanisms: statistical transfer, joint projects, and joint support schemes. Additionally there is the option to physically import RES electricity from third countries outside the EU (joint projects between member states and third countries).

Finally, the Directive sets binding targets for all EU member states to reach the European target of 20% RES share in EU gross final energy consumption by 2020. For this purpose each Member State adopts a national renewable energy action plan while it has to submit a report to the Commission on progress in the promotion and use of energy from renewable sources in settled dates.

To sum up, regulative and institutional framework conditions are extremely effective means of ensuring that RE is used to a greater extent in Europe. But we should always take into consideration that the natural conditions for renewable energy sources differ widely across Europe. Consequently the European regulatory framework, although it enhances the use of renewable energy sources, it includes only complementary mechanisms, while the main regulatory decisions rely on each Member-state, according to its potentials and needs.

2.6 THE SOCIOTECHNICAL APPROACHES

New technologies, like renewables, do not enter into a virgin market terrain, but instead they have to compete with pre-existing technologies. This means that new technologies often have to adapt in path-dependent ways to previous investment and policy decisions, made often decades in the past. In this case there is not only a technology substitution, but a transition to a new sociotechnical system and more specific a paradigm shift. Three of the most important sociotechnical approaches which take into consideration both social and technological factors for the paradigm shift, are being presented in this section.

2.6.1 THE EVOLUTION OF LARGE TECHNOLOGICAL SYSTEMS APPROACH

This theory was developed by Thomas Hughes (1987). The definition of the large technological systems is that technological systems contain messy, complex, problem-solving components, which are both socially constructed and society shaping. Among the components in technological systems are: physical artifacts (such as turbogenerators, transformers and transmission lines in electric light and power system), organizations (such as manufacturing firms, utility companies, and investment banks which incorporate components usually labeled scientific, such as books, articles and university teaching and research programs), legislative artifacts (such as regulatory laws) and natural resources (such as coalmines) because they are socially constructed and adapted in order to function in systems.

Furthermore, artifacts (physical or non physical) interact as components in a system with other artifacts, and all of them contribute directly or through other components to the common system goal. And when a component is removed from a system or when its characteristics change, there is a change in the characteristics of the other artifacts in the system too.

The organizational components of a system, conventionally labeled social, are created by system builders. As Hughes (1987) notes: “One of the primer characteristics of a system builder is the ability to construct or to force unity from diversity, centralization in the face of pluralism, and coherence from chaos. This construction often involves the destruction of alternative systems. System builders in their constructive activity are like heterogenous engineers.

Technological systems may be either “open” or “closed”. “Open” systems have to deal with social factors such as the environment (the social context of technology and the social background of technological change). On the other hand, the ideal situation would be a “closed” system (which does not feel the environment), because this would eliminate any source of uncertainty.

As far as it concerns “open” technological systems, there are two kinds of environment related to them: ones which they depend on and ones that depend on them. In neither case is there interaction between the system and the environment, there is simply a one-way influence. Environmental factors affecting the system should not be mistaken for components of the system because they are not under system control, and should not be seen as part of it either, because they do not interact with it.

Technological systems solve problems or fulfill goals using whatever means are available and appropriate. The problems have to do mostly with reordering the physical world in ways considered useful or desirable, at least by those designing or employing a technological system.

One of the main characteristics of technological systems is that they are bounded by the limits of control exercised by artifactual and human operators. And human operators, besides their obvious role in inventing, designing, and developing systems, have to complete the feedback loop between system performance and system goal and in so doing to correct errors in system performance. Also, they mostly prefer hierarchy, so the systems over time tend toward a hierarchical structure.

The history of evolving or expanding systems includes the following phases: invention, development, innovation, transfer and growth, competition and consolidation. As systems mature they acquire style and momentum. The phases in the history of a technological system are not simply sequential, they overlap and backtrack. After invention and development, and innovation there is more invention. Transfer may not necessarily come immediately after innovation but can occur at other times in the history of a system as well. Once again it should be stressed that invention, development, innovation, transfer, and growth, competition, and consolidation, can and do occur throughout the history of a system but not necessarily in that order. The thesis here is that the pattern is discernible because of one of several of these activities predominating during the sequence of faces suggested.

The phases can be further ordered according to the kind of system builder who is most active as a maker of critical decisions. During invention and development, inventor-entrepreneurs solve critical problems. During innovation, competition, and growth manager-entrepreneurs make crucial decisions. And during consolidation and rationalization financier-entrepreneurs and consulting engineers, especially those with political influence, often solve the critical problems associated with growth and momentum. Depending on the degree of adaptation to new circumstances needed, either inventor-entrepreneurs or manager-entrepreneurs may prevail during transfer.

The next session includes a more detailed description of the above mentioned phases.

- Invention

Holding companies, power plants and light-bulbs are all inventions. Inventions occur during the inventive phase of a system and during other phases and can be either conservative or radical. Those occurring during the invention phase are radical because they inaugurate a new system. But even though radical inventions inaugurate new systems, they are often improvements over earlier similar inventions that failed to develop into innovations. Conservative inventions predominate during the phase of competition and system growth and they improve or expand existing systems.

Furthermore, Hughes provides a clarification of the terms “independent” and ‘professional” inventor. Independent inventors are free from the constraints of organizations, such as industrial or government research laboratories, and can roam widely to choose problems to which they hope to find solutions in the form of inventions. They often have their own research facilities or laboratories, but these are not harnessed to existing systems, as is usually the case with government and industrial research laboratories. Not all independent inventors are “professional’. Professional inventors support their inventive activities over an extended period by a series of commercially successful inventions. They are not salaried employees, although they might take consulting fees.

- Development

Radical inventions, if successfully developed, culminate in technological systems. One inventor may be responsible for most or all of the inventions that become the immediate foundation of a technological system. The same inventor may preside over the development of the inventions, until they result in an innovation, or a new technological system in use. If one inventor proves responsible for most of the radical invention and the development of these, then he or she fully deserves the designation inventor-entrepreneur.

Development is the phase on which social construction of technology becomes clear. During the transformation of an invention into innovation, inventor-entrepreneurs and their associates embody in their invention economic, political and social characteristics that it needs for survival in the use world.

Because new problems arise as the system is endowed with various characteristics, radical-inventor entrepreneurs continue to invent during the development period. Because problems arise out of the systemic relationship of the system components being invented, the choice of problems during the development process becomes easier. If for instance, during development the inventor varies the characteristics of one component, then the other interrelated components' characteristics usually have to be varied accordingly. This harmonization of component characteristics during development often results in patentable inventions. An entire family of patents sometimes accompanies the development of a complex system.

- Innovation

Innovation clearly reveals technologically complex systems. The inventor-entrepreneur, along with the associated engineers, industrial scientists and other inventors who help to bring the product into use often combines the invented and developed physical components into a complex system consisting of manufacturing, sales and service facilities. On the other hand, rather than establishing a new company, the inventor-entrepreneur sometimes provide specifications enabling established firms to manufacture the product or provide the service.

Once innovations occur inventor-entrepreneurs tend to fade from the focal point of activity. Some may remain with a successful company formed on the basis of their patents, but usually they don't become the managers-entrepreneurs of the enterprise.

- Technology transfer

The transfer of technology can occur at any time during the history of a technological system. Transfer immediately after innovation probably most clearly reveals interesting aspects of transfer, for the technological system is not laden with the additional complexities that accrue with age and momentum. As a system has embodied in it characteristics suiting it for survival in a particular time and place, manifold difficulties often arise in transfer at another time or to a different environment. Because a system usually needs adaptation to the characteristics of a different time and place, the concepts of transfer and adaptation are linked.

Furthermore, exploration to the theme of technology transfer leads to the question of *style*, for adaptation is a response to different environments and adaptation to environment culminates in style.

Factors shaping style are numerous and diverse. One of them is natural geography. Because regions as traditionally defined are essentially geographical, and because geography so deeply influences technology, the concept of regional technological style can more easily identified than national style. When regulatory legislation applies on national level, however, regional styles tend to merge into national ones. Regional and national historical experiences also shape technological style.

- Growth, competition and consolidation

In modern industrial nations, technological systems tend to expand, as shown by electric, telephone, radio, weapon, automobile production and other systems. A major explanation for this growth, and one rarely stressed by technological, economic or business historians, is the drive for high diversity and load factors and a good economic mix. This is especially true in twentieth century systems in which accountants pay close attention to, and managers are informed about, interest or capital investment. The load factor is the ratio of average output to the maximum output during a specified period. Best defined by a graph or curve, the load factor traces the output of a generator, power plant or utility system over a twenty four hour period. Because many technological systems now using the concept are capital intensive, the load curve that indicates the load factor, or the utilization of investment and the related unit cost, is a much relied on indicator of return on investment.

The load factor does not necessarily drive growth. A small technological system can have a high load factor, for example if the load or market for output is diversified. In general, extension over a larger geographical area with different industrial, residential, and transportation loads provides increased diversity and the opportunity to manage the load to improve the load factor. The load factor is probably the major explanation for the growth of capital-intensive technological systems in capitalist, interest-calculating societies.

Entrepreneurs and organizations presiding over expanding systems monitor the appearance of reverse salients, sometimes identifying them by cost accounting techniques (bottlenecks). Having identified the reverse salients the organization assigns its engineering staff or research laboratory to attend to the situation, if it is essentially one involving devices, machines, processes and the theory and organized knowledge describing and explaining them. The inventors, whether engineers or industrial scientists, then define the reverse salient as a set of critical problems, which when solved, will correct it. When a reverse salient cannot be corrected within the context of an existing system, the problem becomes a radical one the solution of which may bring a new and competing system.

Moreover, technological systems, even after prolonged growth and consolidation, do not become autonomous. They acquire *momentum*. The have a mass of technical and organizational components. They possess direction or goals. And they display a rate of growth suggesting velocity. A high level of momentum often causes observers to assume that a technological system has become autonomous. Mature systems have a quality that is analogous, therefore, to inertia of motion. The large mass of a technological system arises especially from the organizations and people committed by various interests to the system.

It is a fact that many points of criticism against the theory of 'large technological systems" has been raised. One of the main critiques is that in LTS research there is a tendency to focus on heroic actors, at the cost of other less visible actors whose action or non-action has been important for system development and change. Another main theme in the criticism of LTS is the issue of technological determinism as related to the concept of momentum. Finally, it is being suggested that there is a biased focus on system-building, as the creation of integrated, well-controlled systems that have been shaped in ordered processes and with clear phases of development rather than highlighting the inherent chaos, challenges, and conflicts as well as the high level of uncertainty in system-building. Many important perspectives will be lost in the future as well, unless this bias is corrected (Ewertsson and Ingelstam, 2004).

2.6.2 THE SOCIOTECHNICAL SYSTEM APPROACH

This approach addresses the question of how technological transitions come about, trying to identify the particular patterns and mechanisms in transition processes.

