Flexible & binding: can it be effective? Thesis on the Renewable Energy Directive, the flexibility of instrument choice and the binding national targets

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FLEXIBLE & **BINDING**: CAN IT BE **EFFECTIVE**?

Thesis on the Renewable Energy Directive, the flexibility of instrument choice and the binding national targets

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Preface

This thesis marks the end of my master *Public Administration.* The fight for a better climate has always been intriguing to me. It especially interests me when the European Union gets involved: on the one hand this introduces an actor that has a lot of power to get things done. On the other hand, this actor always introduces a lot of political and scientific debate. When all these subjects converge, we get to the *Renewable Energy Directive* introduced in 2009. The policy goal was set in 2020, which was the year I started writing this thesis. This fact lead me to ask the question: looking back, has this directive actually been efficient at promoting the production and use of renewable energy? Does this directive make a good case for the Eurosceptics, or was it actually a great success? These questions are the starting point of this thesis.

Writing this thesis has been more of a challenge than previously expected. When the writing just kicked off, the Corona crisis happened, during which all universities were closed. The uncertain and unprecedented times made the process much harder, especially in the first weeks. Besides that, during the writing of this thesis both my beloved grandmother and grandfather died, which had a lot of impact, especially in these times. The writing was delayed, but in the end the final product is here. I want to thank everyone that has been of any help during these times. Special thanks to my girlfriend and Martijn for their help in reviewing and giving feedback.

Lastly, I want to thank my supervisor, Dr. H. Vrijburg, who has been very understanding and helping in giving guidance and feedback on my thesis during these months. Thank you very much for your patience with the changing circumstances. The Corona crisis must have complicated the task of supervisor as well, as guidance via a Skype call is not as easy and requires adaptability.

I wish you a good reading experience and hope this thesis inspires you to dive deeper into the subject or get a better insight in making policy choices.

Thomas ten Voorde
Nijkerk, June 2021

Abstract

The European Union has been promoting the use and production of renewable energies through various policies. In 2009, the *Renewable Energy Directive 2009/28/EC* was introduced. The Directive also set mandatory targets for the EU-28 Member States individually. The Member States are free to choose the instruments with which they promote the use of renewable energy consumption. In achieving these goals two main instruments were used: price-based or quota-based instruments. Therefore, the central question to this research is '*what effect does the introduction of mandatory national targets, combined with the freedom of instrument choice, introduced by the Renewable Energy Directive (2009), have on the share of renewable energy in the EU-28 from 2004 to 2018?'*

The academic debate does not give a clear answer on both of these topics. The effectiveness of the mandatory national targets and which instrument for promoting renewable energy is the most efficient is disputed. The most popular policy for promoting renewable energy are the price-based policies (FIT/FIP). This can also clearly be seen in the EU-28, where the FIT is in the clear majority.

The research question will be tested by using three statistical models. First, a pooled regression model will be used to estimate the effect of the introduction of the RED and the instruments that were used on the share of renewable energy in the EU-28. Secondly, some biases will be corrected for by using a Fixed Effects regression model. The dependent variable that will be used is 'the share of renewable energy in the gross final energy consumption' in the EU-28 countries. Our final model will investigate the presence of beta-convergence, which will be used to test how the ambition of the national targets played a role.

The results show that the levels of renewable energy increased after the introduction of the RED in 2009. The results from the method of beta-convergence show that countries that had a more ambitious national goal set for them in 2009 showed a more substantial growth in their share of renewable energy. Besides that, the results give no reliable and clear answer to the question which promotion instrument is more effective. The only significant result shows that price-based policies show higher levels of renewable energy in their energy mix, which is in line with our expectations.

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1. Introduction

In recent years, an important global concern has been making headlines more and more: the adverse effects of climate change and the belief that it should be stopped. One of the solutions that is proposed for this problem, is the reduction of emissions of greenhouse gasses. This could be achieved by switching and replacing fossil fuels with renewable energy sources (RES). Renewable energy is defined as "energy produced from sources – such as sunlight, rain, waves, tides, and geothermal heat – that are naturally replenished, but flow-limited." These sources are "inexhaustible in duration but limited in the amount of energy that is available per unit of time" (EIA, 2019). These 'infinite' resources can help protect the environment and reduce greenhouse gas emissions. The European Commission introduced legislation in form of the *Renewable Energy Directive 2009/28/EC* to promote the production and use of renewable energy.

This Renewable Energy Directive (RED) is a policy set out to 'establish an overall policy for the production and promotion of energy from renewable sources in the EU'. The RED has been one of the pillars of the European energy strategy for the past ten years. One of its targets was for the European Union to fulfil at least 20 percent of its energy needs with energy from renewable sources. The RED is part of a package of energy and climate change legislation, which provides a legislative framework. The motivation behind the Directive is to reduce greenhouse gas emissions, promote the security of the energy supply, promote technological development and innovation and to provide opportunities for employment and regional development, especially in the rural and isolated areas. Another goal that is set in the RED, is for the Member States to reach a target of 10 percent share of renewable energy for transport (European Commission, 2009). In 2018, the European Commission revised the policy to set a new binding energy target. This target was set for 2030 with a 32 percent renewable energy target, which has a clause for a 'possible upwards revision by 2023' (European Commission, 2018). As the circumstances in every country were very different, national renewable energy targets were specified for every country, taking into account the different starting points and potentials, as well as the differences in GDP. These national targets were mandatory and binding, which meant that each MS has to achieve the RE target that was set for them. The RED indicated that the policy instruments applied to promote the introduction of renewable energy remained the competence of the Member States. The most commonly used instruments can be divided into two groups: price-based (feed-in tariff) and quota-based (tradeable green certificate) promotion systems.

The effectiveness of renewable energy policies and instruments has been a topic of scientific and political debate for a long time. In recent years, the call for attention for the environmental concern is growing, and policy makers need to consider solutions and tackle this problem. The road to sustainable energy (i.e., renewable energy) production is expedited even more by the call for energy independency. Recent political events urged Member States not to rely too much on other countries for their energy needs. We could therefore conclude that this thesis certainly has political and societal relevance. Besides that, the promotion of renewable energy and the instruments that are used, have been subject of scholarly debate for a long time (see for example: Haas, et al., 2011; Marques, Fuinhas, & Manso, 2011; Jenner, Groba, & Indvik, 2013). These papers all focus on different periods for different types of RE policy instruments. The purpose of this explanatory research is to contribute to the theory regarding the policy instruments that can be used to promote RE. And also, specifically focus on how the national goals that were set for the RE consumption played a role in the effectiveness. Even though the subject of RE promotion in Europe has been widely reviewed, a recent and broad research over the years before and after the introduction of the RED has not yet been conducted. Besides that, the literature on the national binding targets, or even target-setting and the ambitiousness in general, is very slim. Even though targets are widely used in the (environmental) policy arena, they have hardly been reviewed. The flexibility the directive gives the MS in their approach to RE promotion, combined with the binding national targets, gives an interesting and academically relevant combination to review.

Therefore, the aim of this thesis is to review the use of certain RE promotion instruments from the year 2004 to 2018 across the EU-28 countries, and whether the starting point and the national goal that was set can account for different achievements in the share of renewable energy consumption. The central question to be answered in this research is the following:

'What effect does the introduction of mandatory national targets, combined with the freedom of instrument choice, introduced by the Renewable Energy Directive (2009), have on the share of renewable energy in the EU-28 from 2004 to 2018?'

The first part of this thesis will start with an overview of the Renewable Energy Directive (2009), in which the historical context and the Directive itself will be described. The second part presents a literature overview and theoretical framework on the policy instrument of a directive, with a specific focus on the mandatory national targets and target-setting in general. After that, we will investigate the growth of renewable energy and the policy instruments that were used to promote the production and consumption of renewable energy. This framework allows to formulate hypotheses to test in the empirical analysis. The third part describes the research design, in which the variables are operationalized and conceptualized. Besides that, the quantitative methods and the dataset are discussed. After that, the results from the regressions will be shown and discussed. Finally, the conclusion follows, in which I will summarize and discuss the findings to the research question.

2. Case description Renewable Energy Directive (2009)

Before the introduction of the RED in 2009, energy policies were already a topic of debate in international and European politics. We will start by exploring and explaining the history of European energy policy. This will draw the historical and political lines in which we can place the introduction of this legislation to promote RE. After that, we will focus on the introduction and implementation of the RED in 2009 and the goals the EU aims for.

2.1 Energy policy in EU before introduction of RED

Climate policy has been around for a long time and has been closely related to the negotiations organized by the United Nations. In 1990, climate policy was discussed for the first time by the European Council, because of the first report by the Intergovernmental Panel on Climate Change, which was followed by negotiations over the United Nations Framework Convention on Climate Change. Besides preparing for these negotiations, the European Union also introduced a European climate target in this year, which aimed to stabilize the Greenhouse Gas emissions in Europe at the 1990 levels by the year 2000. All EU members were "urged to introduce extensive energy efficiency and conservation measures and to adopt as soon as possible targets and strategies for limiting emissions of greenhouse gases", because it was concluded that "a business-as-usual approach will lead to global warming in the decades to come" (European Council, 1990, p. 27). After this initial kickstart in 1990, it took six years to consolidate these policy plans into a specific goal: keep global temperatures below two degrees Celsius, compared to pre-industrial levels.

Before the European Union decided to promote renewable energies in the whole Union by implementing a policy to do so, some Member States were already developing their renewable energy sources. For instance, Germany introduced their 'feed-in law' in 1990, through which they provided financial incentives and feed-in-tariffs in order to support energy from RE sources (Gerhardt, 2017, p. 108). Even though the European efforts were there, the progress was very little. In 1997, the European Union introduced their first explicit renewable energy policy, when launching the white paper 'Energy for the Future'. This paper states that "renewable sources of energy are unevenly and insufficiently exploited". At that time, less than 6 percent of the overall gross inland energy consumption came from renewable sources. Even though "many are abundantly available, and the economic potential is considerable" (European Commission, 1997). However, the white paper also acknowledges that even though some countries are already making efforts by pushing renewable energies, there were some barriers. These barriers include (relatively) high costs, lack of consumer information, administrative barriers and other planning and management issues. Besides that, if the total energy consumption is rising rapidly, even significant growth in renewable energy may not alter the percentage share (Howes, 2010, p. 120). Because of these barriers and the slow progress in renewable energy the European Commission proposed legislation on the topic three years later. In 2001, they translated this goal of increasing the share of renewable energy for electricity generation into Directive 2001/77/EC. This earlier directive focussed on the electricity sector and set challenging national indicative targets to increase the share of renewable energy electricity *consumption*. In line with the aforementioned white paper, the EU target of the share of renewable energy in the electricity mix was set at 12 percent by 2010. Article 5 to 7 of this directive prescribe that "all Member States should be required to set national indicative targets for the consumption of electricity produced from renewable sources". The European Commission assesses whether the MS set targets that are consistent with the global indicative target of 12%, still bearing in mind the different national circumstances (European Commission, 2001). Besides Directive 2001/77/EC another directive was implemented for the transport sector in 2003: Directive 2003/30/EC.

This first 'energy directive' from the European Union did not only aim at establishing renewable energy targets for Member States or removing barriers in terms of grid management and other procedures, but it also introduced 'guarantees of origin certificates'. These certificates would prove the origin of the electricity in question, which could then be traded. These certificates would separate the electricity that was generated from renewable sources, from all the 'other' electricity, which would give it an advantage. The trade of the certificates could either be on the 'green market', where an electricity supplier could sell his electricity explicitly as 'renewable' or 'green', or it could be traded between Member States. This latter trading mechanism was in place to ensure that all Member States could be flexible in terms of meeting their own renewable energy targets. The final component of Directive 2001/77/EC was the framework it provided for the national support schemes, which included investment and operating support. These support schemes were already in place in some Member States, like the Feed-in-Tariff for renewables policy Germany introduced in 1991. The most common form of support was the operating support, which included price subsidies and green certificates. And also, tax deductions or exemptions on the production of electricity. The investment support focussed on the financial side by providing capital grants, and tax exemptions or deductions on the purchase of goods (Howes, 2010, p. 120). The promotion instruments of the national support schemes will be central to this thesis: *Feed-in-Tariffs* and *Feed-in-Premium* schemes and *Tradeable Green Certificates* regimes, which will be elaborated on in further parts. These frameworks were included in the 2001 Directive to create more cohesion between the various support schemes between the Member States.

In 2006, the European Commission acknowledged that the target of 12 percent was unlikely to be met by 2010. They consider this a "policy failure and a result of the inability or the unwillingness to back political declarations by political and economical incentives". Besides that, they conclude that these efforts were mainly achieved by a small number of Member States, which were those with a stable regulatory framework (European Commission, 2007a, p. 8). Following this, the next step in the promotion of RE in Europe would be the Renewable Energy Directive, which was designed to change the landscape of renewable energy for good.

2.2 Renewable Energy Directive

In 2006, the first steps towards the 2009 Renewable Energy Directive were taken. The European Commission published the policy document 'Renewable Energy Road Map', which contained detailed plans for the renewable energy strategy of Europe. It proposes that the EU establishes a mandatory (thus, legally binding) target of 20 percent for renewable energy's share of energy consumption in the EU by 2020. They acknowledge that "the challenge is huge, but the proposed target can be achieved with determined and concerted effort at all levels of government assuming the energy industry plays its full part in the undertaking". The Roadmap examines the question which 'policy road' would be the best to take for the European Union regarding renewable energies. This could either be continuing with a separate renewable policy or abandoning a separate policy. The latter would be under the assumption that the renewable energy use would be driven by other climate policy instruments, like the ETS (see elaboration in Ch. 3.2). The Roadmap concludes that a separate policy would provide more stability, and that "providing targets at European level augments this stabilising impact" (European Commission, 2007b). The plans of the Roadmap of 2006 were worked out in proposal form in 2007 in the proposal 'An Energy Policy for Europe' by the European Commission. Combined with the reviews of energy efficiency policy and emissions reductions plans, this was the birth of the famous '20-20-20 by 2020'. Requiring the EU to reduce the greenhouse gas emissions from 1990 levels by 20%;

improving the energy efficiency by 20% and lastly, fulfilling at least 20% of the total EU energy needs with renewables, and all these goals should be fulfilled by the year 2020.

On 23 January 2008 the European Commission took, what could be called the final step towards the Renewable Energy Directive. They published their ‘climate and energy package’, which looked at all the climate and energy policies and how these worked together. It also reviewed the national efficiency action plans of the Member States (European Commission, 2008). Following this, the Council of Ministers finalized the text of the Renewable Energy Directive in April 2009. It was published in the Official Journal on the 5th of June in 2009 and the legislation was officially in force on 25 June 2009.

