UTRECHT UNIVERSITY

A journey towards sustainable energy security

Lessons learned from Denmark

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Introduction

The European Union's energy security has become a prominent issue on the political agenda as energy supplies run scarcer every day (Commission of the European Communities, 2008). Conflicts in the OPEC countries (Organization of the Petroleum Exporting Countries) and disputes with Russia on several matters such as human rights play a big role in the energy security of the EU. The EU is very dependent on the Russian Federation for the supply of natural gas. In fact, 30 percent of the EU's import of natural gas comes from Russia.[1] Even further, almost half of this natural gas runs through pipelines in Ukraine, making Ukraine the largest transit country of Russian gas to the whole of Europe (Clingendael Institute, 2013). The 2006 and 2009 Ukraine-Russia crises showed that political discontent between the two countries can heavily influence the price of natural gas in Europe and could create widespread shortages. The latest crisis, involving the assimilation of the Krim as a part of Russian territory, once again threatens the supply to Europe (Umbach, 2010).

The EU needs Russia as it is one of its most important trading partners and energy suppliers (Lenoir, 2011). Russian foreign influence is largely based on its importance as a natural gas exporter. Decreasing this importance stance at the base of lessening Russian influence on European energy markets. The EU's energy dependence on Russia can be seen as a big problem because it influences the EU decision making process in the EU – Russia relationship. For example, when Latvia decided that the Ventspils Nafta export facility should not be sold to Russian energy companies, the Russians shut down the pipelines supplying the whole of Eastern Europe (Baran, 2014). And after the Lithuanian government decided that the largest refinery in central and eastern Europe, the Mazeikiu Nafta refinery, should not be sold to Russian energy companies, Moscow once again ceased the natural gas supply (Baran, 2014). EU countries should, according to the view of realism, be independent and sovereign in their decision making (Lenoir, 2011). To accomplish such independence, EU countries have to become less dependent on Russian energy (Lenoir, 2011; Sovacool, 2013; Umbach, 2010).

Besides energy security and its vulnerabilities, climate change is a prominent issue on the political agenda too (Umbach, 2010). Climate change has disruptive effects on a wide range of eco-systems, in the form of rising sea levels, melting of polar ice caps and glaciers, ocean acidification, more disruptive weather concerns, habitat loss, deforestation and greater water concerns in arid regions (Falkner, 2014).

[1] See http://www.cbs.nl/nl-NL/menu/themas/industrie-energie/publicaties/artikelen/archief/2011/2011-3345-wm.htm for additional details and exact numbers.

Climate change and energy security are closely linked. If fossil fuels keep dominating the global fuel mix, increased dependence on imported gas, oil and coal from politically unstable countries and energy-related greenhouse gas emissions will increase concerns about energy security and climate change. This twin challenge needs to be addressed by policymakers in order to reduce greenhouse gas emissions and to ensure the security of our energy system. The absence of adequate and secure supplies of energy at affordable prices is seen as a major threat as rising energy consumption and prices cause irreversible environmental damage for societies (Umbach, 2010). A possible solution for EU countries in both reducing greenhouse gas emissions and becoming less dependent on foreign energy sources is the transition to a renewable energy system (Hinrichs-Rahlwes, 2013; Umbach, 2010). Until now, the academic debate surrounding energy security is mostly focused on searching for diverse energy suppliers of fossil fuels in order to become less dependent on Russia's energy sources [2]. However, the search for more diverse energy suppliers of fossil fuels is only a short-term solution and will not solve the major problems surrounding climate change and the depletion of fossil fuels. To provide long-term energy security and to help mitigating climate change, a sustainable energy security strategy needs to be developed (Hinrichs-Rahlwes, 2013; Sovacool, 2013; Umbach, 2010).

Denmark offers an excellent case study of a country that rapidly utilized renewable energy sources and reduced its dependence on foreign sources of energy (Aslani, Naaranoja, & Wong, 2013; Sovacool, 2013). Denmark transitioned from being nearly 100 percent dependent on imported fossil fuels such as coal and oil for their power plants in 1970 to becoming a net exporter of electricity and fuels today (Sovacool, 2013). Nowadays, Denmark is arguably the most energy secure and sustainable country in the OECD and important lessons can be learned from Denmark's strategies in becoming self-sufficient in its energy production and use (Aslani et al., 2013; Sovacool, 2013).

To overcome the challenges around energy security and climate change, transitions to new kinds of energy supply are required (Aslani et al., 2013). These transitions include interactions between policy, technology, economics and culture. Theoretical approaches are needed to address, firstly, the multi-dimensional nature of transitions, and, secondly, the dynamics of structural change (Geels, 2011). This thesis introduces a socio-technical approach that addresses both of the above aspects (multi-dimensionality and structural change). To understand the dynamics of these transitions, the multi-level perspective (MLP) will be presented. This theory goes beyond studies of single

[2] See for example Cornell and Nilsson, 2008; Baran, 2014; and Van der Meulen, 2009.

technologies (such as electric vehicles and wind turbines), which dominate most of the innovation literature (Geels, 2012). Although the strength of the MLP rests in its ability to capture the bigger picture, this attractive framework is not without its critiques. Since the MLP has been criticised for underplaying the role of agency in transitions (Geels, 2012; Smith, Voß, & Grin, 2010) and global energy problems ask for interdisciplinary approaches (Falkner, 2014) this thesis will incorporate a case study in which the energy policy of Denmark since 1970 is analysed. This thesis aims to include the role of politics within the MLP in order to extract important lessons for other EU countries in becoming less dependent on foreign energy sources. Therefore, the research question of this thesis is as follows:

> *What can other EU countries learn from Denmark's approach in becoming an energy secure and sustainable country?*

Justifying an interdisciplinary approach

In order to analyze how EU countries can overcome the intertwined problems around energy dependence and climate change, an interdisciplinary research focus is needed. In his book *'Interdisciplinary Research; Process and Theory'*, Allen F. Repko (2012) states that there are several criteria to justify using an interdisciplinary approach. The research question fulfills four of these criteria:

1. The problem or question is complex.
2. Important insights into the problem are offered by more than one discipline.
3. No single discipline has been able to address the problem comprehensively.
4. The focus question is at the interfaces of disciplines.

Minimizing CO_2 emissions and the dependence on foreign import of fossil fuels are widely seen as the most problematic goals of the next two decades for EU countries (Umbach, 2010). A successful energy transition requires consideration of many factors including social, political, economic and technical ones (2). The concept consists of a network of research activities that relies on a broad spectrum of disciplines (1). In order to address these transitions in a more comprehensive way the insights of the different disciplines have to be integrated (3). In this thesis the energy transition in Denmark will be analyzed. In order to extract useful lessons for other EU countries, transition theories, and the political history of Denmark have to be studied. Therefore, the research question is at the interface of the following two relevant disciplines: Innovation Sciences, and Political History and International Relations studies (4).

Identifying relevant disciplines

Innovation Sciences (IS)

The analysis of fundamental transformations of entire economic sectors like the energy sector, is one of the classical research fields in IS (Markard & Truffer, 2008). Sectors like energy are conceptualized as socio-technical systems. These systems include (networks of) actors (companies, private and collective actors), institutions (regulations, norms, standards of good practice) and even knowledge and material artifacts. Large-scale transformations in the way societal functions such as energy are fulfilled are defined as transitions (Geels, 2002) A transition involves often major shifts along different dimensions: technological, organizational, economic, political, institutional and socio-cultural (Markard, Raven, & Truffer, 2012). A broad range of actors is involved and the time-spans are typically quite long (e.g. 50 years and more). During a transition new products, services, organizations, and business models appear. Some of them complement and others substitute the existing ones. In the end, technological and institutional structures are fundamentally changed, as well as the way consumers view a particular service (or technology). A few examples of socio-technical transitions are the shift from carriages to automobiles, from sail to steam ships, and from coal to gas (Geels, 2005; Shove & Walker, 2007).

The fast growing field of socio-technical transitions is full of complexities. There is a broad range of theoretical approaches, which have been used to study and explain the particularities of these transitions (Markard et al., 2012). The following four frameworks that adopt systemic views of far-reaching transformation processes, have achieved quite some prominence in transition studies: technological innovation systems (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007), the multi-level perspective on socio-technical transitions (Geels & Schot, 2007), transition management (Rotmans, Kemp, & Asselt, 2001), and strategic niche management (Kemp, Schot, & Hoogma, 1998).

The multi-level perspective (MLP) draws on insights from evolutionary economics, neo-institutional theory, and sociology of technology and has been used as a helpful framework to describe and analyze many historical transitions (Smith et al., 2010). The MLP shares a lot of the same concepts as the technological innovation system (TIS) approach, which is based on the systems of innovation perspective (Markard et al., 2012). In the TIS literature a detailed explanation is given about how different institutions and (networks of) actors form a system around a technology (Hekkert et al., 2007). One important difference between the MLP and the TIS approach is the fact that the MLP goes one step further then only addressing the multi-dimensional aspect of transitions. The MLP also incorporates the particularities of structural change (i.e. how innovations struggle against existing technologies) (Geels, 2011). The transition management (TM) and strategic niche management (SNM) approach have both been invoked by the MLP to inform analysis of the development and entrenchment of technology in society (Genus & Coles, 2008). TM focuses both on developments inside and outside niches (in which novel technologies are developed) while SNM takes a more narrow perspective and mainly focuses on the interventions that can stimulate the (technical) developments in niches (Kemp et al., 1998; Rotmans et al., 2001).

Although the literature is already extensive, researchers are just beginning to understand the practical and analytical implications of fundamental shifts in established socio-technical systems as energy (Markard et al., 2012). This thesis will focus on the MLP in particular. This middle range theory has already brought together a growing network of international researchers with a variety of agenda's (Smith et al., 2010) and with a focus on the challenge to transform the energy sector to a more secure and sustainable energy system, the MLP can be a productive framework to organize the broad interdisciplinary analysis that is needed (Smith et al., 2010).

So far, there has been little attention to the role of the agency within the MLP (Markard et al., 2012). This is quite remarkable, because the role of power and politics seems really important in the analysis of governing socio-technical transitions (Geels, 2011). Transition management (TM) is specially designed to address the need for system-wide policy rationales, but actual policies still mainly rely on advice from neoclassical economics, or at best from advice of technological innovation system (TIS) literature (Markard et al., 2012). The innovation literature, and in particular the MLP needs to be extended to address the policy needs of energy transitions.

