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TRANSITION THEORY APPLIED TO THE EU

A joint strategy for renewable energy

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List of abbreviations

EC	European Commission
ECJ	European Court of Justice
EEG	Erneuerbare-Energien-Gesetz
EU	European Union
GHG	Greenhouse gases
GIS	Geographic information system
GJ	Gigajoule
GW	Gigawatt
GWh	Gigawatt hour
J	Joule
KJ	Kilojoule
kW	Kilowatt
kWh	Kilowatt hour
LFG	Landfill gases
MJ	Megajoule
MW	Megawatt
NREAP	National Renewable Energy Action Plan
P	Power
PJ	Petajoule
PJ	Petajoule
PR	Performance Ratio

PV	Photovoltaic
PW	Petawatt
PWh	Petawat hour
RED	Renewable Energy Directive
RES	Renewable energy sources
TJ	Terajoule
TW	Terawatt
TWh	Terawatt hour
W	Watt
Wh	Watt hour

Abstract

The EU is making a start towards renewable energy with the Renewable Energy Directive, which obligates Member States to achieve a total of 20% final energy consumption from renewable energy in 2020. However, each country focuses on a myriad of renewable energy measures and structures. From a spatial perspective this is not a logical choice. The reason for this is that some renewable energies know greater potential when adjusting their location to geographical and meteorological standards. Northern countries have on average a higher wind speed and therefore wind energy has greater potential in those areas, while Southern countries know on average more sun hours per year and thus yield from the sun is higher in these Member States. The EU as a whole, would achieve a greater share of renewable energy when Member States would focus on those renewable energy sources that know the most yield according to the conditions within their boundaries. Transition theory is applied as a perspective to understand the energy transition in the EU. Transition theory explains that there is an interaction between the micro-level, the meso-level and the macro-level and that all these levels have an influence on the transition. These levels are identified as the local level, Member States and the EU, respectively. As not all renewable energies know a spatial relevance, only wind energy, solar energy, geothermal energy and hydro energy are analysed in terms of spatial potential. The analysis consists of calculations that estimate the yield of solar and wind energy and a study of maps on basis of yield. The calculations are used to investigate to what extent location matters. A case study of Germany and the Netherlands explains why differences exist between Member States in achieving the target. In addition, a strategy is made with several steps in order to realise that countries focus on their prioritised renewable energy sources and ultimately achieve 100% renewable energy.

Keywords: space, planning, renewable energy, EU, transition theory, transition management, yield

1. Renewable energy in the EU, dream or reality?

1.1 The potential of a EU perspective on renewable energy

In the field of sustainability and the environment, the European Union (EU) is on the move. EU environmental policies lay down rules on matters related to the environment such as pollution and emissions. Besides these issues, attention is paid to renewable energy. A current and foremost example are the 20-20-20 targets (Europe Nu, 2015a) which are part of the Directive 2009/28/EC, also known as the Renewable Energy Directive (RED). One of these goals is to achieve 20% final energy consumption from renewable energy for the EU as a whole. There is a margin in place for member states depending on factors such as the welfare and capacity of the country. The renewable energy target has a binding status (EC, 2015h), however, it is not apparent what happens when a country will not achieve the target in 2020. Nevertheless, Member States aim to meet these objectives. On the one hand, the Member States' perspective does not often go beyond the own national level, on the other hand, the EU (2015b) sees a common energy policy as a sustainable solution. Cooperation by all countries might possibly be more effective when implementing renewable energy. The renewable target shows that the EU is willing to undergo a transition towards renewable energy, but that coercion or inducement is missing and that the focus for now is mainly on the national level. The argument in this research is, that this is a missed opportunity. With cooperation between Member States and the development of an interconnected EU grid, energy can be generated more effectively and use more efficiently (Unteutsch & Lindenberger, 2014). Energy can be generated more effectively as countries are, due to the EU grid, no longer forced to focus on a myriad of renewable energy sources (RES), but can focus on renewable energy sources with the most yield. Energy can be used more efficiently as a surplus of e.g. wind energy would not go to waste.

An example where the narrowed perspective on national level causes problems is the issue between France and Spain. In certain periods, Spain produces solar power to the extent that the country has enough for itself and cannot lose the excess. France would be able to import this energy, but is not willing, because the cheaper solar energy would compete with France's own nuclear energy on the energy market (Energy News, 2014). Such problems between Member States could be solved or at least be mitigated in a joint strategy for the EU as a whole. In this way there is a more efficient use of renewable energy that is already in place and that will be implemented in the years to come. By working together there can be a look at each type of renewable energy and the effectiveness and efficiency of each throughout the EU. Deployment of solar power has more yield in southern countries as the sum of yearly sun hours is bigger in those areas and the potential of wind energy is most apparent in Ireland, the United Kingdom and Denmark due to the higher wind speeds (Held et al., 2010). By analysing where renewable energy has the most potential in the EU, it may be possible to achieve a greater proportion of renewable energy, even with the same investment, than when aiming attention solely at the national level of each Member State.

1.2 Problem definition

The EU is grounded on cooperation between all participating Member States. Examples are cooperation on topics such as security, water, infrastructure and economy. Also, the environment and the use of renewable energy is a common subject. Although there are possibilities to cooperate and supply other Member States with energy, most solutions and policies are regulated on a national scale by each Member State (EUR-Lex, 2015b). Thus cooperation on renewable energy does not happen in such a way that, figuratively speaking, boundaries do not exist. This would be logical with respect to the yield of renewable energy sources as the yield of some is strongly dependent on geographical aspects. For example, solar panels have greater potential in the south of the EU due to the amount of sun hours. Unteutsch & Lindenberger (2014) declare that efficiency gains can be realised with an international cooperation in the distribution of renewable energy, but that most countries only make use of their own national production. It seems that, although the Renewable Directive is meant to make a better world together, the work to get there is mostly done individually by each country.

The EU has a limited budget and limited space. Spatial planning can can help in making efficient use of space. Therefore, a spatial perspective can argue where the most yield can be obtained of each renewable energy source and how this can be realised.

The political sphere and the division of responsibilities are also responsible for the current status of renewable energy in the EU. The EU obligated Member States with the aforementioned directive. However, Member States are free to choose their own measures to achieve their target. Although the EU approves the rapport which holds the measures, Member States could have neglected certain measures. In addition, as Member States are responsible for their own target only, corporation between Member States mostly takes place for the sake of the own renewable energy share.

1.3 Aim of this thesis

The aim of this thesis is to investigate how the transition to renewable energy, which will be elaborated on later, can be boosted with cooperation between the Member States of the EU. Linked to this is finding out where it is reasonable to build new renewable energy constructions when focusing on the yield and potential. This study also intends to indicate in which Renewable energy sources (RES) Member States should prioritise. In addition, the goal is to make a strategy for the EU for prioritising RES and for the future of the energy transition in the EU.

Transition theory is not yet applied to the EU to analyse the energy transition with the EU, the Member States and the local level as the levels of the multiple level perspective (see Section 2.2). Transition theory is often used to analyse functional areas. In this case these areas are also geographical areas (The EU, the Member States and the local level).

The energy transition is a non-linear process (Rotmans et al., 2001), which means that there is uncertainty and complexity to deal with (De Roo & Hiller, 2012). However, the strategy that will be presented in this research will be based on technical rationality. Technical rationality embraces certainty as a starting point (De Roo & Silva, 2010) and is a means-to-ends way of thinking (De Roo & Hiller, 2012). This differs from the contemporary perspective in spatial planning, which is based on uncertainty and communication (De Roo & Hiller, 2012). The reason for technical rationality is used a way of strategic thinking, is that one has to deal with less influencing factors. A communicative rational strategy would go beyond the extent of this research.

1.4 Research questions

How can a joint strategy for the EU, based on transition theory, benefit the energy transition towards renewable energy?

- What is the influence of geographic location on the yield of wind energy, solar energy, geothermal energy and hydro energy?
- How can lessons learned from the differences between Member States with regard to the 20% renewable energy target benefit the strategy?
- How can certain types of renewable energy be prioritised in the Member States?

1.5 Fencing of the area of study

The study focuses on the EU and its Member States. The EU consists of 28 countries at the time of writing, as is shown on Map 1: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, United Kingdom, and Sweden (EU, 2015d). The terms Europe and the EU do not mean the same, and using them interchangeable might lead to confusion as they do not indicate the same area. However, as some of the references study Europe as a whole, the term Europe is used now and then when referring to those sources. Some overseas territories are included in the EU, which means that treaties of the EU also apply there: Guadeloupe, Martinique, French Guiana, Réunion, Saint-Martin (France), the Azores, Madeira (Portugal) and the Canary Islands (Spain) (Europa Nu, 2015b). These areas are displayed on Map 1 in the upper right corner. However, an integration of the energy network of the mainland with these overseas areas is difficult. A great distance must be bridged to connect these areas with the main grid of the EU. Finances could be allocated to renewable initiatives in the overseas areas, rather than be invested in the infrastructure that is needed to be linked with the electricity network of the mainland. Therefore, the selection does not to include these areas in the study. There are other islands in the EU (including the UK), but they are included as they are not as far away from the mainland of the EU and have greater populations. Countries outside the EU are not involved because the study is based on EU policy (which entails the aforementioned 20-20-20 targets). Countries that are not members of the EU, including candidate countries, are basically outside the cooperation. While cooperation with non-member countries can be advantageous for an integrated European energy network (Ee-News, 2015), the study does not go to such an extent due to the complexity of such an investigation.

Map 1: EU-28 (Eurcom, 2013)

1.6 More than an environmental problem

The importance for attaining more renewable energy is numerous. Most notably are climate change and the exhaustion of fossil fuels. Climate change is caused by human actions, which enhance the greenhouse effect which in turn relates to rising temperatures (EPA, 2014). Consequences are for example the rise of the sea level, an increase of heavy rainfalls and other extreme weather events (IPCC, 2012).

In addition, the amount of fossil fuels used for energy production is finite. While Droege (2002) and IER (2015) state that around 2030 half of the world's oil reserves will be exhausted, Shafiee & Topal (2008) declare that oil, coal and gas will be depleted in respectively 27, 99 and 29 years. Though the exact numbers are debatable, they lead to the same conclusion: fossil fuels will be exhausted sooner or later. This is a problem for societies like the Member States of the EU that strongly depend on these finite fuels.

For the EU particularly geopolitical issues are also apparent. The relations with Russia are fragile, which is troublesome as some countries within the EU are dependent on gas from Russia (Tsakiris, 2015). 53% of all the energy that is consumed by the EU is imported (EC, 2015e), hence energy security is a policy objective as well (Morata & Sandoval, 2013). Antics & Sanner (2007) argue that this number of imported energy will increase in the future and that there will be more need to compete for energy resources as the demand in other regions is growing faster. A provision of own energy for the EU could be an outcome, as there would be no more need to compete with other countries for energy.

Alternative energy sources are needed for the energy demand of the EU now and in the future. Spatial planning plays a role as RES might have different yields dependent on location. Space is limited and thus sites for RES should be carefully chosen. However, only focusing on location is unreasonable because many other factors come in play. Spatial planners, although they are by no means expert in every discipline, are known to be multidisciplinary (Vallée, 2012). They can therefore recognise the different stakes that are present in allocating renewable energy constructions. Nevertheless, allocating renewable energy structures is only one part of transitioning to renewable energy.

1.7 Structure

Section 2 explains the transition theory and how it is applicable to this thesis. Sustainability and renewability are clarified, as well as the differences between the two. The relevant energy sources will be selected for this thesis. Lastly, a conceptual model integrates the theory with an EU perspective.

In Section 3, the methodology describes how the study is done. It mentions the methods, how the collection of data sources is done and how they are analysed.

Section 4 lists the primary and secondary sources of EU law. The different EU institutions are introduced. Both sources of law and EU institutions that are relevant for the energy transition are discussed.

Section 5 first explains why the yield of some RES listed by the EU is not dependent on location. Maps and/or calculations will be used to find out the spatial importance for wind energy, solar energy, geothermal energy and hydro energy. The first sub-research question will be answered.

Section 6 presents a case study of the Netherlands and Germany. This case study compares success and failure. The aim is to investigate what leads to success in attaining more renewable energy. The lessons learned are processed in the strategy. The second sub-research question will be answered.

Section 7 provides a strategy for prioritising RES in the Member States. The strategy is a synthesis of all the other sections. The third sub-research question is answered.

2. Theoretical framework

2.1 The controversiality of sustainability and renewability

Sustainability is a concept that can have various meanings; in some cases these meanings even contradict each other. The issue that arises is that it is not always apparent what is meant with sustainability. In addition, renewability is now and then used interchangeably with sustainability. However, they do not necessary mean the same. Therefore, the following identifies the definition of sustainability and renewability that can be applied to this study.

According to Fiksel & Hecht (2014) *sustainability* usually implies ´a state or condition that allows for the fulfillment of economic and social needs without compromising the natural resources and environmental quality that are the foundation of human health, safety, security, and economic well-being´ (p. 613). *Sustainable development* is a method to accomplish said sustainability. The WCED (1987) defines sustainable development as 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs' (p.43). The EC (2015h) uses the same definition as the WCED for sustainable development, but does not give a clear definition of sustainability. The RED does mention sustainability (EUR-Lex, 2009), but does not define the term. There is however a reference to energy sources, the main focus of this thesis. In the directive there is referred to RES and not to sustainable energy sources. The EU sees RES as 'wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases' (EUR-Lex, 2009, p. 27).

What sustainability really implies for the EU remains uncertain, especially because the EU uses renewable and sustainable interchangeable. There is however a difference between those two when studying the literature. Renewable energy is energy which comes from sources that can be replenished (IPCC, 2012). An example is palm oil. This source can be re-planted, so that the generation of energy from this source can be persistent. *Sustainable energy* is inexhaustible and in addition does not affect the environment. Jaccard (2005) mentions so-called *sustainable fossil fuels*. These fuels are sustainable, according to Jaccard (2005), as the consumption of them does not emit greenhouse gases (GHG). These sustainable fossil fuels are 'non-conventional' fossil fuels and comprise among others oil shale, gas hydrates and oil sands. They are not renewable, as these fuels cannot be replenished, at least not in a time scale that is relevant for humanity. However, on the long term they might be renewable. The difference between renewable energy and sustainable energy is that sustainable energy is always renewable, but not the other way around (Aggeliki, 2011). A renewable energy source, such as the previously mentioned palm oil, is not sustainable due to the manufacturing process of the product (e.g. the clearing of rainforest) (Hernieuwbare-Energie, 2015). Sustainable sources are likely to be the better choice for the future as they do not have negative effects on the environment.

Fig. 1 displays the aforementioned types of energy. The author agrees with the definition that is used by Aggeliki (2011). Sustainability should comprehend a way of living which enables a long-term coexistence of humans with the different species on earth. As such, sustainability is both about reusing materials and resources and keeping the living environment as 'clean' as possible. However, as the EU speaks about RES, this thesis does as well. Note that some of the RES mentioned by the EU might be sustainable as well, while some are just renewable.

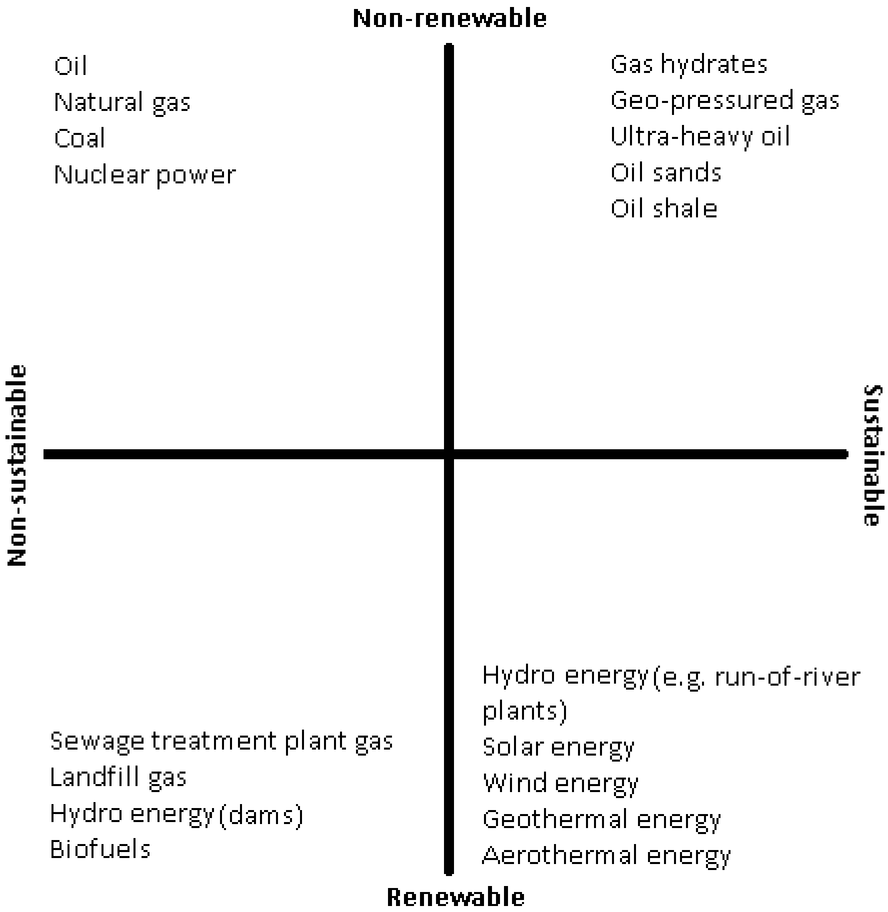


Figure 1: The different kinds of energy sources

The energy transition is 'a genuine design challenge' (Sijmons, 2014, p.11), where the spatial planner has to identify spatial qualities to fit in renewable energies in accordance with those qualities. Nadaï & Van der Horst (2010) emphasise that the exploitability of renewable energy for a large part depends on 'specific physical landscape characteristics that may be much more prevalent in some areas than in others' (p.144). However, the yield of RES is not always location dependent, meaning that, for the yield, it does not matter where the renewable energy source is harnessed. One of those RES is biomass (Sijmons, 2014). Naturally, countries that have more vegetation do also have more opportunity to gather biomass. However, the location of the vegetation does not matter for the yield. This is at least the case for Europe (Sijmons, 2014) and thus the EU. Wind energy could theoretically also be exploited everywhere, but the yield can vary (Sijmons, 2014). This study investigates the importance of location, and therefore not all RES listed by the EU are analysed. Section 5 explains for which RES location matters. Note that hydropower can be both sustainable and non-sustainable. Hydropower dams for example are non-sustainable, can disrupt ecosystems. On the other hand, run-of-river hydropower plants are sustainable, as they do not harm the environment. For now, it is sufficient to know that the RES selected are wind energy, solar energy, geothermal energy and hydro energy (run-of-river hydropower plants, reservoir hydropower plants and pumped storage plants).

2.2 Transition theory

The switch from fossil fuels to RES is a complex issue, as the energy transition does not solely include a technological shift, but also requires economic, political, institutional and socio-cultural changes (Berkhout et al., 2012). One perspective that can help in analysing the way towards renewable energy is transition theory. According to Geels (2002) and Rotmans et al. (2000) *transitions* are 'processes of structural change in societal (sub) systems such as energy supply, housing, mobility, agriculture, health care, and so on' (Loorbach, 2010, p. 166). Transitions occur 'when the dominant structures in society (regimes) are put under pressure by external changes in society, as well as endogenous innovation' (Loorbach, 2010, p. 166). External changes in society for example include the alteration of the mindset due to environmental pollution. This then can lead to new regulations that protect the environment. Endogenous innovation, such as a new technology, can bring about a change in the infrastructure (which is part of the dominant structures). For instance, renewable energy changes the energy infrastructure.

Transitions are unique, but the pattern of transitions is outlined by the interaction between processes at three levels which are part of the *multi-level perspective* (Geels, 2011) (Fig. 2): niches (micro-level), regimes (meso-level) and landscapes (macro-level) (Geels, 2002; Geels and Kemp, 2002; Rip & Kemp, 1998; Rotmans et al., 2001).