The *Renewable Energy Directive* 2009/28/EC requires the Member States to increase the share of renewable energy to 20 percent of gross final energy *consumption* and a separate goal of 10 percent renewable energy in transport by 2020. It is important to keep in mind that these goals are set for the consumption of renewable energy specifically. For this reason, the RED indicates in article 35-39 that MS can increase their consumption by statistical transfers between MS, joint projects and joint support schemes. For example, The Netherlands is not able to reach the set goal before the end of 2020. The government has acknowledged this and is buying the rights elsewhere in the EU (it still remains to be seen if this has been enough) (Boot, 2020). The RED specifies national objectives, which are legally binding, instead of the indicative targets from the 2001 Directive. When specifying the national objectives, the starting point and overall potential of the Member States is taken into account. For this reason, the targets vary from a 10 percent share of renewables for Malta, to a high 49 percent in Sweden (European Commission, 2020a). These specific national targets can be found in chapter 4 (*table 2*) and will be elaborated on in chapter 3.1.1. Article 25 of the RED mentions the different renewable energy potentials, but also the different support schemes for energy from renewable sources that Member States use. They mention that “one important means to achieve the aim of this Directive is to guarantee the proper functioning of national support schemes”. This is important in order to maintain investor support and also allow the Member States to design national measures that would be effective to meet their own national target (European Commission, 2009, p. 4). Member States were allowed and given the responsibility to choose their own policy to reach the national targets. Roughly speaking, the choice was between price-based or quota-based instruments, which will be dealt with in the theoretical section of this thesis. Besides the focus on the promotion of renewable energies, the RED also included a strategic objective to reduce the greenhouse gas emissions in the EU by 20 percent, compared to the 1990 emission levels. The third major element is a set of mandatory sustainability criteria for biofuels and bioliquids. These are required to fulfil all sustainability criteria in order to count towards the targets of the EU set and to be eligible for support (Scarlat, Dallemand, Monforti-Ferrario, Banja, & Motola, 2015).

In December 2018, the revised Renewable Energy Directive 2018/2001/EU entered into force. This RED II raised the overall EU target for RE consumption to 32% by 2030. One particular change in the RED II is that it only provides an EU-wide target, whereas RED I provided legally binding targets for individual Member States. As for the national targets, the new RED describes in article 10 that "the national targets set for 2020 should constitute Member States minimum contributions to the new 2030 framework. Under no circumstances should the national shares of renewable energy fall below those contributions." (European Commission, 2019). These *updated* national targets are yet to be defined by most of the MS. As this new Directive is outside the scope of this research, it will not be considered or elaborated on as such. However, we could conclude that this does show the (political) perseverance of the European Commission when it comes to an EU-wide RE strategy. The results of this research could tell more about whether this perseverance is the most effective path to take, or not.

3. Theoretical framework

Given the policy relevance of the Renewable Energy Directive and the instruments used, various studies have assessed the drivers that push renewable energy and effectiveness of the instruments that were implemented. Jenner, Groba, & Indvik (2013) focus on the effectiveness of feed-in tariffs for 26 EU countries in the period of 1992 to 2008. They show that policy design is more important than the existence of the policy itself. Dong (2012) conducted an empirical comparison between the relative efficiency of feed-in tariff policies and quota systems using data from 53 countries over five years (2005-2009). This paper finds no significant differences between the effects of the two systems on the amount of renewables. Haas, et al., (2011) compare the use of a quota-based system for an efficient and effective increase of renewable energy sources, with feed-in tariffs. They find that "success stories of renewable energy growth in EU member states have been triggered by feed-in tariffs implemented in a technology-specific manner at modest cost for the European citizen." So, we can see that the scientific literature has still not found conclusive evidence which RE promotion policy is the most efficient at promoting the production and use of renewable energy. Besides that, the theory on how the national targets for the Member States have an influence on the amount of RE is very thin. Especially the academic literature on how the ambitiousness of the target-setting plays a role in this.

This section will be used to draw the theoretical lines of the RED and the instruments that were used to promote the growth of RE. To answer the research question '*what effect does the introduction of mandatory national targets, combined with the freedom of instrument choice, introduced by the Renewable Energy Directive (2009), have on the share of renewable energy in the EU-28 from 2004 to 2018?'* the established scientific theory on this topic will be used to formulate hypotheses to test. First, we will look at directives as a policy instrument in general and how the targets for each of the Member States was set. In this part, target-setting in general, and the ambitiousness of targets will also be dealt with. Secondly, we will describe the RE policy instruments and how the EU Member States implemented these instruments. This will allow us to review the effectiveness of the national binding targets and the instruments that were used. Based on this theory overview, this section will conclude with the expected hypotheses. Which will then lead to step three of our analysis: empirically testing our hypotheses.

3.1 Directives as a European policy instrument

The European Union is an unprecedented instance of a regulatory state above the nation state, which works on the basis of providing joint solutions to shared regulatory problems. One of the ways to solving this together is the legislative act of a directive, which sets out a goal that all EU countries must achieve. However, a directive leaves room for the individual countries to devise their own laws on how to reach these set goals. Other forms of legislation are the regulations and decisions, which are binding throughout the whole European Union and must be applied in its entirety (European Union, 2019). Directives are not directly applicable, because they have to be transposed into national law first. A directive is not aiming at a single, uniform rule at EU level but rather to have the Member States strive for common results. In the case of the Renewable Energy Directive, the promotion of renewably energies and the reduction of greenhouse gas emissions is the common result that is targeted. The way the RED is implemented by the MS can be different, because the directive leaves the competence of the introduction of instruments to the MS. This flexibility (partly) explains the differences in the way RE is promoted between different countries.

In the European Union, roughly speaking, two general approaches on how to organise the RE policy support in general can be identified. The first is a fully harmonized system, in which the policy types are decided and implemented top-down in all Member States. The EU ETS is an example of such a uniform policy, which applies to all EU MS' (see Ch. 3.2.). The second approach is more bottom-up, in which all Member States have an independent choice for their policy types and approaches. So, with the current directive the European Union is following the second approach (Kitzing, Mitchell, & Morthorst, 2012). Kingston (2017) notices that the directive has been the preferred environmental legislation in recent years. The reason for this is that directives can be used to achieve a coherent EU-level policy, while still leaving some room for the Member States. Article 25 of the RED conveys this message as follows: "Member States have different renewable energy potentials and operate different schemes of support for energy from renewable sources at the national level. … For the proper functioning of national support schemes it is vital that Member States can control the effect and costs of their national support schemes according to their different potentials." The major advantage of using a directive as the policy instrument, is having the bottom-up approach, in which Member States have the flexibility to fit the policy instruments to the local circumstances.

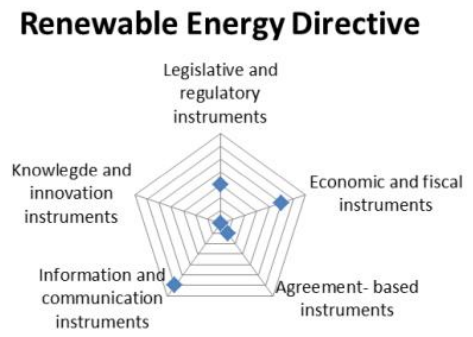

Figure 1 *overview types of instruments mentioned in the Directive (Source: Bouwma, Gerritsen, Kamphorst, & Kistenkas, 2015)*

Figure 1 shows an overview of the types of instruments that were mentioned in the text of the RED. The analysis from the report of Bouwma, et al., (2015) demonstrates that the environmental policies are moving away from 'regulation'. Instead, the focus of the RED is on finances and information and communication instruments. So, the MS are not 'forced', but they are more or less 'pushed' towards the goal to achieve a higher share of RE in their country. The type of 'legal technique' employed in the RED is goal setting, for which the coerciveness can be considered medium. The MS still get a medium margin of discretion in their way of achieving the targets (Bouwma, Gerritsen, Kamphorst, & Kistenkas, 2015, pp. 23-26). By using a directive as an instrument, the EU steers the MS towards a certain goal, instead of forcing MS to comply by using a regulation or decision instrument. With the very complex circumstances of the geological, technological and economical differences between MS, using a directive as an instrument to address RE promotion, makes the most sense.

However, there are also disadvantages to using directives rather than other binding instruments such as a regulation or a decision. One of the disadvantages is that it is not always an easy task to ensure that the actors that are responsible for the problem – if this is clear at all – comply with the rules. To ensure the objectives set out in the directive are fulfilled, the Member States are required to transpose directives into national legislation before a specified date[1]. This transposition means that the line between decision makers and implementers is blurred. According to Thomson, Torenvlied, & Arregui (2007) the "implementers often have incentives and opportunities to deliver policy performances that deviate from the policies they are charged with implementing, which might lead to *bureaucratic drift*." However, they do also state that "in many political systems the policies implemented are generally in line with those decided by policy makers." This phenomenon is known as *the paradox of compliance.* This is also in line with the theory of Thomann &

[1] Transposition for RED was required by 5 December 2010

Sager (2017), who state that Member States play a twofold role in the (successful) implementation. On the one hand, Member States are the actors transposing the rules from the directive into national legislation. On the other hand, Member States are *also* putting these rules into action and are responsible for enforcing them to ensure that the targets group comply. This could result in a scenario where the directive can be transposed perfectly, but still fail due to poor performance in practice. The European Commission does have measures in place to ensure a good implementation of the policy. If an EU country fails to communicate measures that fully transpose the provision of a directive, the European Commission may launch a so-called ‘infringement procedure’. When an EU country is referred to the court for the second time, the Commission proposes the imposing of financial penalties (lump sum and/or daily payments) (European Commission, 2020b). This happened in the case of Poland, who failed to transpose the directive by the set date. Originally, a penalty amounting to 133.228,80 per day was proposed, which was later reduced to 61.380 per day (European Commission, 2015). So, we can conclude that there is an incentive for Member States to comply with the objectives set into the Directive 2009/28/EC.

3.1.1 The ‘mandatory’ binding national targets of the RED

Directive 2009/28/EC sets specific binding targets, each Member State is supposed to realize a fixed share of RE in their energy mix (for an overview of the targets see Table 2). Article 14 of the RED indicates that the goal of these mandatory national targets is to provide certainty for investors and encourage continuous development of technologies which generate energy for all kinds of RE sources. For this reason, the European Commission also states that “deferring a decision about whether the target is mandatory until a future event takes place is thus not appropriate”. Article 15 of the RED addresses the reasons why the 20% target is translated into *individual* targets for each Member State. The European Commission argues that it is necessary to “take into account Member States different starting points and potentials, including the existing level of energy from renewable sources and the energy mix.” These starting points were weighted by their GDP (modulated to reflect their starting point) and “by accounting in terms of gross final consumption of energy, with account being taken of MS’ past efforts with regard to the use of energy from renewable sources”. The targets are set for a reason, but how do they play a role in the real world? This chapter will zoom in on the approach of national goal setting that happened with the introduction of the RED. What are the advantages and disadvantages of these binding targets?

On the one hand, the binding nature of the targets has been widely praised. They were pointed out as one of the significant factors for fulfilling both the MS' targets and the EU-wide target by 2020 (Roßegger, 2013). However, in 2014 the European Commission already wrote a proposal that said that after 2020 national targets will no longer be used. The communication report states that the EU and national targets did drive strong actions by MS and growth in emerging industries, but that they did not always "ensure market integration, cost-efficiency and undistorted competition" (European Commission, 2014, p. 4). Instead, the Commission proposes that the EU target would not be translated into national targets via EU legislation. This would leave "greater flexibility for Member States to meet their greenhouse gas reductions targets in the most cost-effective manner in accordance with their specific circumstances, energy mixes and capabilities to produce renewable energy" (European Commission, 2014, p. 6). This shift to non-binding targets has received criticism of (legal) scholars, because according to them this means that the European Commission is left with 'empty hands to demand national ambitions'. Besides that, the lack of clear rationale other than the generic need for more flexibility, was criticised. Especially in light of the positive results achieved with the binding targets, the shift back to non-binding targets seems like a weaker policy choice (Monti & Romera, 2020). However, they also argue the EU has adopted some other instruments which introduce numerous procedural obligations (i.e., Governance Regulation). These instruments might successfully replace the binding targets, but (in their words) "it remains to be seen whether and how the Commission will make use of such powers" (Monti & Romera, 2020, p. 231). Previous analyses of the binding nature of the targets in the RED concluded that there was a 'dual image'. On the one side the Directive contains a mix of more or less unenforceable obligations, which are "hiding behind a façade of mandatory compliance". And on the other side, the Directive combines old and new forms of governance within one instrument in an innovative way. This way they have given 'bindingness' a new meaning altogether: targets are framed in a legally mandatory language to reinforce the message that the change is vital (Johnston & Marel, 2016). The conclusion that they come to is that binding targets have much promise in the renewables field, but they must be embedded in a carefully designed and robust (legal) regime. They argue that the focus should not just be on the 'end-target', but attention should be paid to the progress that MS make along their trajectories.

On the other side of the debate, Helm (2014) argues that national targets are the most inefficient way to increase the amount of renewable energy. Because climate change knows no boundaries, it would be much more efficient for Europe as a whole to achieve the renewable targets, instead of each country reaching its own targets. His proposed solution is to have a common intervention mechanism, which would result in an EU-wide capacity and renewables market. This leads back to the discussion of full harmonization or differentiated climate policy (see chapter 3.1). With the shift back to non-binding target, the European Commission seems to agree with his view on the ineffectiveness of national (binding) targets. Even though the binding targets had some positive effects, it did not weigh up against the flexibility that non-binding targets allow.

The effectiveness of the binding targets is clearly not undisputed. Before the introduction of the RED in 2009, there were no binding targets, which gives us the opportunity to analyse the difference over the years. In chapter 3.1 the ‘freedom’ of instrument and policy choice under the directive have been discussed. The combination of these two elements leads us to the following hypothesis

H1: the introduction of the Renewable Energy Directive (2009) lead to an increased growth of renewable energies, compared to the growth before 2009.

3.1.2 Target setting and ambitiousness of the targets in the policy arena

The previous chapter explained the reasoning from the European Commission to make use of (binding) targets and why they were set at certain levels. This chapter will elaborate on the general theory of target-setting in the policy arena. An interesting angle in this debate is the ambitiousness of targets. The literature seeking to explain the effect of the ambitiousness is small. In the next part we will try to investigate this topic a little further.