Political History and International Relations (PHIR)

Political History and International Relations is a very broad research field which, in turn, is part of an even broader field, namely that of history in general. As the name says, PHIR puts an emphasis on political history; the occurrences and consequences of political and policy changes throughout history. It focuses on national and international politics, on sketching political landscapes, and on the interdisciplinary field of international relations. The latter combines history with social sciences, political science, conflict studies, and human geography. This shows that the discipline of Political History and International Relations is in itself an interdisciplinary research field.

Historical research can be conducted on all aspects of society. It applies to all fields of study because it encompasses all aspects of it and the collection of historical information can be based on both quantitative and qualitative variables. History, in essence, holds the key to understanding the world

(Tosh, 2006). Historical awareness is needed to understand modern-day concerns without the influence of social memory. To reach this awareness, John Tosh (2006) describes three principles in his book *The Pursuit of History*. The first, difference, recognizes the 'otherness of the past'. The second emphasizes the importance of the context, which should be 'the underlying principle of all historical work because the subject of enquiry must not be wrenched from its setting' (Tosh, 2006, p.10). The last is the recognition of the historical process, in which the relationship between events over time endows them with more significance than if they were viewed in isolation (Tosh, 2006). Following these three principles, historians need to 'explain the past in response to present-day concerns and questions' (Tosh, 2006, p. 28). Only then can historical research contribute to a more comprehensive understanding of the world we live in.

History is often criticized for its two extreme beliefs: meta-history and the rejection of history. Historians of the first extreme, belief that 'our destiny is disclosed in the grand trajectory of human history, which reveals the world today as it really is, and the future course of events' (Tosh, 2006, p.29). Historians of the latter, belief that nothing can be learned from history and that it cannot serve as guidance. The results of historical research therefore are very broad and vague; which claims are relevant and which are not? John Tosh puts it this way:

"The most convincing claims of history to offer relevant insights lie somewhere between these two extremes… The end result is not a master-key or an overall schema but rather an accumulation of specific practical insights consistent with a sense of historical awareness (Tosh, 2006, pp.32-33).

What most historians do believe however is that making predictions about the future based merely on lessons from the past is a tricky thing to do. Moreover, historical research misses the theory to make accurate and well-structured predictions. Although its knowledge is based on practical insights consistent with a sense of historical awareness, its lack of theory compromises the righteousness of its predictions. Historical research can try to predict the future but it should be wary for its own weakness. In this thesis we have therefore chosen to connect a historical research to a theory from IS, in order to create a more comprehensive understanding of the modern-day concerns and questions surrounding climate change and energy dependence.

In short, in order to create guidelines for other EU countries, this thesis will combine the following two disciplinary parts: first, the introduction of a heuristic framework to analyze how sustainability transitions unfold. Second, a historical research of the policy changes which contributed to the process and the achievements of Denmark in their transition to a sustainable and secure energy system.

Drawing on disciplinary insights

In this section of the interdisciplinary research an in-depth literature research will be conducted within both Innovation Sciences (IS) and Political History and International Relations (PHIR).

Innovation Sciences

Sustainability transitions

In the past decade sustainability transitions have received increasing attention within IS (Markard et al., 2012). Sustainability transitions are fundamental change processes in which existing socio-technical systems shift to more sustainable modes of production and consumption. Innovation scholars try to explain how and why sustainability transitions come (or do not come) about, and suggest how these sustainable practices might be accelerated and promoted in order to substitute environmental harmful alternatives (Smith, Voß, & Grin, 2010).

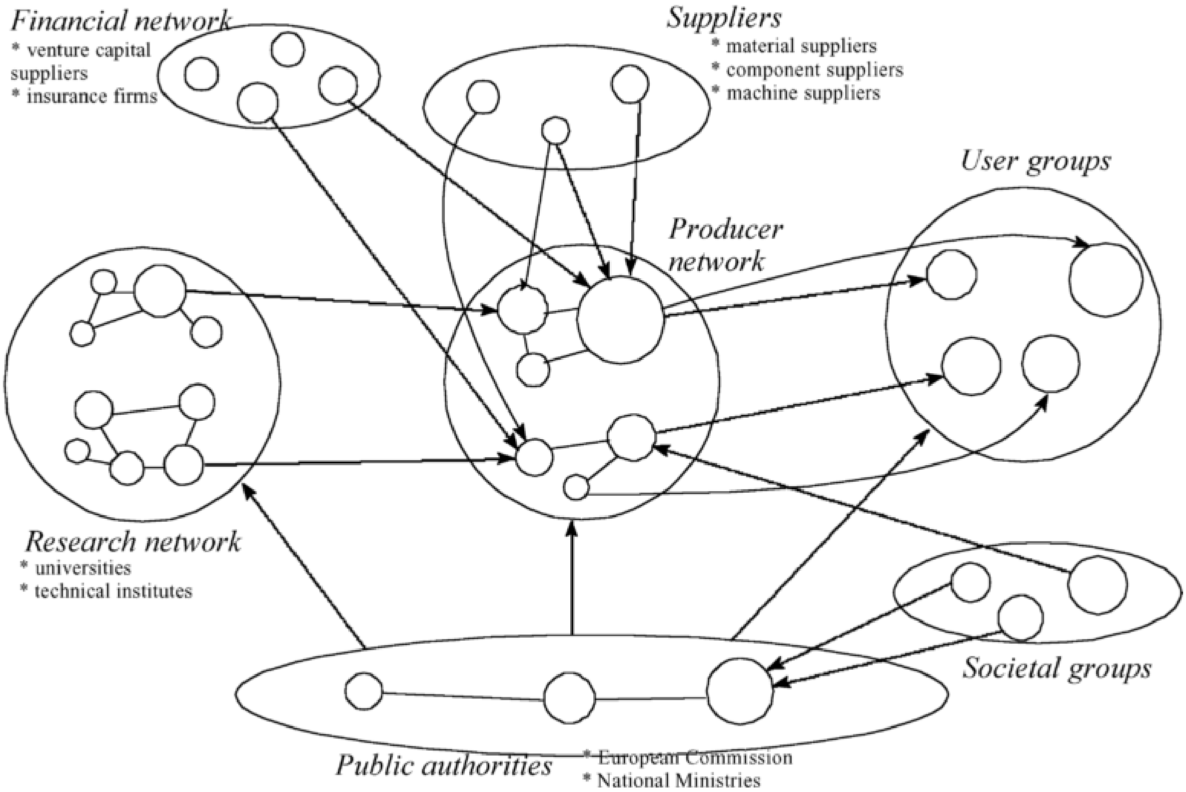
Sustainability transitions are characterized by some features which make them different from many historical transitions (such as transitions from sailing ships to steamships). These characteristics make it especially challenging to stimulate and govern sustainability transitions (Geels, 2011; Markard et al., 2012). A first important feature of sustainability transitions is the fact that these transitions are often purposeful and goal-oriented. Transitions towards sustainability differ from many historical transition since they are supposed to address environmental problems. Historical transition were often emergent, they were initiated by private actors exploring the opportunities of new technologies in different markets. Private actors have little incentive to address sustainability problems since these transitions are related to a collective good. Involvement of the government is therefore crucial in sustainability transitions (Smith et al., 2010).

Second, a lot of sustainability transitions are characterized by the absence of additional obvious user benefits and the price/performance ratio of a sustainable technology is often lower as compared to established technologies. Therefore, it is more difficult to replace existing systems without the support of economic instruments, such as subsidies or emission trading schemes, or other instruments, like technology or emission standards (Foxon & Pearson, 2008). To overcome these difficulties policy interventions are needed, which often entail power struggles since actors with vested interest such as oil companies will try to resist these changes (Geels, 2011).

The last characteristic, is the specific domain in which sustainability transitions are most needed, such as energy and transport domains. These domains are generally dominated by large firms (e.g. oil companies and electric utilities) who are often resistant to radical change (Geels, 2011). Radical innovations are defined as inventions that break with traditions in a domain while incremental innovations are conceptualized as continuous improvements (Fagerberg, 2004). Large firms posses a lot of complementary assets as access to distribution channels, service networks, experience with large-scale test trials, reputation, customer relationships etc. These complementary assets give large firms a strong motive to defend the existing production methods and technologies (Geels, 2011).

These characteristics show that sustainability transitions do not occur as simple as historical substitution processes in which one technology is overthrown another, as was the case with the rapid introduction of natural gas in the UK and the Netherlands (taking over dominant positions from coal and oil) (Raven, 2007) Instead, sustainability transitions take place as a result of complex interaction patterns between multiple actors. Established firms, user groups, public authorities, new (innovative) firms, NGO's and scientist all have their own (often conflicting) strategies, motivations and interests (Geels, 2002). In order to determine how transitions towards sustainability can be accelerated and stimulated, a theoretical approach that addresses the complex dynamics of these transitions are needed (Geels, 2011; Markard et al., 2012; Smith et al., 2010). As mentioned before, this thesis will focus on the MLP because this framework integrates some very important findings from different literatures as an 'appreciative theory' (Geels, 2002) and thereby introduces analytical and heuristic concepts which help to understand the complex dynamics of sustainability transitions (Smith et al., 2010).

Figure 1: Multiple actors involved in transitions (Geels, 2002)



The multi-level perspective

The MLP states that transitions exist out of non-linear processes arising from the interplay of multiple developments at three analytical levels. The first level are the niches, which are the locus for radical innovations. The second level are the socio-technical regimes, these regimes are the locus of established practices and rules. The third level is the socio-technical landscape and entails the wider context which influences what happens in the niches and regimes (Rip and Kemp, 1998; Geels, 2002, 2005; Kemp, 1994; Schot et al., 1994). As can be seen in figure 2, the levels are a 'nested hierarchy' wherein regimes are embedded in landscapes and niches exist outside or inside regimes (Geels, 2002). The three levels will be briefly described below.