Niches (micro-level) are spaces where radical innovation takes place (Geels, 2011). These areas are protected from the market at the regime level and therefore the outcomes of experiments have time to grow. The niche level ´relates to individual actors and technologies, and local practices. At this level, variations to, and deviations from, the status quo can occur, such as new techniques, alternative technologies and social practices´ (Rotmans et al., 2001, p. 14).

A *regime* (meso-level) 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 artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures´ (Rip & Kemp, 1998, p.340). Here are the interests and rules at play that steer private action and policy (Rotmans et al., 2011). All these institutions, rules, practices and so on influence the 'normal' development and use of technologies (Smith et al., 2005).

The *landscape* (macro-level) can be seen as the wider context (Rip & Kemp, 1998). This context has influence on the niche and the regime as it involves political ideologies, societal values and macro-economic patterns (Geels, 2011). Combined, these factors form the landscape.

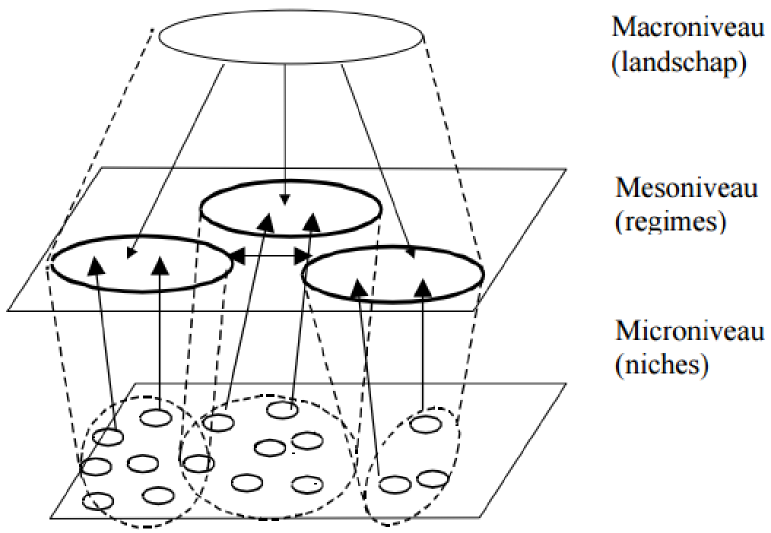


Figure 2: Multi-level perspective (Geels & Kemp, 2000)

The *multi-phase concept* describes the dynamics of transitions over time as a succession of alternating phases and is a complementation on the multi-level perspective. The transition model generally has four phases (Loorbach, 2010; Rotmans et al., 2000; Rotmans et al., 2001), as can be seen in Fig. 3: the pre-development phase, the take-off phase, the acceleration phase and the stabilisation phase. In the *pre-development phase* there is a change in the system, but this change is not visible for the outside world. In the *take-off phase* the process of change receives a boost. In the *acceleration phase*, change takes places through a reaction of multiple changes, like institutional and social changes, and their reaction to each other. In the *stabilisation phase*, the rate of change diminishes and an equilibrium is reached. The S-curve in Fig. 3 shows how an ideal transition develops. Usually a transition takes place with more disturbances and there is less certainty in how the transition will advance (Grin et al., 2010).

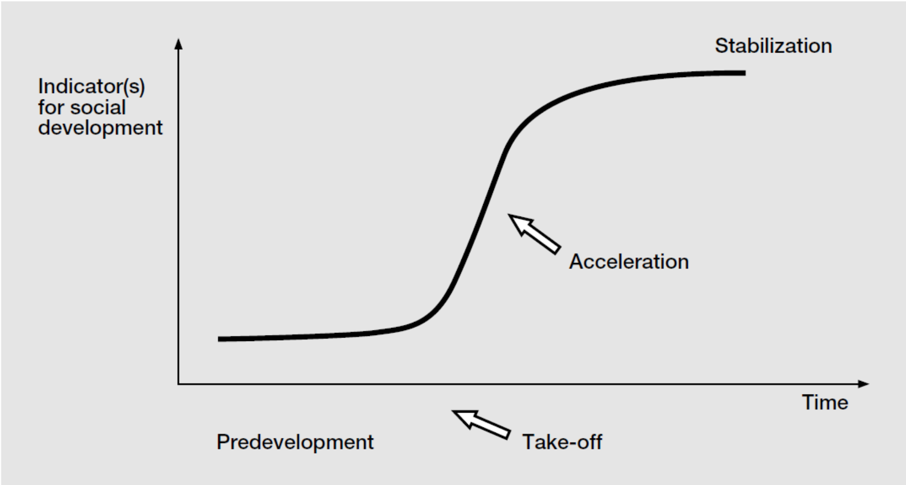


Figure 3: Phases of a transition (Rotmans et al., 2001)

2.3 Transition management

Transition management attempts to guide societal subsystems in the right direction in order to go towards sustainability and focuses on experimentation and learning with the purpose to explore how the transition can be controlled (Loorbach, 2010). It is more about influencing and adapting the transition rather than controlling it, because it sees sustainable development as a long-term aim (Kaphengst & Velten, 2014). The transition management seeks to work towards a transition by using strategic visions and actions (Laes et al., 2014).

Transitions take place among others in so-called *socio-technological systems* (Geels, 2004; Weber, 2003). With this Rip & Kemp (1998) emphasise that society and social factors have influence on the technological system. The EU's energy supply could be defined as a socio-technologic system (Laes et al., 2014). Markard et al. (2012) further talk about *transitions of socio-technological systems* where institutional structures and user practices change. In addition, *sustainability transitions* are mentioned. Such a transition implies that socio-technical systems enter a stage of more sustainable production and consumption. Pisano et al. (2014) mention that a sustainability transition has to be on a variety of levels and on a multitude of systems, such as energy and production, in order to happen. It is also important that values change and how sustainability is regarded, because when this is not the case, sustainability is difficult to obtain (Kemp & Van Lente, 2011).

2.4 Applying transition theory and transition management to the EU

This subsection applies the theory of the previous subsections to the EU. Transition theory, consisting of the multi-level perspective and the transition phases, together with transition management, are used as a perspective to understand a complex process, i.e. the process of the energy transition in the EU.

Part of this thesis is to present a strategy for the EU, which functions as a roadmap to 100% renewable energy in the EU. The strategy is based on the idea that a prioritisation of RES throughout the EU is more efficient and effective than a focus solely on national scale. Transition theory and transition management offer insights in how this strategy should look like. Coenen et al. (2012) talk about a *geography of transitions* with which they point out that when the different levels are used there is generally no clear fencing off of geographical boundaries. They state that further research could show benefits of more directed geographical boundaries. Grin et al. (2010) have suggested that the levels of the multi-level concept are rather functional and not spatial or geographical. Nevertheless, in this thesis, the macro-level, the meso-level and the micro-level specify respectively the EU level, the national (Member State) level and the local level. These are geographical boundaries, but they are more than just that. Each level has its own function and power. Therefore, it is possible to use these levels in accordance with the view of Grin et al. (2010). These levels interact which each other and all play their own role within the transition. Transition theory explains how the interaction between the levels look like and what kind of influence the levels have on a transition and on each other (Geels, 2011). With an adoption of the multi-level perspective on the energy transition in the EU, the role of the EU, the Member States and the local level can be defined. As a transition is a long-term process, the transition phases should be applied to the energy transition of the EU as well. In each phase, each level fulfils a different role. This study comprehends what actions are undertaken in or by the different levels. For instance, the implementation of a new policy at the EU level can be pinpointed to a certain phase. The next paragraphs give examples of how the multi-level model, the transition phases and the transition management are resembled when applied to the energy transition of the EU.

In the multi-level model, the EU has influence on Member States and the local scale by implementing regulations and rules. These can trigger breakthroughs for niches, which causes them to reach the regime level. For example, if it is decided at EU scale that renewable energy will get more political attention, innovations at the local level have more chance to breakthrough and eventually be applied at a national level. In more detail, wind energy might not be economic viable in a Member State and wind turbines are only constructed in areas with the highest yield. With a EU directive which obligates to have more renewable energy, the Member State starts to subsidise wind energy, making it possible for wind energy to be applied on a national scale.

Transition phases in the EU might look as follows. At local level, innovation may take place in small research places. However, innovations are more likely to breakthrough when the conditions are right. These conditions could be set right by EU policy (e.g. the EU makes rules that renewable energy should be subsidised). In this case a take-off of the innovation could take place, as the conditions are favourable. A new type of wind turbine might have been too expensive before, but the EU subsidy could make it possible to sell these turbines on the market. As the subsidy made the wind turbines cheaper, demand grows. And as demand grows, the price falls even lower, which in turn makes it possible for Member States to construct the wind turbines on a large scale. Ultimately, the market is satisfied and the stabilisation phase is reached. Fig. 4 depicts how this process would develop.

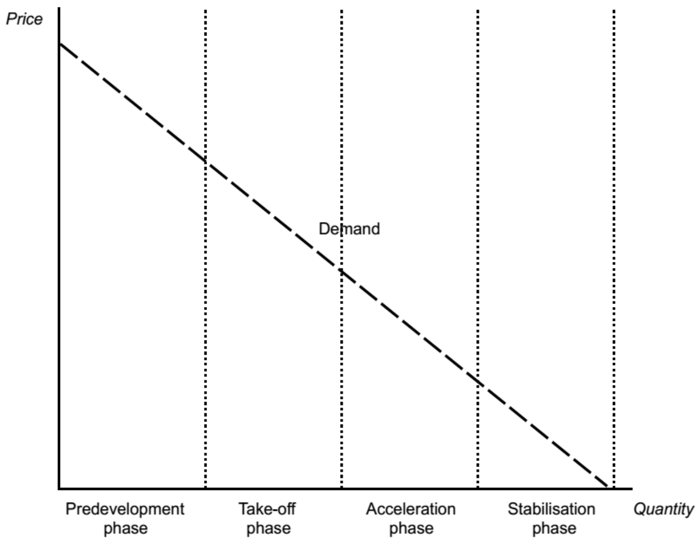


Figure 4: Price and quantity of wind turbines throughout the different transition phases

As mentioned before, transition management is about guiding transitions in the right direction. Transitions are seen as a long-term aim and transition management guides such aims. The RED can be seen as such a long-term aim. Transition management is also about influencing transitions. The directive does not control the transition, as Member States are free to choose how they will achieve the target mentioned in the directive.

2.5 A conceptual energy transition model for the EU

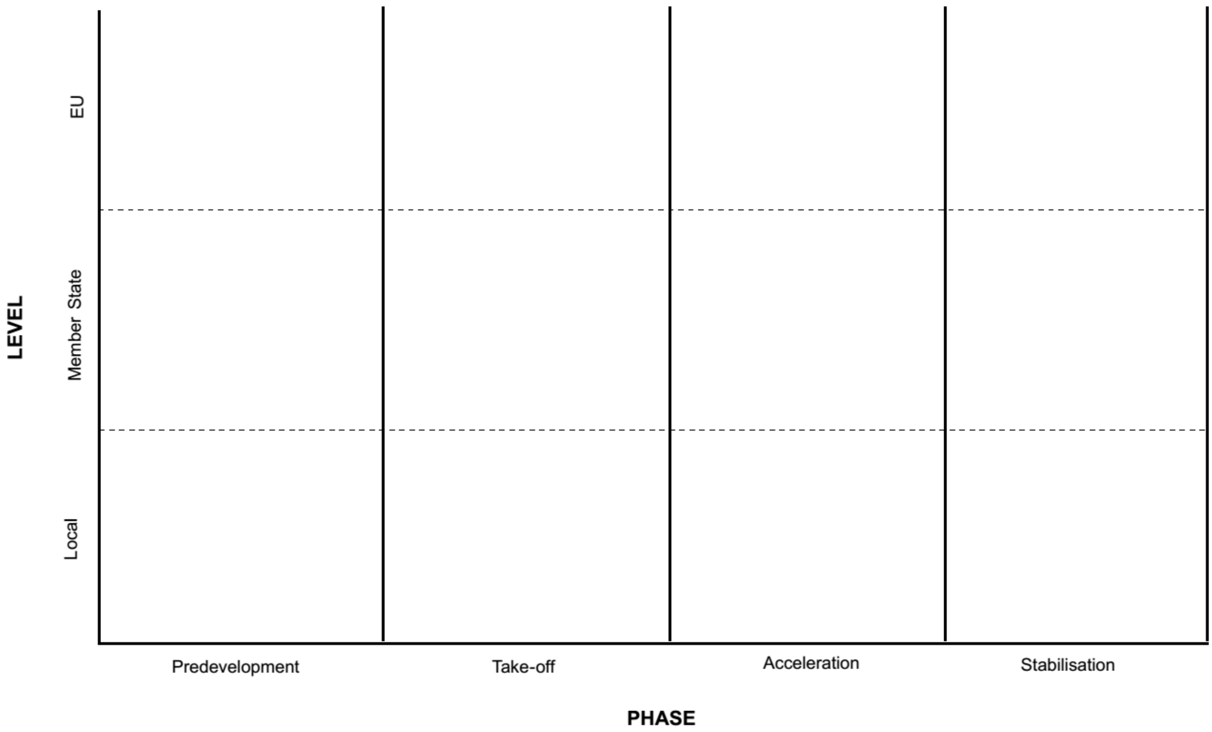


Figure 5: Conceptual model for the energy transition in the EU

The following model combines the three different levels and the four phases of transition theory, while adjusting for an EU scenario. The model is partly based on the model made by Geels (2011). The model is empty for now, but the strategy that is laid down in Section 7 aims to fill it. The hypothesis is that the model can be filled by various tasks for the three levels. In each phase, the task and the role of the levels are different. It is assumed that an interaction and cooperation between the three levels can lead to 100% renewable energy in the EU.

2.6 Beyond spatial planning?

This thesis is written from the view of a planner and therefore focuses on the function of space and how renewable energy can be optimally allocated in this space. There are however many other disciplines that are of importance. The knowledge of the author on these subjects is not sufficient to analyse their roles. The author realises that policies and laws are not easily implemented and above all not in a short time frame. Financial aspects are also of significant concern. The energy market is a complex system and any changes (e.g. new policies) in the system should be carefully deliberated. Additionally, new energy structures might not be prioritised in times of economic regression. Knowledge of physics and mathematics are essential for calculating precise yield and potential of RES. These disciplines, together with other ones, are crucial for innovation and finding new technologies. Also power positions of major fossil fuel companies might hinder the transition to RES, especially when fossil fuels are 'far' from being depleted. Even though the 20% target motivates countries to take action, politicians might be reluctant, as a transition aims at the long-term, while a politician might only focus at the short-term. In short, a spatial perspective is by no means enough to comprehend the full complexity of the transition towards renewable energy. However, it can define what renewable energy structures should be build when and where to boost the energy transition.

3. Methodology

This thesis consists of mixed methods. This this study includes an extensive analysis of literature on transition theory and transition management in order to form the theoretical framework. Laws and policies are reviewed to understand the functioning of the EU and the legal status of the RED. To estimate the yield of RES maps and equations are used. Furthermore, a qualitative case study is carried out with the aim to understand yield differences between Member States.

3.1 Data collection

Literature about the theory is collected by using the search terms ‘transition theory’, ‘energy transition’, ‘transition management’, ‘sustainability’, ‘renewability’, ‘sustainable energy’ and ‘renewable energy’ with, and without the combination of the search terms ´EU´ and ´European Union´ on scientific websites such as Taylor & Francis, Web of Science, ScienceDirect and JSTOR.
A selection for transition theory and management was made on basis of how often certain authors appeared in the search results. Names that frequently appeared were Geels, Loorbach, Kemp and Rotmans. Additional literature that was found repeatedly referred to at least one of these authors. Therefore, literature of these authors is used as a basis for the theory. Additional literature was used to get a better understanding of the theory or if it was relevant for the EU or renewable energy in particular. No special selection criteria were used for the latter.
For sustainability and renewability, the collection of literature was done more loosely. The main point here was to compare multiple definitions of sustainability and renewability to illustrate that there is no real unanimity in what both entail. However, it was essential to also include data from the EU on this topic.

Laws, policies and directives could be gathered directly from EU websites. For the case studies such information was found on both EU websites and websites of the relevant countries. NREAPs were found on EU sites. Evaluation reports were needed to compare the NREAPs. The preference was to find one evaluator of both countries. The preference was to find an independent evaluator, as research founded by a certain organisation could be biased towards the interests of this organisation. The organisation that was found is the Green European Foundation (GEF), which met the criteria.

Maps to explore the yield and to determine whether geographical location matters for RES were difficult to find via scientific search engines. Therefore, non-scientific websites and search engines purposed to fill the gaps. As it is not always possible to verify how the maps were made and on basis of what data, the preference was given to maps from the EU itself. Such maps were not always present. If maps from the EU were lacking, others were picked on basis of completeness. This means that the map displays data for each Member State. This is not a strict criterion and therefore the selection is subject to arbitrariness. However, regarding geographical location the same conclusions can be drawn from any map, albeit that the numbers in terms of yield may differ.

- For wind energy, maps with average wind speed per year were searched. In general, the higher the wind speed, the more energy can be generated by a wind turbine. An average wind speed is more useful than a maximum or minimum wind speed, as they could be only apparent in a short time span. This would not be a good indicator for favourable wind turbines sites.
- Maps with solar radiation per year were sought for solar energy. Radiation is the energy that the sun radiates on the surface of the planet. More of this energy, would indicate a greater potential for solar panels.
- For geothermal energy, maps that indicate the yield or the potential were looked for.
- For hydro energy, maps that indicate the yield or the potential were sought.

3.2 Use of methods

With these collected maps, the spatial potential of RES could be analysed. This was done on basis of observation. Observing the maps is adequate to attain information about the spatial aspects of RES. However, other factors besides space also influence the yield of RES. Therefore, for a more detailed study, calculations were made, which were based on the equations shown below (the equations are discussed in detail in section 5). These calculations demand data. Requirements for the data were not very strict (i.e. the first plausibly reliable data that were found, were used), as the main purpose was to clarify whether the different variables matter spatially. Important is consistency, so only one equation was used per renewable energy source.

For wind energy the equation is (The Royal Academy of Engineering, 2016):

$$P = \frac{1}{2}\rho A v^3 C_p$$

Where
P = Power (W)
ρ = Density (kg/m^3)
A = Swept area (m^2), which is calculated with π * blade length^2 (here this is π * 52^2)
v = Wind speed (m/s)
C_p = Power coefficient, tells how efficient a wind turbine converts wind energy to electricity.

For solar energy the equation was (Photovoltaic software, 2014):

$$E = A * r * H * PR$$

Where
E = Energy (kWh)
A = Total solar panel area (m^2)
r = Solar panel yield (%) electrical power (in kWp) of one solar panel divided by the area of one panel
H = Annual average solar radiation
PR = Performance ratio, coefficient for losses

This thesis offers a limited space for study. For this reason, calculations for hydro and geothermal energy were not included. Another reason was that calculations of these types of energy are more complex. More importantly, calculations are not necessary as the maps give enough information for this thesis.

With the maps, the equations and the data used for the equations the first research question 'What is the influence of geographic location on the yield of wind energy, solar energy, geothermal energy and hydro energy?' could be answered.

Two EU Member States were examined to find out whether the provided measures of the NREAPs are sufficient to meet the target. The case study had as goal to understand why some countries are successful and others are not in achieving the renewable energy target. NREAPs were compared to look at what type of measures both countries undertake to achieve the target. This comparison was done on basis of evaluation reports. In this way the second research question 'How can the differences between Member States with regard to the 20% renewable energy target be explained?' could be solved.

The different types of renewable energy were prioritised per country. Prioritisation was done by comparing the median yields the maps provide. For example, a country that has a yield above the median for solar energy, but below for wind energy, had wind solar energy prioritised over wind energy. Estimation was done by means of observation of the Maps. For example, the map with wind speed displays the wind speed differentiations throughout the EU and not the average per country. Therefore, the average was estimated for each country. The same was done for the other RES. The estimates were then compared with each other and a prioritisation followed. The prioritisation looked at each estimate of renewable energy and selected the highest estimate as the first priority and the lowest as the last priority.

Table 1 summarises Section 3.