Setting targets has been (and is) a common and popular legislative technique. Especially when it comes to the field of environmental and climate law, targets are widely used. Even more because most of the policy goals that are designed in this field are long-term, a target is particularly useful. The targets can be used to quantify the level of progress towards certain policy objectives and (if possible) be acted upon (Monti & Romera, 2020). Haarstad (2019) shows that numbers have a ‘carrying power’. Meaning, when a phenomenon (i.e., policy) is quantified, it transforms from abstract and particular to the language of the universal. Because the metrics that are used in the environmental and climate fields are knowable and measurable in a very precise way, setting (quantified) targets is very well possible. The amount of CO2 in the atmosphere, global temperatures, energy efficiency measures and multiple other metrics can also be traced back for very long periods of time (Haarstad, 2019). Besides the reasons why targets are used in the environmental and climate field, we should also look at the function of targets in general. The functions of targets can be divided into two groups: ‘disciplining’ and ‘signalling’. The disciplining function refers to the role of targets in improving the performance of public services or policies. This ties back into the quantifiable role that targets play, because the numbers can be used as ‘performance indicators’. The signalling role, on the other hand, refers to the symbolic function of targets. Targets can be adopted to signal commitment to, and also highlight the achievement of, political and policy goals (Boswell, 2014). Remarkably, the main function of the targets in the RED seem to be signalling. Article 14 mentions that the main purpose of the targets is providing certainty to investors and encourage continuous development of technologies. This indicates that the national targets are mainly set to show the commitment to the goal of increasing the share of RE. However, the disciplining function is also included, in the fact that the European Commission has made these targets binding for all Member States. The RED states that “Member States have to ensure that the share of energy from renewable sources … is at least its national overall target” (European Commission, 2009, p. 28).

When targets are set for a certain policy goal, several factors are taken into account. As mentioned earlier, the RED takes into account the different starting points and potentials of the MS. However, how does ambition play a role in this process? Of course, it matters at what level a target is set. If a target is set too low, the subject will not be triggered enough and the opportunities for improvement are not fully exploited. On the other hand, if the targets are set too high, the subject can do everything in its power to reach it, but not reach it. Or they might be discouraged to even start trying to reach the target, thus undermining the whole purpose of it. Höhne, et al., (2018) assess the ambition of post-2020 climate targets. Their study provides an overview of several approaches to evaluate the ambition level of climate targets of countries. Following their theory, we consider *ambition* to include both ‘moral obligation’ and ‘technical necessity’. The first refers to the commitments based on countries’ moral obligations, which leads to an equitable and fair regime. The differentiation of the moral obligation if often based on indicators like historical responsibility and capability. The second element of technical necessity refers to whether the efforts of a country are in line what is technically necessary (or possible). For example, developed countries that have a long history of renewable energy consumption and production, might have a high moral obligation, but may also face more technical difficulty to increase the amount of RE. However, they do also state that judging the fairness and the relative ambition of the contribution of Member States is not easy. The reason for this is that countries have different developments, industrial structure, capabilities, responsibilities etc., and these aspects can change over time. However, as these two aspects have been considered by the European Commission when setting that national target for each specific Member State, we can use this definition in our analysis. Tobin (2017) looked into the climate ambition of developed states ('Annex II' countries) and also finds that explaining the variation in ambition is challenging. He does find evidence that EU membership plays a strong role in determining climate policy ambition. Mainly because climate change has been a flagship issue for the EU in the past and the GDP per capita is scored relatively high.

We will use the method of beta-convergence to identify the way the national targets played a role in the effectiveness of the RED (further elaboration in Ch. 4.1.1). In short, convergence means that less developed countries are catching up with the more developed ones, in terms of real economy performance (Barro & Sala-i-Martin, 1992). Convergence studies are getting more and more attention in the field of energy and environmental economics[2]. These studies mainly focus on energy productivity and intensity. The results of these studies do not give undisputed results whether convergence exists or not. More interesting for this thesis is the convergence of the renewable energy shares in countries. Reboredo (2015) investigates a broad set of countries from 1990-2010, but does only find convergence of the share of renewable energy for a small number of countries. More specifically, only countries with a significant and growing renewable energy sector display convergence. The results point towards uneven efforts between countries, which would indicate that greater cooperation is needed. The studies that investigate the convergence of renewable energy in Europe do point in other directions. Sebestyén Szép (2016) analyzes and evaluatues the 20-20-20 goals of the EU for the period 2004-2012, using the convergence method. Of the three 20% goals, he finds that the convergence of the renewable energy sources is the strongest. This means that

[2] See for an overview of studies the papers of (Sebestyén Szép, 2016) and (Berk, Kasman, & Kılınç, 2020)

compared to the energy efficiency and emissions targets, the decreasing in the differences for this target is the highest. Berk, Kasman, & Kılınç, (2020) also find strong evidence for convergence for the core EU-members in the period of 1990-2014. However, they do end on the note that this does not mean that the 20% target will be achieved before 2020. In fact, they do raise concern on the achievability of the the target.

The periods of the papers that are cited do not cover the whole period that is studied in this thesis. For this reason it is relevant to look at the convergence of the goals during this period. The RED clearly recognizes the RE potential of the individual Member States, which is also accounted for in the setting of the target. Following the theory on ambition and the papers on European RE convergence, we expect that countries that had a more ambitious target set for them, will experience a higher growth of renewables in their energy mix. Therefore, we can formulate the following hypothesis:

H2: EU Member States with more ambitious national targets are more likely to experience a substantial growth in renewable energy compared to EU Member States with less ambitious goals.

3.2 Policy instruments used to promote renewable energy use in the EU

According to a report from the European Commission on the status of renewable energy in Europe, "support schemes are currently the major drivers for investment in the EU electricity sector, while investments in grid assets are driven mainly by regulation that guarantees investors a reasonable return of equity." (Banja, et al., 2017). So, government intervention, taking form in RE policy schemes, is still playing a major role in the growth of RE.
There are several support schemes to promote the use of RE. Roughly speaking we could divide them into four categories: feed-in policies, quotas, tax incentives and tenders. Feed-in policies often offer guaranteed prices for fixed periods of time for electricity produced from RE sources. Quotas, or green certificates, are quantity-based instruments, which usually require electricity retailers to supply a minimum percentage of electricity demand from RE sources. The instrument of tax incentives is structured as an investment-based and fiscal policy instrument, for example in way of low interest loans or tax exemptions for RE installations. The intention of tender schemes is to encourage lower electricity generation cost from RE sources. In this process, the provider with the lowest costs receives a contract (from

the government) to produce power. According to Kilinc-Ata (2016), a fundamental distinction can be made between *investment* and *generation* policy instruments. She categorizes the tax and tender instruments as investment driven incentives, whereas FIT and quota policies are generation incentives policies (Kilinc-Ata, 2016). This study focusses on the generation incentives policies that are provided by the EU-28 in the years 2004 to 2018. The effectiveness of these policy instruments is evaluated based on the increase of the share of RE in the overall energy consumption in a country.

Even though it is not really considered in this thesis, we should mention the interaction with the other main instrument for decreasing emissions, the EU Emissions Trading Scheme (EU ETS). This scheme sets a cap on the CO_2 emissions from electricity sector and energy-intensive industries. According to the theory, this interaction between EU ETS and RE support schemes comes down to the following: emissions are reduced by the RE policy, which leads to EU ETS permits being supplied back to the market. This in turn leads to a lower price, which makes it 'cheaper' for the industry to pollute. In their paper on this interaction, Lehmann & Gawel (2013) paint the scholarly debate, which shows that the combination of the two policy instruments has indeed received criticism. It is argued that the cost effectiveness of the EU ETS is undermined by the introduction of RE support schemes. However, while Lehmann and Gawel (2013) agree that these conditions hold in a perfect world, they argue that the energy market is subject to market and policy failures. For this reason, they argue that a policy mix of the EU ETS and RE support instruments can be justified. Firstly, because even though the EU ETS addresses the negative externality of CO_2, the restrictions to technological development and adaptation remain. In short: there are other market and policy failures, besides CO_2 emissions, that may impede a proper choice of energy and abatement technologies. The concept of path dependency is important in this discussion, especially in the electricity sector: RE technologies are competing against the well-established fossil-fuel and nuclear generators. Even more, they are competing on a very homogenous good: electricity. Normally a market for homogeneous goods has high levels of competition. However, in this case the conditions make it hard to have a well-functioning, competitive market without policy intervention. Because the innovation and employment of renewable energy sources is not rewarding enough at this point. Secondly, they propose that the EU pursues multiple policy objectives by the RE support schemes (see Ch.2). Even though the economic justification may be unclear for some objectives, they can provide a further political rationale for implementing RE support schemes (Lehmann & Gawel, 2013).

The same conclusions are also drawn by a recent report requested by the European Parliament. This report shows that in a system with just the EU ETS, only a few RE and energy efficiency (EE) projects are realized, with their costs benchmarked to the CO_2 certificate price. However, in a system with dedicated policies for EE and RE, financing risks, and thus generation costs, are reduced. This leads to an increase of EE and RE employment. The report concludes that "when an ETS system is combined with RES and EE targets, policy support costs decrease, and RES options become more competitive as well" (Winkler, et al., 2018, p. 15). So, we can conclude that both policy instruments do complement each other in the imperfect and politically driven world of the energy market and the EU.

3.2.1 Price-based instruments

The first instrument we will dive into are the price-based instruments. Roughly speaking, there are two approaches to price-based systems. The first option is a fixed-price tariff, which guarantees that electricity generators can sell their electricity to the grid at a set price. The second option is a premium tariff, which adds a bonus to the wholesale market price received by the electricity generators. In the EU, most countries employ a fixed-price design. The difference between the feed-in tariff and the market price can be redistributed among the end-users, but most common is that it is paid from state budgets. Some countries do set a maximum capacity on the total installations that may be installed, others cap the total tariffs that are given out. In Europe, Cyprus, Estonia, Ireland, Latvia, Portugal and Spain set a cap on the total RE installations that can be awarded under the FIT. Austria and the Netherland have set a cap on the total amount of tariffs that can be awarded under the FIT (Jenner, Groba, & Indvik, 2013). A FIT/FIP offers long-term energy contracts to renewable energy producers, and the power plants producers receive a payment amount for each unit of electricity. A specified price for every kilowatt-hour (kWh) of electricity produced is offered in these contracts. The duration of the contract varies, but it normally ranges between 10 and 25 years (Klein, et al., 2008). So, FITs are a generation-based, price-driven incentive, in which a 'transmission system operator' can feed in their full production of green electricity into the electricity system at defined prices.

Typically, FIT policies include 3 elements: (1) guaranteed access to the grid; (2) stable, long-term purchase agreements and (3) payment levels based on the costs of the RE generation

(Mendonça, 2007). One of the most important aspects of a FIT design is how the tariff level and the duration of the tariff is determined.

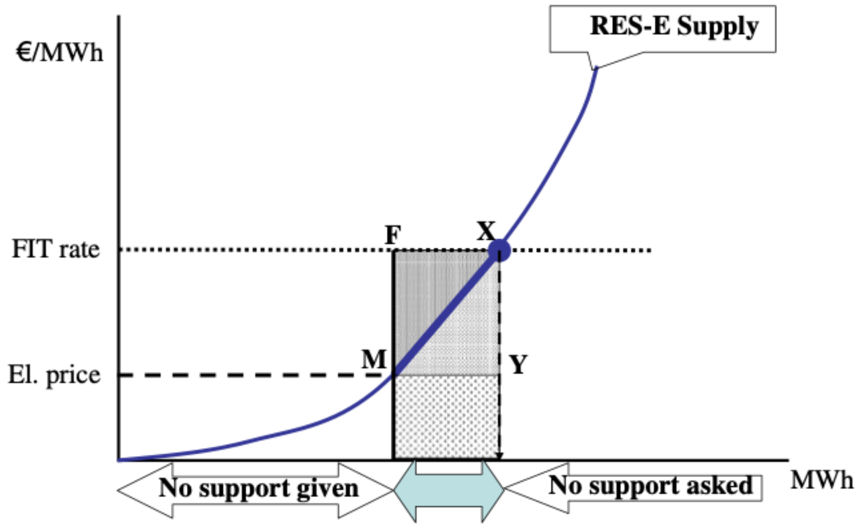

Figure 2 *Optimal FIT for one qualified RES-E category (Source: Verbruggen & Lauber, 2009)*

Figure 2 shows how the *optimal* FIT mechanism, for every well qualified source/technology, functions. The supply of renewable energy sources of one specified technology is represented by the upwards sloping long-run marginal cost curve. The cheapest section of the supply is profitable at the average electricity price (EL price), so below point M. After that follows the MWh-range which is above the wholesale electricity price (between M and X). This range is still attractive for investors, because of the FIT rate. Beyond point X, expenses are no longer covered, and it is no longer profitable for investors, so they will no longer apply for FIT support. The total cost of the FIT support is represented by rectangle MFXY, because this is the total price paid on top of the electricity price (Verbruggen & Lauber, 2009).

Another variation of a price-based policy is a feed-in *premium* scheme, which is a payment scheme in which the RE producers receive a fixed amount that is added to the electricity price. The preferential and technology-specific premiums are still determined by the government and the producers still benefit from a secure demand. However, in case of feed-in premiums the price renewable energy producers receive fluctuates according to the changes in the electricity market price. This does make a difference for the renewable plant owner, because the total price received per kWh becomes less predictable. According to a report from Ecofys (2014), FIPs can be evaluated similarly as FIT-systems. The main difference is the “market compatibility and risk allocation between the public and plant operators.” The main advantage of a FIP-system, compared to a FIT is the market orientation it gives, because the electricity price is part of the overall remuneration for RE producers (Ecofys, 2014, p. 38). Based on the theory we will compare FIT and FIP systems together, if any substantial differences are spotted between countries using either of these promotion policies it will be discussed in the results. Price-based instruments are in use in the most EU countries. At this moment all countries besides Belgium, Sweden and Romania use these policies. Italy, Poland and the United Kingdom switched to price-based instruments after using quota-based instruments for a few years.

3.2.2 Quota-based instruments

Besides price-based instruments, quota-based instruments were used to promote renewable energy consumption. A quota-based system sets a target for the share of renewable energy in the overall electricity consumption. This target is defined by the government and obliges the generators at their fulfilment. The producers of the green energy, the power plant operators, receive green certificates for their produced green final energy. The certificates are a tradable asset that proves that electricity has been generated by a renewable (green) energy source. So, the RE electricity producers can sell these certificates to the actors obliged to fulfil the quota obligation, which provides them additional income on top of the common market price. Typically, a certificate is issued per 1 MWh of renewable power produced. The certificates allow the government to set exact targets for the level of renewable energy production in their country, and the market will find the most efficient way to do so. The generators are then obliged to supply or purchase a certain percentage of electricity from renewable sources and have to submit the required number of certificates to demonstrate the compliance. These certificates can be obtained in several ways: (1) own renewable energy generation, each amount of energy produced represents 1 certificate (2) purchasing electricity and the associated certificates (figure 3) and (3) purchase certificates without purchasing the actual power from a generator (Nicolini & Tavoni, 2017).