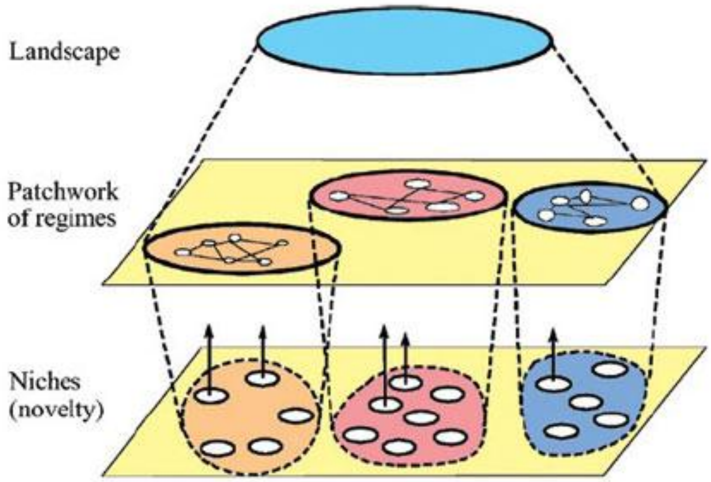


Figure 2. Multiple levels as a nested hierarchy (Geels, 2002)

Niches

Niches represent the micro-level of the framework. At the niche level novelties emerge and therefore niches are crucial originators of transitions (Geels, 2012; Schot, 1998). Niches can be divided in small market niches and in technical niches. Small market niches arise if users have special demands and are willing to support these emerging innovations. In technical niches, such as R&D laboratories, resources are often provided by public subsidies (Geels, 2011). In niches, radical innovations can be developed without being subject to the selection pressure of the existing regime (Markard et al., 2012). Niche protection can be provided by policy interventions for example through subsidizing R&D projects and projects for learning and research demonstration (Smith et al., 2010). Niches typically grow if expectations and visions of the innovation become more concrete and achieve more public acceptance, if social networks become bigger (especially the support of powerful actors such as large electricity companies can add legitimacy), and if the continuous adjustments through various learning processes result in a stable concept (e.g. a dominant design) (Kemp et al., 1998).

Socio-technical regime

The meso-level of the MLP is formed by the socio-technical regime, which is described as the key concept of the framework. Transitions are namely defined as shifts from one regime to another regime (Markard et al., 2012). The present fossil fuel based and centralized energy system is an example of a relative stable socio-technical regime (Ornetzeder & Rohracher, 2013). Socio-technical regimes consist of networks of actors and social groups. Within the energy regime important actors are utilities, large industrial users, households, and the Ministry of Economic Affairs. In socio-technical regimes, cognitive, formal, and normative rules direct the activities of those (networks of) actors and social groups. Examples of cognitive rules are guiding principles and search heuristics. Formal rules are, for example, regulation standards and laws, and normative rules include behavioral norms and role relationships. Another important and interlinked dimension of the socio-technical regime consists of the technical and material elements. Within the existing energy regime these include grids, generation plants, and resources (Geels, 2005; Unruh, 2000). The relative stability within existing regimes is typically caused through path dependency and lock-in resulting from mechanisms which cause stability (Geels, 2002). These stabilizing mechanisms can be classified in three dimensions:

> (a) incumbent actors have vested interests; social networks represent 'organizational capital', (b) regulations and standards may stabilize regimes; cognitive routines may blind actors to developments outside their focus; (c) existing machines and infrastructures stabilize through sunk investments and technical complementarities between components (Verbong & Geels, 2007).

In existing regimes, innovations are often incremental because of these stabilizing mechanisms (Unruh, 2000; Walker, 2000). Changes within existing socio-technical regimes do occur, but these changes proceed in a relative stable and predictable direction. So, radical innovations seldom take place within socio-technical systems (Rik and Kemp, 1998).

Socio-technical landscape

The socio-technical landscape forms the macro-level of the MLP. The socio-technical landscape refers to aspects of the wider exogenous environment which influences activities within the niche- and regime level (Geels & Schot, 2007; Rotmans et al., 2001).

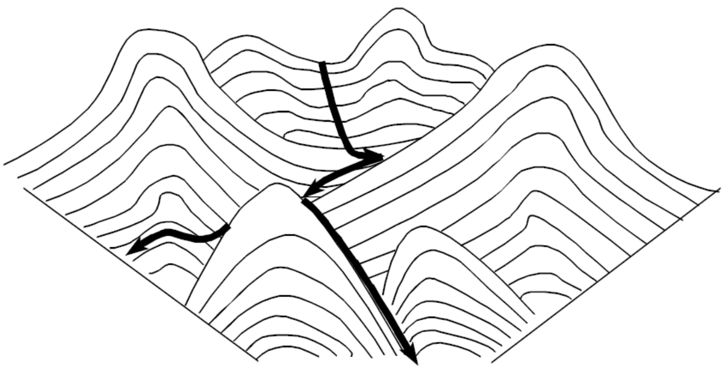


Figure 3: Socio-technical landscape (Geels, 2000)

The wider exogenous environment exists both of material and immaterial aspects of society. The material aspects include the spatial and material infrastructure of society, while the immaterial aspects include social movements, major economic shifts, cultural developments, alterations in general political ideology, and shifting scientific paradigms (Smith et al., 2010). On one hand, landscape processes can work to stabilize regime trajectories. On the other hand, developments within the landscape can also put pressure on regimes in ways that influence their performance and generates opportunities for niches (Smith et al., 2010). The growing awareness around environmental issues can be considered a destabilizing landscape factor. This socio-cultural development questions the performance of the existing energy regime and hereby generates opportunities for new technologies such as photovoltaic's and wind energy (Smith et al., 2010; Verbong & Geels, 2007). Furthermore, oil prices, economic recession, and liberalization can also have a significant influence on the existing electricity regime (Verbong & Geels, 2007). The processes within the socio-technical landscape are beyond the direct influence of actors. Therefore, landscape processes can hardly be purposely changed (Geels, 2005).

The multi-level dynamics

Transitions come about through processes in several phases (Geels, 2011). The first phase is characterized by the emergence of innovations in niches. In this *predevelopment phase* small market or technical niches begin to emerge. The first users get to know the niche technology, reflect their preferences and sometimes specific (lobbying) user groups arise and support the emerging niche (Geels, 2005). Although the innovation is used in specialized market or technical niches, the existing regime is still stable in this phase. Niche technologies have a hard time to break through because the existing regime is stabilized and entrenched in many ways (e.g. culturally, economically and institutionally) (Rotmans et al., 2001). When niche developments do not match the existing regime, they may remain stuck in these niches for decades.

In the second phase the innovation develops an own technical trajectory in which cognitive, formal and normative rules begin to stabilize (Loorbach & Rotmans, 2006). This phase is called the *take-off phase* and the developments in the niche cause initial shifts in the existing regime (Rotmans et al., 2001). In the *acceleration phase*, radical innovations break out of the niche level and cause visible structural changes at the regime level (Geels, 2005; Rotmans et al., 2001). External circumstances at the regime and landscape level can create opportunities for new niches to break through (Geels, 2002). These opportunities may be created by tension in the socio-technical regime or by shifts in the landscape which put pressure on the regime. Tensions in the socio-technical regime can be caused by internal problems which cannot be solved through incremental innovations or by social, economic or cultural changes at the landscape level. Changing landscape factors may put pressure on the regime and create opportunities for developments in niches (Van Bree, Verbong, & Kramer, 2010). Also internal developments in the niche are viewed as an important driver for their own wider break through. These developments can include an improved price/performance ratio and the support of an influential actor or social group. To sum up, both internal development in the niche and external regime and landscape forces are described as important forces in the wide break trough from the niche- to the regime level (Geels, 2002).

While the initially small technology or market niche slowly becomes a larger niche, elements supporting the innovation increase (i.e. awareness and popularity of the innovation, regulations and infrastructure) and market shares of the innovation grow (Geels, 2005). The growing niche market becomes increasingly stable because more and more elements become linked together. A competitive relationship with the established regime arises when the innovation enters mainstream markets. The innovation is then in the fourth phase which is called the *stabilization phase* (Rotmans et al., 2001). This phase is characterized by the actual replacement of the socio-technical regime. A new dynamic equilibrium is reached and sometimes even wider landscape developments are influenced (Geels, 2005).

Figure 4: The four phases of transition (Rotmans et al., 2001)

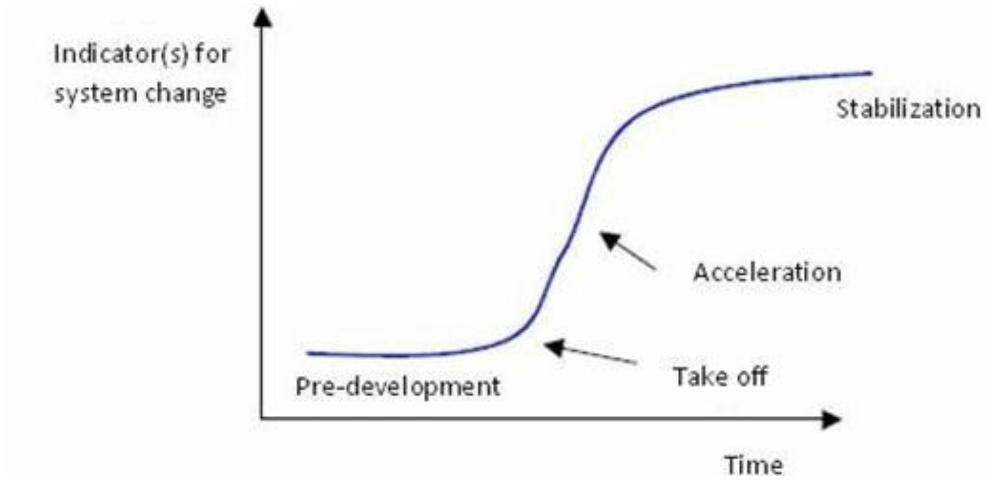


Figure 5 illustrates the typical situation of how the three conceptual levels interact dynamically when a socio-technological transition unfolds (Geels, 2012). Even though each transition is unique, the general dynamic of transitions shows that they come about through the following interaction:

> (a) niche-innovations build up internal momentum, (b) changes at the landscape level create pressure on the regime, and (c) destabilisation of the regime creates windows of opportunity for niche-innovations (Geels, 2011).

