MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

„ A Methodological Approach to Analyzing the Effectiveness of Feed-In Tariffs for Biomass "

verfasst von / submitted by

Caroline Ayasse

angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (M.Sc.)

Wien, 2017 / Vienna 2017

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	A 066 914
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Internationale Betriebswirtschaft
Betreut von / Supervisor:	Univ.-Prof. Dr. Franz Wirl

Eidesstattliche Erklärung:

„Ich erkläre hiermit an Eides Statt, dass ich die vorliegende Arbeit selbständig und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sind als solche kenntlich gemacht. Die Arbeit wurde bisher in gleicher oder ähnlicher Form keiner anderen Prüfungsbehörde vorgelegt und auch noch nicht veröffentlicht.“

Danksagung und Widmung

An dieser Stelle möchte ich all jenen danken, die mich im Rahmen dieser Masterarbeit begleitet und zu ihrem Gelingen beigetragen haben.

Zuerst möchte ich mich bei meinem Betreuer bedanken, Herrn Prof. Dr. Franz Wirl, der meine Arbeit durch seine fachliche und persönliche Unterstützung begleitet hat.

Danken möchte ich außerdem meinen Freunden und Kommilitonen, die mich mit viel Geduld immer moralisch unterstützt haben und durch anregende Gespräche meine Arbeit verbessert haben.

Meinem Freund Daniel danke ich aus tiefstem Herzen, für die wundervolle Unterstützung während meiner gesamten Studienzeit, insbesondere aber für die vielen ermutigenden und lieben Worte während der Fertigstellung der Masterarbeit.

Mein besonderer Dank gilt meiner Familie, insbesondere meinen Eltern, die mir mein Studium ermöglicht und mich in allen Entscheidungen unterstützt haben.

Zuallerletzt möchte ich diese Arbeit meinem Großvater widmen, der mir schon früh das Interesse an der Natur und am Leben beigebracht hat.

Table of Contents

List of Abbreviations

Abbreviation	Explanation
BFB	Bubbling fluid bed gasifier
°C	Degree Celsius
c/kWh	Cents per kilowatt hour
CFB	Circulating fluid bed gasifier
CH_4	methane
CHP	Combined Heat and Power production
CO	Carbon monoxide
CO_2	Carbon dioxide
CRES	Contribution of Renewable Energy to Energy Supply
EU	European Union
FIT	Feed-in Tariff
FIP	Feed-in Premium
FT synthesis	Fischer-Tropsch Synthesis
GDP	Gross Domestic Product
HFC	hydrofluorocarbons
H_2O	water
IV	Independent Variable
kWh	Kilowatt hour
ktoe	Kiloton of oil equivalent
Mtoe	Millions of tons of oil equivalent
MWh	Megawatt hour
NO_x	Nitrogen oxides
NREAP	National Renewable Energy Action Plan
OECD	Organization for Economic Co-operation and Development
PV	Photovoltaic
PAH	Polycyclic aromatic hydrocarbons

Abbreviation	Explanation
RE	Renewable Energy
RES	Renewable Energy Source
RES-E	Renewable Energy Source Electricity
RET	Renewable Energy Technology
R&D	Research & Development
SF_6	Sulphur hexafluoride
TND	Tenders
TGC	Tradeable Green Certificate
TWh	Terawatt hour
VIF	Variance inflation factor

List of Figures

List of Tables

Introduction

In November 2016 at the Marrakech Climate Change Conference of the Parties to the United Nations Framework Conference on Climate Change (UNFCCC), the respective heads of state confirmed the commitment to the full implementation of the Paris Agreement, adopted under the Convention. The Parties to the Convention called for political action to combat climate change and the repercussions that it will have and already has on our environment. It is important to recognize that political action needs to translate into the respective areas of the economy and social context. One significant way to measure if policies are effective in achieving their targets is empirical analysis. Some work has already been done that connects empirical studies with the topic of policy effectiveness. Carley (2009), S. Jenner et al. (2013), and A.C. Marques et al. (2010) have previously carried out analyses on this topic, but overall there have not been very many. S. Jenner et al. (2013) did a study on the effectiveness of Feed-in Tariff (FIT) policy on wind and solar power and in their conclusion they suggested to extend the study to other renewable energy sources (RE), which we attempt to do here. Following the work and methodology of A.C. Marques et al., we will conduct a panel data analysis of European countries. We propose to build on their work by first examining the factors which come into play when it comes to renewable energy policy, followed by an empirical study.

This study is composed of three main parts. Part One begins by exploring and reviewing the different factors that influence Renewable Energy policy. The areas of interest include country-specific aspects such as geography and meteorology, as well as socioeconomic elements, financial aspects, and, in particular, political aspects. For this we will first look at international obligations such as the Kyoto Protocol and the Paris Agreement, then we will focus on the European Directive 2009/28/EC. It was this Directive that introduced the requirements and legal obligations the EU member countries need to follow in terms of their actions regarding energy and environmental policy, as well as the different support policies. Risks for investment in renewable energy projects are identified in the next part and subsequently Feed-in Tariffs are introduced as an effective and reliable support instrument. The first hypothesis which is formulated asks whether FIT is a good support instrument for any renewable energy source. The second hypothesis specifically asks whether it is in fact the case that FIT is a good support instrument for biomass. In the Part Two of this work, biomass is defined and its different processing technologies and the possible benefits and drawbacks are illustrated. Part Three of this work builds on the first two parts and sets out to perform an empirical analysis to measure if Feed-in Tariffs are effective in increasing a country's biomass capacity or not. We then proceed to present the results of the analysis and a discussion of the results. The result is unexpected since the Feed-in Tariff does not appear to be effective in boosting the capacity of biomass. In the Conclusion, we end with a summary of our findings and provide an outlook for further research.

1. Literature Review

1.1 Factors influencing the effectiveness of RE Policies

The prevalent literature that is concerned with Renewable Energy Policies and their effectiveness in achieving a higher capacity of renewable energy in the energy mix finds a common set of elements that influence RE Policies. This chapter will form clusters that group similar elements together. For this ‘factor clustering’, one needs to recognize the differences that exist in each country concerning the definition of what constitutes a renewable energy source (RES). In European countries, the majority of RES’s, which are accepted as such, are made up of onshore wind energy, solar power (PV), biomass and biofuels, solar thermal energy, and hydropower up to a certain size.[1]

We will start by first looking at the geography and meteorology as one factor, followed by some socioeconomic elements that can influence RE Policies. The most important factor examined here will be the ‘political elements’, specifically international treaties and EU law. National law will not be included specifically because the EU law is the primary target for this study and all European national laws must conform to EU standards.