Number of research question	**Research question**	**Strategy to answer**	**Data sources**
1	What is the influence of geographic location on the yield of wind energy, solar energy, geothermal energy and hydro energy?	Explore academic literature to form an understanding of the energy sources, use maps and equations to estimate the yield and the importance of location of each energy source.	EU maps, other maps, academic literature, equations either academic or non-academic.
2	How can the differences between Member States with regard to the 20% renewable energy target be explained?	Compare measures of NREAPs and their effectiveness.	NREAPS, evaluation reports, policies of Member States, news websites.
3	How can certain types of renewable energy be prioritised in the Member States?	Link the results to form a strategy, use Table 6 to prioritise energy sources.	EU policy, EU law, academic literature.

Table 1: Overview of research questions and how and with what to answer them

4. The functioning of the EU

4.1 Primary sources and secondary sources of EU laws

The importance of describing the following lies therein that the sources of EU law all have a different effect. One is not as binding or compulsory as the other. This has implications for sustainable energy, as a stimulus to invest in sustainable energy might not be enough.
The following lists all the sources of EU law. Not all are relevant, but a discussion of only the relevant law does not give a full picture of the legislative system of the EU and might therefore lack in giving a complete understanding of EU law.

4.1.1 Primary law

Primary sources of law in the EU are (Eur-Lex, 2015a):

- Treaty on European Union.
- Treaty on the Functioning of the European Union.
- Charter of the EU on fundamental rights (Art 6, EU).
  (+ General principles of EU law and International treaties)

4.1.2 Secondary law

Secondary sources of law in the EU are more important in the sense that they can directly or indirectly obligate member states to follow the will of the EU. The secondary sources are (Eur-Lex, 2015b; EU, 2015e):

- Regulations: Are the same in their effect as a national law and apply directly to all the member states. Therefore, the status is higher than the national law. One can directly base itself one a regulation at any court of the union.
- Directives: Are equally strong as regulation, but there is a difference. A directive says how the law should work, which implies that it has to be transferred into a national law. It gives an order to the member states to set a law. When a country does it wrong or too late, then the directive automatically has the status of a regulation.
- Decisions: Are specifically addressed to e.g. a country or a company and are only binding for the addressee and are directly applicable.
- Recommendations: Allows the institutions to make their views known and to suggest a line of action without imposing any legal obligation on those to whom it is addressed.
- Opinions: Allows the institutions to make a statement in a non-binding fashion, in other words without imposing any legal obligation on the addressee(s).

4.1.3 Relevant EU law

Primary sources are not relevant with regards to renewable energy measures, because they are focused on the general functioning of the EU. However, it shows that renewable energy is not a community task. Community affairs are those affairs that are determined on a EU-level and where Member States transfer power to the EU (Europa Nu, 2016).

The RED is currently the only binding secondary source with respect to renewable energy (EC, 2016c; Eur-Lex, 2016a). There are other secondary sources about e.g. the energy market and energy efficiency. However, they are not concerned with renewable energy production (at least not directly). This means that the directive is the only legislation in place regarding renewable energy.

4.2 Institutions of the EU

EU policy, law and regulations are made by institutions that are part of EU. However, not all institutions have the power to do so. As some institutions have political power to influence the energy transition in the EU (think of the RED), they will be briefly discussed. In the EU there are seven institutions (besides these there are also two advisory committees and thirty agencies and decentralised bodies, but since they are not engaged with the legislative process, they will not be discussed), four which are political, and three which are not.

The first four are (EU, 2015c):

- European Commission (EC): can be seen as the government of the EU, it represents the interests of the EU as a whole.
- The European Parliament: represents the people of the EU.
- Council of the European Union: comprises the ministers of each state who meet to discuss and decide specific policy on external (foreign) relations, economic & financial affairs, transport, energy, agriculture, etc.
- European Council: consists of the head of states, provides impetus and defines political priorities.

The first three of these institutions form the so-called 'institutional triangle'. This triangle decides what the secondary law of the EU is going to be. The EC is the only one that has the power to do a proposal for a law. If the council of the European Union and the European Parliament agree with the proposal, then there is a new regulation or directive.

There are also three non-political institutions (EU, 2015c):

- European Court of Justice: interprets what the idea of Treaties is.
- Court of Auditors: monitors the expenditures of the EU.
- European Central Bank: realises that there is no inflation.

Thus the EC, the European Parliament and the Council of the European Union implemented the RED. As stated before, a directive is binding. Section 4.3 will explain what this implies for Member States that do not have 20% renewable energy in 2020.

4.3 Legal status of the Renewable Energy Directive

RED binds every country to determine how it will achieve the set goal of 20% renewable energy. Because each country is different, the path to meeting the directive is also different for each country. That is why all member states outline in a National Renewable Energy Action Plan (NREAP) how they will achieve 20 percent renewable energy (EC, 2015g).

In 2014, the EU as a whole had 15.3% renewable energy (Eur-Lex, 2016b). It is forecasted that 25 of 28 Member States will meet their target, 19 of which will reach a renewable energy share beyond their target (Eur-Lex, 2016b). Fig. 5 shows the renewable energy share for all Member States and the EU as a whole in 2014 and the 2020 target.

The assumption in this research is that space matters for the potential of renewable energy. For example, in Sweden, which has the most renewable energy in the EU (EC, 2016d), 95% of the renewable energy is hydro energy (Swedish Institute, 2016). Such hydro energy potential is not present in most Member States. Other Member States have different potential (which is elaborated on in Section 5), and making good use of this potential can help in achieving the target.

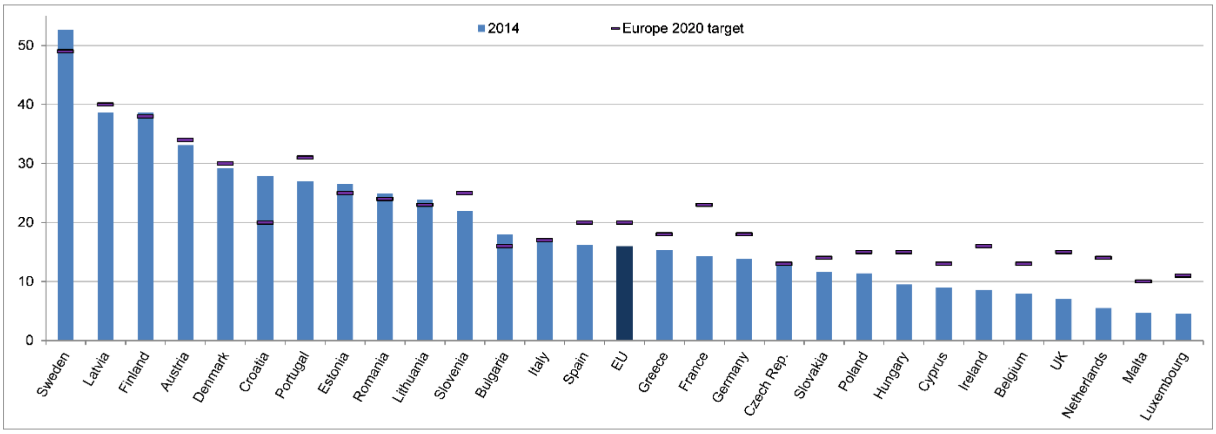


Figure 6: Renewable energy share in the EU in 2014 (EC, 2016d)

What can happen when a member state does not achieve the goal? The EC or a member state can bring a legal proceeding before the Court of Justice of the European Union. When the EC starts proceedings it first has to give the member state a reasoned opinion. When the Member State does not change its situation with respect to the obligation, the EC can go to the Court of Justice of the European Union. In case that a Member State initiates proceedings, it first goes the EC. The EC considers the arguments of the Member State that wants to start proceedings. If the EC regards the arguments as sufficient, it sends a reasoned opinion. After this procedure, proceedings may begin (Eur-Lex, 2015b).

When the Court of Justice concludes that there is indeed a failure to fulfil an obligation, it presents a set of measurements that should be taken by the member state. If there is still no improvement, then the Court of Justice may enforce a penalty in money (Eur-Lex, 2015b).

5. Yield of renewable energy sources throughout the EU

This section analyses the importance of location for the yield of wind energy, solar energy, geothermal energy and hydroelectric energy in the EU. One could argue that renewable energy construction costs differ per Member State, and that thus location is also of influence for those costs. From this point of view, one could try to allocate certain energy structures only in countries with low construction costs or as much as reasonable feasible. However, a study of IRENA (2015) showed that from the countries it analysed (included EU countries were Austria, Denmark, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain and Sweden and the United Kingdom), Austria had the highest average wind turbine price in 2010, while Ireland had a relatively low average wind turbine price in the same year. As Map 2 shows, Austria is not very suitable for wind energy, whereas Ireland has great potential for wind energy. The report indicates that there are also cases where the countries with considerable potential also have low energy construction prices. As such, it would not be necessary to look at the financial aspects of location, as Member States with high yield could also have low construction costs. For this reason, an analysis of the financial aspect of location is excluded. In addition, according to Creutzig et al. (2014) investment in renewable energy in the European periphery could work as an economic stimulus and have positive effects such as improvements in employment opportunities. However, if the aim would be to pursue relatively cheap energy constructions, some of the countries in the European periphery would be neglected and thus there would be no economic boost for these countries. For instance, the cost of onshore wind in Bulgaria and Romania is higher than in the UK, France, the Netherlands, Denmark (WEC, 2013).

Section 5.2-5.5 discuss for each renewable energy source in what way location matters for the yield. However, energy structures cannot just be built, as laws, regulations and policies might prohibit construction in certain areas. Wind energy (Section 5.2) will be used to exemplify what restrictions can show up in finding suitable sites.

5.1 Spatial relevance of renewable energy sources

As stated in section 2.1 not all energy sources matter spatially. Spatial relevance refers to the varying yield of RES based on location. RES that have an 'independent' yield, but are on the list of the EU, are: aerothermal energy, hydrothermal and ocean energy, biomass, landfill gas and sewage treatment plant gas and biogases. In the following there will be short overview of these energy sources, to outline why a spatial analysis is not required.

'[A]erothermal energy' means energy stored in the form of heat in the ambient air' (EUR-Lex, 2009, p. 27). Here, heat is generated by using the calories in the air that are produced by solar radiation (Repsol, 2015). A heat pump placed near e.g. a home obtains the air and utilises said calories to heat a liquid (Repsol, 2015). The heated liquid is then distributed throughout the building.
This renewable energy source is not as much dependent as wind energy and solar energy on geographical and meteorological circumstances. However, climate does matter (Shibata, 2011). In a warmer climate the captured temperatures are higher. Spatially, there are not any further recommendations as the method is usable to -20 °C and is therefore in most Member States of the EU. In some Member States, the temperature might drop below -20 °C. However, even then this temperature does not occur throughout the year and thus aerothermal energy might still be useful.

'[H]ydrothermal energy' means energy stored in the form of heat in surface water' (EUR-Lex, 2009, p. 27). Hydrothermal energy is a subdivision of geothermal energy. Geothermal energy is discussed as a whole in Section 5.4.

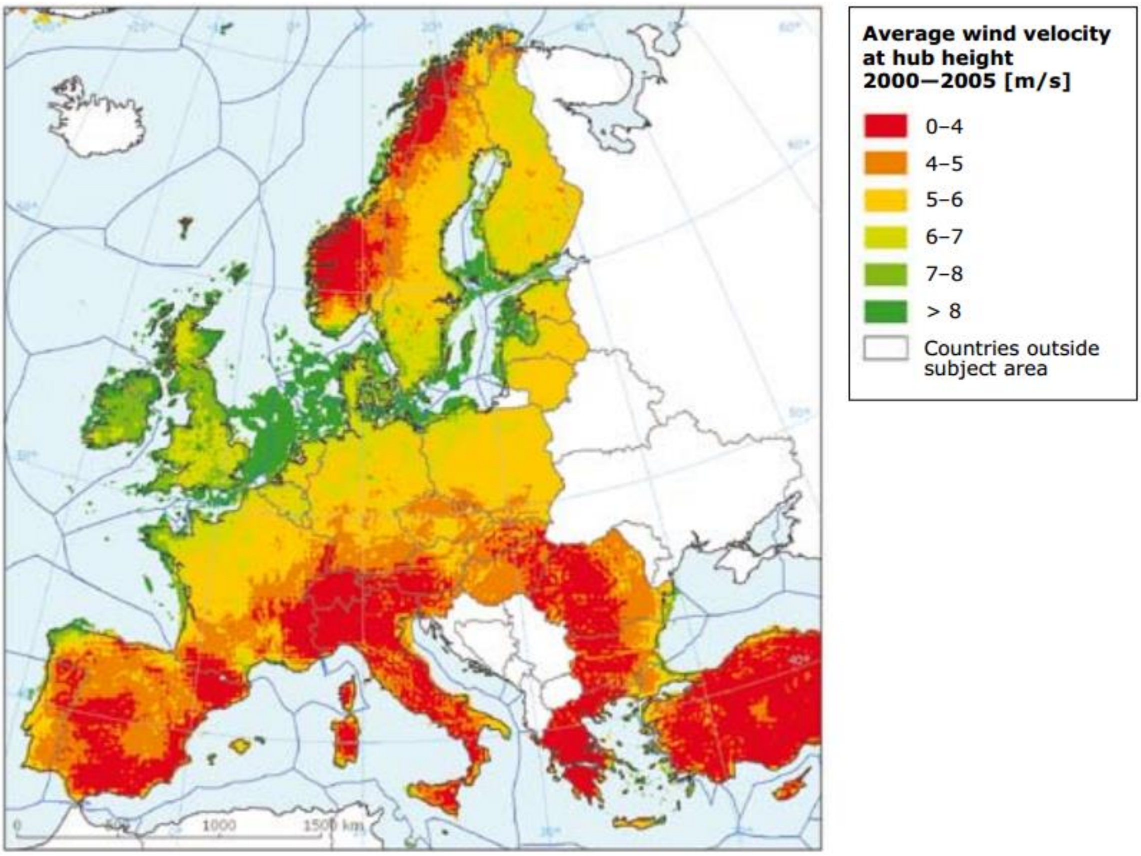
'[B]iomass' means the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including

fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste' (EUR-Lex, 2009, p. 27). Landfill gas is a subgroup of biogas. Landfill gases (LFG) are produced when organic waste is degraded naturally. The waste is disposed by burial.
According to the EC (2015a), biomass can account for two-thirds of the renewable energy target in 2020, if the biomass doubles. As biomass from forestry and waste is relatively stable over time, most potential lies in the biomass from agriculture.
Elbersen et al. (2012) divided biomass in three categories: forestry, waste and agriculture. The reason for this is that they have a distinct territorial element. Spatially, it is difficult to pinpoint certain areas that should contribute particularly to biomass production, as biomass 'can be found virtually everywhere' (Sijmons, 2014, p. 91). All EU countries have biomass to collect from all the mentioned three categories. Therefore, each Member State should look at its own potential with regards to biomass.

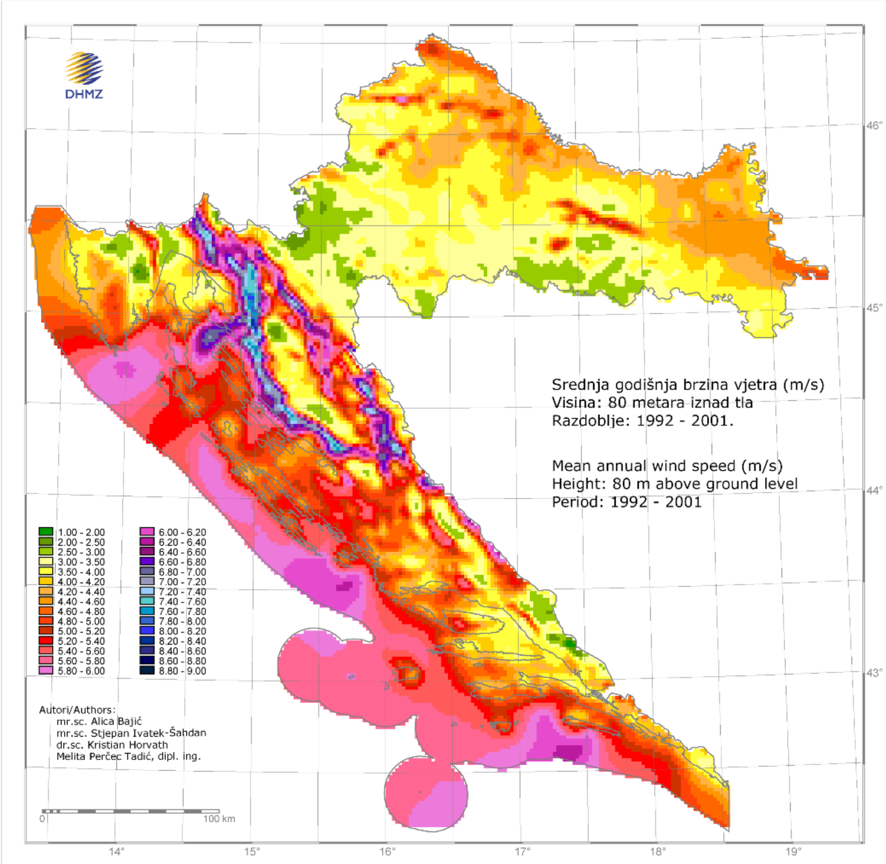
This leaves the following RES: wind energy, solar energy, geothermal energy and hydro energy. The next sections will analyse these energy sources in their spatial potential and yield.

5.2 Allocating wind turbines

Map 2 and 3 show the wind velocity at hub heights, which are 80 meter onshore and 120 meter offshore. As Map 2 does not include Croatia (because the map was made at a time when Croatia was not part of the EU), Map 3 is added. This map is from the Croatian Meteorological and Hydrological Service. Note that on Map 3, green indicates a low wind velocity and red only an average wind velocity.



Map 2: Average wind velocity in the EU (EEA, 2008)



Map 3: Average wind velocity in Croatia (DHMZ, 2016)

Wind speed matters, as twice the wind speed means eight times the energy (DWIA, 2013). Besides geographical location, height also affects wind speed. With greater height, more speed can be attained. It can be derived from the maps that West-Northern countries obtain the highest wind speeds and are thus favourable for placement of wind turbines, either offshore or onshore. With this observation, the first step is taken to allocate sites for wind turbines. With software such as ArcGIS (software that works with geographic information systems) criteria can be added, to look which locations are optimal for wind energy.

Engineer Live (2013) states that noise, surroundings, electromagnetic interference and the distance to the grid should also be considered. According to Renewables First (2015), one of the UK's leading consultancy on hydropower and windpower, a good windpower site should have the following five features: a high average wind speed, a distance of 250-620 metres depending on the turbine size, great connection with the grid, good accessibility of the wind turbine location, no special landscape or environmental designations. Yet these criteria are not enough, as each country has its own laws and policies. Even if criteria like distance to built-up areas might have a universal presence, the distance itself can be diverse. Above that, requirements or criteria do not have to be same for offshore and onshore energy.

To illustrate how far going criteria can go for wind turbine sites, the Netherlands is taken as an example. In the Netherlands several laws apply when one wants to build wind turbines RVO (2015). Province Gelderland (2014) made a list of the criteria while considering those laws:

1. Wind turbines should not be placed within 300 metres from residential buildings due to noise pollution.
2. Wind turbines should not be placed in silence areas.
3. Plans for wind turbines acknowledge Natura 2000 areas, areas that belong to the 'ecologische hoofdstructuur', valuable landscapes and bird areas.

4. Wind turbines are not allowed to be built in protected townscapes or villagescapes.
5. Plans for wind turbines acknowledge terrains with a high archaeological value.
6. Wind turbines are not allowed to be built in the proximity of fragile and not near areas where storage or transportation of dangerous substances takes place.
7. Plans for wind turbines recognise the current three-dimensional height limiting surfaces of the Inspectie Leefomgeving en Transport (ILenT) to guarantee the safety of airplane operations around civil airports.
8. Plans for wind turbines consider the current three-dimensional verification surfaces for communication, navigation and surveillance machinery, as determined by the Luchtverkeersleiding Nederland (LVNL).
9. Plans for wind turbines consider the current radar interference areas, as determined by the Ministry of Defence.
10. The distance between the centre line of the wind turbines and the centre line of the protected connection tracks is bigger than the rotor diameter, with a minimum of 35 metres.