Geels (2002) provides a definition of technological transitions: “TT are defined as major technological transformations in the way societal functions such as transportation, communication, housing, feeding, are fulfilled”. Consequently, TT do not only involve technological changes, but also changes in elements such as user practices, regulation, industrial networks, infrastructure, and symbolic meaning.

Under the sociotechnical approach, Rip and Kemp (1998) analyse technology as ‘configurations that work’. The term ‘configurations’ refers to the alignment between a heterogeneous set of elements, while the addition ‘that work’ indicates that the configuration fulfils a function.

In this context, technological transition includes a change from one sociotechnical configuration to another, involving substitution of technology, as well as changes in other elements. As Freeman and Perez, (1988) suggest, such reconfiguration processes do not occur easily, because the elements in a sociotechnical configuration are linked and aligned to each other. Radically new technologies have a hard time to break through, because regulations, infrastructure, user practices, maintenance networks are aligned to the existing technology. New technologies often face a mis-match with the established socio-institutional framework.

Geels (2002) makes an analysis of the multilevel perspective on technological transitions. This multilevel framework has been described by many authors (Kemp, 1994, Rip and Kemp, 1998, Geels, 2002). According to this approach, there are three different levels, which are not ontological descriptions of reality, but analytical and heuristic concepts to understand the complex dynamics of sociotechnical change. The three levels are:

- Regimes

A technological regime is being formed by a routine-based behavior that is shared by both firms and engineers (Geels, 2002). Technological regimes create stability because they guide the innovative activity towards incremental improvements along trajectories. Rip and Kemp (1998) widened the technological regime concept by defining it with the sociological category of rules: “A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems, all of them embedded in institutions and infrastructures”.

- Landscapes

Technological trajectories (that result from technological regimes) are situated in a sociotechnical landscape, consisting of a set of deep structural trends. The ST-landscape contains a set of heterogeneous factors, such as oil prices, economic growth, wars, emigration, broad political coalitions, cultural and normative values, environmental problems. The landscape is an external structure or context for interactions of actors. While regimes refer to rules that enable and constrain activities within communities, the ST-landscape refers to wider technology-external factors. The context of landscape is even harder to change than that of regimes. Landscapes do change, but more slowly than regimes (Geels 2002).

- Niches

While regimes usually generate incremental innovations, radical innovations are generated in niches. Because these niches are protected or insulated from ‘normal’ market selection in the regime, they act as ‘incubation rooms’ for radical novelties (Schot, 1998). Niches require relatively low technical performance and they are often cumbersome and expensive. Niches also provide space to build the social networks which support innovations, e.g. supply chains, user–producer relationships. These internal niches processes have been analyzed and described under the heading of strategic niche management (Geels, 2002)

The relation between the three concepts can be understood as a nested hierarchy or multi-level perspective as the following figure indicates. There is the meso-level of ST-regimes which accounts for stability of existing technological development and for the occurrence of trajectories. On the other hand, the macro-level of landscape consists of slow changing external factors, providing gradients for the trajectories. And finally, the micro-level of niches accounts for the generation and development of radical innovations. The important point of the multi-level perspective is that the further success of a new technology is not only governed by processes within the niche, but also by developments at the level of the existing regime and the sociotechnical landscape (Geels, 2004).

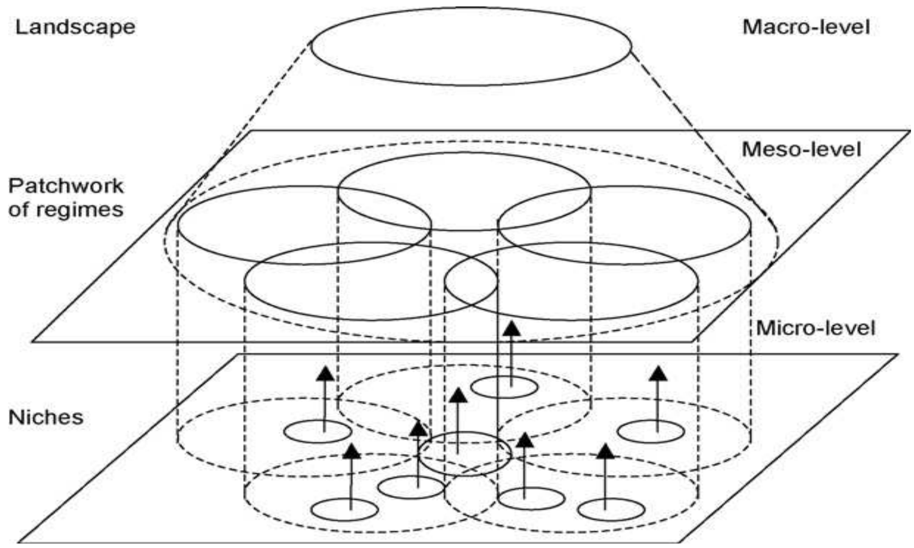

Fig. 1. Multiple levels as a nested hierarchy (Geels, 2002)

Nevertheless, a number of criticisms have been made regarding the multi level approach as conceived and applied within the systems in transition literature and transition management. Genus and Coles (2008) express the following concerns:

First of all, none of the previous studies systematically identifies or analyses the meso-level socio-technical regimes which are thought to be central to stability and change in socio-technical systems. Consequently, there is need for greater clarity and robustness in the use of multi-level models of technological transition.

In addition, the definition of transitions seems to be rather problematic, especially in relation to the establishment of the start and end points of transitions. In fact, the characteristics of transitions differ from case study to case study and may be represented by different sets of vents. On the other hand, the end of a transition also varies in definition across cases, while further criticism concerns the point that is not easy to disentangle whether radical transition rather than ongoing system renewal has taken or is taking place. Therefore, there is a question mark over the definition, on conceptualization and verification of transition paths within transition research.

Furthermore, transition research has emphasized the needs of technology (as ‘artefact’) in terms of adaptation to technological determinants. This has given rise to linear analysis, in sympathy with ideas such as path dependency and technological trajectory, and undervaluing the role of agency and politics.

Another limitation of the previous research is that applications of the multi-level perspective have tended to feature case studies which focus on a technology traditional artifact. In this way it neglects transitions with important cultural and societal aspects.

One more limitation concerns the fact that previous research is based on case studies which do not set out adequately the research methods governing the collection and analysis of secondary data. As a result, the interpretation of these cases provides a poorly constructed empirical foundation to the multi-level approach.

Moreover, some concerns have been expressed on the failure of the sociotechnical approach to identify the exact role of transition managers (it should not be taken for granted that the intervention of transition managers necessarily improves things). Also, by positioning managers as external rather than internal to transition contexts, we underestimate their politics within the systems.

Besides all these, it is not clear that all of the previous studies are in fact concerned with the same core research question, even within each subset of transition research. Some of them pose the question of how changes at the level of technology systems occur (systems innovation), while others are directed at radical technical innovations.

Finally, one fundamental issue is that on the one hand, in systems in transition research the MLP is being presented mainly as a global model, while on the other hand, transition management research seems capable of differentiating transition contexts in particular cases, but it neglects some aspects of the everyday politics of transition.

2.6.3 THE ACTOR NETWORK THEORY

The initial development and application of actor network theory was concerned with the sociology of science and was pioneered by Michel Callon (1986) and Bruno Latour (1987).

The theory deals with the social-technical divide by denying that purely technical or purely social relations are possible. ANT attempts to trace the complex relationships that exist between governments, technologies, knowledge, texts, money and people. By examining these complex relationships it becomes easier to describe why and how we have the science and technology that we do.

Besides all that, the name of the theory implies that an actor-network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of” (Callon, 1986).This theory distinguishes itself from other sociotechnical approaches, because it considers both human and non-human elements equally as actors within a network. More specifically, it argues that both human and non- human actors be conceived within a network wherein their identity is defined through their interaction with other actors.

The theory in order to stress the need to treat both human and non-human actors fairly and in the same way, includes three principles: agnosticism (impartiality is demanded towards all the actors involved in the project, whether they be human or non-human), generalised symmetry (explains the conflicting viewpoints of different actors in the same terms by use of an abstract and neutral vocabulary) and free association (requires the elimination and abandonment of all a priori distinctions between the technological or natural, and the social), (Callon,1986).

Furthermore, the ANT includes three sets of unique concepts: Black-Boxes/Punctualization, Engineer-Sociologist/Heterogeneous Engineer and Translation/Delegation. A more detailed review of these concepts is following.

- Black-Boxes & Punctualization

For technology studies, a black box is a technical artifact that appears self evident and obvious to the observer. Opening the black box of technology leads to an investigation of the ways in which a variety of social aspects and technical elements are associated and come together as a durable whole, or black box (Latour, 1987).

On the other hand, the concept of “punctualization” refers to the process by which complex actor-networks are black boxed and linked with other networks to create larger actor-networks. In this way, the idea that everything is both an actor and a network is being illustrated. And the technical objects are rather processes and not things.

- Engineer-Sociologist/Heterogeneous Engineering

The ANT is following the methodology of Thomas Hughes (who developed the theory on large technical systems), and turns its attention to the System Builders. At the individual level these are usually scientists and engineers while larger actors typically include representatives of industry and government. These are the actors who initiate scientific and technical innovation and exert influence over its direction and trajectory.

Additionally, these actors are constantly defining and re-defining a sociotechnical world. This means that they not only “design” a technology, but also a social world in which this technology will have a place. The process that is occurring here is termed “heterogeneous engineering” (Latour, 1987).

- Translation/Delegation

It is widely accepted that technology cannot be presupposed as an autonomous thing that exists outside of the social world. Technologies embody a variety of political, social and economic elements as well as science, engineering, and the particular histories of these practices.

Within ANT translation is a concept that bridges the gap between the varied aspects that are combined in technology. Translation involves all the strategies through which an actor identifies other actors and arranges them in relation to each other. According to Latour (1987), the mere ‘possession’ of power by an actor does not automatically confer the ability to cause change unless other actors can be *persuaded* to perform the appropriate actions for this to occur.

In addition, the translation process includes four stages: “Problematisation” during which the problem that needs to be solved is being identified, “Interessement” in which the actors that are interested are negotiating the terms of their involvement, “Enrolment”, during which the actors accept the roles that have been defined for them during interessement and finally “Mobilization of allies” in which it is being examined if the delegate actors in the network adequately represent the masses. If so, enrollment becomes active support (Latour, 1987)

On the other hand, the term “delegation” describes the reciprocal relationship between the social and the technical. In any situation in which technology is used, it is used to delegate, or translate, a major effort into a minor effort. Delegation, then, is a particular instance of translation whereby the social and the technical co-constitute each other.

Furthermore, Latour provides a few clarifications on the most common misunderstandings of his theory. Three misunderstandings are due to common usages of the word network itself and the connotations they imply.