1.1.1 Geography and Meteorology

First we have to examine the *non-changing conditions* in each country, which include the geographical features such as the distribution of fossil fuels, and the meteorological conditions. Both of these constitute a major part of the available resources for generating power. An abundance of fossil fuels will logically diminish the need and motivation for developing RES, since fossil fuels can generally be priced more competitively. When examining the different RE technologies, rainfall and an even distribution of water resources play an important role regarding hydropower production. Average sunshine hours per year influence how much a country or region benefits from Photovoltaic Installations as well as solar thermal installations. The harvesting of wind energy also depends on geographical and meteorological characteristics; however, some countries with moderate winds still exceed other windier

[1] Reiche et al. (2004), p.843

countries in wind energy capacity. One example here is Germany, which in 2002 generated twelve times more energy through wind than Ireland, the United Kingdom, and France combined.[2] In addition to the authors Reiche and Bechberger, other researchers such as Carley (2009) and Menz and Vachon (2006) take natural resources into account (as variables) for modeling the effectiveness of RE policies (specifically, with regard to wind power in the United States).

1.1.2 Socioeconomic Elements and Context

The second cluster of factors influencing RE policies can be classified in the widest sense as socioeconomic factors. Mainly, we speak here about public awareness. This includes awareness of the dangers of climate change, awareness about renewable energies and how they work, as well as public information and participation in projects that further the use and development of renewables. Resistance against building RE installations or electrical power lines to transfer RES electricity still exists, so it is important to enlist citizens to cooperate with these type of projects. The resistance to renewables has a strong 'NIMBY' aspect to it, meaning that citizens are accepting of RE projects as long as it does not directly affect them negatively in any way, or as long as it is "Not In My Back Yard". Public awareness campaigns and the inclusion of the people in public decision making and planning have proved to be effective in reducing public resistance. One particular example from Denmark shows that co-operative ownership of plants, and in particular wind turbines, led to a wider acceptance of this form of energy.[3] This could be used as one approach to bring people behind renewable energies. Also, the size of a plant seems to be of importance since smaller plants are generally more easily accepted as well.[4] Reiche et al. (2004) mention this in examples for hydropower from France and other countries. Then there is the issue of the willingness to pay higher prices for renewable energy source electricity (RES-E). In the Netherlands, green electricity can be exempted from taxes, and in Austria the electricity bills that end-users receive need to display the different types of energy which were used to bring electricity to this person's house. This builds consumer awareness and confidence, and might inspire them to switch to green electricity companies.

[2] Reiche et al. (2004), p. 844
[3] Reiche et al. (2004), p. 846
[4] Reiche et al. (2004), p. 846

Technical Aspects

In order for the National Renewable Energy Action Plans (NREAP) to be implemented, certain technical requirements need to be met. The technical aspects which influence RE policies are the pre-existing capacities in each country. This includes the general infrastructure and the distribution grid. The transmission grids should be up to date and allow easy access for new energy installations. Although such accessibility is the ideal, it is not a reality everywhere in Europe. The grid size and distribution vary in every EU member state, and grid capacity can cause problems. An example is France, where the electrical grid is not designed to take in electricity produced from decentralized sources, or in Sweden where reinforcements are needed to deploy higher wind energy capacities. What is needed in these cases are feasible plans to finance net-reinforcements. For example, Reiche et al. (2004) mention a plan that would allow all investors pay for access to the grid, but more like it are needed as well as "fair and transparent regulation on third party access to the grid".[5]

Financial Aspects

In order to address the financial aspect of how RE policies are influenced, we start with the basic investment volume needed in RE projects for the EU to reach its targets by 2020. Kitzing et al. (2012) state that between 60-70 billion Euros are needed so the set targets will be reached in time. The numbers in 2012 were around 20-53 billion Euros in investment volume in the EU energy market, and therefore member states must increase spending a great deal. The target is likely unachievable without more policy support, since the RE investments are largely policy driven. However, the effectiveness of the support policies varies. The RES generation costs need to be reflected in the level of financial support. The initial capital costs of a RES installation are generally high, yet the operating expenditures can be low.[6] It is important that an investor can count on a long run time for the installation in order to see sufficient returns on an investment.

Investment stability is what is most needed to attract more financial investments, with the investors showing the most interest in support instruments like the Feed-in Tariff. This system seems to guarantee long-term planning security for investors and is responsible for fast growth in the wind power and PV sectors of the industry. We can see clear evidence of this trend in Germany.[7] This policy also allows for exploration of new technologies since financial stability

[5] Reiche et al. (2004), p. 846
[6] Klessmann et al. (2013), p.392
[7] Reiche et al. (2004), p. 847

is ensured. Tradable green certificate schemes have been proven to mostly direct the flow of investment towards already mature technologies, as one study found when looking at Sweden, the UK, and Flanders (Belgium) where this policy has been instituted.[8] It was discovered that with this policy there was not a great deal of incentive to bring less mature technologies up to the industrialized level. Also, most of the larger utilities profited from this scheme. This can hinder the innovation process and capacity building of RE, which in the long-run might be contributing to the potential failure to reach the EU's 2020 energy targets.[9]