Above all these criteria the land use plan of the involved municipality has to be changed and a permit has to be obtained in order to build wind turbines (Province Gelderland, 2014). In some cases, a 'milieueffectrapportage' has to be composed which shows the consequences for the environment before the decision is taken, i.e. to allow the construction of a wind turbine.
For wind energy on sea the rules are different. Wind turbines and wind farms may only be built on locations that are designated in a so-called 'kavelbesluit' (decision that determines where and under which conditions can be built) (Eerste Kamer, 2015).

The criteria, laws and regulations illustrate that one cannot build wherever and whenever and therefore it is not always possible to build in the areas with the highest yield. Some criteria, laws and regulations are the same throughout the EU due to EU Directives (Hansen, 2011). Examples are the Birds Directive and the Habitats Directive which prohibit the construction in certain areas (e.g. Natura 2000 areas). However, there are differences between Member States (Hansen, 2011). When each Member States maps the possible locations of wind turbines and other renewable energy structures, the EU has a better understanding of how prioritisation of renewable energy could take place.

To look at each country and its laws and criteria is also not the focus of this thesis. The aim is to look at what countries should have which energy constructions when focusing purely on yield. When building constructions in a country all the laws, rules and criteria that are valid should be considered. The European Environment Agency (EEA) (2009) supports this, as it mentions that wind energy potential is huge in Europe (the focus of the report was not specially the EU) and that evaluations should also be made at national, regional and local scales, which correlates with criteria such as mentioned in the Dutch example.

5.2.1 Calculating the yield of wind energy

The key point of this subsection is to make clear why geographical location matters by looking at the yields of different wind speeds. It also aims to clarify how wind power and wind energy is calculated and what different types of wind turbines could mean for the EU. The difference in yield between onshore and offshore wind turbines is discussed.

Before starting with the calculations, also the difference between energy, power and electricity will briefly be explained, as these terms are frequently used incorrectly. For example, an uninformed reporter might say that a solar farm generates a certain amount of megawatt per year. The following will demonstrate why this is false. *Energy* is a measure of how much fuel is contained within something, or used by something over a specific period of time. In other words, it is the capacity to carry out work. Watt-hour (Wh) and Joule (J) are units of energy. *Power* is the rate at which energy is

Box 1: Basic definitions and equations

Energy: the capacity to carry out work
Power: the rate of energy production or usage
Electricity: a form of energy

Energy = power * time
Wh = W * hours
Joule = Watt * seconds

Power = energy / time
W = Wh / hours
1 Watt = 1 Joule / 1 second

1Wh = 3.6 KJ
1J = 2.78 * 10^{-4} Wh

Amount of energy		**Rate of flow of energy**	
J		W	
kJ:	10^3 J	kW:	10^3 W
MJ:	10^6 J	MW:	10^6 W
GJ:	10^9 J	GW:	10^9 W
TJ:	10^{12} J	TW:	10^{12} W
PJ:	10^{15} J	PW:	10^{15} W

generated or used. Put differently, it is the rate at which work is done. Watt (W) is a unit of power. *Electricity* is a form of energy. Electrical equipment such as computers and coolers convert the electric energy into other forms such as heat or motion. Electricity can also be generated by wind turbines or by solar panels which take energy from the wind or the sun respectively and turn this energy into electricity. Although this might be a simplified explanation, it is sufficient for this study and to understand the next equations. Box 1 shows the basics that are required to grasp the rest of section 5.

The final energy consumption in the EU is around 12500 TWh (EC, 2013b). This number may differ each year, as strong winters result in a higher energy demand and hot summers increases the need for air conditioning.

On average a 2.5-3.0 MW wind turbine onshore produces more than 6 GWh a year (EWEA, 2016). The EU would need approximately 2.1 million of these wind turbines to be solely supported by wind energy.

The EU covers nearly 4.4 million km^2 (EC, 2016a) and thus a wind turbine on every 2.11 km^2 would be needed. To compare, in 2010 there were 70 488 onshore wind turbines and 1 132 offshore wind turbines in the EU (EWEA, 2016).

The data the Royal Academy of Engineering (2016) uses, gives the following equation:

P = Density (kg/m^3): 1.23kg/m^3
A = Swept area (m^2): 8495m^2
v = Wind speed (m/s): 12m
C_p = Power coefficient: 0.4

$$P = \frac{1}{2} * 1.23 * 8495 * 12^3 * 0.4 = 3.6\text{MW}$$

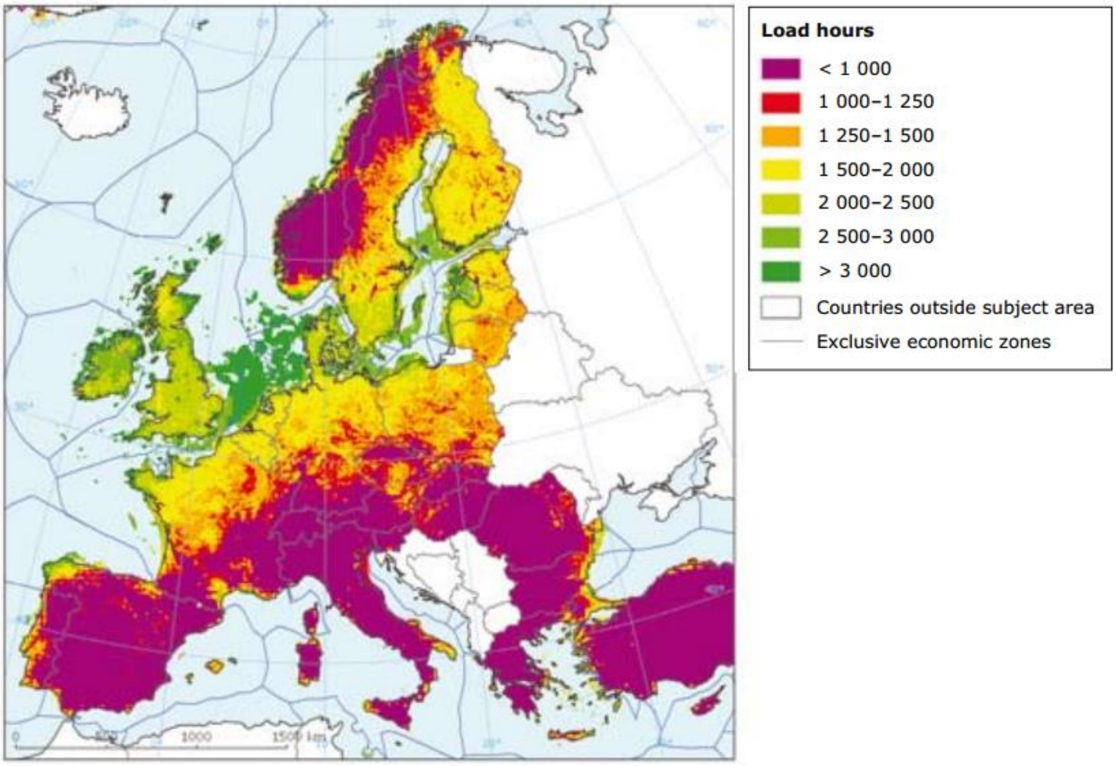
To translate this number to Watts it is necessary to know how many hours a year a wind turbine is operational. There are 8 760 hours in a year, but as the wind is not blowing constantly the total amount of hours a wind turbine operates is lower. The EWEA (2016) provides two average numbers (2.5-3.0 MW and 6 GWh), with them it is possible to calculate the average full load hours. Full load hours indicate the amount of time a wind turbine operates at full load. The average of 2.5-3.0 MW is 2.75 MW. This number is taken for the sake of simplicity.

Time = 6 000 MW / 2. 750 MW
Time = 2 182 hours

However, in an older report the EWEA (2009) states that the average full load hours are between 2 000 and 2 500. The value between these numbers is 2 250, which is close to 2 182. The RVO (2016), a

Dutch institution, which is part of the Ministry of Economic Affairs, uses 2 190 as an average. The EEA (2008) provides a map (Map 4) in its report with the full load hours throughout the EU. The load hours vary between 1 000 and 3 000. Graabak and Korpås (2016) assert that the average number is between 1 800 and 3 500. All numbers considered, the average of full load hours is around 2 250 hours and this number will be used for the next calculations. Note that full load hours are different per Member State. An example, which is elaborated on further below, emphasises the effect a difference in full load hours can have.

For offshore wind turbines, the average full load hours are almost 4 000 hours according to EWEA (2009), between 4000 and 5000 according to Graabak and Korpås (2016) and between 3 200 and 4 000 according to the EC (2014a). An average of 4 000 full load hours for offshore wind turbines is adopted for the calculations.



Map 4: Full load hours (EEA, 2008)

Table 2 presents the amount of wind turbines that are needed per type and the distribution per square kilometre. In addition, the number of households one wind turbine can support is added to the table, to put the number into perspective. However, to understand the amount of households one wind turbine can support, it is required to estimate the average household demand in the EU. As reported by the EWEA (2016), the average household demand is 4 000 kWh. The EC (2016b) mentions that a household demand varies between 2 500 and 5 000 kWh. Accordingly, an average of 3 750 kWh is selected.

The EWEA (2016) lists the power of several wind turbines: 2.75 MW, 7.5 MW, 15 MW, 20 MW and 3.6 MW for an offshore wind turbine. The problem with those numbers is that the calculation is already computed. Factors like wind speed and the size of the wind turbine cannot be retrieved. However, it is possible to calculate the energy output. The following calculates the output of a 2.75 wind turbine:

2.75 MW * 2 250 hours = 6.2 GWh

In addition, to take wind speed and the length of blades of the wind turbines into consideration, other calculations are included as well in Table 2. Different blade lengths and different wind speeds are used to resolve what the influence of both is on energy output. The following calculates the swept area for wind turbine with blades of 50 metres. Blade lengths are derived from the DWIA (2003b) and LM Wind Power (2016) The equation is acquired from the Royal Academy of Engineering (2016).

Swept area = $\pi * r^2$

Where
r = blade length

$\pi * 50^2 = 7854\ m^2$

This number can be used to calculate the energy production of the wind turbine. This example uses a wind speed of 4 m/s.

$0.5 * 1.23 * 7854 * 4^3 * 0.4 = 0.28$ GWh

To stress the importance of location, Spain and Ireland are taken as examples. Spain has an air density of 1.22 kg/m3 (see below how this number is attained), a wind speed of 4 m/s (EEA, 2008), approximately 1 000 full load hours (EEA, 2008), and a household demand of 3 944 (WEC, 2015). Ireland has an air density of 1.28 kg/m3 (see below how this number is attained), a wind speed of 8 m/s (EEA, 2008), approximately 3 000 full load hours (EEA, 2008), and a household demand of 4 723 (WEC, 2015). For both countries a wind turbine with a blade length of 50 metres is chosen.

Air density is calculated with the following equation (Jones, 1978):

$$\rho_{dry\ air} = \frac{p}{R * T}$$

Where
$P_{dry\ air}$ = Density of dry air (kg/m^3)
P = air pressure (Pa)
R = specific gas constant for dry air, 287.05J/(kg.K)
T = Temperature (°K: 273.15 + x°C)

However, the air always has some moisture, and therefore the calculation needs an extension (Shelquist, 2016). To find out the partial pressure of dry air and the partial pressure of water vapour there is yet again a need for new equations. For this study, the calculation of dry air is sufficient to know whether air density is of importance for wind energy.

The air pressure on 22 February 2016 was 1022hPa in Ireland and 1024hPa in Spain, the temperature was 6°C in Ireland and 19°C in Spain (Weather Online, 2016). With this data the air density can be determined:

Air density Ireland = 1022*100 / (287.05 * (273.15 + 6)) =1.275 kg/m^3
Air density Spain = 1024*100 / (287.05 * (273.15 + 19)) = 1.22 kg/m^3

Air density can now be entered in the equation:

Ireland: 0.5 * 1.275 * 7854 *8^3 * 0.4 = 1.03 MW * 3000 = 3.1 GWh (651 Irish households)
Spain: 0.5 * 1.22 * 7854 * 4^3 * 0.4 = 0.12 MW * 1000 = 0.12 GWh (31 Spanish households)

In Table 2, the examples of Ireland and Spain are applied to the average EU household demand, the other variables of the examples are kept the same.

Wind turbine	Average energy production in GWh	Amount of average EU households (3.75 Wh) supported with one wind turbine	Approximate amount needed for the whole EU	Distribution per km2
Average wind turbine (2.5-3.0MW)	6.2	1 653	1 991 544	2.2
Offshore wind turbine (3.6 MW)	14.4	3 840	857 470	5.13
High capacity wind turbine (7.5MW)	16.9	4 507	730 626	5.71
Future capacity wind turbine (15 MW)	33.8	9 013	365 313	12.04
Theoretical capacity wind turbine (20MW)	45	12 000	274 390	16.04
Blade length of 88.4 metres, v = 1	0.014	4	881 969 357	0.0050
Blade length of 80 metres, v = 1	0.011	3	1 122 506 455	0.0040
Blade length of 50 metres, v = 1	0.0043	1	2 871 528 140	0.015
Blade length of 88.4 metres, v = 4	0.87	23	14 192 610	0.031
Blade length of 80 metres, v = 4	0.71	19	17 390 945	0.25
Blade length of 50 metres, v = 4	0.28	7	44 098 468	0.19
Blade length of 88.4 metres, v = 8	7	1867	1 763 939	2.49
Blade length of 80 metres, v = 8	5.69	1517	2 170 048	2.03
Blade length of 50 metres, v = 8	2.23	595	5 537 027	0.79
Blade length of 88.4 metres, v =	23.48	6261	525 876	3.37

12				
Blade length of 80 metres, v = 12	19.24	5131	641 766	6.86
Blade length of 50 metres, v = 12	34.63	9236	356 516	12.34
Irish example (household demand EU)	3.1	826	3 983 087	1.11
Spanish example (household demand EU)	0.12	33	102 896 425	0.43

Table 2: Output of wind turbines in GWh, the amount of households they support, the amount needed for the EU and the distribution per km²

5.2.2 Spatial lessons

The previous sub-paragraph took wind speed, full load hours, air density and swept area into consideration for the yield of wind energy.
Wind speed is by far the most important factor for the output of a wind turbine. As stated earlier, multiplying the wind speed by two, results in an energy output that is eight times as big (DWIA, 2013). Since wind speed varies spatially (as shown on Map 2 and 3), it is crucial for determining sites with the most yield.

Full load hours vary between 1 000 and 3 000 hours in the EU (Map 4). Full load hours are therefore also an important factor to take into consideration. The maps demonstrate that the countries with the most favourable wind speeds, roughly also have the most favourable full load hours. This affirms yet again that location has an essential impact on the wind energy output.

Air density does not vary that much. According to the DWIA (2003a) the kinetic energy (the energy of motion) in the wind is determined by the density of air. The higher the air density, the more energy can be gained by a wind turbine. Air density is dependent on humidity, temperature and altitude. A higher humidity, a higher temperature and a higher altitude all result in a lower density (DWIA, 2003a). With temperatures around -40 °C, the air density can reach 1.514 kg/m3, whereas the air density reaches 1.109 kg/m3 with temperatures around 50 °C (The Engineering Toolbox, 2016). The effect of air density is therefore small.

Swept area, which is determined by the length of the blades, varies per type of wind turbine. A wind turbine with larger blades can generate more wind energy. The length of the blades is not geographically bound.

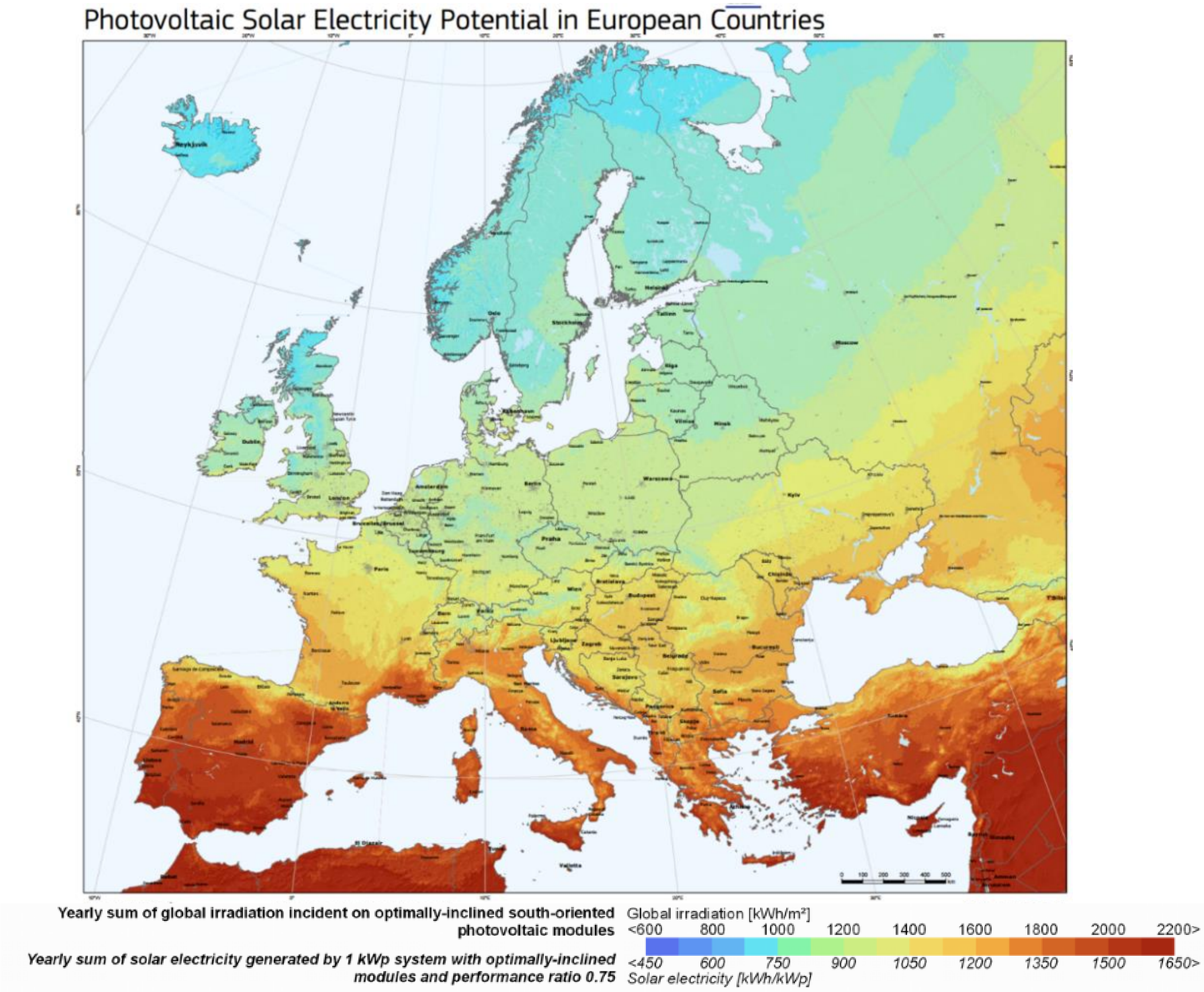
The spatial lessons that can be derived is that some factors are dependent on location (wind speed, full load hours and air density) and others are not (swept area). It is important to note that not all factors that matter spatially, also matter for the yield. Air density has relatively a low impact, and thus it has no benefit to determine locations based on this factor. However, determining locations based on wind speed and full load hours is beneficial as these factors influence the energy output the most. The EU would therefore benefit from strategically allocating wind turbines and farms.

5.3 Allocating solar panels

Map 5 illustrates both the irradiation in kWh/m^2 in a year and the yearly sum of solar electricity generated by 1 kWp (kilowatt-peak) system with optimal tilt (the degrees of which dependent on the average height of the sun throughout the year) and a performance ratio of 0.75 (the ratio of real output and the theoretical output).

When analysing the map, it can be derived that southern countries have more potential to generate solar power than northern countries.

In some cases, this is twice as much. The countries that have especially great potential are Portugal, Spain, Italy, Greece and the countries that also have great potential, although to a lesser extent, are Bulgaria, Romania, Hungary, Croatia, Slovenia and France. Considering Section 5.2, this is a convenient situation, because some of the northern countries are useful for wind energy, while the southern countries are useful for solar energy. A division of sustainable energy sites is therefore possible. However, to make such conclusions, a more detailed investigation is necessary. The next section will go into more detail of the potential of solar energy.