The first mistake would be to give the term “network” a common technical meaning. As the author suggests, an actor network may lack all the characteristics of a technical network -it may be local, it may have no compulsory paths, no strategically positioned nodes.

The second misunderstanding is that the actor-network theory has very little to do with the study of social networks. Whereas social network adds information on the relations of humans in a social and natural world, the ANT aims at describing the very nature of societies, by extending the word actor not only to human, but also to non-human, non individual entities.

In addition, the word actor has been open to the same misunderstanding as the word network. Actor” is traditionally thought to be a human intentional individual actor. While in ANT an “actor” is a semiotic definition -an actant-, that is, something that acts or to which activity is granted by others. An actant can literally be anything provided it is granted to be the source of an action (Latour, 1990).

Nevertheless, this theory has been critically assessed by other authors, which highlighted it’s weaknesses.

Although Actor Network Theory is widely valued for its apparently anti-essentialist or relativist ontology, in fact it continues to rely upon the notion of inherent agential capacities when attributing properties to natural and material objects (Wittle and Spicer, 2008). The point here is that ANT relies on the idea that natural objects and man-made artifacts have certain ‘real’ properties that explain the relative durability or weakness of the network. So, one of the main weaknesses of the theory is that by attributing organizational outcomes to the effects of a technology, it is unable to understand how or why the same technology can be interpreted and used in different ways. Thus, ANT is left vulnerable to universal statements about the characteristics of objects and artifacts that are abstracted from the context of their development and use.

Moreover, ANT makes a clear separation of human and non-human, a distinction between the social and the technical. The point missed by ANT is that the separation between human and nonhuman is neither natural nor inevitable but is instead the outcome of a ‘labour of division’ (Wittle and Spicer, 2008). By making this separation the theory has to face the impossible task of trying to gather evidence about the properties of nonhuman elements without involving human participants. In this way ANT re-creates and reinforces the very dualisms it claims to deconstruct.

Another weakness of ANT is that it tends to impose its own theoretical lexicon, attempts to verify and generalize a linear model and engages in limited reflexivity about its own claims to truth. This means that ANT is unable to provide a thoroughly reflexive account of how, as field of knowledge, it is implicated in the production of power/knowledge relationships (Wittle and Spicer, 2008).

Finally, although ANT considers both human and non-human elements equally as actors within a network, it actually degrades the meaning of political action by elevating the status of non-human actors and reduces meaningful action of utility maximization (Wittle and Spicer, 2008). The point here is that ANT brings a tendency to legitimize hegemonic power relations, ignore relations of oppression and sidestep any normative assessment of existing organizational forms.

3. SELECTED CASE STUDIES

In this chapter we are going to examine the renewable energy policies of four countries, which are thought to be the most successful ones in a European level as far as it concerns the deployment of renewables and especially of wind energy: Denmark's, Netherlands', Spain's and Germany's. We will scrutinize the most important policy instruments, energy projects and strategies that led them to a sustainable development.

3.1 DENMARK

Denmark is thought to be a world leader in the development of wind power. Not only does this country generate a greater portion of its electricity consumption with this technology than any other country in the world, but wind turbines have become a very important export product. The Danish wind turbine industry is the largest in the world (Hadjilambrinos 2000).

At the time of the first oil crisis, Denmark's energy system was heavily dependent on oil. In 1973, petroleum, all of which had to be imported, and its products, accounted for 88.7% of the nation's energy consumption (Hadjilambrinos 2000). The crisis, understandably, had a severe effect on the country. Consequently, the first official energy plan became a reality in 1976. Meyer (2004) notes that the main proposals of this plan included the introduction of nuclear power in the Danish supply system, and the implementation of a natural gas system based on the resources in the Danish part of the North Sea.

In 1981 the Danish government proposed another energy Plan, which created conditions that did not favour nuclear development. This was rather an energy conservation programme that was setting out standards for the residential and commercial sectors. It also included the development of a national heating plan, the exploration and development of domestic oil and gas resources and finally emphasized on the use of new renewable energy sources (Hadjilambrinos 2000).

In 1990 the overall goal of Danish energy policy was to promote sustainable energy development and to comply with commitments to reduce greenhouse gas emission in an effort towards the mitigation of climate change (Meyer 2004). Wind power was given an important role in these plans. In March 1999, the main political parties struck an agreement to introduce a green certificate system based on an obligation to buy a certain share of electricity from renewable sources (Agnolucci 2007).

The Danish strategy for promotion of wind power combines a number of different elements: Long-term government support for research, development and demonstration, Certification of wind turbines, Feed-in tariffs and regulations, Investment subsidies, Government energy planning and targets and local ownership of wind turbines and careful selection of sites (Meyer 2004).

More specifically, the diffusion of wind energy in Denmark was enhanced by the introduction of FIT which was the stimulus needed for widespread wind development and allowed projects to move beyond wind enthusiasts to a bigger share of the population (Lipp 2007). Other policies complemented the FIT, like direct subsidies, and tax exemptions e.t.c. were combined with early investment in R&D and thoughtful land-use planning to encourage widespread participation in turbine investment.

Nevertheless, there is a criticism against the feed in model. Meyer and Koefoed (2003) recommended that a fixed price level does not conform to traditional market principles. Moreover, the favourable tariffs have not been reduced in step with technological development. Windfall profits have been obtained by operators of the most modern wind turbines located at the most favourable sites.

Finally, in 1999 the FIT was removed and according to Mendonca et. al. (2009) this happened for two reasons: Firstly, FIT was funded from the state budget, and was therefore considered to be one of the causes of rising electricity prices. Secondly, the incoming Government showed no political interest in supporting renewable energy.

It is also worth to point out the Danish cooperative model of wind ownership. In formal terms, the wind co-operatives are general partnerships. This is a contractual relationship between several entities – in this case electricity consumers – to pool certain resources in order to run a business, and is the only joint form of ownership to qualify under Danish power law (Bolinger 2001).

The first private wind turbine cooperative was formed in 1980, and the only limitation to cooperative turbine ownership was a residence criterion. Members had to live within the same municipal area and within 3 kilometres of the turbine. In 1985 a key policy change came when the Government introduced limitations to the size of cooperative investment shares. This encouraged distributed development and prevented developers from using a centralized development approach to dominate the market. The move was in response to developers beginning to favour larger wind farms (Mendonca et. al. 2009).

In the mid-1990s, individual ownership increased greatly due to declining turbine costs and lower interest rates, and Government incentives for repowering older turbines replacing older turbines with new, more efficient ones (Mendonca et. al. 2009). As Mac Laren (2007) suggests, since the late 1990s the situation in Denmark changed. New government targets to increase wind energy use lead to relaxed ownership criteria, and this resulted in a move away from cooperatively owned projects toward more single-owner projects. Today around 20% of installed capacity is owned by cooperatives (Sorensen 2008).

Moreover, in Denmark, most wind turbine owners are organized in the Danish Wind Turbine Owners' Association publishing a monthly magazine with production figures and notes on technical failures for more than 1,500 turbines. The statistical database, user groups, and technical consulting services for members have been important instruments to secure a transparent market based on shared knowledge (Christensen et. al. 2005).

The manufactures of wind turbines have their own organization too – the Danish Wind Turbine Manufactures Association. The organization carries out an extensive information work, makes policy analyses, takes part in standardization activities, and is involved in national and international R&D activities. From the above one can conclude that knowledge sharing and interactive learning among key players have been important characteristics of the evolving Danish wind power innovation system.

Engineers at the Danish Wind Turbine Test Station (DWTS) were another group of actors to play an important role. The DWTS was established in 1978 to service the emerging wind turbine industry (Garud and Karnoe 2003). The mix of competencies at the DWTS made it possible for the engineers to understand the complexities of wind turbine operations and to participate meaningfully in the development of the industry.

Consequently, progress in wind turbine technology in Denmark can be attributed to R&D programs and accumulated experience in producing wind turbines. As Lewis and Wiser (2006) suggest, Denmark's R&D budget, although smaller in magnitude than some other countries, is thought to have been allocated more effectively among smaller wind companies developing varied sizes and designs of turbines in the initial years of industry development.

In addition, Denmark was the first country to promote aggressive quality certification and standardization programs in wind turbine technology and is still a world leader in this field. There are currently several international standards for wind turbines in use, the most common being the Danish approval system and ISO 9000 certification (Lewis and Wiser 2006). Indeed, those standards contribute to building consumer confidence in this unfamiliar product. In this way Denmark achieved to be considered one of the most reliant turbine manufacturers in the world.

The wind industry is Denmark's third largest exporter in wind turbines. Danish companies Vestas, NEG Micon and Bonus had all been among the 10 largest wind turbine manufacturers. The two former merged and consolidated the Danish number one position in the world market, while the latter was bought by Siemens. The largest independent blade manufacturer (LM Glasfiber) is also Danish, and there are also many other leading subcontractors (Buen 2006). In fact, the benefits of local wind turbine manufacturing for Denmark were limitless: economic development opportunities through sales of new products, job creation, and increased local tax base, opportunities for the export of domestically made wind turbines to international markets, further enhancing the prospects for local economic development, and cost savings that result in lower-cost wind turbine equipment, a lower cost of wind-generated electricity, and therefore higher growth rates in domestic wind capacity additions (Lewis and Wiser 2006).

Moreover, the further development of Danish turbines to modern industrial products was stimulated by a boom of wind turbine export to the United States in the early 1980s and to the European markets of the 1990s (Moller 2010). Gipe (1991) stressed that about one half of the California's wind capacity was built in Denmark and imported to the USA by Californian importers.

Indeed, during the period 1982-1985 California opened up as an international political niche market for the Danes. Rich Californians could obtain tax rebates for wind turbine investments, and Danish turbines turned out to be more solid than their competitors. In the mid-1980s, the Danes had more than 50% of this rapidly growing market, covering 90% of global market activity (Buen 2006).

The California experience proved to be essential for industrial development, as it stimulated mass production and competition. It also forced the Danes to adjust to the differences and the logistics related to service and support in a market far from Denmark.

Nevertheless, as Gipe (1991) notes, in 1985 the federal energy tax credit and investment tax credit were both removed, and California's own additional tax credit was reduced in 1986. The Danish dependence on California was essential in explaining the bankruptcies in this period.

Overall, the Danish experience is associated with two ‘‘Political Economy’’ paradigms during which the interests groups (the associations, the governance, the producers e.t.c.) had a rather important role: the neoclassical approach and the ‘‘concrete institutional economy and innovative democracy’’ approach.

First, there was the neoclassical approach, which was underlying the policy landscape during the whole period from 1974 to 2008, and was mainly marketed by the Danish Ministry of Finance. But in long periods it was, overruled by the innovative democracy approach, which was mainly marketed by the Danish Ministry of Environment (Mendonca et. al. 2009).