Another aspect which, according to Reiche et al. (2004), was helpful for new RES-E producing entrants into the market was the liberalization of the electricity energy market. This liberalization process formally started with the EU Electricity Market Directives in 1996 and 2003. The Directives triggered the development away from state-owned monopolies towards a liberalized single European energy market. Member states were supposed to gradually open up their national markets and prepare themselves for competition. Main aspects of the Directives were (i) the gradual opening of the markets, (ii) installing independent regulators, (iii) the unbundling of the entire industry, which involves separating the transmission and distribution system operators from the generation part of the industry, (iv) improve cross-border trading, (v) improve cross-border transmission links, and (vi) clear regulated third-party access to the market.[10] The 2003 Directive requires that all non-household customers are free to choose their electricity provider by 2004, the household customers should be able to choose their energy company by 2007. The hopes for the liberalization are that the regulated third-party access to generation and the legal separation between distribution and supply would be good for the competition and lead to a price convergence, ideally to lower electricity prices for consumers and a single European energy market. Whether or not these hopes are being fulfilled cannot be discussed here. Regarding the positive impact on the entry opportunities for RES-E producers, it is at least legally easier now for them to enter the market due to the Directive's policy, but whether or not this actually occurs would be an interesting analysis to carry out. In any case, Jamasb and Pollitt (2005) state "the long-term effects of liberalization on the choice of low-carbon technologies will depend on the level and predictability of the subsidy they receive. (…) It is clear that liberalization across Europe does not stand in the way of differences of national

[8] Jacobsson et al. (2009), p.2144
[9] Jacobsson et al. (2009), p. 2145
[10] Jamasb/Pollitt (2005), p. 6

emphasis on renewables policy."[11] As for the EU's vision of a single European energy market, the authors express the view that the most feasible way to achieve this is through using regional markets as interim stages in the process. The regional electricity markets are the Nordic, UK-Ireland, Baltic, East European, West European, Southeast European, Iberian and Italian zonal markets. The largest of these is the West European market with the participating countries of France, Germany, Switzerland, the Netherlands and Belgium, and "its central geographic position implies that further progress toward an integrated electricity market in the EU will be dependent on the development of this market".[12]

For further information on the current situation see the interesting viewpoint expressed by Eva Barrett (2016), but further analysis is beyond the scope of this work.

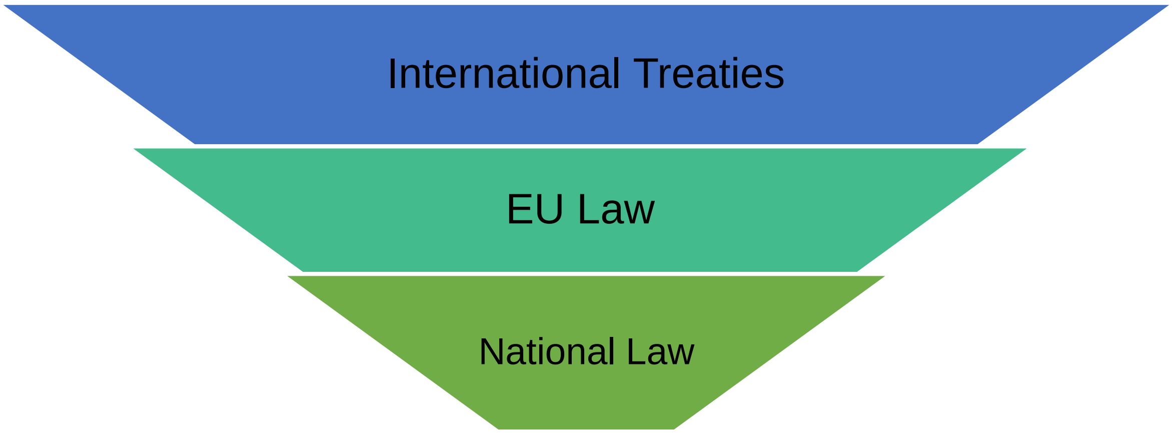
1.1.3 Political Elements

The third cluster includes the *political elements* which impact RE policies. Here we can observe different levels of obligations, ranging from the wider scope of international treaties, such as the Rio Declaration and the Kyoto Protocol, to more specific EU Directives and obligations. Finally, there are also conditions imposed by national and regional laws in the respective countries. The first international agreement of this nature was the Montreal Protocol on Substances that Deplete the Ozone Layer, which was signed in Montreal, Canada in 1987. The treaty formally recognizes the risk that certain chemicals which are emitted into the atmosphere can deplete the delicate ozone layer. It is therefore concerned with reducing these chemicals that can cause a change in the ozonosphere and it was ratified by all states, making it very unique to have inspired such global participation.[13] The Rio Declaration was formulated and signed in Rio de Janeiro in 1992 at the United Nations Conference on Environment and Development. It lays down twenty-seven principles which all are aimed at protecting the environment and building a sustainable future. While it is a non-binding agreement, it has nevertheless become an important document in international environmental law. The most recognizable principles are principles 15 and 16. Principle 15 is the 'precautionary principle', which states that in order to protect the environment, the absence of the proof of harmful effects of a certain action should not be a hindrance for parties to stop said action in order to avoid

[11] Jamasb/Pollitt (2005), p. 24
[12] Jamasb/Pollitt (2005), p. 26
[13] UNEP Montreal Protocol (1987), Preamble p. 1

serious environmental damage. Principle 16 is known as the ‘polluter pays principle’; it calls for the party which is responsible for the pollution to bear the costs which result from it and for “national authorities should endeavor to promote the internalization of environmental costs and the use of economic instruments”.[14] Other principles include taking into account the needs of future generations, conducting environmental impact assessments before undertaking any major project likely to cause harm to the environment, recognizing the important role of women in environmental management and sustainable development, the significance of community and public information and participation in environmental matters as well as cooperation on the state level and the interdependence of peace, environmental protection, and economic development. All of these principles form the foundation for policies aimed at furthering sustainable development and environmental protection.

Figure 1: Policy Levels



International Obligations

One of the major milestones in international climate change policy is the Kyoto Protocol, which was adopted in 1997 by the Conference of the Parties to the United Nations Framework Convention on Climate Change in Kyoto, Japan. The Protocol is one of the first international treaties that formulates binding targets for reducing emissions and establishes a limited commitment period for this purpose. The first commitment period encompasses the years 2008-2012, while the second commitment period, which was adopted later during the UN Climate Change Conference in Doha, Qatar, in 2012, lasts from 2013 to 2020. In 2001 in Marrakesh, the Conference of the Parties laid down the details for the mechanisms, which are used as tools

[14] UNECD Rio Declaration (1992), Principle 16

to achieve its objective of lower emissions.[15] Ultimately, the objective of the Protocol is to lower emissions as stated in its Article 2(a)(iv), wherein involved parties should: "Implement and/or further elaborate policies and measures in accordance with its national circumstances, such as: Research on, and promotion, development and increased use of, new and renewable forms of energy, of carbon dioxide sequestration technologies and of advanced and innovative environmentally sound technologies". Additionally, the Protocol emphasizes the need for cooperation to achieve the goal in Article 3.1:

> The parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by at least 5 percent below 1990 levels in the commitment period 2008 to 2012.