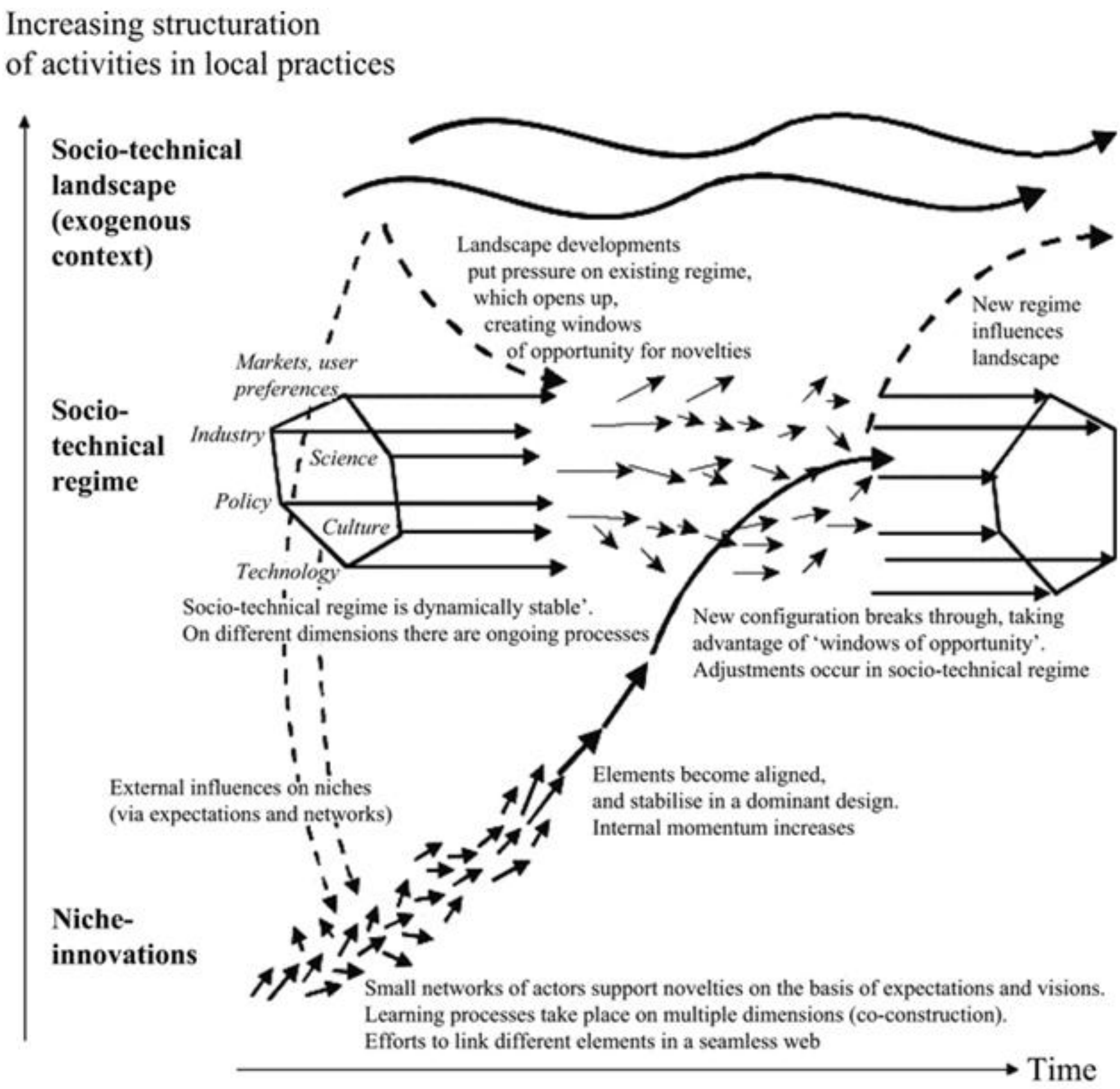


Figure 5: Multi-level perspective on transitions (Geels, 2002)

Conclusion and implications

With the help of the heuristic framework of the MLP the following sub-question can be answered: How do sustainability transitions unfold? An important insight of the MLP is that transitions are not merely caused by processes within the niche, but also by developments at the level of the existing socio-technical regime and landscape. Transitions seem to come about when processes at all three levels link up and reinforce each other. The combined developments (successful processes within the niche, tensions at the regime level and pressure from the landscape) determine if a regime shift will occur (Geels, 2012). An important aspect of the MLP is the so called 'circular causality' of transitions. There is no simple cause that drives transitions (Smith et al., 2010). According to the MLP, governing transitions towards sustainability is a very difficult process and even impossible for a single actor. The difficulty to govern sustainability transitions is caused by the interdependence between multiple actors, the different stabilizing mechanisms causing lock-in, and the role of heterogeneous developments in the socio-technical landscape (Raven, 2007).

Although the MLP provides a relative simple and organized analysis of large-scale structural changes in socio-technical systems, the pitfalls of the framework also have to be taken into account (Geels, 2011). An important weakness of the MLP is that it does not provide public policy recommendations about how transitions can be stimulated and accelerated. Only a few references to policies that stimulate socio-technical change are made, for example, R&D funding and market interventions. However, policy remains an external factor in the MLP (Smith et al., 2010). So it is safe to say that the framework is less compelling in devising transparent rationales for policymaking (Geels, 2011; Markard & Truffer, 2008; Smith et al., 2010).

Political history and international relations studies

Introduction

Over the past decades, history has shown that the price of fossil fuels depends heavily on political interaction. One such example is the 1973 oil crisis where all OPEC countries decided to proclaim an oil embargo. This was a reaction to the United States' decision to re-supply the Israeli military and to gain leverage in the post Arabic-Israeli war peace negotiations (Office of the Historian, 2013). This embargo resulted in widespread oil shortages and skyrocketed oil prices. The price per barrel quadrupled, imposing higher costs on consumers and putting pressure on the stability of nations as a whole (Office of the Historian, 2013). The 1973 oil crisis shocked the West by showing its vulnerability of being too dependent on foreign sources of fossil fuels. This had to change.

Worldwide, countries tried to reform their energy system in order to become less dependent on imported sources of fossil fuels. Denmark was among the first to respond to the 1973 oil crisis. The Danish government was shocked when it realized its dependency on imported fossil fuels. In 1970, Denmark was almost 100 percent dependent on imported fossil fuels such as oil and coal for their power plants (Sovacool, 2013). Since 1970 however, Denmark has reduced its dependency by instigating a successful approach to energy efficiency and renewable energy. At the core of this approach was a commitment to energy efficiency, prolonged taxes on energy fuels, electricity and carbon dioxide emissions, and incentives for combined heat and power (CHP) and wind turbines (Sovacool, 2013). Nowadays, Denmark leads the world in renewable energy and is almost 100 percent independent on foreign sources of fossil fuels. In addition, Denmark has set a '100 percent renewable energy' goal for 2050.[3] The following chapters will describe how Denmark was able to become less dependent on imported fossil fuels, and achieved impressive amounts of renewable energy in less than 50 years. This part of the thesis will describe the policy changes which led to the contemporary situation in Denmark. This historical research will analyze agreements, taxes, restrictions, legislative changes, policy plans, and commitments in order to provide a comprehensive overview of Danish energy policy since 1970 until now. With this overview the thesis will look at possible lessons for the future and for other countries. Historical research cannot always make adequate predictions for the future, but it can help understand the difficulties which we need to overcome in order to become more self-sufficient through renewable energy. In addition, it can provide practical knowledge to supplement the MLP as described above.

This historical research will be split up in three central pillars of Danish energy strategy. First, the research shall look at the history and prospects of wind electricity. Second, it shall focus on district heating and Combined Heat and Power (CHP). Third, it will focus on energy efficiency measures. Within these subchapters, the research will describe policy changes and their implications, mainly in chronological order. The MLP has, as described earlier, the weakness that it does not deal with the agency in transitions. This historical research will focus on just that by answering the following question: *Which political factors played a role in the history of Danish energy transition since 1970 towards a more independent and environmental friendly energy system?*

The research will conclude that Danish energy policy since 1970 has been proactive and consistent in realizing their ambitious goals. The main goal of this research is to supplement the MLP in order to provide a guideline for other countries to set and realize their own ambitious energy goals.

Chapter 1: Wind electricity

One of the most well-known renewable energy source is wind. It is reasonable easy and cheap to generate while it can produce a lot of electricity under the right circumstances. Denmark is one of the windiest countries in Europe, making it perfect for generating wind electricity. In addition, Denmark has large areas of sea territory with shallow depth which are the most feasible for large offshore wind turbine sites. These sites offer high wind speeds of up to 8, 5-9m/s on 50 meters height (Psarras, 2005). It was no surprise then that Denmark decided that if a transition towards renewable energy was needed, its main focus should be on wind energy. Their efforts paid off: nowadays, Denmark leads the world in both the per capita use of wind electricity as well as the share of wind electricity as a percentage of national supply (Lund and Mathiesen, 2009). How did Denmark achieve this and what can we learn from it?

[3] See for example http://ec.europa.eu/energy/efficiency/buildings/doc/dk_letter.pdf

Since 1976, Denmark has gone through several phases of energy restructuring. Each phase started with a proactive and ambitious energy plan, also known as the Denmark energy plans (Danish Energy Agency, 200?). These plans will be dealt with in chronological order.

Phase 1: First Energy Plan (Dansk Energipolitik, 1976)

Denmark's development of wind energy was closely linked to the technological development of wind power in the 1970s' such as the beginning of wind turbine manufacturing (Möller, 2009). The history of Danish wind energy starts after the shock of the 1973 oil crisis when Copenhagen realized its energy dependence on imported fossil fuels. Since then, Danish energy policy consisted out of three main objectives: the diversification in use of energy sources, promotion of environmental and climate aspects of energy, and cost effectiveness of energy supplies (Maegaard, 2009). These objectives could be achieved by following various new policies such as the promotion of and focus on new energy solutions and the development as well as utilization of new energy technologies (Maegaard, 2009). In 1977, the first commercially available modern wind turbines were erected (Möller, 2009). These wind turbines were relatively small in height (20 meters) and in production capacity (tens of kilowatts). To promote the use and technological development of wind electricity, Copenhagen promoted an investment subsidy that reimbursed individuals, municipalities, and farming communities for installing renewable energy sources such as solar and wind digesters (Sovacool, 2013). This subsidy covered around 30 percent of the expense of renewable energy systems (Sovacool, 2013). Such measures increased the renewable energies' popularity among the population. Or as Maegaard (2009) puts it: "As a result, Denmark has a long tradition of implementing vigorous energy policies with a broad political support and the commitment of a wide range of actors: energy companies, industry, grass roots, municipalities, research circles and consumers." According to Benjamin Sovacool (2013), Danish wind energy policy enshrined three basic principles which contributed to the popularity of wind energy among the Danish population:

> *"(1) All farmers and rural households had the chance to install a wind turbine on their own land; (2) local residents had the possibility to become members of local cooperatives in their municipalities or neighboring municipalities, and exclusive local ownership was a condition for operating permits; and (3) electric utilities could only build large wind farms in agreement with the government and if it did not violate the wishes of farmers and local residents* (Sovacool, 2013, p. 2)."

These principles reflected a long history of promoting cooperatives in Denmark, which became one of the basic aspects of Denmark's transition towards energy independence (Mendonca et al., 2009).