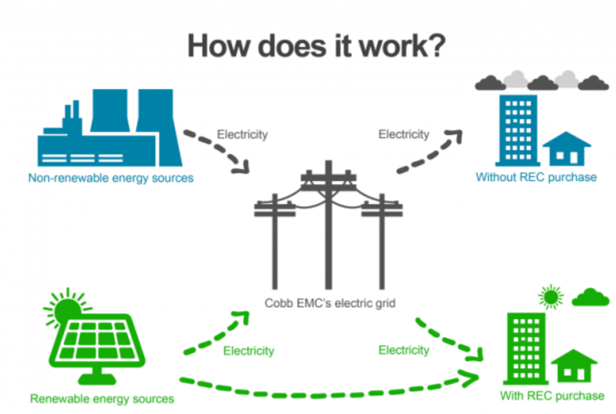

Figure 3 *simplified overview of quota-based RE policy instruments (Source: COBB EMC, 2017)*

Figure 3 shows a simplified overview of the process of a quota-based policy instrument. The RE generation, in this case photovoltaic (sun) energy, provides their generated energy to the grid, just like a 'traditional' or non-renewable generator. However, the RE power plant operator also provides the user of the RE with a certificate. Whereas other users that do not purchase energy specifically from RE sources still receive energy from the 'same' grid, but do not receive a certificate that adds to their total obliged amount. The other 2 options are either generating their own renewable energy and receiving a certificate or purchase just the certificates without purchasing the energy.

In a quota-based system the consumers/producers are required (compulsory) to buy a certain number of green certificates from generators of RE. The compulsory amount is set as a percentage of their total consumption. When they do not comply, they will receive a penalty for the number of kWh not supplied with the certificates.
The demand within the TGC system is created by increasing the quota over time, and the market has to generate the supply of the certificates. The government decides the amount of green energy for the whole country first, and it is then divided among each of the operators (consumer, retailer, distributor and producer).

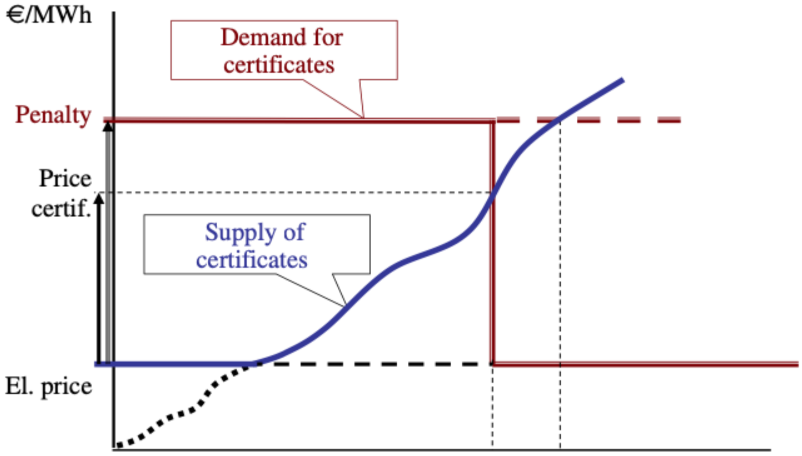

Figure 4 *Certificates market on top of psychical electricity market (Source: Verbruggen & Lauber, 2009)*

Figure 4 shows how the market for certificates functions in a given year. It is important to keep in mind that the quota are set as yearly targets and that the storable and non-perishable certificates are valid for one year or longer. Demand for the certificates is determined by the size of the quota that is set. So, the demand depends on the number of certificates that generators, suppliers or consumers have to submit in a given year and on the size of the penalty that has to be paid when not enough certificates are submitted. Demand for the certificates is an annually predictable curve, as the quota are (mostly) expressed as percentage of the total energy consumption. The blue line indicates the cost of supplying a certificate, how expensive it is to generate a kWh of RE. The supply of certificates is "the result of investing in and running plants that generate electricity qualified as RE." For technologies that extract from 'flows of nature' the main weight is on the fixed costs, but for example for bio-energy technologies the investment and operation costs are equally high as fossil fuel plants. For this reason, the supply curve in figure 4 is shown as an irregular pattern, to indicate that it is a combined curve of several RE sources and technologies (Verbruggen & Lauber, 2009, p. 5740).

Uncertainty in the certificates markets can come from the uncertainty that the final total energy consumption has for the following years. Even more uncertainty comes from the regulatory changes, for example by allowing import and export of certificates, which may shift the domestic demand for certificates completely. Verbruggen & Lauber (2009) showcase some regulatory interventions from countries using quota-based instruments, of what they call 'doubtful quality'. For example, a law in Flanders (Belgium) that "provides for yearly ex-post adaptation of due quota according to the number of certificates that were created during the year". These kinds of interventions create uncertainty in the market for certificates.

The quota obligation with TGC markets has some main advantages over other policy instruments. One of the advantages is that they are highly compatible with the general market principles and thus with the competitive price determination. Because both the RE electricity and the certificates are subject to market mechanisms. However, the downsides are the high-risk premiums resulting from uncertain development of the electricity and the certificate price typically increase the policy costs. Besides that, empirical evidence on quota-based system shows that the theoretical advantages cannot fully be realized in practice (Ecofys, 2014). This research will compare price-based and quota-based policy instruments that are used for the promotion of renewable in European Member States. Based on the previously mentioned theory of the price-based instruments, and the advantages and disadvantages of quota-based systems we come to the following hypothesis

H3: EU Member States that have introduced price-based instruments (FIT/FIP) are more likely to experience a substantial growth in renewable energy compared to EU Member States that have introduced quota-based instruments (TGC).

Several studies have evaluated the use of FIT and FIP regarding their effectiveness towards renewable energy deployment. Jenner, Groba, & Indvik (2013) review the effectiveness of feed-in tariffs in European countries employing an econometric analysis, using panel data from 1996 to 2008. Their research uses a new indicator for FIT strength, capturing the variability in tariff size, contract duration, digression rate, electricity price and production cost to estimate the resulting return on investment. This indicator is regressed on the RE capacity in the MS, for which the results show that FITs do drive deployment for photovoltaic (sun) renewable energy. However, they note that these effects shows are "overstated without controlling for country characteristics and concealed without account for policy design". Their final conclusion is that "the interaction between policy design, electricity price and electricity production is a more important determinant of RE development, than policy enactment alone". Haas, et al., (2011) also point towards policy design as the main reason for the effectiveness of FIT policies. In their research, they compare the quota-based RE promotion policies with price-driven promotion instruments. They review these RE promotion strategies using several case studies in the EU, starting from the 1990s to around 2008. The major conclusion from their paper is that "the major success stories of growth in RE in EU MS in recent years has been triggered by FIT which are implemented in a technology specific manner and involve rather modest cost for European citizens". Mainly pointing towards the long-term price security of FIT, combined with the technology diversification of support, which gives these systems an intrinsic stability. Whereas the quota-based systems are more geared towards short term trading in the certificates market. They also point out that market mechanisms seem to fail in TGC systems. Nicolini & Tavoni (2017) focus on policy support levels in the five largest countries of the EU in the period from 2000-2010. They collected data on the exact amount of monetary incentives and average tariffs granted, and employed an econometric analysis to find the effect of the subsidies on the production of incentivized (RE) energy and the installed (RE) capacity. Their results suggest feed-in-tariffs are more effective in promoting electricity from renewable sources than tradeable green certificates.

3.2.3 Technology specific policies

Another interesting debate is about whether the support of renewable energy should be specified for every technology, or whether there should be a 'one size fits all' solution; the support for renewable energy installations is technology neutral. The European Commission even expresses its specific support for the use of technology-neutral support, because this would promote a more cost-effective deployment of RE technologies. The reason that is given for this, is that government should not be picking the 'winners', but this should be left to the market. However, the EC does also acknowledge that the different stages of technological development for technologies, a technology-specific scheme may also be motivated (Banja, et al., 2017, p. 27). Certificate systems are often deemed to be neutral. Feed-in tariffs are more open to debate on this topic, the question whether there should be a single tariff for all electricity from RE sources, or not.

Klein, et al., (2008) argue that the electricity generation costs vary between different technologies that use renewable energy techniques. In their evaluation of different feed-in designs they argue that this is the reason that a FIT should provide technology-specific tariff levels. Disagreeing with the EC, they argue that there are some factors that influence the power generation costs of different renewable energy technologies, which have to be taken into account. Factors like the initial investment, the operational costs, interest rates on the invested capital et cetera. This is also the reason that most countries in the European Union use technology-specific tariffs in order to compensate for the differences. These preferential and technology-specific tariffs are regulated by the government. Haas, et al., (2011) complement this argument in their research. In their paper they argue that a differentiated system lowers producer rent, and it is better at reducing the electricity prices than a uniform tariff. Azar & Sandén (2011) reviewed whether it is necessary to design technology-neutral support policies and concluded that it should not be used as an objective when designing them, as technology-neutral instruments are often "an elusive objective that neither can, nor should be prioritized as the main guiding principle.".

However, Requate (2014) disagrees with this, and states that the assumptions for a differentiated system do not hold. Neither the implicit assumption that the marginal costs per unit of electricity and technology are constant, nor that there is a fixed capacity for technology in reality. The space for the three major renewable energy technologies (i.e., wind turbines, PV panels and bio-gas electricity power plants) is just not really limited, except by some legal constraints. Requate argues that when arguing in favour of technology-specific some basic economic principles are ignored. First of all, the 'equal marginal-cost principle', which tells that it should be equally costly for the marginal producer (i.e., the facility) to produce the last unit of a homogenous good, which electricity is. An argument that proponents of technology-specific will then point towards is the 'learning-by-doing' effects that will occur, which would cause the prices to drop. However, this argument does not take into account that rational producers have an incentive to internalize cost decreases through private learning-by-doing effects on their own. If there are no learning spill-overs at all, there would be no market failure and thus no policy intervention needed. And if learning spill-overs *do* exist, "the marginal spill-over effect should determine the subsidy rate, not the present average or the marginal costs of producing the renewable energy." (Requate, 2014, p. 234). Cosima (2014) shows that the technology-specific design of the FIT policy in Germany carries has flaws, because the design fails to expose the German wind and solar power producers to the wholesale market. The excess costs that come from this design are more than 6.6 billion euros, which are burdened by society.

As we can see, the choice between a technology-specific or technology-neutral policy instrument is not uncontested. In our empirical research we will test and review whether having technology-specific *or* technology-neutral policies makes a difference in the amount of RE that is produced. In line with the preference of the European Commission and the last authors mentioned in this section, we can hypothesize the following

H4: EU Member States using a technology-neutral instrument to promote renewable energy production are more likely to have a more substantial growth than EU Member States using technology-specific instruments in the share of renewable energy in their country

3.3 Overview of hypotheses

With the overview of the academic literature and theory four hypotheses have been be formulated. First, I will investigate whether the introduction of the Renewable Energy Directive, which introduced mandatory (thus, binding) national targets and the freedom (of instrument choice), lead to an increased growth of renewable energy consumption. Especially since the previous and the next Directive aimed at renewables do not include such binding targets. Secondly, we will investigate whether the ambitiousness of the targets had an influence on the growth of renewable energy. Following the academic literature, we hypothesize that MS with more ambitious goals will experience a more substantial growth of RE, compared to MS with less ambitious goals. The third hypothesis I will test will zoom in on the main types of instruments that were employed by the Member States. The academic literature finds a slight advantage in favour of price-based instruments (FITs and FIPs). However, this is not uncontested, as there are advantages to using quota-based instruments (like TGC). We expect that the Member States that have introduced these price-based instruments are more likely to experience a substantial growth in renewable energy consumption. Lastly, we want to find out whether technology-neutral or technology-specific make a difference in the amount of renewable energy that is consumed in a European Member State. We hypothesize that Member States using technology-neutral instruments are more likely to have a more substantial growth, which follows the line of the European Commission. A short overview of the hypotheses can be found in table 1 below. The hypotheses will be empirically tested. First, the methodology and data will be presented and explained.

Hypothesis	**Summary**
H1	The introduction of the Renewable Energy Directive (2009) lead to an increased growth of renewable energies, compared to the growth before 2009.
H2	EU Member States with more ambitious national targets are more likely to experience a substantial growth in renewable energy compared to EU Member States with less ambitious goals.
H3	EU Member States that have introduced price-based instruments (FIT/FIP) are more likely to experience a substantial growth in renewable energy compared to EU Member States that have introduced quota-based instruments (TGC).

H4	EU Member States using a technology-neutral instrument to promote renewable energy production are more likely to have a more substantial growth than EU Member States using technology-specific instruments in the share of renewable energy in their country.

Table 1 Overview of expected hypotheses derived from literature review

4. Methodology and data

In this chapter I will describe and discuss the empirical approach that is chosen to study the growth of renewable energy in European countries from 2004 until 2018. I will examine the effect of the introduction of the RED and its binding targets and the performance between the policy instruments. I will first describe the method of analysis and explain how I collected the data. After that, the most important concepts, including the dependent variable and explanatory (independent) variables, will be explained and operationalized.

4.1 Research methods

4.1.1 Method of analysis

This thesis aims to answer the research question by examining the link between the dependent variable and the independent variables in a quantitative manner. The purpose of this research is to review the effectiveness of the introduction of the RED and the instruments that were used to promote the use of RE. The data that will be used to estimate the effects is gathered for each of the EU-28 Member States over the period of 2004 to 2018, resulting in a total of 420 observations for each variable. The dataset takes the form of a longitudinal or panel dataset, which varies across time and the cross-sectional units.

For the empirical analysis three different models will be used. First, a pooled regression model and a Fixed Effects model. Using these two different models allows us to correct for potential biases that are inherent to estimating the effects for the share of renewable energy in 28 European Member States. Second, the method of beta-convergence will be used to estimate the differences between the countries and their growth rates towards the goals set by the RED.

A pooled regression allows us to control for observable differences in other factors (Angrist & Pischke, 2015, pp. 56-69). Equation 1 shows the equation that is used for the pooled regression model

$$Y_{i,t} = \alpha + \beta Q_{i,t} + \gamma A_{i,t} + \varepsilon_{i,t} \tag{1}$$

In equation 1, $Y_{i,t}$ is a measure of the share of RE in the Member States. Where i=1, … ,N (number of Member States) and t=1, … ,T (number of years). Then parameter $Y_{i,t}$ is the outcome for member state i in year t. The intercept, α, indicates the size of the dependent variable when all other variables are equal to zero. The coefficient β indicates the treatment effect caused by the treatment variable Q_{it}. Several independent (or treatment) variables will be used to estimate the effect on the dependent variable: the introduction of the RED, the choice of instrument, and also the 'bonus' explanatory variable: whether a country used a technology-specific or technology-neutral instrument. The parameter γ specifies the effect of the control variables A_{it} that are added into the analysis. Lastly, ε_{it} indicates the standard error.