The Protocol encourages countries to work together to achieve their commitment goals; Article 4 outlines the details of such agreements. Equally, the Protocol allows for transfers of emission reduction units if both parties have agreed upon them beforehand. In Article 10 it also recognizes the parties' "common but differentiated responsibilities, and their specific national and regional development priorities, objectives and circumstances (…)". [16] Each country needs to achieve different target goals, since they are not equal in their energy consumption and economic progress. Overall, the Kyoto Protocol calls for lowering the levels of six different greenhouse gases. The first and most prominent of these is carbon dioxide or CO_2. The rest of the greenhouse gases listed in Annex A are methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). The three market-based mechanisms that the parties can use to lower emissions are International Emissions Trading, the Clean Development Mechanism, and Joint Implementation. Emissions Trading, as described in Article 17, allows parties to trade their allowed emission units in addition to their country internal activities to fulfill their commitments. This is now more commonly known as the carbon market, and the largest member of this market is the European Emissions Trading Scheme. The Clean Development Mechanism, established in Article 12,

[15] UNFCCC – Kyoto Protocol http://unfccc.int/kyoto_protocol/items/2830.php
[16] UNFCCC Kyoto Protocol (1997), Article 10

allows parties to conduct climate change mitigating projects in developing countries. This is designed to help developing countries in "achieving sustainable development" and to help parties in "achieving compliance with their quantified emission limitation and reduction commitments under Article 3."[17] In this way, they can gain additional emission reduction credits, which can be used to meet their targets or sold on the carbon market. Joint Implementation is a way for parties to cooperate and thus to fulfill their commitments together. Article 6 sets up this mechanism in which any of the involved parties can earn emission reduction units by conducting projects "aimed at reducing anthropogenic emissions by sources or enhancing anthropogenic removals by sinks of greenhouse gases in any sector of the economy".[18] This has to be done in addition to any other emission reduction activities that would otherwise occur. Altogether, the Kyoto Protocol serves as a baseline for policies on a regional or national level.

In 2015 in Paris, a new international agreement was drafted, hereafter referred to as the Paris Agreement. The parties to this agreement sought to enhance and improve the Convention's earlier commitments. In particular, the Paris Agreement focuses on keeping the average global temperature below 2°C above pre-industrial levels, while also striving to eventually lower the global temperature to 1.5°C above the pre-industrial baseline. Keeping the constant question of the influence of growing renewable energy resources and food production in mind, the Agreement seeks to ensure that food production is not threatened by climate mitigating actions and strategies. It reminds the parties of the principle of "common but differentiated responsibilities" that every participating party has according to their own specific situation.[19] In a way that is similar to the commitments in the Kyoto Protocol, the document, specifically Article 4, asks for "nationally determined contributions".[20] These contribution objectives should be achieved together with the usual overall emission reduction objectives for developed countries, and developing countries are encouraged to improve their climate change mitigation efforts and eventually also move towards emission reduction targets that encompass the whole economy. Every five years the nationally determined contributions are to be revised, improved, and reviewed by the Conference of the Parties to measure the progress achieved in implementing the agreement. Article 14, paragraph 2 states that the so-called 'global stocktake' will be starting in 2023, and is to be repeated every five years. Support for developing countries

[17] UNFCCC Kyoto Protocol (1997), Article 12 (2)
[18] UNFCCC Kyoto Protocol (1997), Article 6 (1)
[19] UNFCCC Paris Agreement (2015), Article 2 (2)
[20] UNFCCC Paris Agreement (2015), Article 4 (2)

will be provided in terms of financial resources, but also in technological development and technology transfers, as well as capacity building by developed countries in developing countries. These steps will help to achieve the overall goal of lowering emissions. Cooperation is also promoted in the area of education and raising awareness about climate change. This is in-step with the general call for transparency in the agreement and granting the public access to information, thereby allowing them to be well equipped to participate. Article 13 in the document establishes a transparency framework in order to make it easier to implement its requirements. The parties need to communicate their progress in terms of an emissions report, quantified by source, but also the parties should receive enough information so that there is a clear understanding of support mechanisms and guidelines and actions. This is essential to "…build mutual trust and confidence and to promote effective implementation (…)."[21] The Paris Agreement came into force on 4 November 2016 after 55 parties responsible for 55% of global emissions had ratified the document at the UN headquarters in New York City. It is an effort to bring all nations together in a joint action to combat climate change, with better support for developing countries and also through engaging with non-governmental stakeholders such as the general public, financial authorities, and the industrial private sector. The work program for the Paris Agreement was discussed at the international climate change conference in Marrakech in November 2016 and the conference was open to the public.[22]

European Directive

Moving from the level of international agreements, we will now take a look at a type of agreement that involves the countries in the European Union. The EU Directive 2009/28/EC on the promotion of the use of energy from renewable sources attempts to set more specific reference values for their member countries, in accordance with the Kyoto Protocol. The Directive seeks to "…comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change, and with further Community and international greenhouse gas emission reduction commitments beyond 2012."[23] The previous EU document, the Renewable Energy Roadmap, already set out the energy savings objectives, but these were taken up again in the Directive which states as its objective that it wants to achieve the following: 20% of the overall energy share should be from renewable sources and 10% of energy from renewable