Map 5: Solar radiation in the EU (EU, 2012)

5.3.1 Calculating the yield of solar energy

The equation that is presented in Section 3 will be used to determine the output of (a) solar panel(s).

Wp (Watt peak) is the power of one solar panel in laboratory circumstances which are 1 Kwh/m2 and 25 degrees Celsius.

A = For simplicity the total surface of the EU will be picked, which is 4 000 000 km^2.
r = A solar panel with 315 Wp (0.315 kWp) and an area of $18m^2$ has an efficiency of 16.23%. Would the solar panel have the same Wp, but only an efficiency half as big as 16.23%, the area would be twice as big: $36m^2$. So with higher efficiency, less space is needed (Pure Energies, 2014).
H = The median of the average solar radiation in the EU is 1400 kWh/m^2 (see Map 5), this number will be included for now.
PR = This is the relationship between the theoretical and the actual output and depends on the type of solar panel and the place of the site (e.g. shadows of buildings could influence the PR). Here the default of 0.75 that Photovoltaic software (2014) uses, will be applied. The same default is used by Bhandari et al. (2015). In addition, Mondol & Hillenbrand (2013) use data that is provided by the EC, which refers to a performance ratio of 0.75.

Now that there is enough data it is possible to calculate the theoretical energy generated with solar panels in the EU:

$$4\ 000\ 000\ 000 * 16.23 * 1400 * 0.75 = 68 * 10^3 \text{ TWh}$$

Section 5.2 showed the final energy consumption of the EU, which is 12 500 TWh (EC, 2013b). The following calculation shows that the theoretical solar energy generated in the EU is more than sufficient to support the final energy consumption in the EU:

$$68\ 166 / 12\ 500 = 5.52$$

However, to find out the importance of location, further calculations are needed with other numbers for solar radiation. Also the effect of different efficiencies and performance ratios will be measured to find out whether their importance outweighs the influence of location or not. Efficiency and performance ratio are not bound geographically (although locally, the site of solar panels could matter for the PR) per se, but rather on technology (Chen et al., 2012). So the site does matter, but even countries with a high solar radiation have less appropriate sites. Technology is the determining factor for the PR.

CompareMySolar (2016) uses 6%, 12% and 18% to indicate low, medium and high efficiency respectively of solar panels. The NREL (2016) measured an efficiency of 46% of single cell. Solar cells are part of solar panels. Solar cells convert sunlight into electricity. Solar panels consist of several solar cells and a protective layer. Pure Energies (2014) argue that such techniques are too expensive, because manufactures have not yet found out how to convert these techniques in viable products for the market.

The range of solar radiation in the EU is between 600 and 2200 kWh/m^2 (see Map 5). For the next calculations 600 will be named low solar radiation, 1400 medium solar radiation and 2200 high solar radiation.

0.75 will be used as a medium PR in the next measurements, as multiple sources use this number as the default (Bhandari et al., 2013; Mondol & Hillenbrand, 2013). Reich et al. (2012) assert that solar panels with a performance ratio above 0.9 are realistic. This number will be used as a high PR. In Germany the PR ranges between 0.7 and 0.9 where the PR is lowest for the oldest (from 1994) solar panels (Reich et al., 2012). Woyte et al. (2013) listed the average PRs of among others Germany, France and Belgium. They had an average PR of 0.76, 0.78 and 0.84 respectively. France and Belgium had the same minimum PR of 0.52, while Germany had a minimum PR of 0.7. A PR of 0.60 will be chosen as a low PR, as this number is somewhat in between those minima and fits with the range of the numbers mentioned above.

In the next calculations the effect of solar radiation, efficiency and PR will be estimated. In those calculations only the variable that is analysed will differ. For the other factors the medium numbers will be used. The area is again the total surface of the EU. The author acknowledges that not all area can be used for solar panels. The results of the calculations are put in the table below (Table 3).

	Energy production in GWh	Km^2 area of the EU needed	% area of the EU needed
Low radiation	23 760	2 880 000	52
Medium radiation	55 440	968 000	22
High radiation	87 120	616 000	14
Low efficiency	27 720	1 980 000	45
Medium efficiency	55 440	968 000	22
High efficiency	83 160	660 000	15
Very high efficiency	212 520	25 564	5.8
Low PR	44 352	1 232 000	28
Medium PR	55 440	968 000	22
High PR	75 600	1 028 800	25.72
Every variable low	9 504	5 720 000	130
Every variable high	156 816	34 760	7.9
Radiation and PR high, efficiency very high	400 752	135 568	3.1

Table 3: Yield of solar panels with different radiations, efficiencies and PRs

5.3.2 Spatial lessons

The calculations of the previous sub-section presented variables that are of influence for solar energy output: the average annual solar radiation, the performance ratio and the efficiency of solar panels. Table 2 shows that solar radiation matters the most for the yield of solar panels. The outcomes demonstrate that a difference in radiation has the biggest effect on the yield (when disregarding the solar cell with very high efficiency).

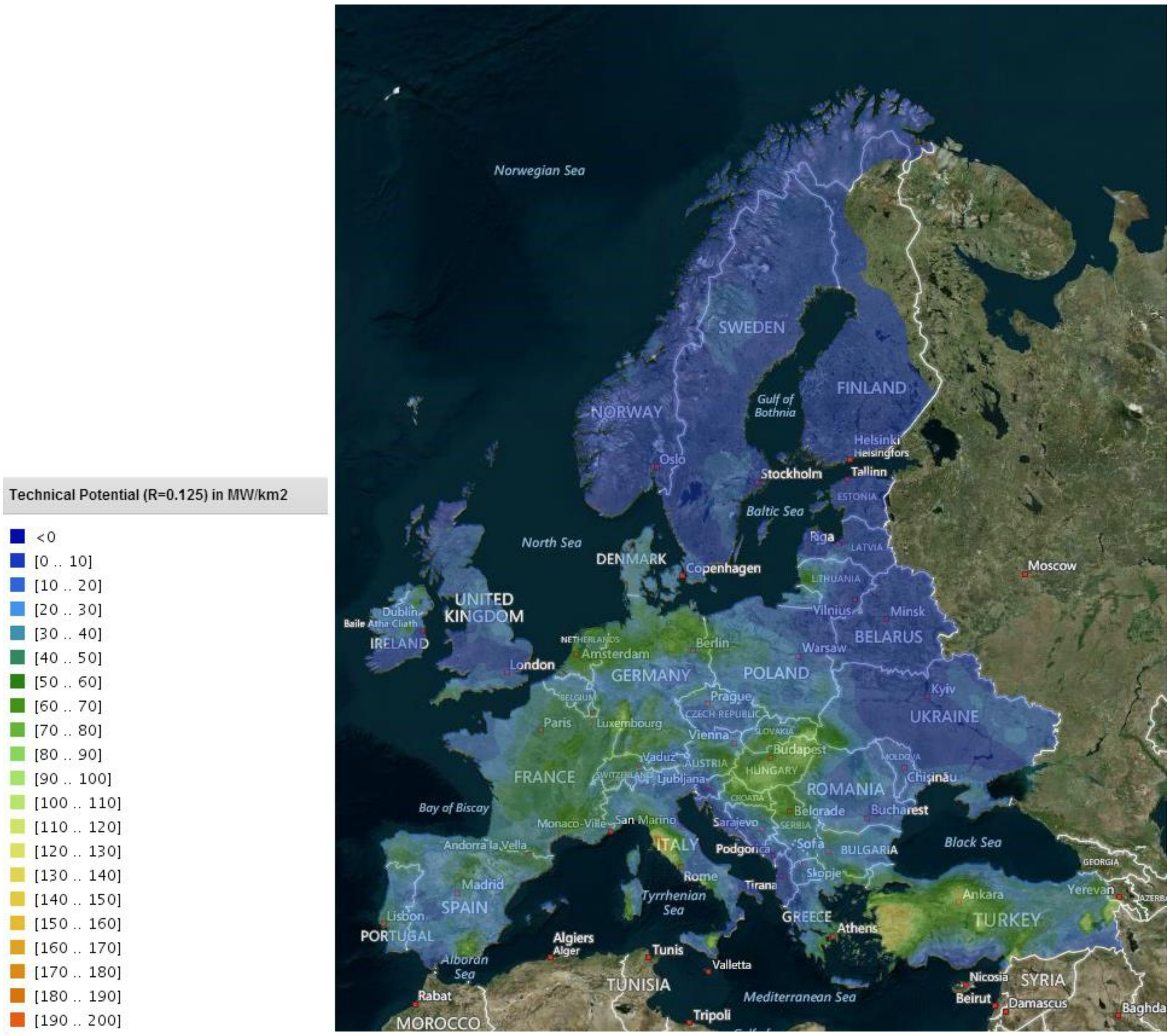
The PR is second in terms of impact on yield. Photovoltaic software (2014) asserts that the PR is 'dependent on the site, the technology and the sizing of the system' (p. 1). As stated before, Reich et al. (2012) affirm that PRs of above 90% are feasible. The research spoke about Germany, a country with only an average solar radiation according to Map 5. Apparently the PR is determined by technology rather than geographical location.

Efficiency has the lowest influence on the yield. Efficiency rates are also dependent on technology (Clover, 2015). In short, technology can alter how efficient solar radiation is converted and how well solar panels perform.
From Table 3, it is clear that location is crucial for the yield. A higher efficiency and PR both boost the yield, but radiation is the only one that cannot be influenced by technology. Just as with wind turbines, the newest and most efficient technologies could be used to gain greater yields. As these technologies can in principle be applied anywhere, one has only one factor left to keep in mind: radiation. Radiation differs throughout the EU, as is shown on Map 5. Locations with high radiation should be selected for the application of solar panels if one strives for the highest possible yield.

5.4 Geothermal energy

''[G]eothermal energy' means energy stored in the form of heat beneath the surface of solid earth' (EUR-Lex, 2009, p. 27). One advantage of geothermal energy is the constant presence of its availability, something that is lacking with other forms of renewable energy (Geo Energy, 2014). A disadvantage is that drillings are necessary to know the exact potential of a certain area.

There are two main categories, which are direct application of heat and electricity production. Direct application is diverse as it is used for heating of buildings, baths, window heating and greenhouses. Utilising the earth´s heat is possible almost anywhere in the world and is done mainly with geothermal heat pumps (National Geographic, 2015). However, geothermal electricity production potential varies, which is linked to geographical availability, but also to expensive drilling operations to reach deep into the earth (Watson, 2015). An area needs to have the following criteria of the underground rocks to be able to produce geothermal electricity: not too thick, so that drilling is possible, very high in temperature to power the turbines of the power plant and ample porosity so that water can be pumped through (Zactruba, 2010). In this study, the interest goes towards electricity potential.



Map 6: Technical potential of geothermal energy in the EU in MW/km2 (GeoelEC, 2016c)

Geoelec (2016b) provides a map (Map 6) with the calculated technical potential of geothermal in the EU. Geoelec (2016a) first calculated the heat in place. With the outcome they estimated the theoretical capacity by multiplying it with an electricity conversion factor. The result was used to determine the technical capacity by working with a recovering factor (R) which 'includes available land areas, limited technical ultimate recovery from the reservoir based on recovery of heat from a fracture network […] and limitation of operations as an effect of temperature drawdown' (Geoelec, 2016b, p. 1). The recovering factor is 0.125, meaning that 1.25% of the theoretical capacity of geothermal energy could be recovered.

The map displays that geothermal energy does not have as much potential as the other types of renewable energy that are analysed. Nonetheless, it is clear that some countries do have more potential than others, especially Italy and Hungary. It should be mentioned that data is missing for Cyprus, Finland (for some of the country) and Malta. However, none of these countries have the ambition to convert geothermal energy into electricity, which could be related to the lack of potential yield (see for Cyprus: Ministry of Commerce et al. (2010), for Finland: Ministry of Employment and the Economy (2010) and for Malta: MRA (2010)). For Finland this is specifically stated: 'Foreseeable technologies do not, regrettably, seem to make possible the use of geothermal energy in Finland' (Ministry of Employment and the Economy, 2010, p.27).

5.5 Hydro energy

'Hydropower is generated by first converting the potential energy stored in water into the kinetic energy of running water, which is then converted into electrical energy via turbines' (Eurostat, 2015, p. 1).

Precipitation has potential energy as the water can 'do work' when it flows through the valleys to the sea. Countries that are mountainous and have the necessary precipitation are especially feasible for making use of hydropower (GENI, 2007).

The main focus in the EU is to upgrade existing systems and develop newer and better technologies (Hydro World, 2009). The greatest expansions in hydropower production are expected in Spain, Portugal, Austria and Romania (Pedraza, 2015).

As the different types of hydropower technologies have different spatial implications, the main three will be discussed briefly.

In the case of run-of-river hydropower plants, water flowing downwards is diverted by a weir (a construction build across a river to change the flow of the river) and eventually led through pipes that go down the mountain to build up pressure. The pipes end in a power plant to turn on the turbines and the water is returned to the river.
Helston (2012) states that two geographical characteristics are needed for run-of-river power plants. The first is a substantial water flow that comes from either rainfall or melting snow. The second is enough pitch to boost the energy within the water.

Reservoir hydropower plants use water in reservoirs for electricity production. The reservoir offers flexibility, as there is less dependence on the variability of inflows. Many reservoirs are established by the constructing a dam. In some cases, natural lakes can be used as reservoirs. Water falling down the sluice produces the energy as it hits the turbines. The capacity of the water is determined by the available flow and the height from which it falls (USGS, 2015).

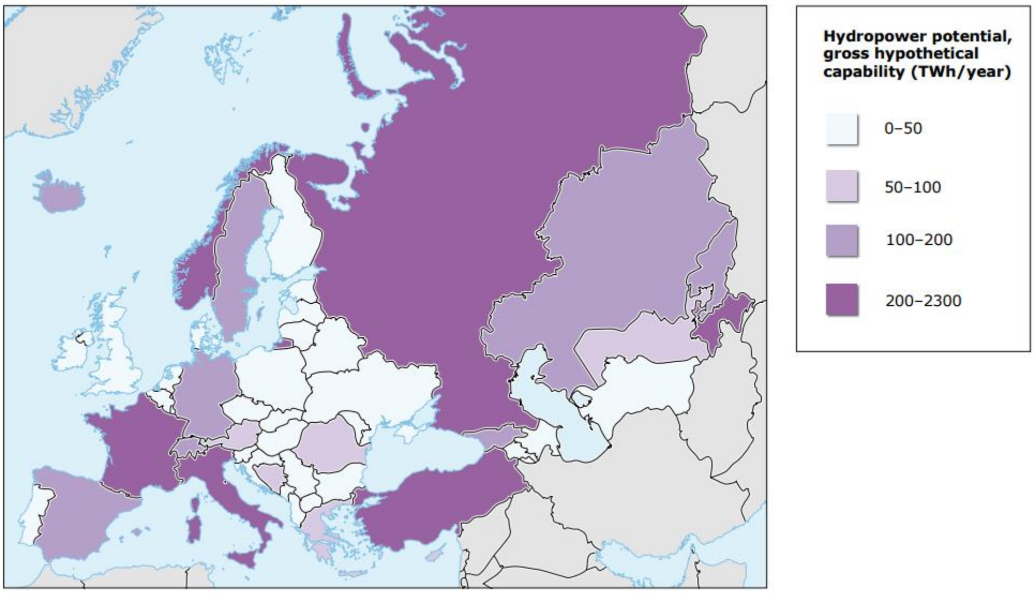
Pumped storage plants use electricity to pump water from a lower reservoir (also often created by dams) into an upper reservoir when there is more supply than demand. When the demand is high, the water is sent from the upper reservoir to the lower reservoir, where it passes turbines which produce electricity. Due to the dependence on electricity, pumped storage plants are not renewable by definition (IEA, 2010).

5.5.1 The potential of hydro energy

Calculations need to be made to know how much power there can be produced by a power plant in a certain area. The BCSEA (2015) provides a calculation to find out the power potential based on the geographical features:

P = Q * H * Gravity * Efficiency P = Power produced in kW Q = Water flow in m^2/s, H = Hydrostatic head (the pressure rise caused by gravity) of the water in m Gravity = Set at 9.81 m/s, because this numbers corresponds to the acceleration due to gravity (REUK, 2016)

Hydropower plants are able to convert 90% of the energy into electricity (RWE, 2016). This number can vary between 85% and 90%. However, smaller hydropower plants can have an efficiency as low as 50% (Sonu, 2011). As water inflow and hydrostatic head differ for each site, it is difficult to make meaningful calculations. However, the UNEP & GRID Arendal (in EEA, 2007) provide a map (Map 7) that displays the gross hypothetical capability in TWh/year, which refers to what 'could be extracted if all run-off was turbined down to the lowest level of the specified country (sea-level)' (GRID-Arendal, 2012, p.1). The calculations are made on basis of topography and precipitation in the countries.



Map 7: Hypothetical potential of hydropower (EEA, 2007)

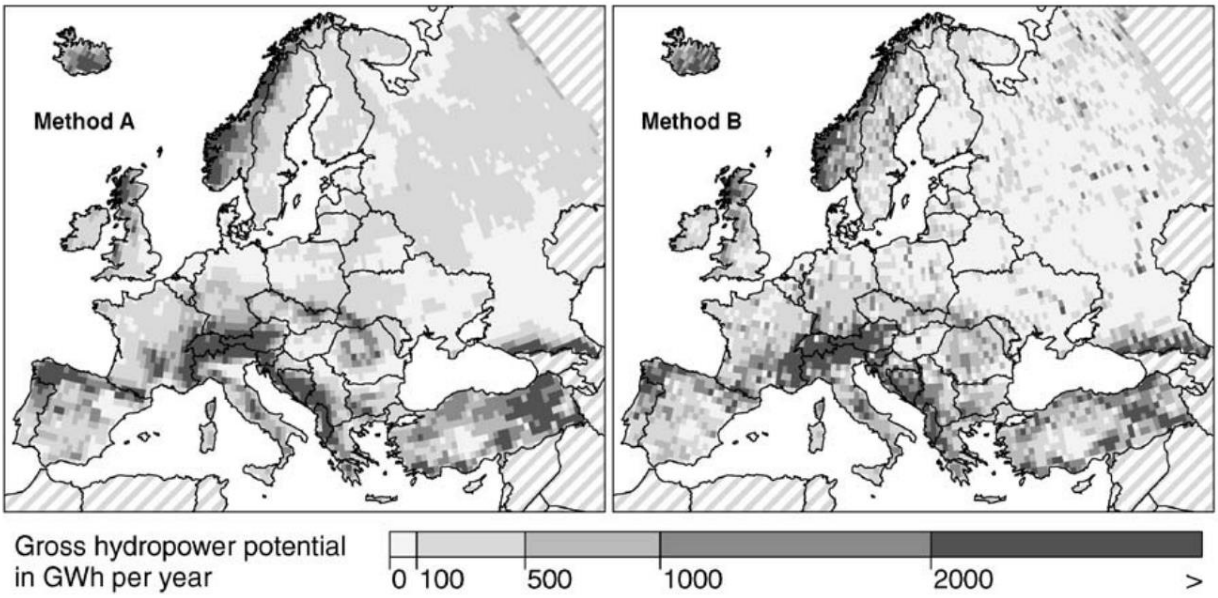
This information can be used to make calculations (Table 4). Three categories are made for each country. For example, '0-50' can be divided in 'low: 0', 'average: 25' and 'high 50'. At the end of the table the total energy, and the percentage it covers of the total EU demand, is presented. It seems that the EU cannot be provided solely with hydropower in contrary to wind and solar energy. The latter two can be placed anywhere, even when the yield is low, there is still yield. Hydropower does not have this opportunity. The total given capability could be lower, as it is only a hypothetical number.