In this approach the role of the Parliament was to keep the ‘‘free market’’ institutions in order, to establish research programmes and to make sure that the external climate costs of energy production are internalized in the market prices. This approach was also partly supported by the Ministry of Finance, in general by right wing parties and also partly by the left wing in the Parliament. It was to some extent based upon the belief that the fossil fuel companies will be able and willing to make the transition to renewable energy technologies (Mendonca et. al. 2009).

On the other hand, the innovative democracy model was developed and more or less implemented in Denmark in the period 1974–2002. This model created the relative Danish success within global renewable energy development in this period. Its main characteristics are: the supporting research in renewable energies and especially the required infrastructure for variable renewable energy sources, the support of a ‘‘feed-in’’ scheme for renewable energy technologies, the establishment of ownership rules that support local and regional ownership of renewable energy technologies and the establishment of an infrastructure that supports flexible energy sources such as wind energy (Mendonca et. al. 2009).

In brief, the period 1974–2008 had as a main characteristic the coexistence one of both economic approaches, with the innovative democracy model dominating during important periods between 1974 and 2002.

To sum up, Denmark has been a pioneer in supporting wind power development, and today its wind industry is world-leading (Unander et. al. 2004). An explanation of this success should include factors of change as well as factors of long-term stability. Vleuten and Raven (2006) noted that the reasons of this success are: first the fact that next to large utilities, smaller urban municipalities and rural cooperatives became system owners. Second, the fact that the state chose not to have an ownership stake in centralized supply prior to the 1970s. Third that the Danish stakeholders built up experience with specific DG technologies as wind-electric and decentralized CHP generation from the early 20th century. These technologies became less visible in the centralization regime, but capabilities remained latently present nevertheless.

Denmark today faces two challenges: providing 'green electricity' and efficient markets, while striking a balance between centralisation and decentralisation of electricity supply systems (Lehtonen and Nye 2009). Although the success of the Danish wind power industry provides an example of a bottom-up 'learning-by-using' strategy, many things still have to be done in order Denmark to meet the challenges of the future.

3.2 THE NETHERLANDS

Netherlands' policies for promoting renewable energies were developed in a rather complex manner. A source of complexity was the great number of policies that were introduced to help the diffusion of RE. The Dutch government experimented with different approaches both in terms of policy instruments (renewable quota vs. feed-in tariff) and in terms of the focus of the policy (demand side vs. supply side) (Agnolucci, 2007).

The renewable energy market in the Netherlands started its development in the early 1970s (Van Rooijen and Van Wees, 2006). The Dutch NOW programme, the National Research Programme on Wind Energy, started in 1976. Within this programme, subsidies were provided for R&D into the potential of wind energy in the Netherlands and into wind turbine building. The goal of this programme was to develop a significant wind turbine capacity in the Netherlands, consisting of a large number of large wind turbines (

Kamp et. al., 2004). But since 1990 we are able to identify three phases in its policy development.

The first phase concerns the early 1990s, and includes a mix of instruments. The introduction of the Feed in tariffs became in 1989 (Agnolucci, 2007). FIT were a legal obligation on distribution companies to purchase RE produced in their area of supply, while the price paid for RE was negotiated between distribution companies and generators. But given the then very high generation costs of RE, the feed-in tariff scheme on its own could not bring about a market for these technologies (Agnolucci, 2007).

Furthermore, the government negotiated voluntary agreements with the energy distribution sector. The latter committed itself to voluntary sales targets for renewables amounting to 3.2% of electricity sales and 0.7% of gas sales by the year 2000. However, since the targets were not compulsory, compliance was poor and targets were never met (Van Rooijen and Van Wees, 2006).

This early period included also investment incentives, which are widely known as ‘‘MAP subsidies’’. In more detail, the government established the Environmental Action Plan (MAP) in 1991, according to which a tax on consumption was charged, the so called “MAP Levy”. The MAP Plan provided for a series of measures for energy savings and conservation, and for the introduction of renewable energy sources (Do Valle Costa et. al, 2008).

Finally, in 1995 the government introduced a green funding programme. In this scheme due to the fact that 60% of the interests from the investment were tax free rates paid by banks to investors, banks could lend to developers building green projects at a reduced rate (Agnolucci, 2007).

The second phase of Netherlands’ policy development includes the introduction of a regulatory energy tax—also known as the ‘‘ecotax’’, for small and medium scale energy users in 1996. This new tax system was also used to stimulate green electricity consumption and partly production. Consumers of green electricity were exempted from the energy tax (Van Rooijen and Van Wees, 2006).

Furthermore, in 1998 the government introduced the ‘‘Nil Tariff’’, which consisted of tax exemption for all domestic generators of renewable energies and for sale of imported energy stimulating in this way the demand for renewable energies (Do Valle Costa et. al, 2008).

Additionally, the green label scheme (GLS) was introduced in 1998 in order to verify the compliance of a voluntary target agreed between the distribution companies and the government for the supply of 1700 GWh of RE by 2000 (Agnolucci, 2007). And as the labels could be easily traded, they were supposed to make renewable generators no longer dependent on the local distribution companies for the purchase of electricity (Agnolucci, 2007). In 2001 the government transformed the informal, voluntary green label system into a formal green certificates system managed by the government (Van Rooijen and Van Wees, 2006).

The third phase of policy development includes a new policy, called the ‘‘environmental quality of electricity production’’ (MEP), which was implemented in 2003. The two main objectives of the MEP were to reduce investment risk and to improve the cost-effectiveness of renewable electricity. Support was provided by means of a feed-in tariff, combined with a partial exemption from the ecotax (Van Rooijen and Van Wees, 2006).

In this phase the policy support measures had three main targets: to improve competitiveness by supporting research and development of existing and new RE technologies, to stimulate market penetration by financial regulation and by liberalizing the renewable electricity market and to encounter political & administrative bottlenecks by streamlining planning and building permit procedures (Junginger et. al., 2004).

Despite various policies to promote renewable energy, growth of the renewable energy market in the Netherlands has been limited and targets set by the government have not been fully met (Van Rooijen and Van Wees, 2006). There were several obstacles that hampered the development of the renewable energy market in the Netherlands.

Firstly, and most importantly, is the complexity and diversity of instruments, which confuse the investor, who fears lack of security in the long term (Do Valle Costa et. al, 2008). Indeed, the government didn’t provide a stable investment climate and overall didn’t succeed in building confidence through stable policies, on the contrary it failed to reduce market uncertainties (Van Rooijen and Van Wees, 2006).

Other barriers are: the gas industry, which has a significant role in the economy and there does not seem to be any prospect for changes in that area (Do Valle Costa et. al, 2008), the debate over whether goals can best be met by means of a voluntary or a mandatory approach (Dutch policies have always been voluntary) and the fact that although the government emphasized the importance of investments in local capacity, imports were always seen as an alternative option (Van Rooijen and Van Wees, 2006).

It is a fact that, besides the various barriers, the shaping of the above policies in energy sector at national level affected the development of the wind power supply market. New wind power entrepreneurs emerged and shifts occurred in market shares of different entrepreneurial groups.

More specifically, we are able to identify the following types of entrepreneurs:

- Small private investors (mainly farmers): this entrepreneurial group consists of farmers, other companies and sometimes individuals. Wind power exploitation is supplementary income for this entrepreneurial group. Their core business lies outside the energy sector.
- Electricity sector (energy distributors): this entrepreneurial group consists of companies that belong to the traditional energy sector. Wind power exploitation is a small business component in these companies. Their core business is producing and selling a portfolio of (renewable) energy sources.
- Wind cooperatives: this entrepreneurial group consists of cooperatives that are owned by individual members. Wind power exploitation is not a means of making money, but a device to use in working for a sustainable society.
- New independent wind power producers: this entrepreneurial group consists of companies, commercially interested and specialized in wind power exploitation. Wind power exploitation is a part of their core business, which is most likely, related to the renewable energy sector (Agterbosch et. al. 2007).

The above mentioned groups of entrepreneurs are being identified in three successive market periods: in Monopoly powers (1989–1995), Interbellum (1996–1997) and in Free market period (1998–2002).

The first period known as Monopoly powers (1989–1995), started with the implementation of the Electricity Act in 1989, which separated production from distribution. This was a major turnabout in the vertically integrated monopolistic electricity supply sector of those days. The electricity sector and energy distributors dominated this period, both with regard to the number of turbines and total capacity installed (Agterbosch et. al. 2004).

The second period known as Interbellum (1996–1997), ran from the implementation peak in 1995–1998, which saw the reversal in dominance by the electricity sector to dominance by small private investors. During these intermediate years, small private investors and farmers changed places with the electricity sector with regard to the number of turbines and total capacity installed annually (Agterbosch et. al. 2004).

Finally, the third period known as free market (1998–2002), started in 1998. Since 1997 and 1998, small private investors have dominated the market in all areas: the number of turbines, the number of projects and total capacity installed annually. Also, for the first time in the short history of the wind power supply market, in 2001 and 2002 new independent wind power producers surpassed the electricity sector slightly in importance (Agterbosch et. al. 2004).

Apart from the policies, we should also pay attention to the Dutch innovation system. Kamp et. al. (2004) distinguished two parallel wind turbine development paths and two accompanying innovation subsystems: the large-scale subsystem and the small-scale subsystem.

The large-scale wind turbine innovation subsystem was oriented towards building many large wind turbines in the Netherlands. In this subsystem a large amount of theoretical knowledge on wind turbines was gained during research projects in various Universities.

Within this subsystem, the manufacturing companies and the research institutes and the universities of technology were completely in line with each other. They had the same frame of meaning regarding the technology: their goal was building a large number of large wind turbines that together would make a significant contribution to the national energy provision (Kamp, 2002).

On the other hand, the intended turbine buyers within this subsystem were electricity production companies, which were aiming at the building of large wind power stations, which would deliver great amounts of electricity, while at the same time they were not involved in the design and manufacturing of the wind turbines (Kamp et. al., 2004).

In the end, due to the large financial risks and the small home market, the large companies in the large-scale wind turbine innovation subsystem, stopped producing wind turbines. An important cause of the turbine problems was the lack of learning by using. In this subsystem the knowledge gained was mainly based on learning by searching (Kamp et. al., 2004).

In the small-scale wind turbine innovation subsystem small companies in the Netherlands started to manufacture wind turbines, because of the R&D subsidies into wind energy and wind turbines that had been made available by the National Research Programme on Wind Energy (Kamp et. al., 2004).

In this system the knowledge base was, in contrast with the large-scale subsystem, learning by doing. The first small wind turbines were built and were gradually improved and scaled up. Because the turbines were sold in the vicinity of the manufacturing companies, problems were observed and solved quickly in interaction with the users, enabling the manufacturer to learn from these problems (Kamp, 2002).