[21] UNFCCC Paris Agreement (2015), Article 13 (1)
[22] UNFCCC – Paris Agreement http://unfccc.int/paris_agreement/items/9485.php
[23] EU Directive 2009/28/EC, Recital 1

sources in the transportation sector, as well as a 20% improvement in energy efficiency since this would be "…appropriate and achievable objectives, and that a framework that includes mandatory targets should provide the business community with the long-term stability it needs to make rational, sustainable investments in the renewable energy sector…"[24] The Directive also stipulates that the "use of agricultural material such as manure, slurry and other animal and organic waste for biogas production has, in view of the high greenhouse gas emission saving potential, significant environmental advantages in terms of heat and power production and its use as biofuel."[25] In general, as stated in Recital 14 of the Directive, these targets serve as a binding force for the member states, but also play an important role insofar as they increase certainty for investors and encourage technological developments in the field of RE so that innovation will move forward in this area. A difference in energy consumption and the various possibilities for member states to pursue an increase in renewable energy, and therefore also in the potential for renewable energy, is recognized in the Directive. The Directive calls for monitoring the progress; according to Article 22 member states are obliged to send reports biannually to the EU Commission about their progress regarding the use of renewable energy. The Commission itself is also, with reference to Article 23, required to prepare reports based on the Member states' reports which shall be examined by the European Parliament and the Council biannually as well. The Commission monitors the implementation of the Directive's measures, with a special focus on biofuels and bioliquids and will "monitor the commodity price changes associated with the use of biomass for energy and any associated positive and negative effects on food security."[26] Within these reports, the sustainability of biomass and biofuels with their increase in demand will be analyzed, as well as indirect land-use connected to their production. Recital 65 demands that biofuel production needs to meet certain sustainability standards. The document takes into account the different starting points for each member state regarding renewable energy levels. It also encourages cooperation on bilateral and multilateral levels to achieve the Commissions' RE 20% target for the European Community. The individual targets for member countries also take the respective levels of RE energy potential into account, so countries like Luxembourg are on the lower end of the targets with only 11% of RE share in final energy consumption by 2020. Countries like Sweden and Latvia, with 49% and 40%, set the highest targets respectively. Germany, Austria, and France

[24] EU Directive 2009/28/EC, Recital 8
[25] EU Directive 2009/28/EC, Recital 12
[26] EU Directive 2009/28/EC Article 23 (1)

are in the middle with 18%, 34%, and 23% RE share of respective final energy consumption.[27] On the road to achieving these goals, the "procedure used by the administration responsible for supervising the authorization, certification, and licensing of renewable energy plants should be objective, transparent, non-discriminatory and proportionate when applying the rules to specific projects."[28] This is supported in addition to the request that energy prices should reflect all costs incurred during production and after consuming the energy, while taking into account environmental costs as well as possible social and healthcare costs as laid out in Recital 26.

European and National Cooperation

The Directive requires the member states to develop National Renewable Energy Action Plans (NREAP) to have a basic schedule and framework to meet their individual targets by the end of the commitment period. The specific NREAPs effectively form a bridge between the EU and national level of environmental law. Each member nation is required to adopt EU standards, expressed as a NREAP with specific target and goals that fit within the wider framework. For example, Germany's NREAP projects a decrease in primary energy consumption from 314.3 Mtoe in 2008 to 276.6 Mtoe in 2020. Everything depends on the actual change in GDP, weather, and other related factors. However, final energy consumption will presumably decrease from 220.7 Mtoe in 2008 to 194.3 Mtoe in 2020. This projection has been made under the assumption that energy efficiency will increase 2.1% per year at an assumed yearly increase of GDP of 1.1%.[29] In Austria, the NREAP sets the national goal for energy efficiency at 1100 Petajoules of final energy consumption in 2020, (which converts to 305.55 Terawatt hours) and 1320 Petajoule Primary Energy Consumption in 2020 (which converts to 366.66 Terawatt hours).[30]

A closer look at some of the literature about RE policies reveals many different issues surrounding their implementation and efficiency. Reiche et al. (2004) identified several different areas from which RE policies can be influenced. One of those areas is the administrative side which they label 'differences in planning cultures'. Bureaucracy levels involved in planning new RE projects can be very difficult to navigate and a major barrier to entering the market. Long permit procedures and a multiplicity of different public sector entities raise the level of bureaucracy and can hinder potential investors' motivation to invest in clean

[27] EU Directive 2009/28/EC Annex I, A. National overall targets
[28] EU Directive 2009/28/EC Recital 40
[29] NEEAP (2014) Bundesrepublik Deutschland
[30] NEEAP (2014) Republik Österreich

energy. Social and political groups that put pressure on the public sector when new projects are developed, for fear of noise pollution and bird endangerment for example, also delay decisions regarding new installations. This is the case in the Netherlands since environmental and building permits are both needed there. In Greece, complicated licensing procedures prolong the process, since one needs the approval of more than thirty different offices at different levels for RE projects. The workability of permit procedures is a key factor for investors' willingness to invest in renewable energy projects. Planning and building permit procedures need to be transparent in order to accelerate the process of conducting new RE projects.[31]

There are different support policies in place to help along the development and implementation of RE installations. The policy instruments include Feed-in Tariffs, Quota Obligations, Tenders, Energy Tax Exemptions, Subsidies, Soft Loans, Tax Allowances, RES Tax Exemptions, Information Campaigns, etc. The Feed-in Tariffs are, according to Reiche et al. (2004), the most dominant form of support policy. Germany provides a good example for why that is the case. First, the contract duration is around 20 years with fixed tariffs, giving a stable outlook for potential investors. They have strong financial subsidy programs that support the energy producing installations. Secondly, the remuneration itself gradually decreases over time, so for example PV installations receive 5% less payment each year than in the previous year. This accounts for electricity production costs and internalizes future cost reductions within the fixed Feed-In Tariff. Another important condition for success that is mentioned is a differentiation according to the specific technology and sometimes even according to the location in the promotional systems. Photovoltaic is expensive, while technologies such as hydropower, biomass and wind energy are cheaper. Incidentally, higher remuneration for windier sites are more quickly reduced. The authors recommend a stronger reduction of fossil fuel and nuclear energy subsidies in their conclusion, in order to help the Renewables to grow as well as stronger investment into their promotion.