Besides using a pooled regression model, a Fixed Effects model will be used to correct for certain biases. This model is the most widely used panel data model, for the primary reason that it corrects for a certain 'omitted variable bias': unobserved heterogeneity (Moody, 2005, p. 188).

$$Y_{i,t} = \alpha_i + \alpha_t + \beta Q_{i,t} + \gamma A_{i,t} + \varepsilon_{i,t} \tag{2}$$

Equation 2 shows the Fixed Effects model, which is similar to the one used for the pooled regression. The only aspect it differs in is the fact that each Member States receives its own intercept α_i and α_t. This gives us the possibility to generate outcome variables for all Member States, holding all other things the same. The FE model allows us to control for European trends and events, because each year has its own effect of α_t. This way we can control for things that affect the dependent variable, like an economic crisis or change in the political landscape, while holding everything else the same.

The pooled regression and FE models suffer from potential biases and problems. The first bias that should be taken into consideration is the reverse causality. It is possible that countries that were having a low growth of RE in their energy mix, switched to the price-based instrument to achieve a more substantial increase in RE. This reversed causality would cause an underestimation of the share of RE variable in the pooled regression model, the FE model corrects for this bias to a large extent (Angrist & Pischke, 2015). Another limitation that puts a real constraint on the results is the fact that our data does not have a lot of variation in time. The fixed effects estimates are based on characteristics that change overtime. To be effective, the model needs variation between countries *and* variation in time.

In our model the variation is limited to the policy instruments that countries used, which is a limitation for our statistical power. In our interpretation of the results, we should keep this limitation in mind, because the results might be slightly skewed because of this (Hill, Davis, Roos, & French, 2020). The last potential limitation that needs to be corrected for in these models, is serial correlation. The share of RE consumption only changes slowly over time, and the implementation of the policy support instruments takes time before becoming effective. A large share of each observation thus reflects developments in previous years. This problem can be solved by including a time-lagged independent variable. This is done by adding $\beta y_{i,t-1}$ to the equation, which lags the share of renewable energy by one year for each MS.

The third and last model that will be used to analyse the effectiveness of the RED, is the so-called beta-convergence. β-convergence was first developed to explore the convergence of economic growth (Barro & Sala-i-Martin, 1992). For our research, it can be used to compare the effectiveness in light of the targets that are set for every MS, and whether the ambitiousness of the target played a role in this. Because the targets are different for each MS, we can translate this into the distance from the target for each specific MS. The basic assumption of our β-convergence is that countries that were closer to their target show slower growth over time. In the long run this would mean that the countries further away from their target will catch up with the MS that were ahead. Equation 3 below shows the model that will be used to test the beta-convergence

$$\Delta y_{it} = a_i + \beta y_{i,2008} + \ Q_{i,t} + \varepsilon_i \qquad (3)$$

In equation 3, Δy_{it} is the examined indicator. This indicator is the extent to which the national targets has been achieved in 2018, compared to the extent of achievement in 2009. This is calculated by dividing the share of RE in 2018 by the target *minus* the share of RE in 2009 divided by the target. Dividing by the target creates a specific value for each MS, which is what we need for our analysis. We will explain this by the value that β takes, which is the extent to which the target was achieved in 2008. Parameter Q specifies the effect of the control variables that will be used. To be useful for our analysis, these control variables will also be normalized by dividing the value of the indicator in 2018 by the value in 2008. This creates a specific growth value for each MS. In the equation, α_i is the constant, ε_i is the error term (Sebestyén Szép, 2016). We expect that countries that were closer to their national target in 2008 show a slower growth over time compared to countries that were further away from their national target. If the estimated value of the β turns out negative, we can conclude that β-convergence can be verified.

4.1.2 Method of data collection

In this section, I will explain how the dataset that was used for the analysis is constructed. The data used in the analysis mainly comes from the Eurostat database. Other sources were used to construct other variables, which will be specified later. Eurostat is a General Directorate of the European Commission and is responsible for giving statistical information to European Institutions, by favouring the harmonization of statistical methods across all the Member States. The data for all variables was available and collected for the years 2004 until 2018 for all EU-28 countries, still including the United Kingdom. This gives us information about the status of the renewable energy in all 28 European Countries over the period of 15 years, providing around 400 usable observations for our analysis.

The dependent variable is the 'share of renewable energy in gross final energy consumption', which measures the share of renewable energy consumption in the gross final energy consumption within each Member State. The indicator measures how "extensive the use of renewable energy and, by implication, the degree to which renewable fuels have substituted fossil and/or nuclear fuels is and therefore contributed to the decarbonisation of the EU economy." This allows us to compare the 'whole' share of RE in a MS, as it is calculated as a share of the gross final energy consumption, which is all energy used by the end-consumers, plus grid losses and self-consumption of powerplants.

The independent variable is the policy instruments that the Member States used to promote the growth of RE in their country. Besides that, we will look at whether the instruments were technology-specific and technology-neutral. The information for these independent variables can be found in Appendix A. For this overview, information from the International Energy Agency (IEA, 2020) and the RES-legal website[3] (RES-legal, 2019) is combined. This

[3] An initiative from the European Commission, which provides all relevant information on support schemes, grid issues, and policies for renewable energy sources … for all 28 EU Member States. Last updated in January 2019.

provided all relevant information on the status of the renewable energy (policies) in all 28 Member States for the years 2004 until 2018.

4.2 Conceptualization & operationalization

In this section the variables will be conceptualized and operationalized. Conceptualization means turning the ideas and theory described earlier into well-defined concepts. Operationalization is the process of making these concepts measurable. First, I will provide more information on the dependent variable and after that I will give more information on the independent variables, to close off with the control variables used.

4.3 Dependent variable

This research will examine the effectiveness of the Renewable Energy Directive and the instruments that are used to promote the use of renewable energies within the EU-28 countries. The dependent variable $Y_{i,t}$ is therefore represented by the indicator 'share of renewable energy in the gross final energy consumption'. This indicator from the Eurostat database measures the share of renewable energy consumption in the gross final energy consumption. The data for this indicator is published annually and is available from 2004 to 2018 for the EU-28, which includes all current EU members and the United Kingdom. As the United Kingdom was (still) part of the European Union during this time, they are included in the analysis.

We use this dependent variable following Marques, Fuinhas, & Pires Manso (2010); D'Adamo & Rosa, (2016) and many others, to test the effectiveness of renewable energy promotion strategies. This dependent variable allows us to compare the Member States for their progress in the promotion of renewable energy. Besides that, this indicator is important for the target(s) set in the RED; the EU overall RE share should be at 20% and each MS has their individual target to reach, which is measured by this indicator from Eurostat. Using this variable, we want to examine what the effectiveness of the policy instruments has been on the increase of RE in EU Member States. Besides that, we want to study the effects of the introduction of the policy of the RED in 2009 and how the ambitiousness of the national targets that were set, played a role in the employment of RE. In the literature other options are suggested, like the RE source capacity or the annual added capacity. This would allow to isolate the effect of the policy from the capacity development in prior years. We take this into account by adding a time-lagged control variable of the share of renewable energy into the regression. Jenner, Groba, & Indvik (2013) suggest that using more specific capacity data would be better. However, this is not possible due to data constraints.

Table 2 shows a detailed overview of the share of RE in the energy mix of the European Member States and the European Union as a whole (EU-28). The second column indicates whether the MS were using price-based (FIT) or quota-based (TGC) instruments. The data is shown from the start of the data measurement in 2004 until the latest available data in 2018. For every MS, the individual target set by the European Commission is shown. In case a MS reached this goal, the number has been made bold in the year the target was hit. The last two columns of table 2 show the ambition and change from 2008. The column 'ambition 2008' shows the percentual change that is needed to reach the national target in 2020, compared to the amount of RE in 2008. This column gives us an insight into the ambitiousness of the target, compared to the levels of RE that were already in the energy mix of a specific MS. This data can then also be compared to the last column 'change 2008'. This column shows the actual percentual change of the share of RE compared to the last status in 2018. With this data we can identify how much the amount of RE actually changed since 2008, which gives us a little insight into the degree to which a county hit the national target. This will later also be empirically tested by the beta-convergence method.

Table 2 Overview of RE share in EU-28 Member States in the period 2004-2018, the instrument, the individual targets and the ambition and change in 2008 compared to resp. the target and 2018

Geo/time	**FIT/ TGC**	**2004**	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**	**2018**	**Target 2020**	**Ambition 2008**	**Change 2008**
EU-28		8,52	9,68	11,36	13,15	14,69	16,21	16,99	17,97	*20*	+76.1%	+58.2%
Austria	FIT	22,52	26,24	28,85	31,19	32,67	33,65	33,36	33,42	*34*	+17.8%	+15.8%
Belgium	TGC	1,89	2,63	3,59	5,64	7,18	8,03	8,71	9,42	*13*	+262%	+162.4%
Bulgaria	FIT	9,23	9,41	10,34	13,92	15,83	**18,05**	18,76	20,52	***16***	+54.7%	+98.5%
Cyprus	FIT	3,07	3,26	5,13	6,17	7,13	9,17	9,85	**13,88**	***13***	+153.4%	+170.6%
Czech Republic	FIT	6,77	7,36	8,67	10,51	12,81	**15,07**	14,93	15,15	***13***	+49.9%	+74.4%
Germany	FIT	6,21	8,47	10,08	11,68	13,55	14,38	14,88	16,48	*18*	+78.6%	+63.5%
Denmark	FIT	14,84	16,33	18,54	21,88	25,46	29,31	**31,83**	35,70	***30***	+61.8%	+92.6%
Estonia	FIT	18,38	15,96	18,64	24,57	**25,52**	26,14	28,68	29,99	***25***	+34.1%	+60.9%
Greece	FIT	7,16	7,45	8,18	10,07	13,74	15,68	15,39	**18**	***18***	+120%	+120%
Spain	FIT	8,32	9,14	10,73	13,81	14,28	16,12	17,42	17,45	*20*	+86.4%	+62.6%
Finland	FIT	29,25	30,06	31,36	32,44	34,43	**38,78**	39,01	41,16	***38***	+21.2%	+31.3%
France	FIT	9,50	9,33	11,18	12,67	13,43	14,58	15,68	16,59	*23*	+105.7%	+48.4%
Croatia	FIT	**23,40**	22,66	21,98	25,10	26,75	27,81	28,26	28,02	***20***	+0%	+27.5%
Hungary	FIT	4,34	7,43	8,56	12,74	**15,53**	14,61	14,31	12,48*****	***13***	+51.9%	+45.8%
Ireland	FIT	2,33	3,03	3,92	5,70	7,05	8,59	9,25	11,06	*16*	+308%	+182.1%
Italy	FIT (2008)	6,31	8,32	11,49	13,02	15,44	**17,08**	17,41	17,77	***17***	+48%	+54.7%
Lithuania	FIT	17,22	16,88	17,82	19,64	21,43	**23,59**	25,61	24,44	***23***	+29.1%	+37.1%
Luxembourg	FIT	0,9	1,47	2,81	2,86	3,14	4,51	5,44	9,05	*11*	+291.5%	+222,1%
Latvia	FIT	32,79	31,14	29,81	30,37	35,70	38,62	37,13	**40,29**	***40***	+34.2%	+35,2%
Malta	FIT	0,102	0,149	0,195	0,979	2,82	4,74	6,20	7,97	*10*	+5028%	+3987.2%
Netherlands	FIT	2,03	2,77	3,59	3,91	4,65	5,41	5,82	7,38	*14*	+290%	+105.6%
Poland	TGC (2015)	6,91	6,88	7,71	9,25	10,89	11,49	11,26	11,28	*15*	+94.6%	+46.3%
Portugal	FIT	19,20	20,78	22,94	24,16	24,57	29,50	30,85	30,32	*31*	+35.1%	+32.2%
Romania	TGC	16,81	17,09	20,20	22,83	22,82	**24,84**	25,03	23,87*****	***24***	+18.8%	+18.2%
Sweden	TGC	38,67	42,44	44,66	46,95	**50,32**	51,87	53,37	54,65	***49***	+9.72%	+22.4%
Slovenia	FIT	16,13	15,58	14,99	20,42	20,81	21,53	21,29	21,14	*25*	+66.8%	+41%

Slovakia	FIT	6,39	6,58	7,72	9,09	10,45	11,71	12,02	11,89	*14*	+81.3%	+54%
United Kingdom	TGC (2009)	0,907	1,33	2,69	3,78	4,41	6,73	8,98	11,01	*15*	+458%	+309.3%

Among the EU-28 Member States, 14 have already hit a share equal to the national 2020 targets. Two of which (Hungary and Romania) have dropped below their target again in 2018. Of the 14 remaining Member States, two are less than 1 percentage point away from hitting their goal, nine are between 1 and 4 percentage points away and three countries are more than 4 percentage points away. The first row (EU-28) shows the average growth of RE in Europe over time. We can see that from 2004 onwards the EU as a whole is slowly creeping towards the overall target of 20 percent renewables. However, in 2018 they are still 2 percent points away from hitting this goal.

The first thing to notice in the table, is the large differences in the share of RE that is needed to hit the individual goals between the MS (ambition column). On the one hand, we see some of the countries (e.g., Austria, Estonia, Finland and others) already had a substantial amount of RE in their energy mix, even before the introduction of the RED. These countries did not even need to double their share of RE to hit the target set for them. On the other hand, we see countries having a very low share RE (e.g., Ireland, Malta, the Netherland, UK), which need to invest heavily in their RE production to reach the mandatory national goal. Another striking detail is the fact that Croatia had already hit their national target *before* the introduction of the RED.

Following this, table 2 can also be used to analyse the effectiveness of the mandatory national goals that the RED set. In chapter 3.1.2 the theory on goalsetting and the ambitiousness has been discussed. The hypothesis that followed from this was that countries with more ambitious national goals would experience a more substantial growth of RE. Although this will be empirically analysed in chapter 5, we can already draw some interesting conclusion by eyeballing the data. For example, Austria (+17.8%), Portugal (+35.14%), Slovenia (+66.8%), and other countries were all relatively close to the national target, compared to their amount of RE in 2008. Even though the growth they had to achieve was relatively little, these countries did not hit the 2020 target in 2018. This might have something to do with the 'technical necessity' that was mentioned in chapter 3.1.2. These MS might possibly already be exploiting their RE sources to a high level, so an increase in RE might be harder to achieve. However, it might also be possible that the targets were set too low (not ambitious enough) and the MS were not encouraged enough. On the other hand we see that, for example, Cyprus (+153.4%) and Greece (+120%) had a relative longer way to go to hit their national target, but they still managed to hit their goals in 2018. These notable differences between the EU Member States combined with the theory on target setting and the ambition, lead to a few interesting questions. These questions will empirically be elaborated on in chapter 5.