Nevertheless, many problems raised in the Dutch wind energy sector. The small Dutch home market and the inability of the Dutch manufacturers to compete with the Danes on the large Californian market resulted in severe difficulties for the Dutch manufacturers in the 1990s, while in the year 2000, only one Dutch turbine builder, remained (Kamp et. al., 2004).

To sum up, we are able to identify that the Dutch government used a broad and diverse set of policies, which included complex instruments and frequent changes. These policies proved to be rather opaque, confusing, and didn’t succeed to build confidence in order to reduce market uncertainties. Overall, the Dutch policies didn’t bring about a systematic removal of economic and technical impediments.

3.3. SPAIN

Spanish policy on the promotion of renewable energy was developed in a highly decentralized political system, in which the government played an important role in the industrial policies and decision making processes and got involved in regulatory design in strategic sectors, as in the regulation of the electricity industry (Perez and Ramos-Real, 2009).

More specifically, apart from the National Government, there are autonomous Communities and other Local Entities that have important contributions in the energy sector (De Alegrıa Mancisidor et. al., 2009). Five regions account for 85% of the total installed capacity in Spain: the province of Galicia leads the way, followed by Castilla La Mancha, Castilla y Leo n and Aragon (Del Rıo and Unruh, 2007).

Furthermore, we should identify the main actors concerning the RES-E policy in Spain: the National government, the RES-E generators and the National Energy Commission (CNE).

As far as it concerns the national government, the Ministry of Industry is responsible for energy policy and has as a main objective to ensure security of energy supply and to keep costs for consumers at reasonable levels (Montes et. al., 2007).

It should also be pointed out that the Spanish government coordinated the policies towards the RES promotion through the National Energy Plans (PEN). In 1991 the PEN included a 1991–2000 energy savings and efficiency plan, setting specific targets for energy production from renewable energy sources, while the 1999 PEN called for a doubling of the renewable energy share in the primary energy supply. The last PEN emphasized the promotion of renewables in keeping with the public’s concern over environmental issues (Perez and Ramos-Real, 2009).

As for RES-E generators, two major categories of RES-E producers can be distinguished: large ones usually linked to the big players in the traditional electricity sector, and smaller (independent) RES-E generators. The latter are well organized in the influential Association of Small Renewable Energy Producers (APPA), which negotiates directly with the authorities (Del Rıo Gonzalez, 2008).

Finally, there is the National Energy Commission (CNE), a regulatory body for Spain's energy system. The goals of CNE are to ensure effective competition in Spain's electricity market and its objective and transparent functioning. Its functions are: to implement legal rules and standards, to issue reports and proposals for the determination of tariffs, rates and remuneration of energy activities, to settle electric power transmission and distribution costs and the permanent costs of the system, to defend competition, to arbitrate in any disputes arising between the agents in the electricity industry and to perform inspection (Del Rıo Gonzalez, 2008).

As far as it concerns the specific policy instruments, the feed in tariff scheme played a rather important role in Spanish policy and proved to be a successful instrument. The introduction of FIT for various classes and capacities of technologies followed the planning period that started in 1986, during which the first renewable energy plan set targets for production from renewable energy and targets for private and public investments in renewable energy systems (Perez and Ramos-Real, 2009).

After its introduction, the FIT scheme was reformed for several times bringing about different outcomes. Some elements of the basic system were first modified in 2004, giving renewable energy producers two remuneration options: sell output to the distributor at a regulated (feed-in) tariff, or sell output directly in the market at the market price plus an incentive and premium, in addition to a capacity payment. Most producers chose the fixed tariff system, simply because it provided a better deal and less uncertainty over future income (Perez and Ramos-Real, 2009).

The second reform of the FIT scheme took place in 2007 and achieved to tackle three major issues: It enhanced the security of electricity supply by giving RES-E priority access to the grid, it encouraged the participation of RES-E in the electricity market by making changes which were driven by the goal of minimizing consumer costs, and finally, it included provisions in order to limit the increase in system costs (Del Rıo Gonzalez, 2008).

Overall, the FIT scheme proved to be rather successful instrument as its reforms allowed the continuation and stability of the system while at the same time encouraged investors to make long-term investments at moderate costs.

In addition, the Spanish regulatory framework provided a significant support towards renewable energy sector. In 1980 the first policy document which provided a justification for the support of RES and energy efficiency and clearly motivated to reduce energy import dependence was published. Other regulations are: the Law of the Electricity Sector with the aimed to achieve the EU target of 12% of gross energy consumption coming from RES in 2010, the Royal Decree on Special Regime which developed the administrative procedures and conditions of the plants to access the Special Regime and the Royal Decree 436/2004 according to which generators may sell their electricity to distributors or directly to the market (Del Rıo Gonzalez, 2008).

Furthermore, it should also be stressed that Spanish public actors (agencies or departments of local/regional/ national governments) and several private actors formed legal partnerships for joint equity investments in wind projects. Dinica (2008) distinguishes three types of partnerships: the project-vehicle partnerships which make investment in one wind project only, the wind-specialized partnerships which is a group of actors that invest in more than one wind projects and the renewables-specialized partnerships which invest not only on wind projects, but also in other renewable energy projects.

The project-vehicle partnerships dominated in the investment picture in mid 1990s and the projects that were developed were based on internally financed partnerships. At the end of the 1990s as technological innovation was taking place, the new turbine models were tested in the framework of technology-demonstration partnerships, or even by individual companies. After testing them, early-commercialization partnerships were being developed to prove the commercial viability of the new technological designs. After the1990s the majority of the projects that entered into operation were developed by renewables-specialized partnerships and project-vehicle partnerships, while a much smaller number of partnerships were conceived as wind-specialized partnerships (Dinica 2008).

With regards to wind generators industry, it should be pointed out that the business framework is made up of more than 170 companies that include manufacturers (wind turbines, blades, towers, generators, multipliers, electrical equipment, etc.), suppliers (hydraulic and electrical equipment and equipment for controlling and regulating), mechanical construction and public works companies, installation companies and maintenance, exploitation and engineering companies (Montes et. al., 2007).

Overall, the Spanish policy on renewable energy was rather efficient. Spain has been one of the most successful countries regarding the public promotion of electricity from renewable energy sources and particularly from wind (Del Rıo Gonzalez, 2008).

The diffusion of wind energy in Spain cannot be attributed to any single factor but, rather, several interrelated factors are involved. Resources are thought to be the first important factor. Indeed Spain benefits from high-quality wind potential. Additionally, learning effects, economies of scale and R&D efforts have substantially reduced wind energy costs and system components. Another important factor is the highly supportive institutional framework which provides a strong incentive through generous high feed-in tariffs awarded per kWh generated (Del Rıo and Unruh, 2007).

On the other hand, the larger social context has been supportive of wind energy and is generally regarded by local actors as highly beneficial for its associated employment and development opportunities. Finally, the role of pioneer entrepreneurs has been important in the development and initial adoption of wind electricity in Spain while the financial institutions have been also supportive of wind energy, given the proven profitability of wind energy investments (Del Rıo and Unruh, 2007).

Nevertheless, there are still substantial barriers that influence the diffusion of wind energy in Spain. Some of those barriers have to do with authorization procedures for construction, connection to the grid and initiating production in wind farms. Regulations often delay the granting of permits, increasing lead times, transaction costs and risks for project developers (Del Rıo and Unruh, 2007).

Additionally, wind farms are usually located in low-density rural areas where grid infrastructure is often weak. Investments to improve or extend the existing electricity infrastructure are required, but the costs fall on project developers, who must make large investments in the connection lines (Del Rıo and Unruh, 2007).

To sum up, there is a delay in the installation of wind farms which is caused mainly by the lack of infrastructures along with systemic and institutional difficulties of grid connection.

In conclusion we have to note that Spain developed a successful model in renewable energy industry and achieved significant technological advances in the area of wind energy. Several factors have played a part in making wind energy a success: The stable regulatory framework governing electricity generation that permits wind farms to have a reasonable return, the Regulations in several autonomous regions governing the procedures to authorize the installation of wind energy, the better understanding of wind as a resource, the improved technology and mass production and the lower investment and exploitation costs and improvements within the financial framework (Montes et. al., 2007).

3.4 GERMANY

Germany has been very successful in increasing the share of renewable electricity over the past decade, and this has largely been achieved by effective public policy. Within the public policy mix, the feed-in system was most significant (Wustenhagen and Bilharz, 2006). It is clear that German success would not have been achieved without adequate political support. Therefore, the policy instruments that promoted the development and use of RES, and especially of wind energy, should be analyzed.

- The Act on Supplying Electricity from Renewables (StrEG)

Especially for wind energy, the StrEG was the most important promotion instrument in Germany during the 1990s. It obliged the public energy utilities to purchase and pay for electricity from solar and wind energy, hydro power, biomass, sewage and landfill gas on a yearly fixed basis (Bechberger and Reiche, 2004). This act, normally called feed-in law, was strongly biased in favor of wind and had as a result a very large increase in wind energy in Germany (Agnolucci, 2006).

The rationale of StrEG was to create a level playing field between RE and conventional electricity generation, by reflecting the external costs of fossil fuel and nuclear energy. But even though this first FIT was a great boost for the wind sector, opposition to the FIT was expressed, especially by the utilities which had underestimated the impact of the law when it was first introduced. The main concerns were about the level of support, especially to wind, and the uneven cost burden given that RE developments were concentrated in certain parts of the country (Lipp, 2007).

- The renewable energy act (EEG)

The Renewable Energy Act (EEG) superseded the Feed-in law in 2000 and its main aim was to contribute to the goal of the EU and Germany to at least double the share of RES in electricity generation in the year 2010 compared with the 1997 level (Lipp, 2007). The basic principles underlying the EEG were: Fixed payments for new installations, no compensation for inflation, and a long period for reimbursement (Do Valle Costa et. al., 2007).

In more detail, the most important structural elements of the EEG can be summarized as follows. Firstly, the remuneration system was replaced by fixed, regressive and temporarily limited feed-in tariffs for the whole amount of RES electricity generated. Secondly, a priority purchase obligation for RES power was introduced, to be met by the nearest grid operator. Thirdly, a Germany-wide equalization scheme was adopted for the costs that grid operators incur as a result of the different amounts of RES each region feeds into the power grid, which leads to an even distribution of the RES power amounts and extends remuneration to all energy supply companies and ultimately to all end-consumers. Fourth, the EEG also contained for the first time provisions concerning the financing of grid connection and grid extension (Bechberger and Reiche, 2004).

Nevertheless, the major barrier found in this policy to promote renewable energy in Germany was the resistance of electricity companies in paying the prices established for the renewable energy generators. They argued that the reimbursement paid to renewable energy generators would be an extra tax, which, under the German constitutional Law, would only be legal under certain circumstances. The electricity companies also questioned this Law in court, however, the German Federal Court resisted and did not deny the constitutionality of the Law (Do Valle Costa et. al., 2007).