The transition towards energy independence through renewable energy did not however go without jolts. For example, when Copenhagen realized its dependence on oil after the 1973 oil shock, it was not the government's strategy to become independent through renewable energy but through coal. Furthermore, in 1976, Copenhagen drafted the first of four Danish Energy Policy plans, which was aimed at safeguarding Denmark against another supply crisis, not at renewable energy (Handelsministeriet, 1976). Copenhagen decided that while oil was often a dangerous and unreliable fossil fuel because of its scarcity and political influence, coal was not. In 1976, an abundance in coal made Copenhagen decide to transform almost all oil-fired power plants to coal-fired ones in order to become less dependent on imported oil (Sovacool, 2013; Maegaard, 2009). As a consequence of this measure, Danish energy production changed drastically from 90 percent oil-based to 95 percent coal-based in just five years (Sovacool, 2013). In 1979, Denmark created the Ministry of Energy and issued the 1979 Heat Supply Act which was aimed at strengthening the popularity of coal even further. Its purpose was to 'promote the best national economic use of energy for heated buildings and supplying them with hot water and to reduce the country's dependence on mineral oil' (Mortensen and Overgaard, 1992). The popularity of coal lasted until 1997 when Copenhagen put a moratorium on coal. However, before this happened, several other policies were implemented in the 1980's which caused a radical restructuring of the energy sector. This was phase two.

Phase 2: Second Energy Plan (Energiplan81, 1981)

This next restructuring of the energy sector was aimed more at renewable energy and less at promoting the use of coal. In 1981 several feed-in tariffs were passed by the government, 'requiring utilities to buy all power produced from renewable energy technologies at a rate above the wholesale price of electricity in a given distribution area' (Morthorst, 2000). The revenues of these feed-in tariffs were used to promote the Research and Development (R&D) of wind energy, the development of a nationwide natural gas grid, and gas and oil recovery in the North Sea (IRENA, 2012; Danish Ministry of Energy, 1981). Examples of these R&D programs are the 1976 Energy Research Program, and the Development Program for Renewable energy between 1981 and 2001, both managed by the Danish Energy Authority (Danish Energy Agency, 200?). These R&D programs were largely government sponsored, but this changed in 1985.

In 1985, after long talks between energy utilities and the government, an agreement was reached. "This agreement committed utilities to install 100 MW of wind capacity over a five-year period (Sovacool, 2013, p. 2)." Copenhagen did not stop at this agreement. 1985 proved to be an influential year, because two more important policies were passed by Copenhagen. First, the Danish Wind Turbine Guarantee was established, providing long-term financial support for large wind projects which encouraged local manufacturing (Sovacool, 2013). Second, the Danish Energy Agency

(DEA) provided open access to the national grid in which the connection costs were divided between the owner of the wind turbine and the electricity utility (Sovacool, 2013; Danish Energy Agency, 200?). With this second policy, Copenhagen reduced the capital subsidy and required utilities to take an active role in order to fill-up the gap (IRENA, 2012).

These early policy changes and R&D programs formed the basis of the Danish wind electricity growth from 11 TJ in 1978 to 28,114 TJ in 2010 (Sovacool, 2013). This marked the start of a progressive wind energy growth with substantial consequences on the Danish energy market and the Danish economy in general.

Phase 3: Third Energy Plan (Energi2000, 1990)

Energi2000 was an "ambitious attempt to increase the use of environmentally desirably fuels (Danish Ministry of Energy, 1990)." This policy-plan entailed the following aims for 2005: Reduce the energy consumption by 15%, increase the consumption of natural gas by 170%, increase the consumption of renewable energy by 100%, reduce the consumption of coal by 45%, reduce the consumption of oil by 40%, reduce the CO2 emission by at least 20%, reduce the SO2 emission by 60%, reduce the NOx emission by 50%, and providing 10% of electricity from wind energy (Danish Ministry of Energy, 1990). These aims, although ambitious, were met by Denmark through various vigorous activities such as CO2 emission taxes and energy savings (Danish Energy Agency, 200?).

During phase three, more attention was given to siting and planning. Together with civilians, public hearings were held in order to gain a heightened public acceptance for the installation of new sites (Sovacool, 2013). Furthermore, Copenhagen decided in 1993 that promoting wind projects was of big importance to achieving their goals before 2005. Therefore, wind projects received a refund from the Danish Carbon Tax and a partial refund on the energy tax (IRENA, 2012). This cooperative approach to wind energy was part of a long history of promoting of local cooperatives in other sectors of society such as economy and agriculture (Mendonca et al., 2009). The outcome was a heightened popularity of wind electricity with which the 2005 goals were met.

Phase 4: Fourth Energy Plan (Energi21, 1996)

During the fourth phase of Danish energy reform, the focus lay on reducing the consumption of finite fossil fuels and reducing emissions resulting from energy consumption and production (Danish Energy Agency, 200?). Energi21 mostly added long-term aims to the Energi2000 plans. For example, while Energi2000 stated that 10 percent of electricity should come from wind energy by 2005, Energi21 articulated that renewable energy would provide 12-14 percent by 2005 and 35 percent by 2030 (IRENA, 2012). In addition, during this phase the amount of local cooperatives had risen spectacularly. In 1996 there were 2100 cooperatives that were at the basis of creating and maintaining popular support for wind electricity (IRENA, 2012). Energi21 closed a transitional period and started another: one with higher ambitions for renewable energy and with a focus on new energy policy guidelines (IRENA, 2012). In 1999, a new era began in Danish energy policy.

Phase 5: Electricity Market Liberalization

The most important policy adjustment during this phase was the liberalization of the energy market as proposed by an EU directive (Danish Energy Agency, 200?). As a consequence, they hoped, the energy market became more competitive and would thus develop faster. Unfortunately, the opposite was true. As a result of the policy adjustment towards a liberalization of the energy market, feed-in tariffs were abandoned and made place for a Renewable Portfolio Standard (RPS). This, in turn, had drastic effects on the growth of Denmark's wind energy market (IRENA, 2012). From 2004 until 2008, the wind energy market halted and wind power development stagnated (IRENA, 2012). Unambitious policy developments and other political interests made Copenhagen stray from its own progressive, proactive and ambitious policy of the last two decades.

In 2008, Copenhagen realized that the liberalization of the energy market in 2002 was a mistake. The government committed to increase the use of renewable energy to 20% of gross energy consumption by 2011 (IRENA, 2012). In order to achieve this ambitious goal, Copenhagen 'increased funding for R&D and demonstration of energy technology' (IRENA, 2012). As a result, a revival of the Danish wind energy market was ushered in 2009.

Phase 6: Revival and strengthening of wind sector, 2009-2012.

In 2008, the Danish government promised to increase the use of renewable energy to 20 percent of gross energy consumption by 2011 (IRENA, 2012). In 2009 they acted in order to achieve their 2011 goal; two new installations (116 MW onshore and 238 offshore) were built, bringing the total amount of wind capacity up to 3482 MW (IRENA, 2012). Financial measures, such as an environmental premium added to the market price, were taken by the government in order to actively promote wind energy again. These measures worked, because nowadays almost 20 percent of renewable energy consumption comes from wind energy, making Denmark the world leader in wind energy consumption and production (Sovacool, 2013; IRENA, 2012; Danish Energy Agency, 200?; Energi Styrelsen, 2009).

The Danish economy grew nearly 45 percent from 1990 to 2007 while the energy consumption stayed nearly the same (Energi Styrelsen, 2009). This is partly due to the proactive and ambitious wind energy policy of Denmark. In addition, CO_2 emissions have dropped more than 13 percent since 1990 (Energi Styrelsen, 2009). Nowadays, almost 20 percent of renewable energy consumption comes from wind energy. The costs were relatively high in the beginning but these dropped when fossil fuel prices increased and renewable energy sources became more competitive (Energi Styrelsen, 2009). Analyses shows that if Denmark keeps up its proactive and ambitious wind energy policy they could reach their 2050 goal of 100 percent self-sufficient on wind energy. The road shall not be without backdrops, like the 2004-2008 stagnation, but they can overcome these as long as Denmark keeps committing itself to its original plans and keeps promoting wind energy, local cooperatives, financial support, and off-shore grids. From 1973 to 1998, Denmark showed the world that political consistency resulted in an extraordinary expansion of the wind energy market. From 1998 to 2007, unnecessary policy changes, such as market liberalization, were implemented which stagnated the energy industry (Sovacool, 2013). From 2008 however, a new government set course for a 100 percent fossil fuel free Denmark by 2050, by reinstating old policies. Benjamin Sovacool (2013, p.10) is optimistic and calls it "a testament, to both a very strong and active energy lobby, and the realization that sometimes energy transitions can occur but only under the 'right' political circumstances."

This shows the world that a transition towards renewable energy is indeed possible. Commitment on various levels of society is an important factor for the transition to succeed. In addition, government subsidies, R&D programs, local cooperatives, financial measures and favorable taxes contribute to the popularity and thus use of wind electricity. The most important feature however is the multilevel cooperation between the government, utilities, municipalities and civilians. "Cooperatives have played an important role in the development of wind power by helping create public acceptance. Their engagement has ensured that communities directly benefitted from wind power development (IRENA, 2012)."

Chapter 2: District Heating and Combined Heat and Power (CHP)

Combined Heat and Power is the simultaneous production of electricity and heat. According to the Danish Energy Agency, Denmark is the best performing EU country in CHP development (Hammar, 1999). Its cogeneration produces 50 percent of electricity. In addition, cogeneration lowered the CO2 emission with one tenth since 1990 (Hammar, 1999). These impressive achievements are a result of nearly three decades of political activities and promotion. In these decades, Copenhagen went through several phases which can roughly be linked to different periods in Danish energy development: Large-scale and small-scale CHP development. The question which will be answered here is how exactly did Denmark achieve their ambitious goals? What is behind the success story and what can we learn from it?

Large-scale CHP

After the 1973 oil crisis, Danish policymakers encouraged the use of Combined Heat and Power (CHP) plants for district heating. The first energy plan, the 1976 Dansk Energipolitik, therefore articulated the short-term goal of increased oil-independence by meeting two-thirds of the total heat consumption with 'collective heat supply' (Lund, 2010, 2000). In 1979 the Heat Supply Act further emphasized the importance of CHP. The main aim of this act was to promote the best national economic use of energy for heating buildings and supplying them with hot water (Mortensen and Overgaard, 1992). In the earliest period of Danish energy reform, the following two goals became central aims for Danish policymakers: decreasing oil dependency and increase the use of CHP and district heating (Sovacool, 2013).