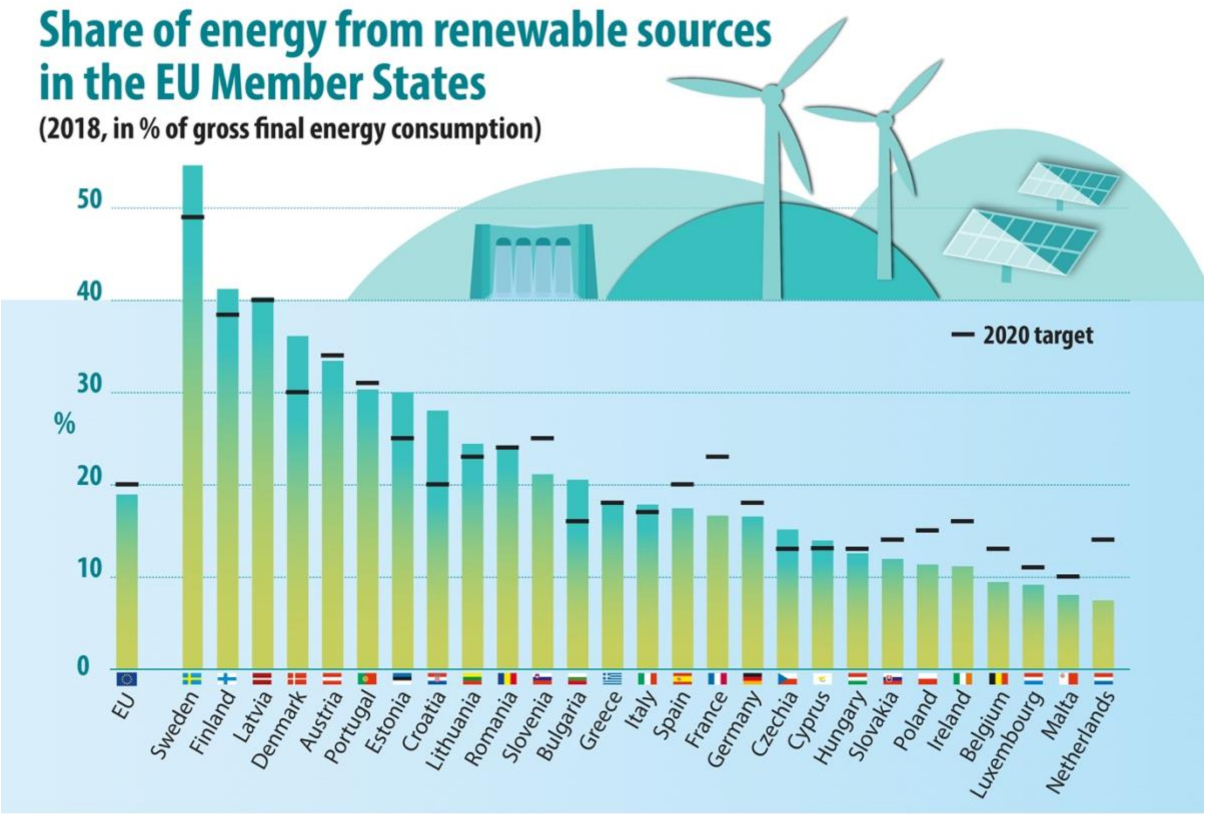

Figure 5: *Share of energy from renewable sources, 2018 (% of gross final energy consumption) (Eurostat, 2020)*

Figure 5 gives us a graphical overview of the data showcased in table 2. We can see the large differences between Member States, which could be expected, as every country has its own RE generation capacity. Just eyeballing both data overviews, we could safely suggest that some countries appear to be ‘carrying’ the policy goal of total share of 20 percent of RE in the whole of Europe. Both data overviews showcase data from the RE share in 2018, which is only two years away from the year for which the goal was set. This leads to the very interesting question ‘how are they going to manage this, and what would be the most effective way?’ This once again shows us the importance and (policy) relevance of this research.

4.4 Independent variables

Three independent variables will be used to measure correlations and investigate the effects on the growth of RE in the Member States. The main independent variable is the policy instrument for the promotion of RE, as explained in the theory. This could either be a quota-based or price-based promotion system. Secondly, we will also investigate the effect of the introduction of the Renewable Energy Directive in 2009. Lastly, one ‘extra’ variable will be tested. This independent variable will investigate the effects of either using technology-specific or technology-neutral distribution policies. As the theory on this topic is quite thin, we want to investigate this particular area a little further.

4.4.1 Policy instrument (FIT / TGC)

The policy instrument (FIT/TGC) that Member States choose to promote renewable energy has been a topic of debate in both politics and scientific literature for a long time, as seen earlier. Before the RED was introduced in 2009, most MS were already using one of the policy instruments to promote the use and production of renewables in their country. This independent variable is set up as a dummy variable, in which is indicated which policy instrument a European country used. The variable ‘TGC’ indicates with the value 1 when a country used a quota-based instrument to promote the use of RE and a value of 0 thus indicates that countries used a price-based instrument (or feed-in tariff). The policy instruments are explained in chapter 2. Appendix A provides a clear overview of all policy measures concerning the Renewable Energy Directive for the European countries. In some cases, the use of an instrument is a little more nuanced than the sharp division of FIT and TGC, but for the purpose of this research this distinction suffices. Currently, three countries are using quota-based instruments: Belgium, Sweden and Romania. In the past, Poland, the United Kingdom and Italy also used quota-based system. The variation that is needed for good statistical research is a bit thin, this will be accounted for in the analysis.

4.4.2 Introduction of the RED (2009)

The second independent variable we will test in our analysis is introduction of the Renewable Energy Directive in 2009. The political and economic reasons for the introduction of this policy have been discussed in chapter 3.1. This variable is constructed as a dummy variable, in which value 1 indicates the period after the introduction of the RED in 2009. Because this variable only changes over time, we will only test this variable in the models without time effects.

4.4.3 Technology-specific or technology-neutral instruments

The third independent variable allows us to delve deeper into the reasons for success or failure of the renewable energy promotion strategies. This variable looks at the way the price-based and quota-based instruments are distributed. This could either be specific to a technology: e.g., PV receives higher tariffs per megawatt generated than hydro, or technology-neutral, in which there is just one specified rate for all technologies. This variable is constructed as a dummy variable, in which a value of 1 indicates that a country uses technology-neutral instruments and a value of 0 thus indicates technology-specific instruments. The data for this variable and the sources from which it has been gathered can be found in Appendix A. There are, however, data constraints for this variable. Because currently there are only six countries using technology-neutral instruments, which might skew the results. Because the variation for this variable is only between countries, we will only consider this variable in the pooled regression models, as it cannot be used in a regression with country effects.

4.5 Control variables

Various control variables have been added, which according to the literature, affect the share and growth of RE in a country. Adding these control variables increases the validity and accuracy of the results from the regression models. These political, economic and geographical control variables allow us to compare the differences between the EU-28 MS better.

4.5.1 Import dependency

The first control variable is the import dependency of a country. The indicator of import dependency from Eurostat shows 'the share of total energy needs of a country met by imports from other countries.' The calculation is done by dividing net imports by gross available energy. The indicator used in this study will be the percentage of imports in the total energy consumption for all products. Dependency of energy security is a crucial policy concern for governments, and for that reason energy security is one of the other key aspects of the Renewable Energy directive. Research has shown that energy security has an impact of renewables development (Dong, 2012; Aguirre & Ibikunle, 2014). Marques, Fuinhas, & Pires Manso (2010) suggest using energy import variables as a proxy for energy security. We expect that, when a country has a higher level of reliance on their energy imports, their level of investment in renewable sources will be also be higher. Most countries do not only invest in RE to reduce dependence on imported oil, but also to increase the supply of secure energy and minimize the price volatility associated with fossil fuel imports. Thus, we expect that energy imports will be positively related to renewables growth (Aguirre & Ibikunle, 2014).

4.5.2 Final energy consumption

The second control variable is the final energy consumption. The Eurostat indicator measures the 'energy end-use in a country excluding all non-energy use of energy carriers.' This variable covers all energy consumption by end-users such as industry, transport, households, services, agriculture etc. It excludes the energy consumed by the energy sector itself. The unit of measurement is 'the tonnes of oil equivalent per capita'.

In the literature, final energy consumption is considered a development indicator. It also reveals the energy needs a country has, which are both relevant in the process of reviewing the effectiveness of the RED and its instruments. It would almost be inappropriate to estimate a model that considers renewable energy without controlling for the total energy needs of a country. The variable is used in other analyses of renewable energy policies (e.g., Marques, Fuinhas, & Pires Manso, 2010; Carley, 2009; Jenner, Groba, & Indvik, 2013). The literature does not really give a prediction of the effect of a larger energy consumption. On the one hand it could encourage RE development, and on the other hand it could be a force leading to higher levels of fossil fuels use.

4.5.3 Real GDP per capita

The third control variable is the GDP per capita. The Gross Domestic Product is a measure of economic activity and is commonly used as a proxy for the development in a country's material living standards. The Eurostat indicator that is used shows the chain linked volumes of euros per capita. The literature is split on whether the causal relationship between economic growth (GDP per capita or other measure of wealth) has a positive or negative effect on RE consumption. On the one hand, higher income countries are relatively more capable of sustaining the costs of RE technologies and stimulate RE through economic incentives (Aguirre & Ibikunle, 2014). Jenner, Groba, & Indvik (2013) argue that the effect is dependent on the type of technology that is used. On the other hand, it is argued that a higher income would imply additional energy consumption to support higher production levels, which would come from fossil fuel sources (Marques, Fuinhas, & Manso, 2011). Following (Menegaki, 2011; Amri, 2017; Koçak & Şarkgüneşi, 2017), and many others, we will use GDP per capita as a proxy for sustainable economic growth for the European Member States. Using this control variable, we will examine the effects on the renewable energy development further. For our analysis in chapter 5, the values of the GPD will be divided by 1000. This makes the coefficient and the explanation more relevant for our research. We expect that the growth in GDP will have a positive effect on the renewable energy consumption in EU-28 countries.

4.6 Descriptive statistics variables

In table 3 below you will find the descriptive statistics of the variables that are used in the analysis. The dependent variable *Share RE* has also been dissected in table 2. The values for the independent variables show the levels of renewable energy for that specific variable. The values in brackets after the instruments indicate the number of countries that are using this specific instrument. It should also be noted that Estonia did not report any values for their GDP, which causes 15 missing values.

Table 3 Descriptive statistics of the variables used in the analysis (source: Eurostat, 2020)

Variable	***Type of Variable***	***Observations***	***Mean***	***Std. Dev.***	***Min.***	***Max***
Share RE	Dependent	420	16.61	11.43	0.102	54.65
Instrument (TGC)	Independent	63 (6)	19.90	17.38	1.096	54.64
Instrument (FIT)	Independent	357 (22)	16.02	9.94	0.102	41.16
RED (2009)	Independent	2004-2008: 140	12.81	10.31	0.102	44.29
		From 2009: 280	18.50	11.51	0.221	54.65
Technology neutral	Independent	Specific: 330	14.11	8.45	0.102	35.41
		Neutral: 90	25.75	15.62	2.03	54.65
Import dependency	Control	420	55.94	26.75	-50.62	104.14

Final energy consumption	Control	420	97	7.66	73	142.3
GDP (per capita)	Control	405	25241	16068	3890	84420

5. Results and Analysis

In this section I will show and discuss the results that follow from the regression models. The effectiveness of the policy instruments in the levels of the share of RE is assessed by discussing the models. First, the pooled regression models are shown and after that the Fixed Effects (within) regression. We will finish with convergence analysis to review the effectiveness of the target levels. After that, I will discuss whether these results are in line with the theory and hypotheses that were formulated.

5.1 Main results and interpretation

Table 4 presents the findings from the pooled regression and fixed effects regression for the dependent variable 'share of renewable energy'. Model I presents the regression with the instruments and the 'bonus' variable of technology neutral instruments. In Model II the introduction of the RED in 2009 is added. Model III shows the first fixed effects regression, in which the country effects are added. Model IV adds the time effects to the fixed effects regression, for this reason the variable RED (2009) drops out in this model. Model V adds the control variables. In our last model we control by adding the time-lagged variable of Share of RE to the regression.

Table 4 Results pooled regression model for share of RE and independent variables (I & II) and Fixed Effects regression model with control variables (III-VI)

	Model I	Model II	Model III	Model IV	Model V	Model VI
TGC	1.860	2.416	-1.134**	-0.114	0.148	0.157
	(1.823)	(1.767)	(0.481)	(0.712)	(0.473)	(0.280)
Technology neutral	11.380***	11.306***				
	(1.636)	(1.593)				
RED (2009)		5.818***	5.628***			
		(1.009)	(0.393)			
Import dependency					0.032***	0.012*
					(0.011)	(0.007)
Final energy consumption					-0.065***	-0.022**

					(0.017)	(0.010)
GDP (per capita)					0.040	0.042
					(0.053)	(0.030)
Share of RE - lagged						0.818***
						(0.032)
Constant	13.892***	9.946***	13.028***	11.956***	15.351***	3.094***
	(0.511)	(0.837)	(0.291)	(0.415)	(1.744)	(1.146)
N	420	420	420	420	405	378
R^2	0.178	0.235	0.608	0.827	0.836	0.944
Adjusted R^2	0.174	0.230	0.606	0.820	0.816	0.937
Time effects	N	N	N	Y	Y	Y
Country effects	N	N	Y	Y	Y	Y

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In Model I and II the coefficient for countries using a quota-based promotion policy (‘TGC’) shows an insignificant result of 1.860 and 2.146. These results show that countries that use quota-based policies have higher levels of renewable energy in their energy mix. However, as the results are insignificant, we cannot conclude anything from it. In the first two models we also consider the independent variable of technology neutral support policies. This variable indicates that a country does not differentiate between different RE technologies in terms of subsidy levels. In both models, the coefficient is highly significant at a p-value of 0.01. The coefficients of 11.380 and 11.306 imply that countries that use technology-*neutral* promotion instruments have a higher level of renewables in their energy mix. However, it should be noted that the sample of countries using technology neutral instruments was small (6 of 28), and of these six countries some already had a higher share of RE to begin with (e.g., Sweden, Estonia, Finland). The third independent variable that is tested is the introduction of the RED in 2009. In Model II, the coefficient for this independent variable shows a highly significant coefficient of 5.818. When the country effects are added in the FE regression in Model III, the coefficient only slightly moves down to 5.628 and still shows the same, highly significant result. This leads us to conclude that when the RED was introduced, the levels of renewable energy in the EU-28 were higher than the period before this.