Finally, after the introduction of EEG and its amendments, Germany achieved to more than double its renewable electricity production since 2000 and has already significantly exceeded its minimum target of 12.5% set for 2010, therefore, EEG is widely considered to be very successful in terms of increasing green electricity shares, and has thus been adopted by numerous other countries (Frondel et. al., 2010).

- Other instruments

In general, since its start, the German approach to promoting RES has been based on four main instruments:

· Direct investment subsidies,

· Soft loans

· Tax allowances and

· Subsidies for the operational costs ((Bechberger and Reiche, 2004).

Besides these policy instruments, various public programs (federal and state level) offered financial incentives and support for introducing renewable technologies in the market and particularly wind energy. Among the most important state projects was the REN Program, in the state of North Rhine Westphalia. This program supported circa 300MW of wind energy until 1998, and was an example for other German states. Basically, the decentralized programs were important to convince the Federal Government to support measures to promote wind energy (Do Valle Costa et. al., 2007).

As far as it concerns the development of wind turbines, two projects should be mentioned: The GROWIAN project in the late 1970s and early 1980s, which was a top-down approach by government and established research and industry players aimed at building a large wind turbine from scratch. The project eventually failed. On the other hand, a more successful approach to wind turbine development was pursued by several small new entrants entering in the mid-1980s. The size of newly installed turbines increased from 10 to 50kW in the 1980s to an average of 182kW in 1992. While some of the new entrants from the early days are still active as independent players, others have been sold or merged during the recent industry consolidation (Wustenhagen and Bilharz, 2006).

Germany’s policy instruments should be viewed within its wider political context. Politics in Germany are decentralized. Together with the federal government, local and state administrations have an important role in governance, and the three levels of government have the capacity to legislate in energy policies, whereby the federal level has priority (Do Valle Costa et. al., 2007).

In addition, market liberalization took place in 1998 and brought an interest in promoting renewable energies in the domestic market and for political image, because of global warming and climate change issues, mainly led by the German Green Party.

Furthermore, energy companies were decentralized and scattered throughout the various levels of government and the wind energy industry in certain German states had a strong lobby, facilitating the development of policies to promote renewable energies in these states (Portman et. al., 2009).

Furthermore, the German federal government has taken a very active leadership role in financing science and technology for wind energy development. The federal funding programs are implemented through direct funding of national laboratories, grants and cooperative agreements with universities, and various forms of financial and technical assistance to industry partners (Portman et. al., 2009). These programs subsidized investments mainly in wind turbines, and small niche markets were formed and a set of firms were induced to enter (Jacobsson and Lauber, 2006).

As far as it concerns the stakeholders of the German renewable energy industry, they began to organize in various associations, such as the German Wind Energy Association (BWE), whose members include wind turbine manufacturers, operators, planning offices, financiers, scientists, engineers, technicians and lawyers. The BWE is not solely focused on increasing the use of wind energy, but more generally supports the development of an environmentally friendly and sustainable energy supply by promoting the use of renewable energies, energy efficiency technologies and energy saving measures. The goal of the BWE is the complete transformation of the energy system in order to achieve 100 % dependence on renewable energy (Laird and Stefes, 2009).

Despite the successful policies, Germany has still some obstacles to overcome for the further promotion of RES. We can identify two major issues: On the one hand, there is the strong influence of the coal sector with a high number of lobbyists in the Social Democratic Party of Germany who are opposed to wind power, and on the other hand, there are plenty of natural gas supply contracts which will not expire before 2011 and some contracts are even fixed until 2030. This could seriously hamper future RES development in German, as instead of further expansion of the RES market, the contracted natural gas has to be consumed first (Bechberger and Reiche, 2004).

In conclusion, the overall German successful policy can be attributed to certain factors which were the drivers for green power market development. Those factors are: the desire of electricity marketers to differentiate their offerings which made them show interest on RES, the willingness of retail consumers to pay more for renewables, the emerging demand from business customers and government authorities which are an important buyer group for green electricity, and overall government policy which traditionally had a clear supply side focus (Wustenhagen and Bilharz, 2006).

Overall, we are able to conclude that, although the above countries used the same policy mix for the promotion of renewable energy, the results were not the same. In some cases the policy instruments have been implemented more effectively than in others. The social and technological conditions that were prevalent in each country played also a significant part to their success or failure.

4. THE SOCIOTECHNICAL PERSPECTIVE

4.1. THE CASE STUDIES UNDER THE LENS OF THE SOCIOTECHNICAL PERSPECTIVE

Having identified the key energy policies of the countries, we will now attempt to seed light on the transition process in each case - study, under the lens of the sociotechnical approaches.

After the oil crises in the 1970s, in most of the countries there was a great need for the development of power production technologies that could make them more self-sufficient. Since Denmark didn't own fossil fuels supplies, showed active support to the development of renewable energy. The focus was not only on the production of energy, but on the construction of wind turbines too, which proved to be a great product to export.

Denmark supported equally both large scale and small scale wind turbines through the establishment of two *coalitions*: the dominant established coalition and a less politically powerful but very influential ideological coalition, the cooperative coalition. Over the last years a comprehensive learning process has taken place across those two coalitions. The two distinct ideological coalitions in Denmark can be said to have formed a long-term learning alliance.

As Van Est (1999) suggests, in Denmark there was an established political consensus concerning the development of the electricity system. Socialist and non-socialist parties had a long lasting agreement on energy policy, so they were considered members of one ideological coalition. After the first oil crisis the established coalition recognized that it was dangerous to rely so much on oil. This admission revived the idea of developing large scale wind turbines that could contribute to the centralized electricity generation system as fuel savers.

On the other hand, the cooperative coalition believed that there should be a limit to growth and a gradual and appropriate technological progress. This coalition also saw decentralized energy systems as a means to shift the authority to decide energy matters to the local level, and supported the development of small scale wind turbines.

Overall, the alliance between the Danish established and cooperative coalition exemplifies a long term interactive and integrative learning process. The ideas of cooperative coalition on energy policy and its wish to minimize the environmental impact of the electricity sector, were no longer perceived as being at odds with economic growth, but seen as prudent policy to maintain economic growth.

On the other hand, the Netherlands didn’t support the renewable energy deployment so intensively. The country was already self sufficient in the energy production, as it had a great supply of natural gas.

As it was mentioned in the Danish case, the role of advocacy coalitions is rather important. The coalitions are needed to open a space for the new technology within the regime, to create legitimacy for the new technology, to counteract resistance to change and to mobilize resources in the form of investments or public subsidies (Mander, 2008). Nevertheless, support from advocacy coalitions was larger in Denmark than in the Netherlands. The Dutch wind turbine owners were not well organized and the environmental organizations had an ambiguous role. Although they were in favour of renewable energy, a large number of them opposed wind turbines because of the danger to the landscape. Additionally, siting problems were severe in the Netherlands and this large resistance to the siting of wind turbines seriously hampered Dutch market growth.

With regards to German case, there were several German organizations that worked with industry representatives as well as with local and federal politicians and formed coalitions which proved to be critical for the evolution of the technological systems centred on wind turbines and solar cells.

As far as it concerns the Spanish case the diffusion results can be explained mainly by a policy implemented at all governmental levels, which stimulated investments by means of public-private partnerships (PPPs) between public actors and private actors. Indeed, PPPs formed powerful coalitions that supported intensively the promotions of renewable energy.

More specifically, PPPs proved to be excellent policy instruments to generate and sustain private actors’ interest in wind power especially. Without PPPs many important types of actors, such as energy companies, would perhaps not have entered the market. PPPs were also helpful in generating knowledge related to project development and permitting procedures (Dinica, 2008).

It should also be pointed out that in Denmark a *technology-specific innovation system* (TSIS) was developed. As Carlsson and Stankiewicz (1991) suggest TSIS include the network of actors interacting in a specific technology under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology. Within the TSIS two concepts are central: the policies and technological learning that is the process in which actors acquire knowledge in order to improve the performance of the TSIS.

In the Danish case, most wind turbine owners were organized in the Danish Wind Turbine Owners' Association, the manufactures of wind turbines have their own organization too – the Danish Wind Turbine Manufactures Association, while the Engineers are organized at the Danish Wind Turbine Test Station. All the above lead to knowledge sharing and interactive learning among key players.

In addition, the Danish TSIS included multiple ways of learning. The practical experience is closely connected to the notion "learning by using" while the laboratory research is connected to "learning by searching". Nevertheless, learning by interacting was the most crucial way of learning in the TSIS. Learning by interacting occurred between knowledge institutes, component suppliers, project operators and turbine manufacturers. Indeed, there was a close interaction between private wind turbine owners and suppliers, as well as between suppliers and the research and development (R&D) community.

With regards to *the multilevel perspective*, as it was mentioned above, the social system around a technology is sub-divided into three levels: the socio-technical landscape, or macro level, the socio-technical regime or meso level and the niche, or micro level.

In Denmark, landscape developments favored the expansion of wind power. The oil crisis of the 1970s was a milestone as far as it concerns the Danish energy plans. Since Denmark didn't own its own fossil fuel supply, there was a great need for the development of power production technologies that could make the country more self-sufficient.

With regard to the developments at the regime level, due to this lack of a Danish fossil fuel supply, regime actors were more interested in wind turbines and more willing to negotiate favourable tariffs.

Furthermore, in a niche level, in Denmark two wind power innovation subsystems were developed, a large-scale and a small-scale. The first one was mainly focused on the development of large wind turbines by large companies, whereas the second one was focused on the production of smaller wind turbines.

The large-scale wind power innovation subsystem involved research centers and the Danish Universities in order to develop the knowledge needed to build large wind turbines. Through many years, the production of wind turbines with great capacity was enhanced. Nevertheless, building large wind turbines brought further implications and problems. By that time, the Danish small-scale wind power innovation subsystem was starting to develop.

The small-scale wind power innovation subsystem included small turbine companies which were building small wind turbines. Through the years, more wind turbines were owned by cooperations of people living near the wind turbines. Therefore, they could also reap the benefits from the wind turbines.

It should also be pointed out that in Denmark the market subsidies which were available from the beginning helped to the formation of a relatively large home market at an early stage and created better market conditions. The relatively large home market gave the Danish turbine manufacturers the opportunity to produce a relatively large number of wind turbines and created further opportunities for exports.

On the other hand, in a niche level, we are able to identify two innovation subsystems in Netherlands: the large-scale wind power innovation subsystem and the small-scale wind power innovation subsystem. Those systems came as a result of the implementation of the National Research Programme on Wind Energy, after the oil crisis of 1973 aiming to develop a significant wind turbine capacity in the Netherlands, consisting of a large number of large wind turbines (Kamp, 2008).