To achieve both goals, the energy system needed to be restructured. From now on, authority lay at municipalities instead of the government and other fuel sources would be promoted such as biomass and natural gas (Sovacool, 2013). The 1980's witnessed a large scale growth in the use of CHP in large cities, and cities and communities even started to connect through several heat transmission pipelines (Hammar, 1999). The main boost however came from the introduction of the heat planning system; a system which divided cities by the suitability for district heating or individual supply (Hammar, 1999). Copenhagen cooperated closely with local municipalities, utilities, and power companies in order to gain support for the implementation of their plans. During this period, taxes, subsidies, investment grants, and regulatory incentives contributed to the popularity of the new measures. As a result, district heating and CHP amounted to almost 40 percent of total electricity production in 1980 (Energi Styrelsen, 2009).

Towards small-scale CHP

In 1981, a second phase started when Copenhagen issued district heating systems to utilize straw for energy production. This led to a significant expansion in the biomass heating industry (Voytenko and Peck, 2012). However, the second phase of Danish CHP and district heating development did not really start until 1986, when the Danish Energy Agency started to encourage even more decentralized CHP generation (Sovacool, 2013). In 1986, parliament adopted legislation to implement around 450 Mwe of small scale CHP based on natural gas, waste, or biomass (Hammar, 1999). As a result, the CHP share of electricity and district heating production rose spectacularly from 39 percent in 1980 to almost 60 percent in 1990 (Hammar, 1999). In addition, the CO_2 emission dropped from 1034 grams per kWh produced to 937 grams per kWh (Sovacool, 2013). The following table will show Denmark's progress on several aspects of the energy system from 1980 till 2010:

	1980	1990	1995	2000	2005	2010
Energy intensity, gross energy consumption (TJ per DKK million GDP, 2000 prices)	0.998	0.818	0.748	0.649	0.618	0.591
Gross energy consumption per capita (GJ)	159	160	161	157	157	147
Degree of self-sufficiency (%)	5	52	78	139	155	121
Renewable energy—share of gross energy consumption (%)	2.9	6.1	7.0	9.8	14.7	20.2
Wind turbine capacity—share of total electricity capacity (%)	-	3.8	5.7	19.0	23.9	27.7
CHP production—share of total thermal electricity production (%)	18	37	40	56	64	61
CHP production—share of total district heating production (%)	39	59	74	82	82	77
Renewable energy—share of total domestic electricity supply (%)	0.0	2.0	5.9	15.3	17.8	33.1
CO_2 emissions per capita (tonnes)	12.2	11.9	11.5	10.4	9.7	8.5
CO_2 emissions per kW h electricity sold (gram CO_2 per kW h)	1034	937	807	634	538	505
CO_2 emissions per GNP (tonnes per Million GDP)	77	61	53	43	38	34

Table 1: Key energy statistics for Denmark from 1980 to 2010 (Sovacool, 2013)

This proved that CHP was effective in producing heat and electricity while its CO2 emission was much lower than with single supply systems.

In 1990 Copenhagen laid out their third energy plan: Energi2000. The main aims of this policy plan were to reduce CO2 emissions by 20 percent in 2005 and to grow renewable energy share to 12-14 percent (Danish Ministry of Energy, 1990). In order to achieve these ambitious goals, the government passed in several feed-in tariffs. This 'triple tariff system' paid CHP operators based on their provision of peak, medium, or low-load electricity, thereby shifting the focus from energy quantity to energy quality (Sovacool, 2013). In addition, it granted them extra energy premiums per produced kWh. While the CHP operators were influenced positively, Copenhagen started to take measures against the ever polluting coal-fired power plants. The self-sufficiency Denmark achieved through coal became of lesser value than the environment. For the first time since the major shift from oil to coal, Denmark decided to put a moratorium on coal. No more new coal-fired power plants were allowed, except for two 450 MW plants (Sovacool, 2013). After the triple tariff system and the moratorium on coal, Copenhagen started to actively promote cogeneration units. These units would run on natural gas and would replace the old district heating units. The use of environmental zoning was promoted to 'advance electricity investments in towns and villages outside major cities' (Sovacool, 2013).

These measures brought a significant rise in CHP investment. Together, the moratorium on coal, the triple tariff system, and the promotion of environmental zoning, caused a dramatic rise in CHP investment (Sovacool, 2013). More than three-quarters of all new capacity added to the Danish grid from 1990 till 1997, consisted of small CHP plants for district heating or industrial use, fueled by natural gas or straw (Lehtonen and Nye, 2009). This significantly improved the CHP share of electricity and district heating by 20 percent (Energi Styrelsen, 2009). The 1996 Danish Energy Plan, Energi21 again aimed for a significant expansion of CHP.

As showed in table 1, Danish CHP production as a share of total thermal electricity production rose from 18 percent in 1980 to 61 percent in 2010, while CHP production as a share of total district heating production rose from 39 to 77 in the same period (Sovacool, 2013). Nowadays, cogeneration provides more than 50 percent of all electricity and 80 percent of consumed district heating, making it by far the European leader (Sovacool, 2013). These impressive facts were accomplished through decentralization of the CHP grid, the shift of 'CHP' power from the government to municipalities, dividing according to suitability for district heating or single supply, a moratorium on coal, the triple tariff system, and the promotion of environmental zoning. Above all, the Danish CHP and district heating case shows that proactive governmental interference can significantly alter the course of such energy efficient systems.

Chapter three: Energy efficiency

Both wind electricity, and CHP and district heating are heavily intertwined with energy efficiency. In fact, some argue that CHP is a part of energy efficiency. However, energy efficiency here means the total set of policies aimed at promoting environmental friendly activities, degrading the popularity of fossil fuels, tackling emissions through financial measures, and informing society. Since the Danish government embarked on an informational campaign following the 1973 oil crisis, Danish energy efficiency efforts became popular among the Danes. This popularity contributed to one of the biggest accomplishments of the past decades: Denmark uses nearly the same amount of energy today as it did in 1970, although its economy and population have grown significantly (Sovacool, 2013). In addition, Denmark was able to lower carbon dioxide emission by 19 percent since 1990, surpassing the obligations of the Kyoto protocol (Sovacool, 2013). How did Denmark accomplish such impressive energy efficiency facts?

Denmark's energy efficiency policy rests on four key areas: energy taxes and quotas, obligations, labeling, and the creation of an Electricity Savings Trust (Togeby et al., 2009). After the 1973 oil crisis, Denmark realized that producing more energy and being more self-sufficient was just one part of the solution. A big problem lay in the Danish energy efficiency and consumption; a lot of households had private oil-boilers and public awareness was low (Sovacool, 2013; Lidegaard, 2012). The 1973 governmental information campaign marked the start of a radical change in this behavior, starting with the implementation of energy taxes.

Taxes and subsidies

In 1977, following the 1976 Danish Energy Policy plan, an energy tax was implemented. This tax first aimed merely at energy and oil, but later on fossil fuels in general. Since 1977, the tax has been increased several times and in 1992 it was supplemented by a CO2 tax. The overall aim of these taxes, in the words of Martin Lidegaard, Danish minister for Climate, Energy, and Building, is the promotion of energy savings and CO2 reductions. In addition, its revenues sponsored the state budget for R&D projects (Lidegaard, 2012). A careful consideration regarding taxes on fuel for transport was needed in order to prevent the Danish transport sector to get its fuel in Germany, thereby avoiding tax in Denmark. The implementation of taxes does therefore not necessarily mean higher taxes. It means the deliberately implementing of taxes to discourage the (over-) use of fossil fuels and electricity without negatively influencing the Danish economy (Lidegaard, 2012)

This approach paid off: between 1980 and 2011, the taxes raised nearly $70 billion in revenues and the primary energy consumption rose only four percent from 1980 to 2004 (Sovacool, 2013). These revenues were then used to promote bottom-up approaches to energy efficiency projects and wind turbine development, improving Denmark's energy efficiency and share of renewable energy significantly.

Obligations towards energy efficiency

Denmark obliged utilities and energy companies in 2006 to be more energy efficient. It mandated that all 'electricity, natural gas, and district heating providers realized energy efficiency goals, efforts funded by a slight increase on energy bills that add up to roughly €40 million per year (Sovacool, 2013). It committed companies to contribute to the Danish energy efficiency policy. Such cooperatives between the government and energy companies aimed at achieving specific management targets regarding energy efficiency (Sovacool, 2013).

Energy labeling

Another way of Copenhagen to promote energy efficiency among the Danish society was the labeling of electrical appliances and buildings. Especially the labeling of buildings was a significant feature in Denmark. In 1979, a label regime was established which labeled buildings on their energy use and gave recommendations on how to improve this label. Ranging from 'A' to 'G', with 'A' being the best label possible, buildings increased or decreased in value. In addition, the energy labeling policy required every building to have a specific Energy Performance Certificate (EPC). Energy subsidies were introduced in 1978 to promote the labels of as many buildings as possible (Lidegaard, 2012). These applications resulted in a 75 percent decline in heat demand of new buildings (Lidegaard, 2012).

Electricity Savings Trust (EST)

From 1997 to 2010 the EST promoted energy efficiency for houses and public buildings. Originally, the EST tried to stimulate and promote the use of district heating, but soon it became more than that. It increased public awareness through information campaigns and counseling for households (Sovacool, 2013). In addition, it helped to improve the energy labeling system introduced in 1978. In March 2010 the EST changed in the Danish Energy Savings Trust (Maegaard, 2010). With the trust, the government sponsored even more information campaigns which emphasized energy efficient solutions to daily situations (such as isolated walls and windows), and personal energy audits, creating understanding of the Danish impact on the environment (Olesen, 2006).

The persistent political, informational, and commercial focus on energy efficiency, have meant that the Danish society nowadays is a well-informed and aware society in which energy efficiency measures are of high priority. Environmental friendly taxes, obligations, labeling of buildings and applications, and the Danish Energy Savings Trust all contributed to this understanding. After the 1973 oil crisis the Danish government realized that if it were to transform its energy sector, it could not do this alone. It needed the full support of the Danish society. Therefore, without these informational campaigns, Copenhagen would have had an even bigger task. Again, cooperatives between the government, utilities, municipalities, and civilians proved to be the key to the Danish transition success.

Conclusion and implications

This research tried to analyze the history of Danish energy policy in order to gain a more comprehensive understanding of how to overcome difficulties of energy transitions. It has described and outlined all significant policy changes and their implications on the Danish energy transition since 1970. With this information the following question shall be answered: *Which political factors played a role in the history of Danish energy transition since 1970 towards a more independent and environmental friendly energy system?*

This research shows that the government used economic, social, cultural, and technological measures to achieve their ambitious goals. Here, the research will summarize these changes and arrange them according to their relevance for respectively wind electricity, CHP and district heating, and energy efficiency.