	Low capability (TWh/year)	Medium capability (TWh/year)	High capability (TWh/year)
Austria	50	75	100
Belgium	0	25	50
Bulgaria	0	25	50
Croatia	0	25	50
Cyprus	50	75	100
Czech Republic	0	25	50
Denmark	0	25	50
Estonia	0	25	50
Finland	0	25	50
France	200	1250	2300
Germany	100	150	200
Greece	50	75	100
Hungary	0	25	50
Ireland	0	25	50
Italy	200	1250	2300
Latvia	0	25	50
Lithuania	0	25	50
Luxembourg	0	25	50
Malta	0	25	50
Netherlands	0	25	50
Poland	0	25	50
Portugal	0	25	50
Romania	50	75	100
Slovakia	0	25	50

Slovenia	0	25	50
Spain	100	150	200
Sweden	100	150	200
United Kingdom	0	25	50
Total TWh/year	900	3725	6550
% of the EU final energy consumption	7.29	30.17	52.05

Table 4: Hypothetical potential of hydro energy, based on data from EEA (2007)

Lehner et al. (2005) produce a more detailed map (Map 8). Here the potential of hydropower is based on average (1961-1990) runoff and discharge calculations. In Method A 'the gross hydropower potential, defined by a cell's runoff volume and its elevation difference down to sea level (or to the final basin outlet), is assigned entirely to the cell in which the runoff is generated' (Lehner et al., 2005 p. 848). In Method B 'only that portion of the gross hydropower potential is assigned to a cell that can be harnessed locally by considering elevation differences within the cell and to the next downstream cell (both the runoff generated within the cell and the discharge from upstream cells are accounted for)' (Lehner et al., 2005, p. 848).



Map 8: Gross hydro energy potential per year (Lehner et al., 2005)

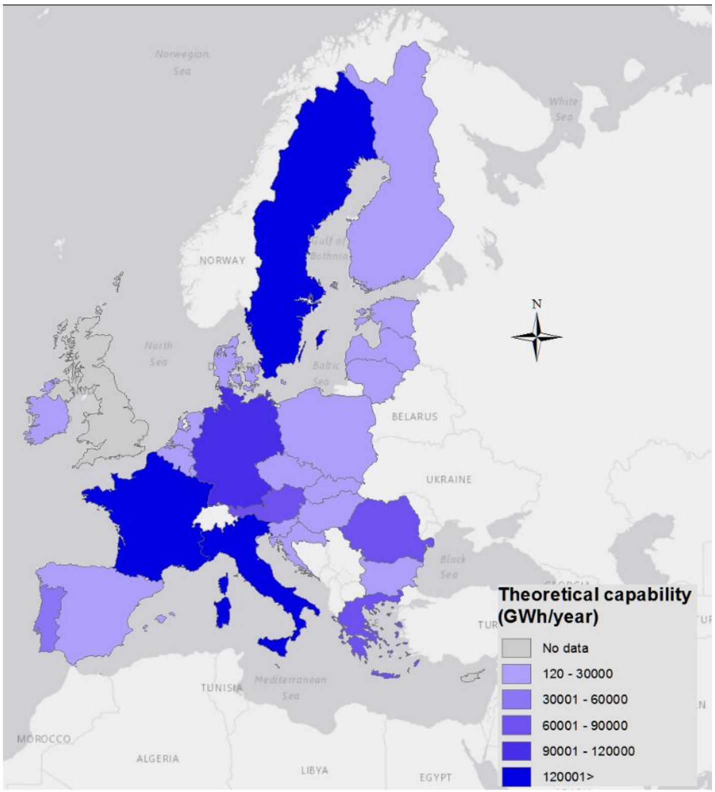
The HDWA (In INTPOW, 2012) determined the gross theoretical capability and the technically exploitable capability of hydropower. The relevant data is put in table 5. The total amount the capability would cover of the EU demand is given in the table. These numbers are quite different than those from Table 4. The reason for this is that the data used for this data are hypothetical and the calculations are rather rough estimates, while Table 5 provides more precise data based on what is theoretical and technical feasible.

	Gross theoretical capability (TWh/year)	Technically exploitable capability (TWh/year)
Austria	90	56
Belgium	9.6	-
Bulgaria	19.81	14.8
Croatia	20	12
Cyprus	-	23.5
Czech Republic	13.1	3.38
Denmark	0.12	-
Estonia	1.50	0.38
Finland	22.60	16.92
France	200	-
Germany	120	24.70
Greece	800	20
Hungary	7.45	4.59
Ireland	1.40	1.18
Italy	190	60
Latvia	7.20	4
Lithuania	6.03	2.46
Luxembourg	0.18	0.14
Malta	-	-
Netherlands	11.40	-
Poland	25	12
Portugal	32.15	24.5
Romania	70	40
Slovakia	10	6.61
Slovenia	12.5	8.80
Spain	162	61

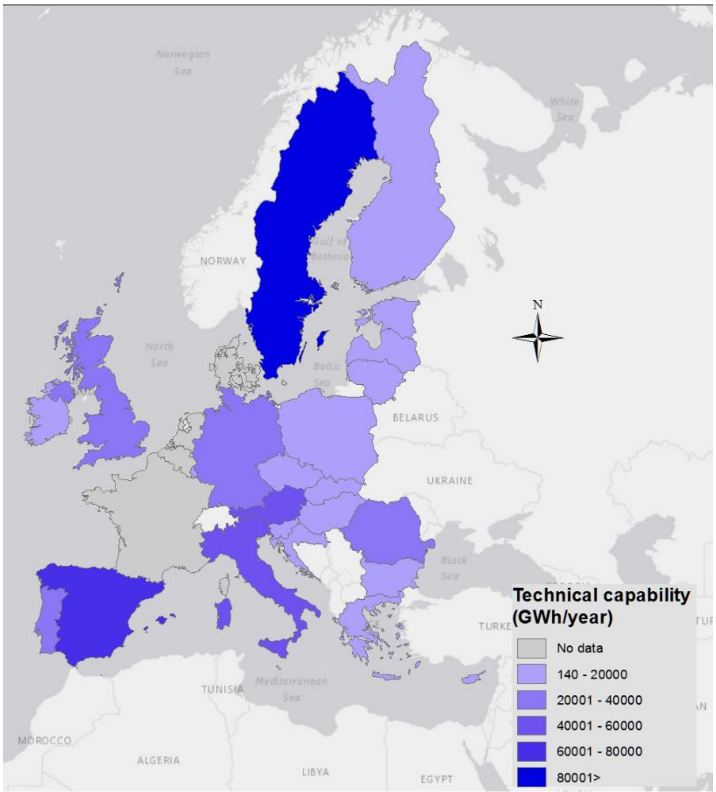
Sweden	200	130
United Kingdom	-	21.5
Total TWh/year	1 213.08	492.45
% of the EU final energy consumption	9.84	3.00

Table 5: Gross theoretical capability and technically exploitable capability in GWh/year, based on data from HDWA (in INTPOW, 2012))

Maps 9 and 10 display the data that is used in Table 5. Although theoretical capability is practical for knowing what might be realised, it is more feasible to look at what can be realised. Therefore, the technical capability will be used when referring to the spatial potential of Member States. Unfortunately, some data is missing. For Malta the reason could be that it has no potential for hydropower at all, for the other countries it is harder to guess (Denmark, the Netherlands, Belgium and France). Map 7 and Map 8 can be used to fill in the gaps. It seems that Denmark, the Netherlands and Belgium have a low theoretical potential and cannot generate much hydro energy, while France has a decent potential for hydro energy.



Map 10: Theoretical capability, based on data from HDWA (in INTPOW, 2012)



Map 9: Technical capability, based on data from HDWA (in INTPOW, 2012)

5.6 Conclusion

Section 5 analysed the spatial potential of RES. For wind energy and solar energy, the factors that contribute the most to the yield are dependent on location, while other factors are dependent on technology. Geothermal energy and hydro energy also have different yield throughout the EU. As location matters, it is possible for Member States to prioritise certain renewable energies. This is done with the method discussed in Section 3, which is elaborated on below. Based on the findings in the previous subsections, Table 6 is created. The table prioritises renewable energies per country, with the numbers, 1, 2, 3 and 4 (where 1 is the first priority and 4 the last). The Maps 10-13 visualise the findings of Table 6.

The different types of renewable energy are prioritised by using the different data. The renewable energy is prioritised per country. This means that a country which has wind energy as the first priority, does not necessarily has more wind energy potential than a country which does not has wind energy as the first priority. It does mean that wind energy has the most potential in that country, compared with solar energy, geothermal energy and hydro energy. Note that the prioritisation mentioned here is only about the yield. The strategy to get to such a prioritisation is laid down in Section 7. Attaining more renewable energy in the EU, which is linked with prioritisation of RES is the goal of the strategy.
Prioritising the RES is difficult to do precisely. With different numbers, different outcomes are possible. However, the mechanism of prioritising is still applicable.
For wind speed, Map 2 and Map 3 are used. Observation is key, but it is difficult to get an exact number for each country. Therefore, the number is an estimation based on those maps. For instance, in Finland the wind speeds are mostly between 5-6 m/s and 6-7 m/s, partly around 7-8 m/s and more than 8 m/s and for a very small part also 4-5 m/s. Based on this, one could conclude that the average wind speed in Finland is somewhere above 6 m/s. This number roughly indicates the average wind speed. In this way, all wind speeds are estimated for the Member States. The same approach is used for solar radiation and geothermal energy, as the type of map (Map 5 and Map 6) displays information in a similar manner.
For hydropower there are multiple datasets that can be used. Map 7 provides data from the EEA. However, the last category is quite different from the other three categories. In addition, it only displays the potential gross hypothetical capability. The HDWA on the other hand also includes technically exploitable capability. Here the issue is that for some countries the data is missing. Also it is not very clear how the numbers are obtained. This leaves Map 8. The numbers the map displays are calculated by using the mass of runoff, the gravitational acceleration and height. The choice is to use observation to estimate the yield of hydro energy in the same way as for the other renewable energies.
The author realises that this method can be perceived as imprecise. However, the collected data did not present average numbers for whole countries. With exact numbers, the prioritisation could be more accurate.

All the estimations of the yields are compared with each other for each country. This is done on basis of the range of the maps (see Table 7). For Croatia (Map 4), the range of Map 23is applied.
For instance, a country with a wind speed of 8 m/s, solar radiation of 1200 kWh/m^2, geothermal potential of 90-100 MW/km^2 and a gross hydropower potential of 0 GWh/year should prioritise as follows: [1] wind energy, [2] geothermal energy, [3] solar energy and [4] hydro energy.

However, the prioritisation is more difficult when the ranges of the different energy sources overlap. For example, in a hypothetical country with a wind speed of 4-5 m/s, 1000 kWh/m^2, geothermal potential of 40-50 MW/km^2 and a gross hydropower potential of 100 GWh/year there is overlap with all ranges. To make the prioritising system not too complex, the energy source that ´ends´ the furthest on the right is the one that has the first priority. This is repeated until all energy sources are prioritised. However, some energy sources have the same ´endpoints´ (e.g. a wind speed of 4-5 m/s and a solar radiation of 1600 kWh/m2). In such cases, the energy source that starts the furthest to the right is prioritised. As such, in the hypothetical country, the prioritisation should be: [1] hydro energy, [2] solar energy, [3] wind energy and [4] geothermal energy.

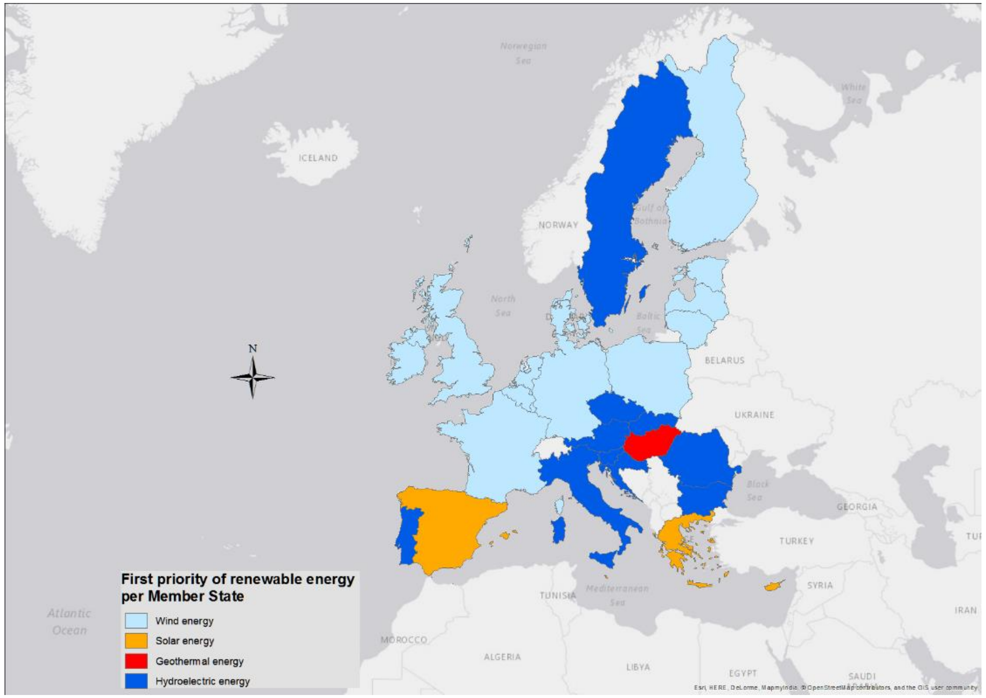
Note that the prioritisation does not imply that a Member States should neglect RES with a lower priority. The prioritisation means that Member States should focus on those RES with the most yield when possible. If it is not possible, then Member States can determine whether the second priority is an option and so on.

	Wind energy	Solar energy	Geothermal energy	Hydro energy
Austria	4	2	3	1
Belgium	1	2	4	3
Bulgaria	4	2	3	1
Croatia	2	3	4	1
Cyprus	2	1	4	3
Czech Republic	2	3	4	1
Denmark	1	2	4	3
Estonia	1	2	4	3
Finland	1	3	4	2
France	1	3	4	2
Germany	1	3	4	2
Greece	4	1	3	2
Hungary	4	2	1	3
Ireland	1	2	4	3
Italy	4	2	3	1
Latvia	1	2	4	3
Lithuania	1	2	4	3
Luxembourg	1	2	3	4
Malta	2	1	4	3
Netherlands	1	3	2	4
Poland	1	3	4	2
Portugal	3	2	4	1
Romania	3	2	4	1

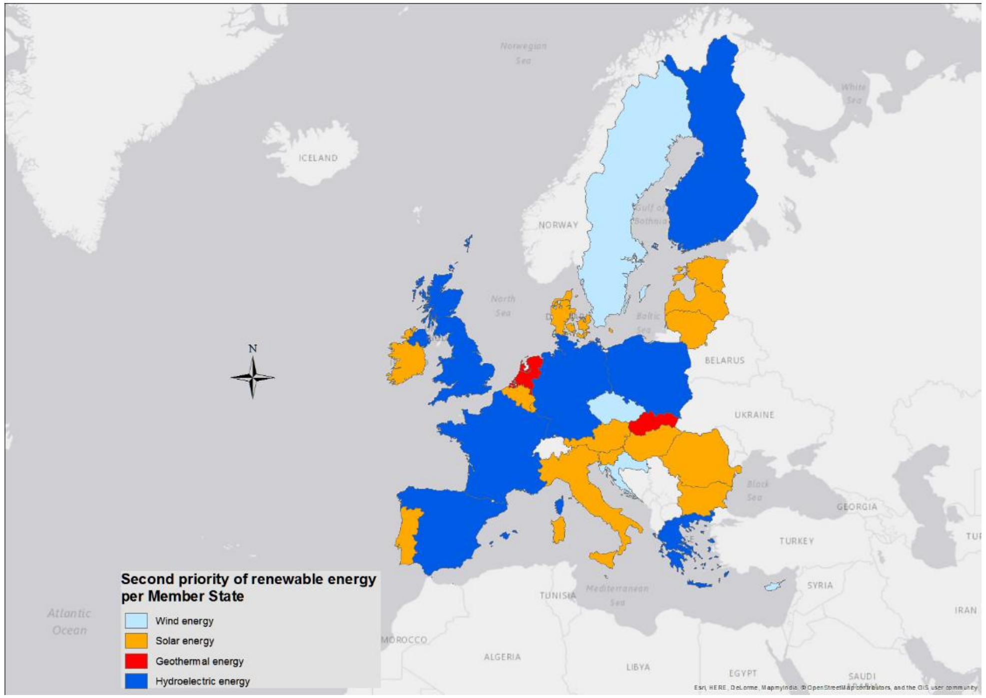
Slovenia	3	2	4	1
Slovakia	4	3	2	1
Spain	3	1	4	2
Sweden	2	3	4	1
United Kingdom	1	3	4	2

Table 6: Prioritising certain renewable energies per Member State

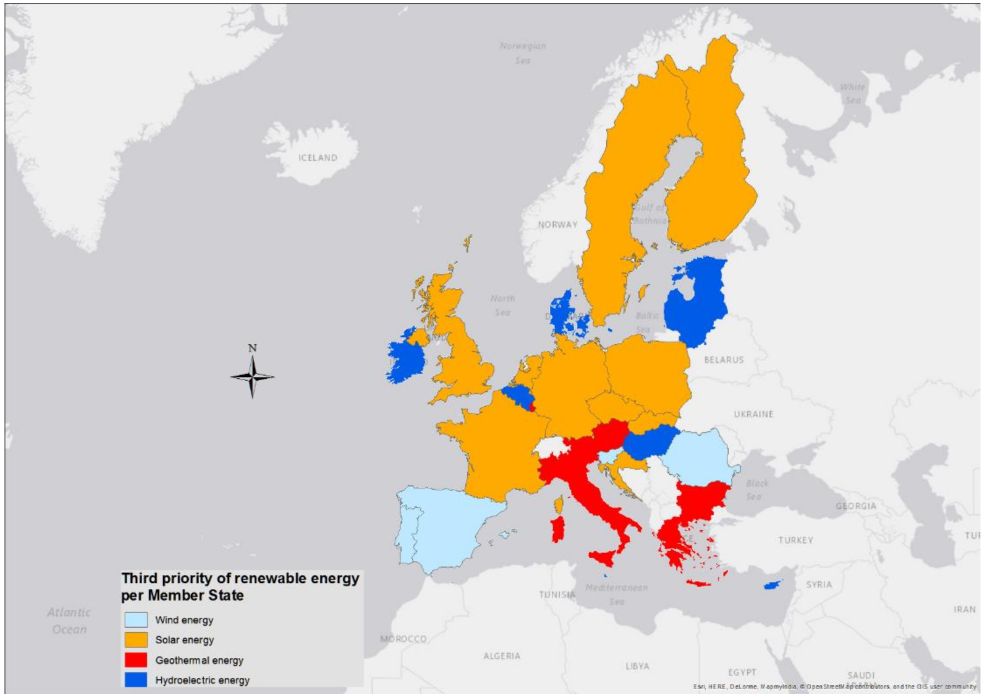
Table 6 shows multiple things. Firstly, there is indeed a north-south division of wind energy potential and solar energy potential, as most northern countries have wind energy as their first priority, while southern countries have solar energy as their first priority. Sweden and Austria have a great hydro energy potential, which was expected. However, countries as Portugal, Romania and Slovenia, also have hydro energy as their first priority. One would expect Portugal to have solar energy as the first priority, just like Spain. However, as Map 7 shows, Portugal has relatively a big potential in hydro energy. Note that Italy has potential for geothermal energy, but that the highest potential is local. Location matters for the potential of RES. However, some countries (e.g. the Baltic States), have the exact same prioritisation. This does not mean that location is not important, but that some countries might have the same potential due to their geographical position on the globe. The Netherlands and Germany also have a similar position, yet their share of renewable energy is quite different. Their prioritisation is also different for geothermal energy and hydro energy. It is difficult to say if this is the cause of the difference in the share of renewable energy. The next Section will discuss this subject in more detail.