The large-scale wind power innovation subsystem was directed towards building many large wind turbines in the Netherlands and the actors involved were mainly large companies, research institutes like Universities, research institutes, electricity production companies and the government. In this subsystem, a large amount of theoretical knowledge on wind turbines was gained while various design models for wind turbines were developed. Although the intended turbine buyers within this subsystem were electricity production companies, they were not involved in the design and manufacturing of the wind turbines (Loorbach et. al, 2008).

Consequently, within the large-scale subsystem, learning-by-interacting between the researchers and companies went well. They shared goals and paradigms and they developed a number of large, high-tech wind turbines. However, the utilities were not very much involved as a result of their lack of interest and the small number of turbines sold to them, so that they did not participate in the learning process. In more detail, the electricity production companies were not very enthusiastic about wind energy. They did not take wind turbines very seriously, because of the small amount of electricity they can produce compared with conventional gas-driven power plants or nuclear power plants.

On the other hand, in the small-scale wind power innovation subsystem, wind turbines were developed at a much slower pace, by starting with very small wind turbines and gradually scaling them up. The companies involved were small. Other actors involved were small wind turbine owners like individual farmers or cooperatives, research institutes and the government (Loorbach et. al, 2008).

This subsystem faced also many problems, like difficulties in building reliable wind turbines and the fact that there was a small size of the domestic market. The Dutch market was and remained small, because in the Netherlands no investment subsidies were available for wind turbine buyers and therefore, payback times for wind turbines were rather large (Kamp, 2008).

Within the small-scale subsystem, learning-by-interacting was also a problem. Because the number of wind turbines sold was not large, not much knowledge could be exchanged between wind turbine producers and owners. Also knowledge exchange between turbine producers and researchers proved to be problematic.

With regard to the developments at the regime level, in the Netherlands, regime actors were not very enthusiastic about wind power. More specifically, the electricity production companies and the utilities were not in favour of wind power because of the small amount of electricity wind turbines could produce compared with conventional gas-driven power plants or nuclear power plants. Instead of it, they were in favour of building fossil-fuel-driven power plants and nuclear power plants. Additionally, the decentralised character of wind turbines did not fit into the existing regime. Utilities favoured centralized electricity production and were not willing to pay good payback tariffs to wind turbine owners (Kamp, 2008).

In a macro (landscape) level, we are able to identify several factors that influenced the further expansion of wind energy in the Netherlands. At first the oil crises of the 1970s made the need for the development of power production technologies that could make the countries more self-sufficient. Nevertheless, this was partly the case of the Netherlands, because the country owned a large natural gas field and had already been to a degree self-sufficient. However, other environmental concerns like ‘acid rain’ in the 1980s and the greenhouse effect in the 1990s continued the legitimacy of the development of renewable power production technologies.

Other important landscape factors were liberalization in a European level. EU member states agreed to liberalize energy markets, with the Netherlands as one of the frontrunners. With liberalization the long-term planning of future power plants and securing the reliability of supply was jeopardized by the preference for short-term return on investments. Liberalization also led to decreasing R&D budgets of energy companies as well as to an emphasis on short-term research (Kern and Smith, 2008).

Overall, the Dutch wind turbine case can be characterized as ‘stunted’ technological system. In this case, a ‘change in gear’ in the rate of diffusion did not occur, largely for institutional reasons: the function ‘formation of markets’ was blocked by problems in receiving building permits, and therefore did not increase greatly in strength in spite of the presence of different types of market stimulation instruments, e.g. continued investment subsidies, electricity taxation that favoured renewables and guaranteed access to the grid for wind power producers (Jacobsson and Bergek, 2004).

In addition, under the *LTS approach* the Spanish electricity sector can be perceived as a large technological system that includes: physical artifacts (transmission lines in electric light and power system large and small wind generators) organizations (the project-vehicle partnerships, wind-specialized partnerships and the renewables-specialized partnerships, the government, the manufacturers of wind technology Made and Ecotecnia), legislative artifacts (the FIT and it’s reforms) and finally natural resources (wind and solar capacity). There was interaction among these components of the Spanish large technological system.

The Spanish case followed the typical way of evolution of Large technological systems theory, which includes: invention, development, innovation, transfer and growth, competition and consolidation. While the energy system in Spain was evolving and growing, additional system components were drawn in from the environment (new technology, additional actor groups, new beliefs and values). When the system was mature enough and had a greater rate of growth, it acquired "momentum".

In addition, the Spanish System-builders had a rather dominant role in system development and growth. In more details, inventors, scientists, engineers, politicians and regulators, supported and sustained the socio-technical system. What emerged from this process was a paradigm shift of the energy system. The old system of electricity generation and distribution based on fossil fuels was replaced by a new one based on renewable energy.

On the other hand, the German electricity sector is a rather complex infrastructural system, which decisively shaped the sociotechnical development of industrial societies throughout the 20th century and developed a kind of "momentum" which was difficult to reverse and which forced the systems to a form an incremental change.

The German electricity sector, as a large technological system, included physical artifacts (like turbogenerators and transmission lines in electric light and power system), organizations (like electricity companies, energy associations, turbine manufacturers and operators, the government), legislative artifacts (like the Act on supplying electricity from renewables and the renewable energy act) and natural resources (mostly wind capacity). All of the above components of the system interact with each other creating an "open" technological system, e which was affected by several environmental factors.

However, the German case didn't follow the typical way of evolution of Large technological systems theory, which includes: invention, development, innovation, transfer and growth, competition and consolidation. Looking back to the beginnings of the process, we see that it was not triggered by new technical inventions but rather by environmental and socio-political blueprints developed in the context of the new social movements. It was basically a matter of a reinterpretation and reactivation of already known technologies (e.g. wind turbines, biogas plants, photovoltaic cells etc.) from a new perspective and within new social contexts.

Finally, decentralised structures of generation and distribution based on renewable energies as well as on small or medium-sized production units replaced the centralized system of electricity generation and distribution based on large fossil and atomic power stations. And the established electricity industry for the renewable energy enhanced a pluralized structure of electricity producers, independent of the existing electricity companies.

Finally, uunder the lens of the *ANT approach*, in the Spanish case the human and non human actors that interacted within the network were: the three types of partnerships (project-vehicle, wind-specialized and renewables-specialized partnerships), the National government, the RES-E generators, the National Energy Commission (CNE), the governmental agency IDAE (which offered political support and provided security to the necessary administrative permits and social approvals), the manufacturers of wind technology (Made and Ecotecnia),the energy companies (Endesa and Union Fenosa which offered technical guarantee of grid connection and other network-related advantages), the various regional and local authorities (because the Spanish political system is highly decentralised with a lot of autonomous Communities), Spanish water, wind utilities e.t.c. The particularly important actors were the government and the partnerships, which acted as 'prime movers' or system builders, an actor because they were technically financially and politically so powerful that it strongly influenced the renewable energy development and it's diffusion process.

The coordination of the Spanish policies towards the RES promotion was implemented through the National Energy Plans (PEN). So, each one of these plans can be seen as a network, in which all the above mentioned actors, human or non human interacted. The national energy plans constituted important channels for the transfer of both tacit and explicit knowledge. These networks were built around markets and therefore they were conducive to the identification of problems and the development of new technical solutions.

The PEN served the following basic functions: They helped to the creation and diffusion of 'new' knowledge, they provided a guidance of the direction of research, and they helped to the formation of markets. Since innovations rarely find ready-made markets, these may need to be stimulated or even created. This process in Spain was affected by governmental actions that cleared legislative obstacles.

The German energy sector can be also seen as an 'actor-network', in which human and non-human elements 'act' upon each other and are mutually formative of each other's contribution to the system. As it was analyzed in previous section, the ANT is attentive to the ways human and material entities interact to produce novel forms, which then impact on other things within the system, producing larger units of influence, all of which together determine how the system works (Jacobsson and Bergek, 2004).

The Actor-network theory supports the ‘process’ of the creation of a new technological artifact, which in the German case can be a wind farm, and sheds light on the complex social and technical environment that must be built, and in which it needs to be embedded in order to work. Consequently, each wind farm planning can be thought as a process of creation of a technological artifact. This creative process involves using existing elements of planning, methods, skills and equipment that have been shaped elsewhere and incorporate important knowledge and experience (Jolivet and Heiskanen, 2010).

Furthermore, it is worth pointing out that the German federal government took very active role in promoting the use of renewable energy sources, mainly through various state programs (for example the REN Program and The GROWIAN project which were analyzed previously). Under the spectrum of ANT, each of the German projects can well be conceived as an actor-network. It consists of such entities as federal state and local politicians, bureaucrats and technologists, electrical materials and their manufacturers and installers, the wind power in Germany, the subsidies for the use of wind energy, wind research establishments, the electricity grid, associations of wind promoters and manufacturers, suppliers of materials for wind facilities, and so on. All the above are being perceived as actors, either human or non-human, and there is an interaction among them in a wider sociotechnical context.

In addition, the German legislation on wind power development provided a general framework, roles and attributes for those various actors. Indeed, the German regulations shaped the roles of the actors and affected to a certain degree the interaction that was taking place among them.

Moreover, the translation process in the German case started right after the first oil crises in 1973, during which Germany dependence on energy imports created a greater need for energy efficiency. The first federal projects on promoting renewables and especially wind energy took place through governments’ initiatives. In this way, the involved actors agreed that renewable energy can be a network that is worth building and defending it.

The translation process in the German case had also the four moments as the theory suggests: “problematisation”, “interessement”, “Enrolment”, and “Mobilization of allies”. First it was the “problematisation”, during which there were several debates on the problem that needed a solution, which was the German energy efficiency and independence from further imports. In the stage of “interessement”, all the actors that were involved, which were mainly the government and the research organizations, negotiated the terms of their involvement. The third stage was the “Enrolment”, during which the actors accept the roles that had been defined for them during interessement. And finally, there was a mobilisation of allies. This meant that the great percentage of Germans expected that wind energy would make an important contribution to the energy supply in the next years and renewable energies acquired public acceptance and active support.

4.2. CROSS – COUNTRY COMPARISON

In the previous section we examined four selected case-studies (Denmark, the Netherlands, Spain and Germany) which established distinguished local wind power industries, in order to explore the paths that they have taken to manage the sociotechnical transition towards renewables. At this point we are going to make a cross-country comparison of the policy support mechanisms that have been employed to directly and indirectly promote renewable energy technology.

It is worth to compare the political environment in which each country developed its policies. On the one hand, German and Spanish policies were developed in highly decentralized political systems, in which together with the central government, local and state administrations had a rather important role in decision making process. On the other hand, the political environment Denmark and in the Netherlands was rather centralized and the central governments supported the promotion of renewable energy through national plans.

In any case, the oil crisis in 1973–74 affected all the above countries and made the need for the development of power production technologies that could make the countries more self-sufficient. But this was partly the case of the Netherlands, because the country owned a large natural gas field and had already been to a degree self-sufficient.