Model III also shows the FE regression model for the instruments, in this model the country effects are included. The result for the instruments shows a coefficient of -1.134, which is significant at a p-value of 0.05. This value indicates that, while holding everything else the same between countries, the countries using quota-based instruments have lower levels of RE in their energy mix than countries using price-based instruments. When the time effects are added in Model IV the coefficient is still negative, but no longer significant. This can be explained by the fact that there is only little change over time for the instruments. Model V and VI add the control variables to the FE regression models. Model V adds all control variables without the time-lagged variable of Share of RE, because this variable has a big influence on the interpretation of the results. When the controls are added, the coefficient for the instrument choice shows a positive, but insignificant result. The control variables that are added in model V and VI show a mixed result in terms of levels of significance. The direction of the coefficients is in line with the expectations we formulated from the literature. We expected countries having a high dependence on energy imports to see an increase in their share of renewable energy. The coefficient of 0.032 implies that for every percentual increase of import dependency compared to the total consumption, the share of renewable energy goes up by 0.032. The academic theory for final energy consumption was not very clear, but our results show that an increase in the total energy consumption of a country leads to a lower share of renewable energy. The coefficient for GDP (per capita) is 0.040, which implies that for every 1000 euro extra the share of renewable energy increases by 0.040. However, because the result is not significant, we cannot conclude anything from it. In Model VI, when the time-lagged variable is added, the coefficients for the independent variable of instrument choice remains positive at 0.157, but the result is still not significant. The direction of the results of the control variables remains the same, but the coefficients drop a little and they lose some significance. The time-lagged value of the share of renewable energy shows a coefficient of 0.818, which is highly significant. This implies that about 80 percent of the value of the share of RE can be explained by the value of share of RE in the previous year.

The coefficients from the different models do not all show results in the same direction, this makes it harder to assess whether the results are reliable. One of the reasons for this might be the small sample we are drawing from when it comes to the countries that are using quota-based instruments. Besides that, the little variation over time and between countries makes it harder to estimate reliable and significant results from our models.

The last method that will be used to analyse the effectiveness of the RED and specifically the ambition of the binding national targets, is the beta convergence method. Table 6 shows the results of this β-convergence. In this model we test the extent to which the national targets have been achieved in 2018, compared to the extent of achievement in 2009. This indicator creates a specific growth value for each Member State. This will be explained by the ambition of the target in 2008, which is calculated by dividing the Share of RE in 2008 by the value of the target for the specific Member State. Besides that, two control variables are employed in this regression: GDP (per capita) and import dependency. Both these variables have also been normalized to a specific growth value. This is done by dividing the value in 2018 by the value in 2008. Even though more control variables are available, only these two will be used, because of the small dataset we are working with for this model. Model I shows the results without control variables, Model II shows the coefficients for the 15 Member States that were a member of the EU in 2001. Following Sebestyén Szép (2016) and others, we cluster this group separately as they can be considered the 'old' members of the European Union and were already subject to an earlier version of a renewable energy promotion policy. In Model III and IV the control variables GDP (per capita) and import dependency are tested separately to test their individual effects. And lastly, in Model V both the control variables are added to the analysis.

Table 5 β-convergence model in the ambition of targets in the share of RE of the EU-28 (I), EU MS 2001 (II) and controls (III-V)

	Model I	Model II	Model III	Model IV	Model V
Ambition 2008	-0.482***	-0.372**	-0.462***	-0.534***	-0.510***
	(0.113)	(0.138)	(0.121)	(0.108)	(0.118)
GDP (per capita)			-0.210		-0.103
			(0.187)		(0.187)
Import dependency				-0.121**	-0.113*
				(0.055)	(0.060)
Constant	0.582***	0.511***	0.595***	0.600***	0.597***
	(0.071)	(0.079)	(0.079)	(0.067)	(0.075)
N	28	15	27	28	27

R^2	0.411	0.357	0.412	0.505	0.491
Adjusted R^2	0.388	0.308	0.363	0.465	0.424

Standard errors in parentheses
** $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*

The results in table 5 show that the β-convergence can be proven. The coefficients are all negative: -0.482 for Model I and -0.372 for Model II. These coefficients show statistically significant results, with respectively p<0.01 and p<0.05. For this reason, we find that β-convergence of the share of renewable energies existed for this period. This means that countries that were further away from their national goal in 2008 show a more substantial growth in the share of renewables than countries that were closer to their national goal. The convergence found in the 'older' MS of the EU shows a little weaker effect than when all MS are included. This can be explained by the fact that these countries were already under a 'climate target regime' that already pushed them towards their country-specific final goals. For this reason, the initial differences between these countries were already lower in 2008.

The coefficient for ambition in Model III, with the control of GDP added, is -0.462 and significant at 0.01. The coefficient for GDP does not show any significance. When we control for import dependency in Model IV, the coefficient for ambition becomes -0.534. The coefficient for import dependency is -0.121 and shows significance at 0.05. This coefficient implies that the countries with higher dependency on imported energy will show less ambitious growth in light of their national target. When both controls are tested together in Model V, the coefficient for ambition does not change very much and is still significant. This means that with the control variables added, strong convergence can still be identified. This leads us to conclude that, based on this model, the countries with less ambitious goals (relative less growth needed from 2009 to 2020) do indeed perform less than the countries with more ambitious goals.

5.2 Feedback to hypotheses

In this section I will give feedback to the hypotheses that were formulated from the academic literature in chapter 3.3. The results from the presented models will be held against the expected results.

H1: The introduction of the Renewable Energy Directive (2009) lead to an increased growth of renewable energies, compared to the growth before 2009.

Based on the results, we can confirm this hypothesis. Both the pooled regression and fixed effects models showed that the introduction of the RED in 2009 had a positive and significant effect on the share of renewable energy in the energy mix of the EU-28. Before 2009, another directive (Directive 2001/77/EC) aimed at the promotion of renewable energy. However, this directive did not include the national mandatory targets, which were included in the RED (2009). The results are in line with what we expected: the new directive would lead to an increased growth of RE. However, to be more precise about the causality of this effect more research, using a longer time span and investigating more indicators which are connected to the RED, needs to be done. Another interesting element of the RED is the binding nature of the national targets. With the data that was used, finding a causal link for this specific element is not possible. However, it is a topic that can be explored further by comparing policy instruments that make use of binding targets and those that do not. Maybe a thorough comparison between the first energy Directive (2001) and the RED (2009) can act as a starting point.

H2: EU Member States with more ambitious national targets are more likely to experience a substantial growth in renewable energy compared to EU Member States with less ambitious goals.

This second hypothesis, which focusses on the ambition and the levels of the targets, has been tested by using the model of beta-convergence. Our results show that β-convergence can be proven, which indicates that countries with more ambitious targets set for them were growing more substantial than countries with less ambitious targets. The results from the time period and set of countries we studied are in line with the findings of Berk, Kasman, & Kılınç, (2020) and Sebestyén Szép (2016), who also find convergence for the share of renewable energy in other time periods.

It should be noted that the method of beta-convergence has its limitations when it comes to the analysis of ambition. Our analysis with this model just scratches the surface of this research area. Following Höhne, et al., (2018) we recommend that researching the area of ambitions requires a larger variety of approaches. Some of which are already employed in their paper and can be used as a starting point for future research.

H3: EU Member States that have introduced price-based instruments (FIT/FIP) are more likely to experience a substantial growth in renewable energy compared to EU Member States that have introduced quota-based instruments (TGC).

Another independent variable that was tested, was the instrument that was used to promote renewable energy. The results from both the pooled regression and FE regression models show ambiguous results. The reason for this might be the relatively small dataset we are using. Especially because the number of countries using quota-based instruments is relatively small. Furthermore, the variation over time and between countries that is needed was quite thin. Nevertheless, the instruments that are used to promote renewable energy take a prominent place in the whole renewable energy strategy that is undertaken and remains an interesting and relevant topic to study. Future research might look into the differences between the instruments more by comparing them over a longer time or between different countries. Research with a smaller set of countries with more specific capacity data per country, like Jenner, Groba, & Indvik (2013) suggest, might give better insight into the reasons for success and failure for either instrument and their effect on the RE growth.

H4: EU Member States using a technology-neutral instrument to promote renewable energy production are more likely to have a more substantial growth than EU Member States using technology-specific instruments in the share of renewable energy in their country.

The extra independent variable that was tested, was the way in which the renewable energy instrument was distributed: technology-neutral or technology-specific. Our results show that countries that using technology-neutral instruments have a higher share of renewable energy in their energy mix. This is line with what we expected. It also supports the preference of the European Commission, who are in favour of technology-neutral instruments. However, the results for this might be skewed because of the small dataset and small set of countries (6) using technology-neutral instruments. Furthermore, the fact that in our analysis this variable does not vary between countries or over time, limits the statistical analysis. The way the instruments are distributed remains an interesting topic to further investigate. For example, by an (econometric) analysis between a smaller set of similar countries that use either of the two methods. This might give a deeper and better insight into the reasons and effects of the difference in distribution.

6. Discussion and conclusion

After 2009, when the Renewable Energy Directive was introduced by the European Commission, the use and production of renewable energy in EU Member States really became a priority. Before 2009, there was most certainly awareness that we should have some action against climate change, but it was not a priority. With the introduction of the RED, the fight against climate change really started, and was taken more seriously (by most countries). The political will and decisions from the EU are recognized, but how effective has it all been? The Directive set a specific target for all the EU MS, by accounting for their economical and geographical circumstances. Table 2 shows the results: some MS reached their target way before 2020 and others will have a very hard time reaching it before this deadline. On the other hand, the Directive left a lot of freedom to the MS in choosing their approach to the policy goals. This illustrates the practical relevance of this research; is a directive for renewable energy an effective way to promote a sustainable future in the EU? How effective are binding national targets in this approach? And how does ambitiousness play a role? And if so, using which instruments achieves the most substantial growth in RE?

This thesis investigated how effective the introduction of the RED has been for the growth of RE in the EU MS. More specifically, how effective the two main policy instruments (quota- and price-based) have been in promoting the production and use of renewable energy in the EU-28 countries, compared to each other. Renewable energy promotion and its instruments have been topic of scholarly debate for a long time. Reviewing this literature, it shows that the findings on the effectiveness of the instruments is not uncontested. Some authors consider quota-based instruments to be more efficient, others find that choosing for price-based policies leads to a more substantial growth of RE. This thesis aimed to contribute to the existing literature by reviewing this specific time period from 2004 to 2018, using data from the EU-28 countries. This showcases the scholarly relevance, as such a review of the instruments used has not been conducted yet. With the results from the statistical analysis, the research question of this thesis '*what effect does the introduction of mandatory national targets, combined with the freedom of instrument choice, introduced by the Renewable Energy Directive (2009), have on the share of renewable energy in the EU-28 from 2004 to 2018?'* can be answered.

The results show overwhelming evidence that the introduction of the RED (2009) has had a significant impact on the share of renewable energy in the EU-28. This is in line with our expectations, as this directive indicated a (more) serious approach to renewable energy promotion. Especially the national targets and their binding nature were a special addition to this directive. Due to data constraints, the causal relation between the effect of the (binding) targets and the growth of renewable energy is hard to find. This leaves an interesting topic for future research. Besides this, the topic of ambitiousness of the national targets has been researched using the method of beta-convergence. The results show highly significant evidence that convergence is present when it comes to the targets and the share of renewable energy. This means that Member States with a larger gap to close to their national target in 2008 were growing at a faster pace than Member States with a less ambitious target. These results were in line with our expectations and the findings of earlier research (Sebestyén Szép, 2016; Berk, Kasman, & Kılınç, 2020). As already indicated, these results could be the starting point for future research concerning targets in general, and more specifically their ambition. Another interesting aspect of the RED was the flexibility concerning the instruments that were used for promoting renewable energy. We investigated the effectiveness of the two main instruments that were used: price-based and quota-based instruments. The outcomes of our model show ambiguous results, which do not give a clear answer to the question which instrument is more effective in the promotion of RE. The only significant result from our analysis comes from the FE regression model without the time dummies added. This result tells us that countries using quota-based instruments show lower levels of RE in their energy mix than countries using price-based instruments. This outcome is in line with the hypothesis that was formulated based on the academic literature. However, as the other results show no significance, the reliability of this finding cannot be checked. This leaves an interesting possibility for future research, in which the effectiveness of the instruments can be reviewed from another angle and possibly produce significant results. Lastly, we also investigated the difference between technology-neutral and technology-specific instruments. The European Commission is in favour of technology-neutral instruments, because this leaves the most effective choice to the market. In line with this and our hypothesis, the results show that countries that use technology-neutral instruments see higher levels of renewable energy in their energy mix. This topic has not received much attention in the academic literature, which leads us to believe that it is a very interesting topic for future research. For example, comparing a smaller set of similar countries might give better insight into the effectiveness of either promotion method.

To conclude and answer our research question, we can definitely say that the introduction of the RED in 2009 has had a positive and significant impact on the share of renewable energy in the EU-28. To be more specific on the mandatory national targets, the causal link is hard to find. However, we can conclude that the level that a target is set at plays a role in the way MS try to reach this target. The answer on the specific point of the effectiveness of instrument choice is harder to find. The only significant result we find points towards price-based models as more effective in promoting RE. However, because our other results are insignificant and show other coefficients, we cannot confirm the reliability and validity.

This research has several limitations, which have been dealt with in previous chapters. The main limitation is the little variance between the countries and over time. This skews the results of our statistical models and limits the analysis of these results. This does open up opportunities for future research, in which other sets of countries over different timespans can be compared and analysed. Besides that, several other interesting topics for future research have already been touched upon. Such as the binding nature of the targets, the ambitiousness of the targets, whether the instrument distributes neutral of specific to technologies et cetera.

The results from this research show the effects of the instruments that are used to promote renewable energy. These results can be used as a basis for future research and policy recommendations. It is important for the European Commission to reflect upon their choices concerning this directive, with the binding targets on the one hand and the freedom of instrument choice on the other hand. For Member States this shows the importance of making an informed decision which instrument to choose, but also whether the instrument should be technology-neutral of technology-specific. This last topic might also be specifically important for the European Commission, who express their explicit support for technology-neutral instrument, but in practice only few MS follow this line. It is certainly in their interest to further pursue research on this topic, to get a clearer view on the difference between either distribution method in practice. Policy makers on all levels of government can take the findings from this research into account when drafting future strategies and policies.