For the EU policy makers, the costs of increasing the capacity of RE are mainly the costs which have to be spent to create investment incentives. These include the support costs paid to the RE producers, a large part of which is passed on to the consumer.[32] Kitzing et al. (2012) conducted an analysis of RES-E support policies between 2000 and 2011 with a special focus on the years

[31] Reiche et al. (2004), p. 845
[32] Klessmann et al. (2013), p.391

2000, 2005, 2010, and 2011 to determine how many and which support instruments were used by EU countries. The analysis was also interested to discover if the policies are similar to each other via either the top-down or through the bottom-up approach. The EU Directive 2009/28/EC implemented a bottom-up approach, by which the member countries have the independent choice of which policies and support schemes they want to use. A top down approach via a "fully harmonized support system, where the policy types are decided top-down and implemented alike in all member states" had been discussed before the Directive was finalized.[33] The idea was to use tradable green certificates together with quotas across all member states. This was abandoned however and with the independent choice of RES-E policies it was possible for a bottom-up approach to develop. With this, regional concepts and cross-border projects started to form as well. A full EU harmonized support system (top-down approach) is argued to facilitate trade across borders, however independent policies naturally become more similar over time in a bottom-up approach. The analysis suggests that the policies do in fact naturally become more similar over time, and their characteristics become quite similar to each other. Kitzing et al. argue that policy type choice is most important and a factor for cooperation since similar choices in RE policy facilitate cooperation. Results suggest that countries typically use a combination of RE policy types, with the major support instruments being Feed-in Tariffs, Feed-in Premiums Tenders, and quota obligations with tradable green certificates. Other instruments also come into play including investment grants, fiscal measures, and financing support. All EU countries have at least one, and on average three instruments in place; most commonly, a Feed-In Tariff (FIT) policy is paired with another policy like investment grants, fiscal measures or financing support, and a combination in parallel can mostly be seen with FIT and Feed-in Premium (FIP) instruments but also with FIT and Tenders (TND). The most prevalent support instrument according to the research by Kitzing et al. is the FIT policy. FITs have a very high growth rate and the complementary instrument, FIP, is also very popular. Price control instruments like these seem to be the most effective ones when it comes to support policies. The type of support is tailored to installation sizes, and the analysis suggests that small installations are more commonly supported by FIT instruments than larger ones. This finding is consistent for every RE technology. Around 44% more countries use FIT policy for small installations than for large ones according to the researchers. In general, it appears that policy instruments are used in combination quite often, taking the form of a major support instrument plus a supplementary support instrument or two major support instruments

[33] Kitzing et al. (2012), p. 193

in parallel (FIT and FIP but also TGC scheme with FIT). Kitzing et al.'s findings suggest that the policy types are being combined more and more often, which does increase the flexibility of the policy makers and benefits cross-border cooperation. Cooperation takes place in form of statistical transfers, joint projects, and joint support schemes. It requires a common ground, common rules, and common policy types to be applied in order to make it work. Another finding is an increased need for market integration and transitional processes, for example a transition from FIT to FIP processes if necessary. FIT is a more direct way of getting RES-E to the consumer bypassing the market, but FIP better integrates the RES-E producers so that they can act on market fluctuations, which also entails a tendency for higher rates the producers are getting to account for the market risk they can experience. Whatever the chosen policies in a member state might be, most European countries have become very similar with regard to deciding for policy types and the scale on which the policies are implemented. This occurs without outside influence by the EU authorities, so harmonization is taking place. Reiche et al. also concluded in their 2004 article that a bottom-up convergence seemed to be a success factor in the wind energy development of Germany and Denmark. Future trends as identified by the authors include more cross-border cooperation and implementation of regional concepts as well as country-independent supports, which are "projects [that] are supported independently from the national support scheme".[34] Specifically, this means financial engineering instruments, such as country-independent renewable support, provided by the European Investment Fund and European Investment Bank.

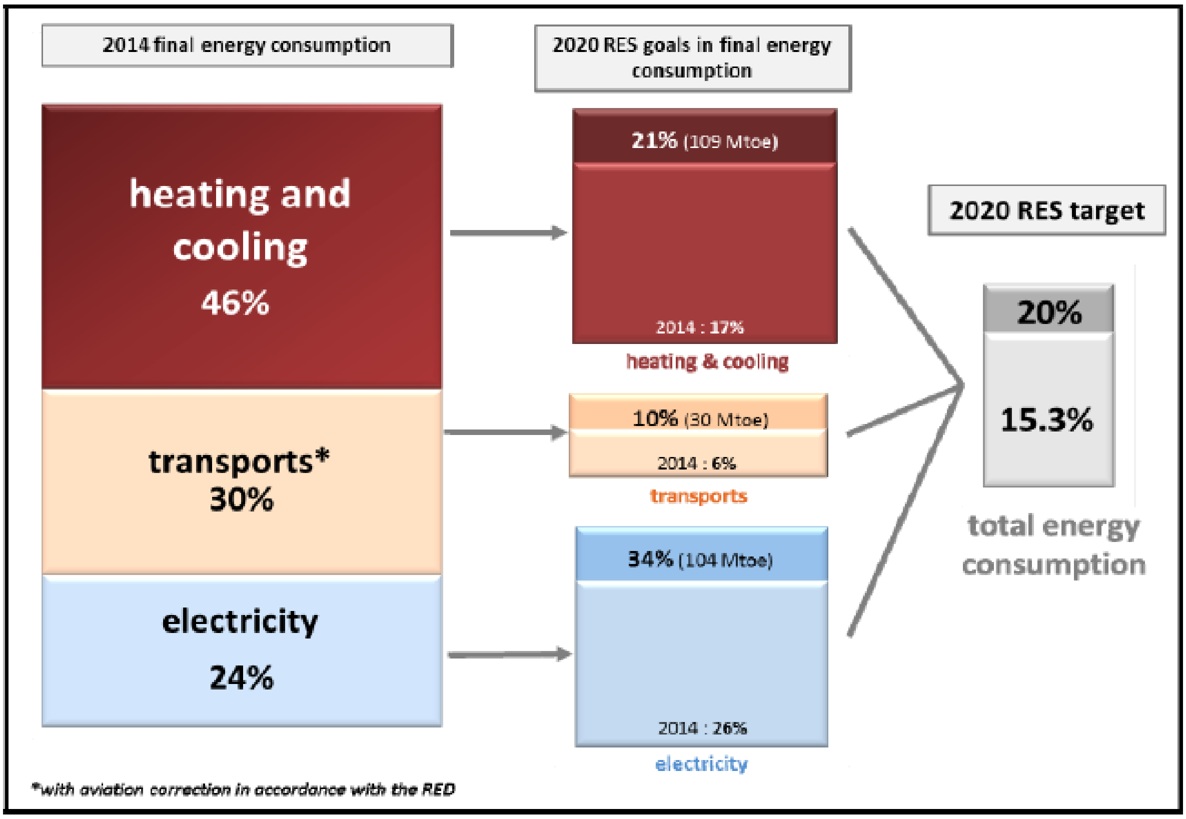
After looking concretely at the different international obligations and at the EU Renewables policy, we conclude this political part of our literature review with a closer look at the current progress and results of the RE Directive of 2009, based on the Renewable Energy Progress Report conducted by the European Commission for the EU Parliament and the other EU institutions. The evaluation was carried out in 2014 based on data from 2013.