Moreover, the FIT scheme was a common policy instrument among the four countries. In some cases its implementation was rather successful, while in some other cases it didn't bring the anticipated results. Indeed, Germany, Denmark, and Spain have a history of stable and profitable feed-in tariff policies to promote wind power development.

Generally it should be emphasized that in the Spanish, German and Danish systems, several important similarities with regard to the observed high effectiveness of the FIT schemes exist. In those three countries the feed-in schemes were implemented with the highest absolute increase of RES-E compared to all other EU Member States (Rao and Kishore, 2010). These FIT systems triggered major investments in renewable energies and were responsible for creating lead markets for RES technologies.

Also, a further very crucial similarity among those countries is that the feed-in tariffs were supplemented by a broad portfolio of additional support measures in particular by tax reductions on RES investments, soft loans with stable financing conditions as well as investment incentives (subsidies, partial debt relief) for some selected technologies. This well balanced policy mix, which increased the stability of the investments, is thought to be one of the key success factors of the applied promotion scheme.

On the other hand, the Dutch case experimented with different approaches in terms of policy instruments: there was an alteration between renewable quota and of feed-in tariff schemes. The FIT were adopted, abandoned and readopted for several times, but overall, given the then very high generation costs of RE, the feed-in tariff was not on its own sufficient to fill the gap between the costs of RE and conventional sources and it could not bring about a market for these technologies.

Furthermore, we should pay attention to the cooperative model of wind ownership, which in Denmark had a significant role for the success of the wind energy, because it involved electricity consumers in the turbine ownership. Wind cooperatives were also present in the Netherlands, but they had a rater complementary role. Conversely, in Spain we meet three types of partnerships: the project-vehicle partnerships, the wind-specialized partnerships and the renewables-specialized partnerships and in Germany we meet various associations, which they all are far from the concept of "Danish cooperative model of ownership" as mentioned above.

As far as it concerns R&D funding in these four cases, it was allocated to wind turbine technology development rather successfully. But even though Denmark's R&D budget was smaller in magnitude than some other countries, it was allocated more effectively among smaller wind companies developing varied sizes and designs of turbines in the initial years of industry development (Lewis and Wiser, 2007).

Having identified the key policy instruments in the four case-studies, we tried to test whether the previously analyzed sociotechnical theories are being verified or not. At first, we approached the case of Denmark and the Netherlands under the multilevel sociotechnical system theory. The analysis provided us with important information about the similarities and the differences between the two cases.

More specifically, in both countries, landscape developments were favourable for the development of wind power. And although the oil crises in the 1970s created the need for the development of power production technologies that could make the countries more self-sufficient, this need was larger in Denmark since it didn't own its own fossil fuel supply, whereas the Netherlands owned a large natural gas field and oil.

With regard to the developments at the regime level, there were more differences in the two cases. In the Netherlands, regime actors were not very thrilled about wind power because of the small amount of electricity wind turbines could produce compared with conventional gas-driven power plants or nuclear power plants. Having a large supply of natural gas, the Netherlands was already self sufficient in the field of energy. Besides, there were many supporters of the nuclear power compared to the renewable energy.

Conversely in Denmark there were more favourable conditions for the renewable energy. Because of the lack of a Danish fossil fuel supply, regime actors were more interested in wind turbines than in the Netherlands. The need for energy independence was greater in this case.

Additionally, we are able to identify that in both countries two innovation subsystems were developed, the small one which favoured the small wind turbines and the large one which favoured the large wind turbines.

Nevertheless, in the innovation subsystems there were differences in the knowledge development. In the Netherlands, the most important form of knowledge development was learning-by searching, or R&D. However, the implementation of the knowledge to the construction of wind turbines proved to be rather difficult. Learning by doing and learning by using were limited in this case. Therefore, there were difficulties in the knowledge diffusion, since some of the actors didn't participate in the learning process.

On the contrary, in Denmark, learning by searching, learning by doing and learning by using are all developed well and complement and reinforce each other via learning by interacting. Therefore, in Denmark knowledge diffusion developed very well as knowledge was exchanged between wind turbine owners, producers and researchers on a regular basis.

With regard to the German and Spanish case, under the spectrum of LTS theory we are able to find both similarities and differences. In both cases the electricity sectors could be perceived as large technological systems that included physical artifacts, organizations, legislative artifacts and natural resources.

However, there are differences as far as it concerns the evolution of those two large technological systems. While the Spanish case followed the typical way of evolution (which includes invention, development, innovation, transfer and growth, competition and consolidation) the German case didn't evolved in this way. The German system was triggered by environmental and socio-political blueprints developed in the context of the new social movements. It was basically a matter of a reinterpretation and reactivation of already known technologies (e.g. wind turbines, biogas plants, photovoltaic cells etc.) from a new perspective and within new social contexts.

Finally, in both cases the decentralized structures of generation and distribution based on renewable energies as well as on small or medium-sized production units replaced the centralized system of electricity generation and distribution based on large fossil and atomic power stations.

Moreover, in these two cases we identified patterns of decentralised systems of diffusion. Those systems evolved into networks of innovation, which were characterised by decentralised transfers of knowledge and experience – with decentralised actors as a main driving force of the diffusion process. The networks provided opportunities of feedback between the operators and the manufacturers of power generation on the basis of renewable energies.

Furthermore, from an ANT perspective, the German federal projects for promoting renewable energy were considered as actor-networks in which human and non human actors interacted, and during the translation process new actors were involved too. The federal projects had a rather important role for the knowledge diffusion in Germany.

This was partially the case in Spain, since the National Energy Plans may also be considered to be actor-networks. Among the actors that interacted in this context, the most important ones were the public-private partnerships (PPPs). But in the Spanish case, the diffusion results can be attributed mainly to the role of PPPs which were additionally helpful in generating knowledge related to project development and permitting procedures.

To sum up, among the four cases studies that we examined, the Danish case is thought to be the most successful. Indeed the successful development of wind power has made Denmark a world leader in this field. Not only does this country generate a greater portion of its electricity consumption with this technology than any other country in the world, but wind turbines have become a very important export product.

On the contrary, the Dutch support system for RE has been opaque, confusing and lacking long-term security because of the frequent changes and the numerous instruments. The diversity of policies in the Netherlands created uncertainty and instability in the market and they failed to bring a systematic removal of economic and technical impediments. Among the four cases, this was the least successful.

Finally, Germany has been very successful in increasing the share of renewable electricity and this has largely been achieved by effective public policy. Within the public policy mix, the feed-in system was most significant. The success of wind energy in Spain is also explained by the FIT mechanism in the Spanish model. In these two cases the countries also managed to provide a certain and stable financial environment and enhanced the level of support when economic conditions changed.

5. CONCLUSIONS

This dissertation focuses on the transition process from one technological paradigm to another. This process does not only involve technological changes (like the deployment of renewable energy sources), but also changes in elements such as user practices, regulation, industrial networks, and infrastructure. Therefore TT do not occur easily because they consist of a change from one sociotechnical configuration to another. During TT there is substitution of the existing technology with new ones. But the deployment of new technologies face a mis-match with the established socio-institutional framework because regulations, infrastructure, user practices, maintenance networks are aligned to the existing technology. Consequently, there are various factors that can lead to the knowledge diffusion and to a sociotechnical paradigm shift.

Thus, four case-studies were selected (Denmark, the Netherlands, Spain and Germany), which have established distinguished local wind power industries, in order to explore the paths that they have taken to manage the sociotechnical transition towards renewable energy.

Three sociotechnical approaches were used in order to identify the key issues of a transition process: the LTS theory of Thomas Hughes, the multilevel sociotechnical system approach and the ANT of Michel Callon and Bruno Latour.

In the first approach, the electricity sector of a country can be perceived as a large technological system that includes: physical artifacts, organizations, manufacturers of renewable energy technology, legislative artifacts and natural resources. This analysis highlighted the critical problems that emerge during the expansion of a technological system.

In the multilevel sociotechnical system approach the transition process was seen as a technological regime which is formed by a routine-based behavior shared by both firms and engineers. This analysis highlighted also the role of the niches which provide space to build the social networks to support innovations, and the role of the landscapes, which are the external context in the interaction of the actors.

The ANT approach sees the energy sector of a country as an 'actor-network', in which human and non-human elements act upon each other and are mutually formative of each other's contribution to the system. Within ANT approach translation is a key concept that involves all the strategies through which an actor identifies other actors and arranges them in relation to each other.

Having examined the case studies under the sociotechnical approaches, we came up with some conclusions.

First of all, in many countries we meet alliances between advocacy coalitions which had a rather crucial role to the learning process. In Denmark the alliance between the Danish established and cooperative coalition enabled a long term interactive and integrative learning process, while in the Dutch case coalitions were not well organized and their influence was limited.

The degree of the support to the renewable energy depended on the energy efficiency of each country. This means that countries which already owned other energy fields, like the Netherlands, didn't promote the use of renewable energy as much as other countries.

Although all the countries used more or less the same policy instruments for the promotion of renewable energy, the results were different in each case. There were many other factors that affected the success of each county. For example Denmark supported not only the wind energy production, but also the construction of both large and small scale wind turbines which were seen as a product to export. On the contrary, the Netherlands showed greater support towards the large scale turbines but didn't achieve the systematic removal of the technical and economical impediments that were created.

In Germany and Spain patterns of decentralised systems of diffusion of knowledge were identified. In both cases the decentralized structures of generation and distribution based on renewable energies as well as on small or medium-sized production units replaced the centralized system of electricity generation and distribution based on large fossil and atomic power stations.

Furthermore, one of the key policy instruments in the promotion of renewable energy was the FIT. The FIT scheme is being met in all the case studies, but its effectiveness depends on many other factors. For example in Spain the FIT scheme allowed the continuation and stability of the system while at the same time encouraged investors to make long-term investments at moderate costs. On the other hand, in the Netherlands the feed-in tariff scheme could not bring about a market for renewable energy technologies, and therefore its implementation was more limited. Germany had a significant FIT system which was a great boost especially for the wind sector.

It should also be pointed out that one common element in the policies of the selected countries was the implementation of national energy plans. In Denmark the first official energy plan became a reality in 1976, while several other national plans that followed emphasized on the promotion of renewable energy. In the Dutch case, the NOW programme was one of the most significant, as it provided subsidies for R&D into the potential of wind energy in the Netherlands and into wind turbine building. In Spain the PEN programmes shaped the Spanish energy sector and settled specific targets for energy production from renewable energy sources. Finally, in Germany the GROWIAN project established research and industry players aimed at building a large wind turbine system.

To sum up, established approaches to policy analysis for the governance of socio-technical transitions tend to treat the socio-technical regimes as networks of actors and institutions clustered around the fulfilment of social and economic functions (Smith et. al. 2005). Therefore, a successful change requires the coordination of both the resources and actors in the wider social context. The notion of sustainability lies in the recognition of the fact that the technological future is a matter of social choice.

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