Promoting wind electricity in order to enhance its popularity was at the basis of Danish wind electricity policy. The Danes needed to be convinced that wind electricity was indeed a proper way to phase out fossil fuels over the long term. Via multilevel cooperation, the government involved the population in decision making, thereby giving them a prominent role in the transition process.

Furthermore, by actively subsidizing the use of wind electricity, Copenhagen tried to improve the popularity of wind electricity. Together with the negative fossil fuel taxes, these financial measures increased the use of wind electricity significantly. The revenues were, in turn, used for R&D programs, further stimulating the development of wind turbines. Altogether, wind electricity has a long history in Denmark in which it has been actively promoted and stimulated by the government. This led to a significant amount of multilevel cooperation between the government, utilities, municipalities and civilians. As a result, wind electricity in Denmark nowadays accounts for 28 percent of total electricity production (Sovacool, 2013).

In the Combined Heat and Power, and district heating sector, the decentralization of energy production and consumption was central to the impressive achievements over the last few decades. It started with a shift in authority to the municipalities. Following this shift, heat planning systems were introduced, aimed at determining suitability for different sorts of heating such as district heating or single supply systems. By introducing a triple tariff system, Copenhagen tried to encourage high quality energy production. The focus changed from energy quantity to energy quality. The moratorium on coal further promoted this by forcing energy producers to focus on energy quality instead of energy quantity. With this stop on coal, Copenhagen tried to limit higher energy consumption in the future and meet the excess with renewable energy. Last but not least, cogeneration units and environmental zoning were promoted in order to advance electricity investments in small cities and villages. Although the Danish economy still managed to grow 45 percent since 1990, these measures lowered CO_2 emissions and lessened energy consumption.

In the area of energy efficiency Denmark has emphasized the creation of public awareness for independency and environmental friendly energy production and consumption. With information campaigns, Copenhagen tried to make environmental friendly energy consumption widely known. In addition, financial measures such as taxes degraded the popularity of fossil fuels. With these taxes the government tried to push customers away from consuming large amounts of fossil fuels and instead focus on being more efficient and thus environmental friendly. Copenhagen tried to show that being efficient and environmental friendly could have financial advantages. With the energy labeling of buildings and applications, the government tried to make inefficient goods financially less attractive, thereby pushing sellers to improve the energy efficiency of their goods. Lastly, the creation of Trusts sponsored information campaigns which tried to win public support for energy efficiency. The main goal of the government in this key area was to create public awareness of the disadvantages of energy inefficiency and the possible advantages of a transition towards environmental friendly energy production and consumption.

These measures lead to conclude that the Danish government actively promoted and stimulated the transition process. This historical research has thus led to the three following main insights:

1) The case of Denmark has shown that the government can be a catalyst in (sustainable) transition processes.

2) In Denmark, this was achieved through a consistent and proactive attitude of the government;

3) And through a polycentric approach to energy planning, combining multiple layers of society.

This historical research has both a strong and a weak point. First, the research is very case-focused. Conclusions and solutions from the case of Denmark do not guarantee success for other countries. Every country has different characteristics which make it difficult to provide a conclusive advice.

As a strong point, this historical research is very comprehensive. It deals with significant legislation, agreements, cooperation, measures, and policy plans. Thereby it creates a comprehensive overview of the case of Denmark.

Identification of differences between the MLP and the case of Denmark

In this thesis the disciplinary part of IS has provided a theoretical framework in which system-wide innovation processes are organized in a hierarchal way. The disciplinary part of political history has presented a case study of Denmark in which the policies promoting the transition to a more sustainable and independent energy system have been studied.

Repko (2012) states that an important part of the interdisciplinary research process involves the identification of conflicts between disciplinary insights concerning the problem. The term insights includes those derived through theories and concepts. According to Repko (2012) interdisciplinary conflicts are 'inevitable, and central to the interdisciplinary enterprise'. Establishing these conflicts however is not enough. An interdisciplinary research must identify the conflicts and then ask the following two questions: where are the conflicting insights located and why do they conflict (Repko, 2012). Do they conflict within or between disciplines and do they conflict on the basis of concepts, assumptions, or theories? Although both disciplinary parts in this thesis have a different research focus, at the interface of both disciplines there seem to be two important conflicting points.

Since disciplinary insights are largely expressed through language it is not surprising that differences in concepts are found (Repko, 2012). As already mentioned, within IS and particularly within the

MLP, the role of the government is not extensively described. When references to the role of the government are made they are mainly described as *policy interventions*. PHIR uses other concepts to describe the same aspect. Within PHIR the government's influence on a transition process is described as *policy changes* or *policy decisions*.

The terminology of the MLP suggests that different policy interventions can influence the transition process. However, in the case of Denmark, the overall energy policy influenced the transition process, not merely interventions. In the disciplinary part of PHIR the various policy changes within the overall energy policy are identified. These policy changes are not necessarily actual policy interventions. Policy changes also entail, for example policy promotions, information campaigns to gain public acceptance, and simple adjustments in policy. The concepts used within PHIR are embracing the whole spectrum of governmental influence of the transition process whereas the terminology of IS (i.e. policy interventions) deals with just one part of politics influencing the transition process.

This conceptual difference arises from a conflict in assumption underlying the concepts. The MLP views the role of the government as one of multiple actors affecting the transition process (see figure 6). Whereas PHIR views transition processes as just one of the many tasks of the government, placing it on the same level as, for example, poverty and homeland security. As can be seen in figure 7, transitions are a mere part of the overall government agenda from the PHIR point of view. The government uses economic, technological, and social- cultural changes to govern the transition process. The conceptual difference originates from the fact that political history zooms in on the role of the government and hereby creates a more complete understanding of its role in transition processes, while the role of the government is nearly neglected in the MLP.

Figure 6: The role of the government in transition process according to the MLP.

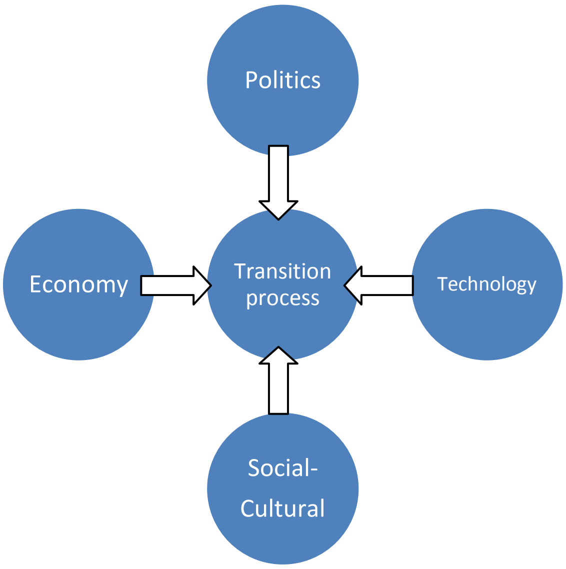
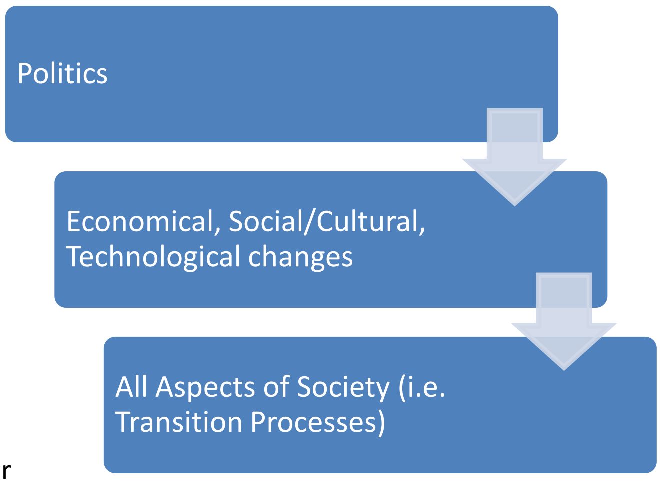


Figure 7: The role of the government according to Political History.



Another difference between the disciplinary insights has been encountered. On the one hand, the MLP assumes that landscape factors cannot be changed at will. The landscape level is described as a collection of exogenous factors and processes that cannot be influenced. On the other hand, the case of Denmark showed that the consistent and proactive energy policy had an important influence on the growing awareness around environmental issues and thereby on the popularity of alternative energy. So in this case, the Danish energy policy influenced a landscape factor namely the awareness and popularity of alternative energy. These contradictory assumptions raise a question about the correctness of the MLP and demonstrates the need to analyze the potential influence the government can have on landscape factors.

In order to overcome the two mentioned conflicts between the disciplines, interdisciplinary common ground needs to be created. Repko (2012) formulates common ground as 'one or more concepts or assumptions through which conflicting insights or theories can be largely reconciled and subsequently integrated'. The difficulty in the creation of common ground here, is the fact that the influence of the government is not integrated in the MLP (yet). As long as policy remains an external factor of influence in the MLP, the role of the government in transition processes remains obscure. The case of Denmark seems to contradict some fuzzy parts of the MLP, however no general statements can be made based on one single case study. In order to internalize the role of the government in the MLP and to verify the conflicting insights found through the case study of Denmark, similar cases in which policies promoted sustainability transitions have to be studied.

The most relevant encountered difference for this thesis does not entail conflicts between concepts, assumptions, or theories, but rather a difference in research focus between the disciplinary parts. While the disciplinary part of IS is merely focused on identifying how sustainability transitions unfold in general, the disciplinary part of PHIR analyzes the specific transition process of Denmark's energy system between 1970 and 2014. Both disciplinary parts thus answer a different sub- question.