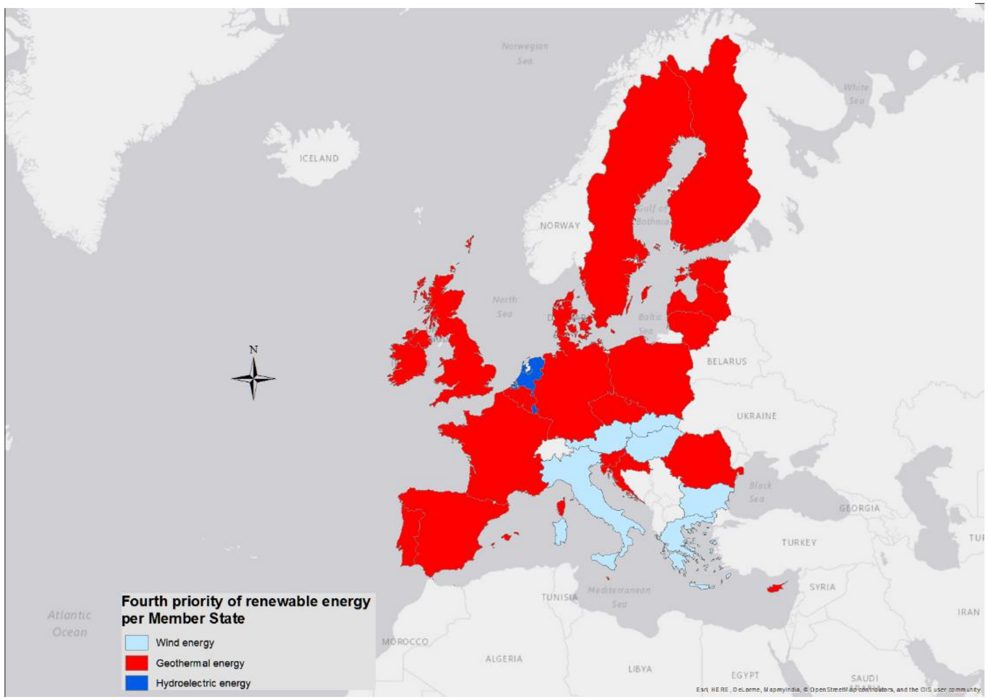
Map 12: First priority of renewable energy per Member State



Map 11: Second priority of renewable energy per Member State



Map 14: Third priority of renewable energy per Member State



Map 13: Fourth priority of renewable energy per Member State

<table>
<tr><td>Wind speed m/s</td><td colspan="3">0-4</td><td colspan="3">4-5</td><td colspan="4">5-6</td><td colspan="4">6-7</td><td colspan="4">7-8</td><td colspan="4">8></td></tr>
<tr><td>Solar radiation kWh/m²</td><td><600</td><td colspan="3">800</td><td colspan="2">1000</td><td colspan="2">1200</td><td colspan="3">1400</td><td colspan="3">1600</td><td colspan="2">1800</td><td colspan="3">2000</td><td colspan="3">2200></td></tr>
<tr><td>Geothermal potential in MW/km²</td><td>0</td><td>0-10</td><td>10-20</td><td>20-30</td><td>30-40</td><td>40-50</td><td>50-60</td><td>60-70</td><td>70-80</td><td>80-90</td><td>90-100</td><td>100-110</td><td>110-120</td><td>120-130</td><td>130-140</td><td>140-150</td><td>150-160</td><td>160-170</td><td>170-180</td><td>180-190</td><td>190-200</td><td>200></td></tr>
<tr><td>Gross hydropower potential in GWh/year</td><td colspan="3">0</td><td colspan="5">100</td><td colspan="4">500</td><td colspan="5">1000</td><td colspan="5">5000</td></tr>
</table>

Table 7: Range of the Maps 3, 5, 6 and 8

6. A case study of the Netherlands and Germany: A comparison of failure and success

Some countries are not to be able to achieve the 20% target (EC, 2015g). This should be troublesome for these countries, as the Directive is binding and no compliance could lead to legal penalties. The main purpose of the case study is to find out why there are such big differences between countries in the total amount of renewable energy. For some, explanations are easy to make. For example, Sweden and Austria have great potential for hydropower, and therefore have a high percentage of renewable energy (EC, 2015g). For other countries, the explanations might be more complex. The Netherlands and Germany have spatially almost the same opportunities for renewable energy. According to Map 2 the Netherlands has greater potential in terms of wind energy than Germany. Map 4 displays that the geothermal potential is relatively also more apparent in the Netherlands. Map 3 and Map 5-8 illustrate that Germany is a more promising country for solar energy and hydropower respectively than the Netherlands. One could say that the capability is, spatially, reasonably equal. Yet Germany is doing a better job than the Netherlands. The following tries to find out how this difference can be clarified and what lessons can be learned from the findings.

The Netherlands and Germany are chosen for the case study. It is feasible that Germany will achieve the target, while the Netherlands will not (GEF, 2010). Both countries offer some of the same opportunities, such as opportunities for wind energy on both land and sea. An additional reason for the selection of these two countries is that the author has a limited knowledge of foreign languages. Reports of these countries should be in a language that is understandable for the author. Another possible choice would therefore be the United Kingdom or Ireland. However, Germany is known to be a frontrunner in renewable energy (Moe, 2015) and the Netherlands has one of the lowest shares of renewable energy in the EU (EC, 2014c). A comparison of two 'extremes' might lead to more insights.

6.1 The Netherlands

Not every country has to achieve 20% renewable energy of the total. For the Netherlands the percentage is set to 14% (EEA, 2014). As of 2014 the Netherlands has only 5,5% renewable energy (EC, 2014c). With regards to the total amount of renewable energy, the Netherlands has the lowest share after Luxembourg and Malta (EEA, 2014). To reach the target, the current number has to be almost tripled.

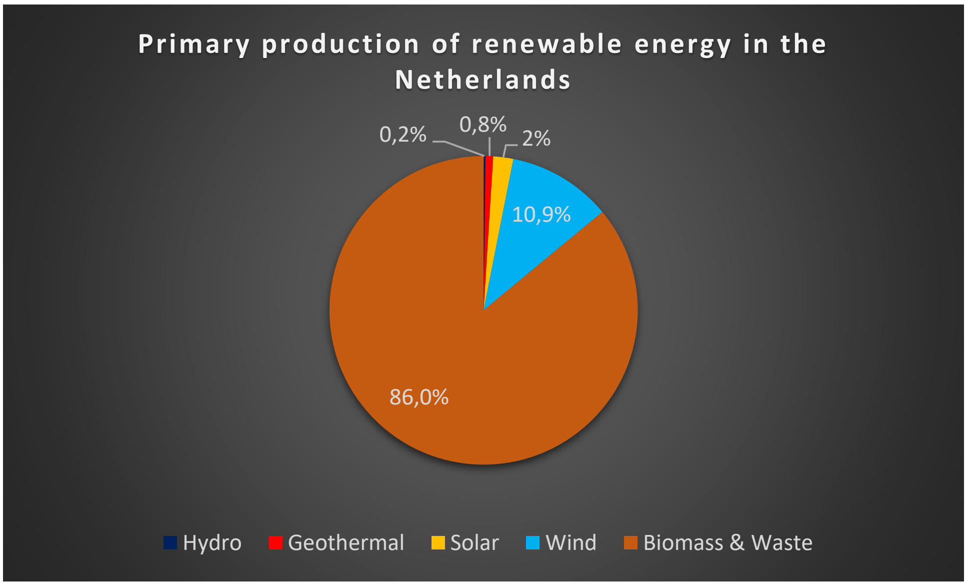


Figure 7: Primary production of renewable energy in the Netherlands, based on data from EC (2014b)

Deloitte (2015) affirms that in the Netherlands 83% of the energy production comes from fossil fuels, mostly from natural gas with 64%. Fig. 7 presents the percentage of the RES in the Netherlands. Fig. 8 shows the renewable energy share from 2004 to 2014.

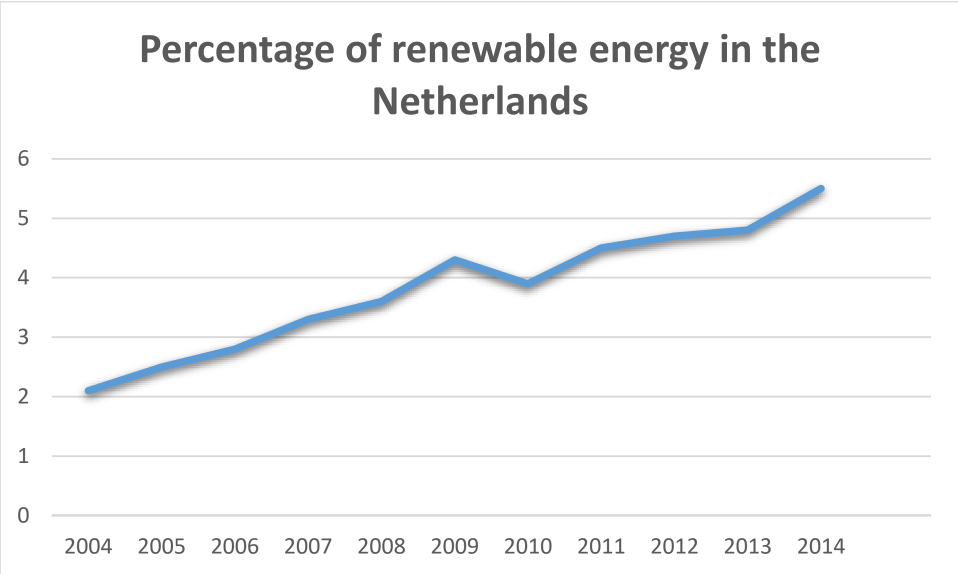


Figure 8: Percentage of renewable energy in the Netherlands, based on data from EC (2014c)

Table 8 lists all the measures that the Netherlands undertake to meet its targets (note that the table is about all the 2020 targets). According to the GEF (2010), measurements 3, 4, 9, 11, 14 and 20 are essential to meet the target.
The GEF (2010) analyses whether the measures listed in Table 8 are sufficient for achieving 20% renewable energy. The following summarises their findings:

- The budget set for renewable electricity usage is not sufficient and needs to increase.
- The measures are feasibly not enough to change policy effectiveness. This change is crucial for changing the energy mix. In addition, there are still large investment plans in fossil fuel power plants.
- A long-term vision, which would help in creating stability and anticipatable policy development, is missing. Subsidies for renewable energy are volatile in the Netherlands. This creates doubt in the market and in turn the refrainment of investments.
- Wind energy onshore, which has relatively low costs, is facing barriers due to planning permits and the lack of society's support. Wind energy offshore would be an alternative, but the costs are considerably higher.
- Technologies that have higher costs and can for now only be constructed on a small-scale, while needing a long-term focus, might receive too little recognition.
- The conclusion is that the Netherlands is not likely to meet the target, but that many measures are striving for the right actions. What is needed is 'predominantly more ambitious, consistent, stable and long-term national policies' (GEF, 2010, p.64).

The GEF (2010) lists a few measures that could help in meeting the target:

- New investments should mostly focus on renewable energy and not on fossil fuels. The government should make investment in fossil fuels less attractive or make investment for renewable energy more attractive.
- Measures such as higher taxes for greenhouse gas emissions are essential to heighten the cost of polluting.

- Renewable energy could become more attractive with financial investments or by making a minimal share of renewable energy mandatory.

	Name and reference of the measure	Type of measure	Expected result	Target group and/or activity
1.	Energy report 2008	Soft	Behavioural change, installed capacity and generated energy	Miscellaneous
2.	Clean and Efficient policy programme	Soft	Behavioural change, installed capacity and generated energy	Government
3.	Government coordination scheme	Regulatory	Installed capacity	Government
4.	Wabo	Regulatory	Installed capacity	Government
5.	EPC	Regulatory	Installed capacity	Government, planners, architects
6.	Climate agreement between the Municipal authorities and Government	Soft	Installed capacity	Government
7.	Climate-energy agreement between the government and provinces	Soft	Installed capacity	Government
8.	National Action Plan i Wind energy	Soft	Behavioural change, installed capacity and generated energy	Miscellaneous
9.	Priority for sustainable	Regulatory	Generated energy	Energy producers
10.	Gas Act and Electricity Act	Regulatory	Generated energy	Energy producers and : carriers
11.	SDE: Incentives for sustainable i energy production	Financial	Generated energy	Energy producers (incl. consumers)
12.	MEP	Financial	Generated energy	Energy producers
13.	OVIMEP	Financial	Generated energy	Energy producers
14.	EIA: Energy investment deduction (Energie investeringsaftrek - EIA)	Financial	Installed capacity	Energy producers
15.	IMIA/VAIMIL	Financial	Installed capacity	Energy producers
16.	Green investment	Financial	Installed capacity	Energy producers and : investors
17.	Energy innovation agenda	Financial	Installed capacity, generated energy, energy innovation	Energy producers
18.	Sustainable heat subsidy scheme	Financial	Installed capacity	End users
19.	Risk ' cover for geothermal energy projects	Financial	Installed capacity	Energy producers
20.	Biofuels obligation	Regulatory	Generated energy	Traders in transport fuels
21.	TAB: Filling stations for alternative fuels	Financial	Installed capacity	Sales organisations for transport fuels
22.	IBB: Innovative biofuels	Financial	Installed capacity	Producers biofuels for transport
23.	Action Plan for Electric Driving;	Soft and financial	Behavioural change	Investors, end users, government

Table 8: All Netherland's measures to meet the 2020 targets (BZ, 2010)

The NREAP and the evaluation are from a few years ago, but even more recent reports criticise the lack of improvement. Some of these critics are the same as the ones from the GEF (2010). According to PBL & ECN (2015) it is uncertain what the total percentage of renewable energy of the Netherlands will be in 2020 due to several insecurities, which concern among others: the development of the energy price, the economic potential of wind energy on land and the co-incineration of biomass depending on the operating hours of coal power plants. Sia Partners (2015) add another three reasons. Firstly, the absence of consistent policies creates an uncertain climate leading to an unwillingness to invest. Secondly, because Ministry Departments either did not take or did not have responsibility, implementation of plans regarding the target failed. Thirdly, consumers did not perceive the necessity of acting sustainable, leading to a continuation of the same unsustainable behaviour. Additionally, there are more arguments to find. Development of technology, finances and policy measures are listed by the ECN & PBL (2014) as reasons for uncertainty. The ECN & PBL (2014), also report that the share of renewable energy will rise due to the new Dutch subsidy program, which the main instrument for the energy transition: the SDE+, which is the successor of the SDE (see Table 8). The SDE+ (Stimulering Duurzame Energieproductie (stimulating sustainable energy production)) is a subsidy with a total budget of 3.5 billion euros that supports businesses and (non-profit) organisations who want to produce renewable energy (EL&I, 2010). However, even with this instrument, the Netherlands is lagging. A greater budget for the SDE+ might help. This requires an increase of 22% of the budget (Algemene Rekenkamer, 2016). Another option could be to enable renewable energy projects in other Member States. The disadvantage is that employment will not rise in the Netherlands. The SDE+ itself is not the culprit per se. The budget is agreed upon, but it does not reflect the reality (Algemene Rekenkamer, 2016). Also, projects are sometimes cancelled and do not provide the promised yield. Adjustments of the SDE+, although their effect will be small on the short-term, could be that projects that only need a small amount of subsidy are prioritised and the maximal amount of subsidy for each renewable energy could be better determined when subsidy recipients are required to provide more information about their technologies and finances (Algemene Rekenkamer, 2016).

6.2 Germany

In the EU, Germany is the biggest producer of wind energy, solar energy and energy from biomass (Observ'ER, 2013). In total numbers, Germany produces the most renewable energy of all Member States. However, with 13,8% renewable energy in 2014 (Ec, 2014c), Germany has yet to realise its target, which is set at 18% (EEA, 2014). Fig. 9 displays the percentage of the various RES in Germany, while Fig. 10 presents the share of renewable energy throughout the years. Nevertheless, Germany is well-known for its *Energiewende*, the German version of the energy transition. Opposition against nuclear power, the oil crisis (with a low share of oil and gas, the impact was especially felt in Germany) and the explosion in Chernobyl were arguments to look for alternative energy sources (Kunzig, 2015).

One could question the proportions of the different RES in Germany. According to Table 6, hydro energy is the second priority. However, the second biggest producer of renewable energy is solar energy as seen in Fig. 9. It could be that Germany preferred to invest in solar energy, as hydro energy is not as easy to develop. This would then be in line with the argument of the prioritisation, which prescribes to invest in the next priority, when one priority has few development opportunities.

Several factors lead to the success of the Energiewende. With the Erneuerba re-Energien-Gesetz (EEG, Renewable Energy Act) in 2000, feed-in-tariffs were enacted for renewable energy. Before this act, renewable energy was not competitive with conventional energy due to high investments costs (Hockenos, 2015). The act boosted renewable energies twofold: by covering the costs of the market price minus the production costs and by obligating grid operators to buy electricity and gas from producers of renewable energy. The renewable energy came for a big part from grass roots as citizens and local associations themselves invested in those kinds of energy (Kunzig, 2015). This was made possible by foregoing EU directives in the 1990s. These directives opened up the electricity and gas markets and required the liberation of the energy markets with the aim to allow more competition (Hockenos, 2015). As this broke the power of the monopolies in German, customers were able to choose their energy supplier, including small renewable energy producers (Hockenos, 2015).

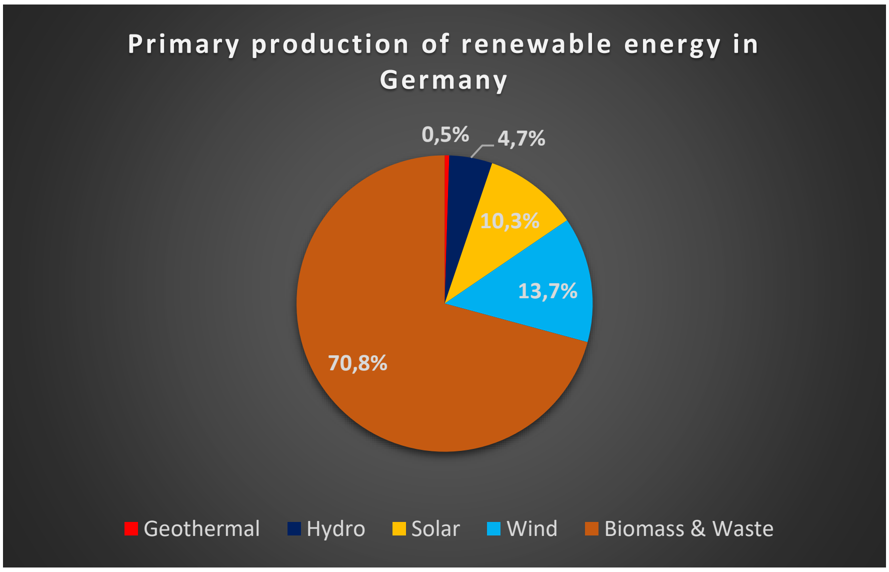


Figure 9: Primary production of renewable energy in Germany, based on data from EC (2014b)

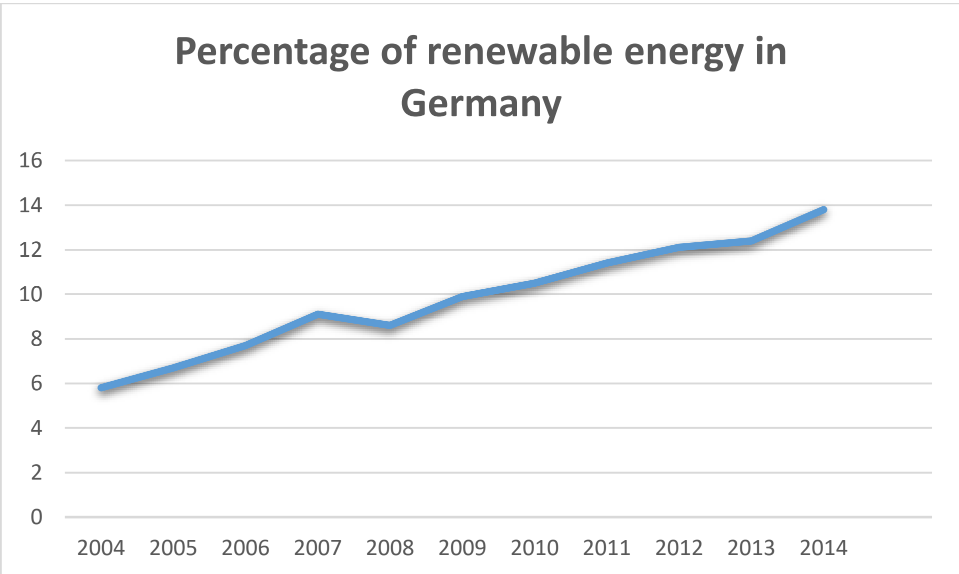


Figure 10: Percentage of renewable energy in the Netherlands, based on data from EC (2014c)

Table 9 lists the measures to meet all the 2020 targets written down in the German NREAP. The GEF (2010) analyses the successfulness of the German NREAP. The following lists their results:

- Germany has good chances of achieving its renewable energy target. When the share is lower than expected in the next few years, altering of legislation could be a solution. However, it is more likely that Germany will reach a number greater than 18%.
- Germany should continue the EEG in combination with a further development of the electricity grid, and implementation of regulation that recognises the variability of energy supply and the need for local energy supply.
- Identified possible obstacles in meeting the 2020 targets are the expansion of the electricity grid and building offshore wind energy structures.
- Germany aims to make renewable energy competitive with fossil fuels.