The Renewable Energy Directive 2009/28/EC which we have described above is a comprehensive policy framework, which aims at supporting the development and integration of Renewable Energy into the current energy market. The Directive attempts to do this with market-based investment incentives and state-aid. It is now the main driver for European global investment in Renewable technology and support policy. At the point in time when this

[34]Kitzing et al. (2012), p. 200

evaluation was carried out, the RE industry employed 1.15 million people. According to this mid-term assessment of the progress the EU as a whole, the EU is on pace to meet their 2020 target of 20%, since the projection for the year 2014 showed a RE share in gross final energy consumption of 15.3% is. However, as the individual targets become increasingly difficult to achieve, the member states need to cooperate more closely and use more cooperation mechanisms to reach their targets. A breakdown of the renewable energy share for the year 2014 in the different sectors is shown in Figure 2. In the heating and cooling sector, which makes up 46% of gross final consumption, 16.6% of this was from Renewable Energy. Electricity makes up around 26% of the final consumption with a 10% share of RE, such as solar power and wind energy. Transport amounts to 30% of final consumption with the lowest RE share of only 5.7%. The main part of Renewables for transport is expected to come from biofuels; reasons for the low percentage in 2014 were, among others, general uncertainty about a policy regulating indirect land use change and a slow progress in the deployment of second-generation biofuels.

Figure 2: Renewable Energy Share in Final Energy Consumption in Europe 2014



Source: European Commission, Renewable Energy Progress Report (2015)

The progress evaluation is partially also based on the REFIT evaluation of the Renewable Energy Directive carried out in 2014 by CE Delft. The consensus is that every article in the Directive is relevant and necessary for the continuing process of reaching the objectives set out by the EU authorities. It is stressed that the implementation at member state level is most important and influences the effectiveness and efficiency of the Directive. An important overall result was achieved by member states in 2011/2012, wherein the majority of member states reached their interim targets. These and the target from 2013/2014 were still relatively easy to reach, while the later ones will be harder to accomplish since the targets are more ambitious, but the EU is still on pace to meet the 2020 goals. Progress was made mainly in the RE heating sector, which helped significantly in achieving the targets. Good examples are from Bulgaria, Sweden, and Finland where low-cost biomass options were the main drivers for the positive development. Italy and Portugal were able to exceed their NREAP targets with a rise in RE electricity. The Netherlands and France did not reach their targets, and their failure was partially blamed on long permit procedures and technical barriers. The Renewable Energy use in transport is only making slow progress, but positive examples can be found in Austria, France, Germany, Sweden, and Finland. Additional measures need to be taken in some countries where the progress is a bit slower. The factors that the evaluation found were hindering progress were regulatory uncertainty and administrative barriers, which impact the private investments in these sectors. In the different sectors, the progress is satisfactory overall. The heating and cooling sector has seen the most progress with 22 member states being on track to meet their targets. Solid biomass, next to heat pumps, biogas, and solar thermal heat, was the largest contributor in 2013 with 73 Mtoe of renewable energy heat produced. One sixth of this biomass heat generation was based on grid connection applications; the majority was based on decentralized units, which also experienced higher growth rates. The largest consumers of biomass heat were France with 10.2 Mtoe and Germany with 8 Mtoe. Biogas played a smaller role with 2.6 Mtoe heat produced from biogas in 2013. Germany is the largest producer with 1.3 Mtoe in 2013.

In the electricity sector, 15 member states were above their projected targets with a total gross RES-E generation of 823 TWh in 2013. Hydropower plants generated the largest share of electricity, followed by wind power and solar electricity generation. Wind and solar power has increased in electricity generation. Solid renewables consisting of wood and other renewables, but excluding renewable waste, is used in conventional thermal generation power plants and generated 9.5% of RES-E share. Bioliquids and biogas together came up to about 6.7%.

The transport sector has had the slowest progress so far with only 5.4% of RE share in 2013. Only Sweden has reached their 2013 target. Biodiesel is the most commonly used form of RE, around 10.3 Mtoe of it in 2013 and around 2.7 Mtoe of bioethanol. The top three diesel markets in the EU are France with a turnout of 2.3 Mtoe in 2013, Germany with 1.9 Mtoe and Italy with 1.2 Mtoe. Germany was also the largest consumer of bioethanol with 758 ktoe.

The evaluation predicts positive future developments in the heating sector, in the generation of heat from biomass and from heat pumps. In order to achieve the targets set for 2020 and to make sure that the EU member states stay on track can only be reached if a more favorable environment is created for RE development. Specifically, the removal of non-economic barriers has been found by the evaluation to affect such a development in a positive manner.

The factors, which were found out by this study, reflect what is found in prevalent literature. First off, investment decisions in RE projects are affected by spatial planning rules and lengthy administrative and authorization procedures, which concerns large infrastructure projects and decentralized RE projects in particular. Next, we have the need for easier market access for new players such as SMEs. The Directive obliges countries to simplify their procedures, including transparency and the coordination between authorities. However, there appears to be a slow process in administrations simplification, which poses a challenge for RE growth. Some members have positive examples to show, like the Netherlands where permits such as building and environmental permits, can be applied for together in one step. Similar procedures have been introduced in Belgium and Austria. It is also still rare to find online platforms and application procedures. Improvements are being made by most member states regarding the coordination and cooperation between the authorities involved, however further improvements in administrative procedures are needed.