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Appendix A

Overview of the renewable energy support policies in the EU-28

Tabel A1 composed overview of renewable energy measures in EU-28 (RES-legal, 2019; IEA, 2020)

AT – Austria	IEA: energy efficiency, renewable energies and security of supply are the 3 pillars of their energy policy. RE has grown and fossil fuel use has decreased RES: mainly use **feed-in-tariffs** to promote renewable energies, with <u>technology specific tariffs</u>. Electricity from RE is **not given priority/special access** to the grid.
BE – Belgium	IEA: making efforts on RE, but major challenge: decarbonizing the country, while ensuring security of supply and affordability Right now, *nuclear energy* is about 50% of its energy generation, but they are closing their plants and planning on expanding natural gas and renewables. RES: promotion of RE is through a **quota system** based on certificates trade. Electricity suppliers are obliged to present GC to prove that a certain proportion (i.e., quota) of electricity supplied to final consumers was generated from renewable sources. Electricity from RE sources is given **priority access.** As Belgium is split up into three 'regions' (Brussels, Wallonia, Flanders), there is no way to distinguish between the policies. Overall, the certificates are given out on a <u>technology-specific basis.</u>
BG – Bulgaria	RES: promotion of RE is based on a **premium tariff,** this was terminated as of July 2018. Used <u>technology specific tariffs.</u> RE is not given priority access to the electricity grid.
CY – Cyprus	RES: promotion of RE is based on **subsidy** combined with **net-metering/-billing scheme.** The use of RE is given priority to the electricity grid. As Cyprus is a small island, some measures do not apply, because they are not feasible. <u>Technology specific tariffs</u> are used
CZ – Czech Republic	IEA: CZ has experience strong growth, but policy changes make it uncertain. *Coal* dominates the power sector. Besides that, CZs gas supply is strong; they remain a net exporter. RES: RE was promoted through (1) **feed-in-tariff** or (2) **feed-in-premium** ('green bonus'), which plant operators can choose. Programme has been stopped in January 2014. RE is given priority access to the grid. <u>Technology specific tariffs</u> are used.

DE – Germany	IEA: By 2030, Germany wants half of its energy coming from renewable sources. They are phasing out nuclear (2022) and coal (2038). RES: RE is promoted through a **premium scheme,** which is determined through a tendering scheme. *Small plants* are support by a **FIT.** <u>Technology specific tariffs</u> are used. RE is given priority access to the grid.
DK – Denmark	IEA: ambitious country in setting world-leading national energy targets. RE mainly coming from wind and bio energy, with coal no longer being used. They have also successfully decoupled GHG from GDP. RES: RE is promoted through **premium tariffs** and **net-metering.** Wind and solar is granted through tenders. RE is given priority access to the grid. <u>Technology specific tariffs</u> are used: producers receive a variable bonus on top of the market price, for which a statutory maximum is set.
EE – Estonia	IEA: has a unique energy mix, because of oil shale. High energy independency, but also a high carbon intensity. The country has already hit their targets. RES: RE is promoted through a **premium tariff.** In June 2018 this has been replaced with an *auction-based system*. Estonia uses <u>technology-neutral</u> support to promote RE. RE is not given priority access.
EL – Greece	IEA: Greece has already seen a good increase in RE during their economic recovery, they could improve in their energy balance. RES: RE is promoted through a **feed-in-premium** granted by participation in <u>technology-specific tenders</u>. RE access is given priority access to the grid
ES – Spain	IEA: world leader in integration and of variable renewable energy. They have a robust electricity system with high shares of wind and solar. RES: generation of RE was promoted through a **price regulation system,** which was phased out in 2013. After this, a **special compensation regime** and **premium tariffs** were introduced. RE is given priority access to the grid. The ‘premium’ tariff is not technically defined as a support scheme, but as a ‘complementary retribution’. <u>Technology specific tariffs</u> are used in the process of the tender, which are only available for solar and wind energy.
FI – Finland	IEA: Decarbonizing its energy sector at a good pace, mostly in power generation. Possible because of large shares in nuclear, hydro and bioenergy. They are striving for climate neutrality by 2050.

	RES: Finland uses a *tender based* **premium scheme,** which is <u>technology neutral</u>. Also support through state subsidies. Before 2018, Finland used a premium tariff support scheme. RE access to the grid is not given priority.
FR – France	IEA: France has a low carbon use, mainly because of its large nuclear fleet, but the reactors are reaching their end, which will be a problem for France. RES: RE is promoted through a **feed-in-tariff** and a **premium tariff.** There are no special provisions in the grid for electricity from renewable sources. <u>Technology specific tariffs</u> are used.
HR – Croatia	RES: RE is promoted through a **premium tariff** and a **guaranteed feed-in-tariff** for installations producing less than 500kW. The allocation happens through tenders. RE is given priority access to the grid. <u>Technology specific tariffs</u> are used.
HU – Hungary	IEA: Hungary set ambitious, long-term goals, and there has been significant growth in RE, but growth in the sector has slowed, mainly due to political circumstances and the current policies. RES: RE is promoted trough a **feed-in-tariff** for installations of 50-500kW. For installations of 0.5-1 mW a **premium** applies. Only tariff differentiation between solar power and other technologies. So, <u>technology specific tariffs</u> are used, but with an *. RE is given priority access to the grid.
IE – Ireland	IEA: Ireland have the 3rd largest share of wind generation. Energy production is improved through domestic gas production. Ireland is not on course to meet the mandatory targets. RES: Until 31 December 2015, RE was promoted by **feed-in-tariffs.** After that: **one support scheme** (subsidy for purchase and installations of PV panels). No priority access is given to RE. <u>Technology specific tariffs</u> are used.
IT – Italy	IEA: In 2013, clear goals were set in the National Energy Strategy. This policy is very strong pro-renewables. Italy has experienced impressive growth of RE. RES: RE is promoted through VAT- and real estate tax deductions. The RE can be fed sold on the free electricity market or to the GSE (Italy manager of electricity services). On July 2016, Italy replaced their green certificates system with their current system. RE is given priority access. “All technologies are promoted; they are eligible for <u>different incentives</u>”.
LT – Lithuania	RES: promotion of RE through a *sliding* **feed-in-premium,** in which only the already existing RES plants are supported. Plants with a capacity over 10 kW acquire a guaranteed tariff through tenders. For new plants there is currently no support, but

	producers may apply for *subsidies* and *loans* and are exempt from excise duty. RE is given priority access to the grid. <u>Technology specific tariffs</u> are used.
LU – Luxembourg	IEA: sharing signs of decoupling. Luxembourg has adopted ambitious targets to reduce GHG emissions: 50-55% by 2030 compared to 2005. The country has a fossil fuel intensive energy mix, the government is increasing prices to reduce the demand for fossil fuels. RES: promotion of RE through a **feed-in-tariff,** a **premium tariff** and through **subsidies**. RE sources energy is not given priority access to the grid. <u>Technology specific tariffs</u> are used.
LV – Latvia	RES: promotion of RE through a *complex support system* based on a **feed-in-tariff.** Right now, the promotion scheme has been on hold for a while due to corruption and transparency concerns.
MT – Malta	IEA: Malta has a high dependency on oil, their National energy policy was launched on 2012, aiming to ensure a sustainable energy sector. RES: **only** electricity generated by **PV** is support through a **feed-in-tariff (*).** Installations with a minimum of 1000kWp are funded through a tendering scheme. Besides that, solar water heating systems and aerothermal heat pumps for domestic use are promoted through **subsidies**. RE is given priority access to the grid.
NL – Netherlands	IEA: the Netherlands plays an important role as the energy hub of the EU. Although the ambitions are high, the Netherlands remains one of the most fossil fuel and CO2 intensive economies. Investments are mainly made into offshore wind, carbon capture and renewable hydrogen power. RES: the main instrument to promote is an **SDE+ premium feed-in scheme.** This encompasses a phased admission with escalating base tariffs, which favours low-cost RES. Besides that, there is support through **loans** and **tax benefits.** RE is not given priority access to the grid. <u>Technology neutral tariffs</u> are used.
PL – Poland	IEA: Poland has experienced strong growth in RE, but its energy sector is still dominated by coal. The country needs to further its investments in RE to become more sustainable. RES: RE is promoted through tenders for support level of **feed-in-tariff** or **feed-in-premium.** Before 2015, Poland used a **quota system** (TGC), which some older plants are still under. RE is given priority access to the grid. <u>Technology neutral tariffs</u> are used
PT – Portugal	IEA: Portugal is the world leader at integration from wind and solar PV. They embraced targets of 80% RE by 2030.

	RES: For plants registered until 7 November 2012 the promotion of RE was trough **feed-in-tariffs.** After that, support was through a '**general regime':** RES plants can only be remunerated through the wholesale electricity market. <u>Technology specific tariffs</u> are used. RE is given priority in access to the grid.
RO – Romania	RES: promotion of RE through a **quota system (TGC).** The comprehensive scheme is no longer in place for installations installed after 1 January 2017. The system will be in place for installations that commissioned before this date until 2031. Although using a quota system, "the number of green certificates issued <u>depends on the technology used</u>".
SE – Sweden	IEA: Sweden is leading the way to a low-carbon economy. They have the lowest share of fossil fuels in their energy mix of IEA members. Sweden aims to be at 100% RE in 2040. RES: RE is promoted through a **quota system, tax regulations** and a **subsidy scheme.** RE is not given priority access to the grid. Using a quota system, Sweden makes <u>no distinction in the generation technology</u> employed, 1 certificate for every MWh is issued.
SI – Slovenia	RES: RE is promoted through a two-round tender, which determines the recipient and level of support. This is available to RE plants connected after 22 September 2014. Operators connected before this can sell their electricity to the power market operator (Borzan) at a 'uniform annual price', which is basically a **feed-in-tariff,** but they can also choose for a **feed-in-premium.** All technologies are eligible for support, but there are limits to the plants size for certain technologies. These limitations would then be specified in the application document for the tender.
SK – Slovakia	IEA: Slovakia has made significant progress, mainly driven by EU directive and mandatory targets. Slovakia has a high dependence on energy import from Russia. RES: RE is promoted through a **fixed feed-in-tariff.** Energy companies are obliged to purchase and pay for the RE. Besides that, RE is given priority in connection to the grid. <u>Technology specific tariffs</u> are used.
UK – United Kingdom	IEA: Global leader in decarbonization, the UK set ambitious targets for emissions reductions and are aiming to be at a net-zero goal by 2050. RE: Until 31 March 2015, the UK used a **certification scheme.** Right now, RE is promoted through a **feed-in-tariff** and a *contracts-for-difference* scheme (incentivize investment in RE; gives direct protection from the volatile wholesale). Besides that, the UK use *tax regulation mechanisms* as a promotion instrument. <u>Technology specific tariffs</u> are used. RE is not given priority access on the grid.

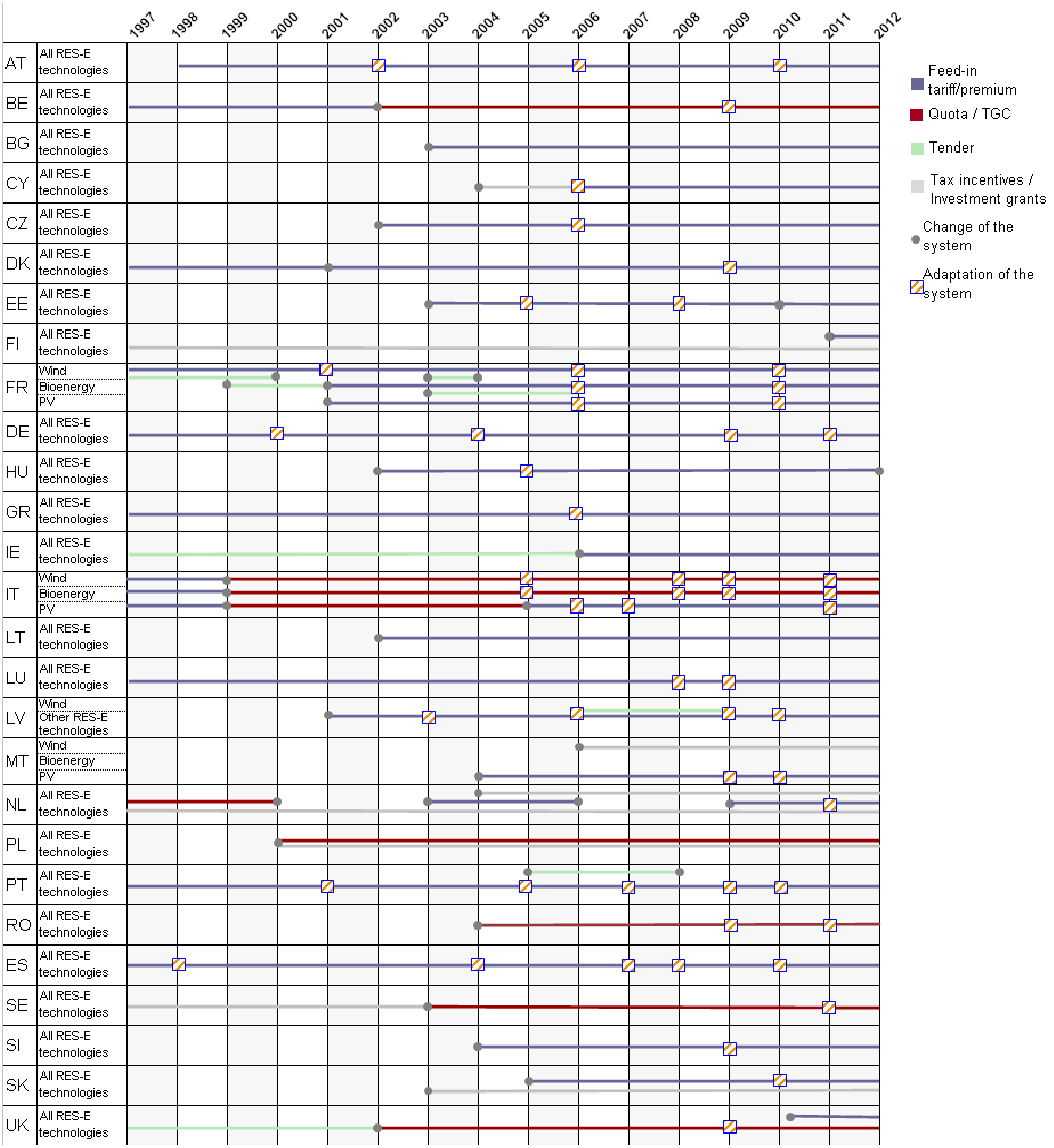

Figure A1 *overview of renewable energy support schemes in EU-27 (European Commission, 2013)*