- In the NREAP there is no focus on the long-term. However, after the NREAP, Germany published a strategy paper. This paper includes new measurements in order to continue the energy transition after 2020.

Name and reference of the measure	***Type of measure****	***Expected Result *****	***Target group and/or activity******	***exists/is planned***	***Date of beginning and end of the measure***
1.Renewable Energy Act (EEG)	Legislative	Increased share of renewable energies in electricity	Investors, private households	Exists	Start: April 2000 (as a follow-up regulation to the Electricity Feed Act of 1991); amendments 2004 and 2009; next revision in 2011; the law is not limited in time.
2. Renewable Energies Heat Act (EEWärmeG)	Legislative	Increased share of renewable energies in the heating of buildings (focus on new buildings)	Building owners (private and public)	Exists	Start: Jan 2009; first revision 2011
3. Market Incentive Programme (MAP)	Financial	Investments in renewable energy in heating	Private households, investors	Exists	Start: 1999 financed from funds established in EEWärmeG; until 2012
4. KfW-funding-programs (e.g. CO_2renovation-program)	Financial	Energy efficiency measures and investments in renewable energy in buildings	Private households, investors, building owners, municipalities, social services	Exists	e.g. Start: 1996 End of measures 2011
5. Combined Heat and Power Act (KWKG)	Legislative	New construction, modernization and operation of CHP-plants and heating networks	Power plant operators, energy suppliers, investors	Exists	Start: April 2002, amendment in January 2009
6. Energy Saving Ordinance (EnEV)	Legislative	Compliance with minimum standards for energy efficiency in buildings and heating/cooling systems in new construction and renovation of residential and non-residential buildings	Building owners (private and public)	Exists	Start (current version dated 1.10.2009): October 2007 Basis: Energy Saving Ordinance of 28.03.2009; next amendment 2011/2012
7. Biofuels Quota Act (BioKraftQuG)	Legislative	Minimum share of biofuels of total fuel put into circulation, and tax incentive for certain biofuels	Companies that bring fuels on the market	Exists	Start: January 2007 Duration: beyond 2020 / tax incentive for certain biofuels until the end of 2015

Table 9: All Germany's measures to meet the 2020 targets (BMWi (2012)

6.3 Comparing the Netherlands and Germany

Table 10 provides an overview of Section 6.1 and 6.2. There is a myriad of reasons why the Netherlands is lagging behind. Therefore, it is difficult to identify one factor as the cause. However, it is possible to look at the differences between the Netherlands and Germany. Political inconsistency in the Netherlands, which leads to uncertainty in the market (which leads to reluctance in investments) is one reason why the Netherlands is not performing at the same level as Germany. Lack of real support of the government either financial or political and (still) too much focus on fossil fuels are other reasons. Without long-term policies, investments are lacking and without policies promoting renewable energy, energy suppliers either might not see the need for renewable energies or are not obliged to invest in renewables. The SDE+, the main Dutch instrument regarding renewable energy, does not provide the desired results. Adjustments of the SDE+ will not increase the share of renewable energy in the short run (Algemene Rekenkamer, 2015). It seems that the target will not be achieved in 2020, but that the share of renewable energy might increase nevertheless.

MEASURE OR FOCUS	THE NETHERLANDS	GERMANY
MEETING THE TARGET	Infeasible or doubtful	Yes
TIME FOCUS	Until the target	Until and after the target
RENEWABLE ENERGY MIX	First priority has the highest share, second priority has a low share	First priority has the highest share, second priority has a low share
POLITICAL CONSISTENCY	Absent	Present
FOSSIL FUELS	Still large investments	Still investments, but renewable energy is made competitive
FEED-IN-TARIFFS	SDE+	EEG

Table 10: Comparison of the Netherlands and Germany

A long-term focus in combination with political consistency and sufficient subsidy are making Germany's energy transition a success. In Germany the right policies helped to increase the amount of renewable energy as the feed-in-tariff opened up the market, made renewable energy economic viable and created a pathway for local initiatives (Hockenos, 2015).

6.4 Conclusion

This Section analysed and compared two cases. Two cases, to demonstrate the difference between success and a lack of success (at least for now). As the case studies only focused on two cases, it is hard to say something in detail about the other Member States. However, it is apparent that political consistency and a long-term focus are necessary to attract investments in renewable energy. In addition, the state has the power to finance renewable energy projects.

Countries that will not meet their target in 2020 might have comparable issues as the Netherlands. However, a feed-in-tariff might be helpful in other Member States. When the status quo is perceived as unsatisfactory, countries could try to learn from other countries by transferring policies (Dolowitz & Marsh, 1996). Policy transfer from countries with a high share of renewable energy to those with a low share could mean that the share will increase. It is important to consider the context of the countries when transferring policies (Dolowitz & Marsh, 1996). The EU could provide a database with the measures of all Member States and whether they were successful or not. Other countries could use this database to implement new measures. The EU has the power to enforce the RED by penalise Member States that do not meet the target in 2020. It could be that a penalty is the only incentive for Member States to take the RED more serious.

7. Strategy for the EU

This section presents a strategy for the EU for prioritising renewable energy. The suggests what the EU and Member States should do mainly based on transition theory, transition management and the findings of the previous sections. Transition management uses strategies for long-term goals (Laes et al., 2014). The strategy provided here, is such a strategy. Relying on the papers of Loorbach (2010) and Kaphengst & Velten (2014), to manage the energy transition, the EU should guide the transition, while learning from experience in the progress. In addition, the transition should only be controlled to a certain extent, as Member States should be able to come with own ideas and projects. The GEF (2010) emphasises the importance of long-term goals for the renewable energy transition. The perspective of spatial planning is used for this strategy, implying what to build where and when.

The 20% renewable energy aim of the EU is a good start. Member States are indeed implementing a myriad of measures to achieve the target. The strategy presented here agrees with the Renewable Energy Directive in the way that it wants to achieve 20% renewable energy. However, to make full use of the potential of renewable energy sources, the aim should be adjusted. The aim should still be 20%, but it should also be to realise those renewable energy sources that have the highest yield in the country the most. In other words, countries should prioritise certain renewable energy sources. Some tasks are carried out by the EU, some by Member States. In addition, the aim is ultimately to achieve 100% renewable energy.

Section 1.3 presented technical rationality as the mindset for the strategy that is laid down in this section. Certainty and a top-down approach are part of the mindset. Certainty refers to constancy in wind speeds and sun hours. It also refers to agreement about the prioritisation among the different levels. The top-down approach refers to the obligation that the EU sets in directives.

7.1 The EU as guider

- The EU determines the yield of each renewable energy sources that are spatial relevant. Section 5 already explains where and why the energy sources should be implemented. It does not in detail describe how many structures are needed and what the local barriers or criteria are (which can go pretty far when looking at the example of the Netherlands in Section 5.2). Such details should also be studied. On basis of this analysis, the EU makes a list with each country and the renewable energy sources they should invest in.
- A new directive should be implemented to bind the countries to the prioritised energy sources. If not, countries might go on with their current implementations of renewable energy sources. In accordance with the transition theory, renewable energies that were not really applied can breakthrough. This directive should also include exceptions. It could be a possibility that locally a wind turbine is not desirable, but that solar panels are optional. Yet the main purpose remains that countries focus as much as possible on those renewable energy sources that know great yield. The benefit is that countries can specialise in energy sources, as the focus is on only one or a few. This specialisation can lead to innovation or improvement of technologies, increasing the yield even more.
- The EU establishes a budget for renewable energy sources. The aim of the budget is that each country contributes fairly with an adjustment for factors like wealth, size and opportunity. In this way, less wealthy countries do not bear a disproportionate burden. In addition, not all renewable energy sources cost the same. An international budget can rectify such unbalances. The budget also finances projects that are otherwise not realised, which could include local projects by EU-citizens. Some countries already have obtained the 20% target. Yet they still have to contribute to the budget. It would be wrongful if these countries would be harmed by the budget. Therefore, two alternatives are proposed. The first alternative is that these Member States benefit from the budget by using it for new projects

or updating their current systems. As it might not be the ambition of these countries to pursue more renewable energy, the second alternative is that they do not have contribute to the budget at all and therefore do not have any benefits of the budget.

- The EU builds an energy network that connects all the Member States together. This network should be able to deal with overproduction of energy. For example, sometimes there is too much production of solar energy which cannot be used in the country of origin. The energy network should be able to transport these spill-overs to other countries. Fluctuations may be compensated for by fossil fuels, as long as this does not get in the way of achieving the target. The energy network should minimise the need for such compensations. The EWEA (2016) answers the question why there is a need for a European grid: 'Much of today's electricity grid was built 40-60 years ago. It was built around large fossil-fuel burning power stations usually sited near large urban areas. European grids are largely national grids. In order to harness the power of renewable energy, including wind, the grid has to be extended to where the resource is located: i.e. where the wind blows most frequently, and where the sun shines the brightest. For wind, this includes out to sea, and in some remote land areas. The grid needs to be expanded so that it can deliver power from where the wind is blowing to where it is needed. The grid also needs to be better interconnected to improve security of supply and prevent black outs – regardless of the source of energy – and in order to improve competition in the electricity market, which would bring down prices. A European grid might also use more modern cables that lose less electricity in transit.' (p.1).

7.2 Development of renewable energy by Member States

- Each country creates a new NREAP, which should include allocations for their RES and how the country expects to achieve the 20% target with its prioritised RES. Other RES may only be considered when the target cannot be achieved otherwise.
- Each Member State regards the spatial criteria that are in place in the own country. With this information, a calculation can be made on how many constructions can be realised. For example, taking the Netherlands as illustration, constructing a wind turbine has to be subjected to all the criteria mentioned in sector 5.2. Maps can display what locations are feasible for the relevant energy constructions. It is not necessary to fill up all locations, but it is handy to know what locations are appropriate when a new target is established.
- Member States should learn from Member States with effective policies when determining their policies. It could be that a policy transfer can boost the renewable energy. However, context has to be taken into consideration, as not all countries have the same spatial potential for the renewable energies.
- When needed, support should be created before a project is initiated. Providing information about the project to citizens and including them in the project (e.g. consensus building) lessens resistance and NIMBYism (Not In My Back Yard). If possible, renewable energy can be partly directed to local residents. Such a measure can make residents agreeable with the placement of energy structures, as these structures are also 'theirs'.

7.3 Room for local projects

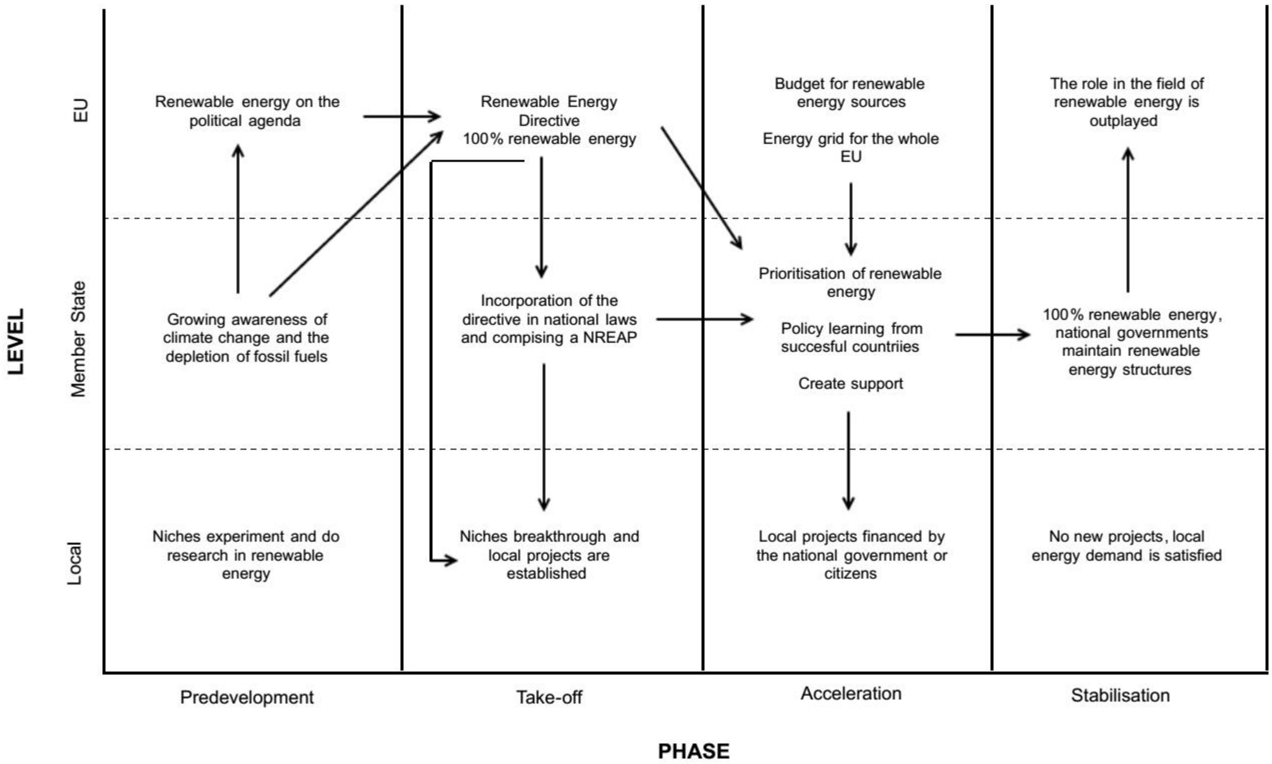
- Local projects can be financed by the national government or by citizens as an initiative. The national government provides laws and regulations which clarify what is legally possible for citizens. Subsidy programmes can be established to help out the local projects.

7.4 After 2020

In 2020 it is possible that some Member States did not meet their target. The strategy has only a few years left to be useful regarding the 2020 target. However, the strategy mainly aims at the long-term. Therefore, it might be the case that Member States are able to reach new targets with the strategy. A new target is a grip to keep going with the transition, as 20% is only a start. All Member States again make a new NREAP in case of a new directive. This NREAP should indicate how a new target that has yet to be determined (for example 50% renewable energy of the total energy production in 2030) can be realised by allocating new locations for their prioritised RES. With new technologies, it could also be viable to replace older structures. In the distant future this might be favourable, because just building new constructions decreases the available land.

7.5 The conceptual model filled in

The conceptual model that is presented in Section 2 can be filled with the various tasks that are laid down in the strategy of this section. An arrow indicates an influence on the level it points at. For example, the growing awareness of climate change and the depletion of fossil fuels in the predevelopment phase lead to political discussions on an international level, which in this case is the EU.



An arrow indicates a certain influence on the level it points at

Figure 11: A 'filled' conceptual model

8. Conclusion

In this research transition theory was applied as a perspective to understand the energy transition in the EU. Transition theory proved to be effective in explaining interactions between the EU, the Member States and the local level. This is contrary to the notion of Grin et al. (2010), who state that the multi-level perspective is not meant to be focused on spatial boundaries. However, the EU, Member States and the local level are not areas merely distinguished by their boundaries. They also possess their own function and power in the energy transition. However, using levels that have a certain function is in accordance with the view of Grin et al. (2010). Transition theory could therefore be used as a perspective to explain interactions between certain areas, provided that they carry different functions. As such, the multi-level perspective cannot be used to analyse three different Member States, as they have (more or less) the same power in the energy transition.

The different phases were applied to the past and the future of the energy transition in the EU. The actions of the EU, the Member States and the local level can be divided among the phases. Transition management is done by means of the RED. It is not a full control by the EU, as Member States are still able to decide how they will meet the target. New directives, in combination with the other steps of the strategy could manage the transition further. Key of the strategy is the prioritisation of RES. Directives can be used to obligate Member States to prioritise RES.

The aim of this research was to find an answer to the following question: How can a joint strategy for the EU, based on transition theory, benefit the energy transition towards renewable energy?

Transition theory together with transition management, formed the theoretical framework in this research. Transition theory includes the multi-level perspective and the four phases of a transition. The three levels of the multi-level perspective in this research were the EU, the Member States and the local level. All these level play their own roles and interact with each other. The proposed strategy was based on the theoretical framework. In addition, the technical rationale way of thinking was the starting point for the strategy. More importantly, the data-collection and the findings made the basis for the strategy. The various tasks and roles, and especially the role of the EU are examples of transition management. The energy transition is a process that has to be guided with a deliberated long-term plan, which in this case is the strategy.

The findings were consistent and had a clear message. Although locally, sites can be of influence for the yield of renewable energy structures, on a bigger scale, the geographical location is essential for the yield of wind energy, solar energy, geothermal energy and hydro energy. The findings suggest, that the EU and Member States can generate more renewable energy when allocating renewable energy structures on basis of location. However, the example of the Netherlands demonstrated that regulations and criteria may be a barrier for construction in certain areas. The case study confirmed that achieving renewable energy targets are not just about developing renewable energy, but that politics and finances also play a role. A long-term focus in combination with political consistency and sufficient subsidy are likely to be reasons for success, as these are present in Germany, a frontrunner, but lacking in the Netherlands.

So how can a joint strategy for the EU, based on transition theory, benefit the energy transition towards renewable energy? Firstly, the EU benefits as a whole from the prioritisation. When Member States prioritise renewable energy, more yield will be achieved. Targets set in future directives are met faster and more efficiently. Secondly, Member States benefit, as prioritisation will increase their own yield. This means they are less dependent on fossil fuels, but are also more likely to meet future targets (or current targets for countries that have not met the target for 2020). The local level benefits as the strategy proposes that national governments support local projects. Citizens could therefore be more eager to initiate a project. Efficient (e.g. agricultural areas with wind turbines) and effective (e.g. wind turbines in areas with high wind speeds) use of space is essentially the key to boost the energy transition in the EU. The strategy presented various tasks and roles for the three levels. However, one task is essential: the development of an energy grid on an EU scale. Surplus of renewable energy of Member States can be used in other Member States. For example, southern countries can have a surplus of solar energy in certain periods, which than could be used in other countries. The grid is important, because without the grid, the surplus is wasted (unless countries cooperate on their own initiative).

9. Discussion

9.1 Reflection

The selection of maps, equations and cases was partly subject to randomness or preference. It is debatable how scientific such a manner of data collection is, even when it is supported by arguments. Nevertheless, it is hard to prevent this entirely.

Estimations of the yields of wind energy, solar energy, geothermal energy and hydro energy were purely based on observation. Such a method might be influenced by error. Errors in observation would spawn two issues. Firstly, the yield would be estimated wrongly. Secondly, due to the wrong estimation of the yield, the prioritisation would also be faulty. Nevertheless, the conclusions would still stand. Different numbers would not affect the value of location for renewable energy. Also, different numbers would not debunk the conclusions that efficiency gains can be realised when RES are prioritised.

9.2 Recommendations

A complex matter like the transition towards renewable energy should not solely be analysed and discussed from the perspective of the spatial planner. Further research could try to integrate other disciplines that are of importance, such as politics, laws, physics and economics. With a full comprehension of multiple disciplines, a renewable energy strategy for the EU might be more effective. Further research could include more precise calculations for the yield of the RES. In addition, calculations could be made for each country to find out how much of each renewable energy source is needed for 100% renewable energy.

Measures of the different Member States to achieve the target can be compared in order to learn what kind of measures are effective and what are not. Lessons could be drawn from frontrunners of renewable energy. However, not every effective measure works in every country. Therefore, the context of the country should be kept in mind. Further research could analyse what successful measures could work in countries with a low renewable energy share.

With ArcGIS or other software detailed maps can be made per country that display all the possible sites for renewable energy structures. Such maps are useful to explore the full spatial potential of a country as they display how much area can be used for RES.

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