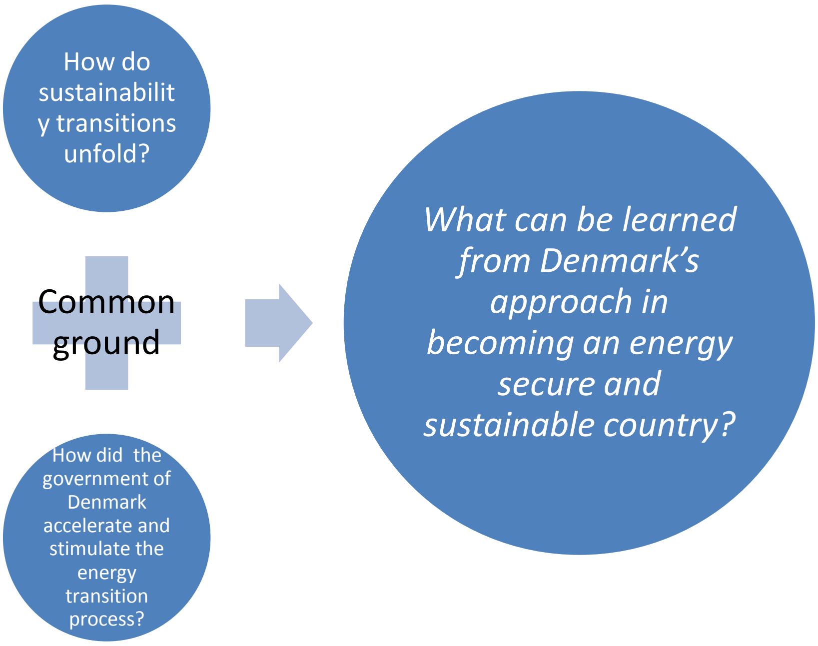


Figure 8: Sub-questions leading to the research question.

The obtained disciplinary answers are alternative but not contradictory. The answers supplement each other by connecting theoretical insights with fact-based practical knowledge. Thereby the disciplinary part of political history supplements the weak point of the MLP (i.e. neglecting the role of the government in sustainable transition processes). Common ground has to be created by assembling the disciplinary answers in order to develop a more compressive understanding to answer the research question.

Common ground; The Danish energy policy mapped in the MLP

The creation of an overview of how the disciplinary answers together answer the research question can be achieved through *the technique of organization* (Repko, 2012). The technique of organization enables the creation of common ground by clarifying how certain phenomena interact and mapping the causal relationships (Repko, 2012). In order to reconcile the alternative disciplinary answers the Danish energy policy is mapped in the MLP, as can be seen in table 2.

Table 2: The Danish energy policy since 1974 mapped in the MLP

The MLP	Wind energy	CHP & District Heating	Energy Efficiency
Main time period	1974 till 2014	1976 till 2014	1973 till 2014
Landscape factors	'Oil crisis' Endowment of the best wind conditions in Europe. Long tradition of windmill development Long history of policy promotion (public hearings, demonstration of energy technology, investment subsidies) in order to gain a heightened public acceptance and popularity for the implementation of wind energy.	'Oil crisis' Policymakers aggressively encouraged the use of CHP units for both electricity generation and district heating.	'Oil crisis' Information campaigns and counseling for households increased public awareness.
Regime de-stabilization factors	Feed-in tariff (FIT) requiring existing energy utilities to buy all power produced from renewable energy technologies at a rate above the wholesale price of electricity in a given distribution area.	The moratorium on coal and no new coal-fired power plants were permitted. Obligating all large utilities in the major cities to use biomass (especially straw) for CHP, and to obey mandatory energy efficiency regulations. District heating units, were prohibited to use oil, diesel, and coal and had to replace it by natural gas. If the local market was not large enough to cater to cogeneration, single supply systems would be set up. The district heating plants were required to utilize biomass.	Energy taxes and quotas. Obliged utilities to be more energy efficient. Energy labeling of buildings and applications.
Stimulation of niche develop-ments	Sponsoring of R&D projects and demonstration of energy technology. Providing open and guaranteed access to the grid. Providing long-term financial support and promoting cooperatives through investment subsidies and clear cooperation guidelines. Feed-in tariffs guaranteeing the purchase of wind energy by electricity distribution companies.	High investments in CHP systems and transmission networks. Encouraging more decentralized CHP generation by building straw demonstration plants. Introducing the triple tariff system which paid CHP operators based on their provision of peak, medium, or low-load electricity and also granted them an energy "premium".	The revenues of the energy taxes sponsored the state budget for R&D projects.

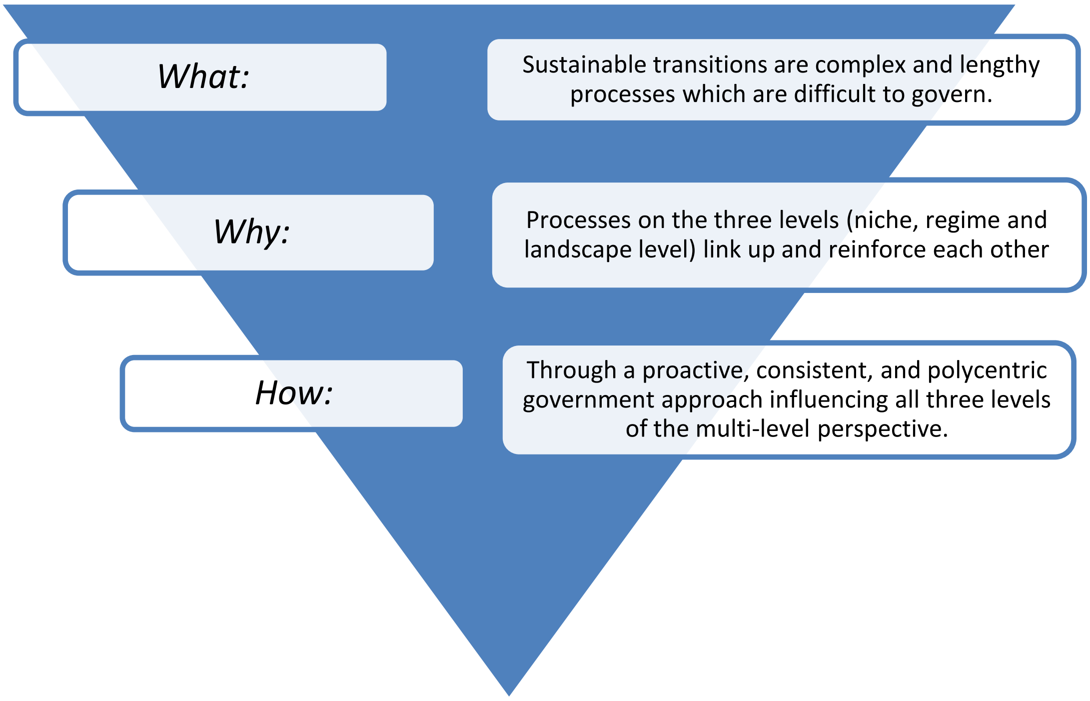
Outcome/ impact	Support of market introduction of wind turbines and simultaneously promoting an accelerated dismantling of unsustainable coal and fossil fuel manufactures	The stop on coal, regulations stimulating environmentally friendly conversions and obligating efficiency improvements encouraged cogeneration and district heating	The persistent political, informational, and commercial focus on energy efficiency, have meant that the Danish society nowadays is a well-informed and aware society in which energy efficiency measures are of high priority.

Table 2 shows that the influence of Danish energy policy is present on all three levels of the MLP. At the niche level, the Danish energy policy stimulates sustainable energy developments. At the same time, the Danish energy policy puts pressure on the existing energy regime. Finally, the Danish energy policy seems to influence the landscape level through the creation of awareness and acceptance of renewable energy in civil society.

Towards an integrated framework of the transition in Denmark

With the help of the created common ground the research will now integrate the main disciplinary insights. The in-depth literature search led to the insight that sustainable transitions are complex and lengthy processes. Because of strong stabilizing mechanisms, the interdependence between multiple actors and autonomous pressure from landscape developments, transition processes are difficult to govern towards sustainability. Sustainable transitions are not caused by a simple driver, they only come about when processes on the three levels (niche, regime and landscape level) link up and reinforce each other. Despite of the difficulties in governing transitions towards sustainability, the Danish government proved to be a catalyst in the rapid energy transition process. This energy transition proves that sustainable transitions can occur rapidly under the “right” role of the government. In table 2, the Danish energy policy was integrated in the MLP. As can be seen, the Danish government seems to have taken into account the contingencies created by multi-level developments by proactively influencing all three levels of the perspective (simultaneously). The right political circumstances for Denmark where the consistent, proactive and polycentric approach of the government influencing all three level of the MLP. The integration of our insights then looks the following:

Figure 9: Integrating insights: How to promote and accelerate sustainable transition processes?



This thesis was aimed at answering the following research question: *What can other EU countries learn from Denmark's approach in becoming an energy secure and sustainable country?* The thesis has answered this question with the following insight: *Although transitions are complex and lengthy processes, they can be promoted and accelerated through a proactive, consistent, and polycentric government approach influencing all three levels of the multi-level perspective, thereby considering the relevant characteristics of the specific country.* Table 2, shows how the policies in Denmark promoted a (sustainable) energy transition. The table provides a successful case to be followed by other EU countries. As a result of the complexities to govern a sustainable transitions, it is impossible to promote and accelerate such a transition by a single dimensional approach. A mix of policy seems to be the key driver to accelerate and stimulate sustainable transitions. The created insight and the practical example provide a more comprehensive understanding of the role of the government in accelerating and stimulating sustainable transitions.

Lessons and implications

As all academic research, this one too has it strengths and weaknesses. A strength of this research is the integration of a practical analysis of what policies stimulated the Danish energy transition in the MLP. This interdisciplinary research of the energy transition in Denmark thereby attempts to supplement the MLP with public policies. Although, this thesis has developed a practical guideline for other countries, further research is needed to answer the following important question: How deeply are the processes within sustainable transitions and the role of the government intertwined?

Additionally, this thesis stimulates and challenges further (interdisciplinary) research. Two remarkable findings were found in the case study of Denmark. The role of the government seemed to have a constant influence on the transition process and this influence even appeared to have an impact on the (exogenous) landscape level. These findings partly contradict the current MLP. More similar cases have to be analyzed in order to verify if the role of the government in other sustainable transition is as decisive as in the case of Denmark and to analyze if and how the government is able to influence the macro-level of transition processes (i.e. the landscape level). This interdisciplinary research of the energy transition in Denmark shines a critical light on the completeness of the MLP by emphasizing its main weakness.

Finally, this research empirically shows that sustainable transitions can indeed happen. It needs to be acknowledged however that Denmark is blessed with several significant benefits for the transition process to take place. For example, the Danish economy is strong, they have large amounts of shallow water with high wind speeds which are perfect for offshore grids, and the civilian population has been supportive of Danish energy policy since the very beginning. Such benefits largely contributed to the short-term success of the Danish energy transition. Nevertheless, this case shows that sustainable transitions can indeed happen. Even further, the case of Denmark proofs that the government can have a significant influence on the speed of this transition process. The research suggests that transitions, largely influenced by the government, can happen on a relative short term which, hopefully causes motivation and provides inspiration for other countries.

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