The REFIT evaluation, which looked at the question of whether or not the Directive was successful in raising the share of Renewables in the EU, came to the following preliminary findings in 2014: The REFIT evaluation found that overall the Directive was successful, and what was particularly effective was the national binding targets and the National Renewable Energy Action Plans combined with the biennial monitoring process. The NREAPs were especially helpful for investors and economic operations in general due to their transparency. In total, the EU avoided a gross of 388 Mt CO_2 emissions in 2013, and was able to reduce fossil fuel demand by 116 Mtoe. The EU was able to reduce the annual cost of imported fuel by 30 billion euros. The binding targets were an effective measure to improve the allocation of RE resources in the member states and improved RE capacity. Additionally, the Directive was responsible for the development of biofuel sustainability criteria. Measures which helped member states in the journey towards lower emissions and reaching the targets set by the EU are the following: lowering the administrative load by either (i) providing templates to the member states for planning and reporting RE projects or (ii) helping in streamlining administrative procedures. This was particularly effective when binding targets like the NREAP were involved and if the measures are carried out at the national level. The targets also need to be well defined, which makes it easier for the member states to follow through with them. Rules and regulations need to be established in the beginning and should not change during the respective legislation period to ensure credibility and transparency. The evaluation points to the fact that the establishment of a post-2020 framework would increase the performance of the Directive and provide some more stability to the investors and stakeholders and more incentives for government authorities. Overall the evaluation concludes that the majority of the member states are on the right way to reach their 2020 targets. Increased use of cooperation mechanisms will be useful and especially aid some member states that are struggling at the moment to reach their goals. The slow progress in the transport sector can only be accelerated with a great deal of work. What is needed here is a breakthrough in the development of alternative biofuels, and especially second-generation biofuels. In addition, the use electricity from renewable energy in transport needs to be expanded. Complementary to this, the decarbonisation of the transport sector is an important task to fulfill over the next couple of years. The support policies of the Directive were key drivers in bringing the EU's Renewable Energies forward. Because of all the progress that has been made so far it is vital to continue with the same level of commitment and, even more than previously, cooperation is essential to the task. The Directive and its policies is successful, yet it remains crucial that the implementation at member state level is continuously improved in order to increase the shares of Renewable Energy across all sectors.

The preceding paragraphs have already touched on some of the challenges inherent to the successful execution of an RE project. This next section will provide some more insight into the risks that investors need to assess before they decide to devote financial support towards a Renewable Energy project.

1.2 Risks associated with RE Investments

Government actions and so-called “regulatory drivers” heavily influence the energy sector.[35] This influence is especially palpable in the way that investments are made in this branch of trade, wherein energy and environmental policies are regarded as a “regulatory risk”.[36] Investments, however, are needed for RE technologies to succeed, especially in the early stages where private investments can help to bridge the “technology valley of death”.[37] The point in time between the development of a successful prototype and full market introduction is more often than not characterized by a funding gap. Government-funded research and development (R&D) has stopped but income from customers has not yet kicked in. Investors balance their decision about whether or not to invest in a new RE technology or a RES-E providing enterprise with the various factors of risk in the energy sector. One risk we mentioned above is the regulatory risk. Governments change once every few years and with them, support policies might be shortened or discontinued. Investors favor a stable long-term policy environment and research suggests that the level of experience with a certain policy is a deciding factor for investing in a project.[38] Some types of support schemes, for example quantity-based support schemes, pose specific risks in terms of volume, price, and balancing. These make it difficult for new companies that just start out with a relatively new technology, hence, entrepreneurship might be lower in these policy environments as might be the willingness of private equity or venture capitalist investors to start projects. In general, investors interviewed in a Bürer/Wüstenhagen study expressed a preference for a mix of market-pull and technology-push policies for a financial stimulus along the entire innovation chain of a technology. New technologies bear the risk of missing successful market application and the guarantee of viability. In the RES-E producing wind energy sector, which is today the most mature RE technology, more investors feel confident enough to take part in new projects. Thus, the later stages of the innovation cycles were preferred for investment, notably is that the investors favored FIT policy in a project’s expansion stage. The attitude towards investment also depends on the fund type, not only the stage in which investment occurs. The preference however, is for less government involvement as the market evolves. For the RES generator, the costs of

[35] Bürer/Wüstenhagen (2009), p. 4997
[36] Bürer/Wüstenhagen (2009), p. 4999
[37] Bürer/Wüstenhagen (2009), p. 4997
[38] Bürer/Wüstenhagen (2009), p. 5003

producing RES-E need to be reflected in the financial support level. The upfront capital expenditure is high, whereas the operating costs are usually low.[39]

The preceding paragraph dealt with a few risks, which are typical for RE project investments. Klessmann et al. (2013) describe these and a few other related risks in their work, categorizing them into the following groups: (a) Country and financial risks, (b) policy and regulatory risks, (c) technical and project specific risks and (d) market risks. In more detail, the risks include in (a) the government-related factors such as its stability, transparency and its currency fluctuations. In group (b), which is connected to group (a), we can see more specifically the risk of changes in the RE support policy framework, restrictions on budget or capacity and how the grid access is handled. The more detailed risks involved in group (c) when looking at specific projects and technical issues are, for example, construction and possible technological problems, environmental risks and operation and management. The last group, (d) market risks, include the risk of a fluctuating market price for a certain energy commodity which can influence revenues and costs such as feedstock prices and carbon prices, as well as the entry of new competitors into the market.[40]

Possible solutions for decreasing these risks are given in the following paragraph based on work done by Klessmann et al. (2013). The main theme that we encounter throughout the literature is stability, which is the most important factor considered by investors. The second group (b), policy makers can most effectively control policy and regulatory risks by keeping the support policy stable and avoid sudden retroactive changes. Reliability and predictability reduce the regulatory risks and are important for market actors to keep project risks down and to avoid a rise in capital costs. Policy makers can influence market risks (d) through introducing and maintaining adequate support policies; this is especially the case when we look at electricity market prices, which impact RES-E technologies. The impact electricity market prices have on RES-E technologies varies depending on the support scheme that is used, and some schemes are more connected to the market price while others are connected to a lesser extent. Feed-in tariff schemes are the least influenced by this since the fixed price per kWh is separate from the market price. In Feed-in Premium schemes and quotas the RES-E generators are unprotected from the market risk. A risk that especially affects quotas with tradable green certificates is the certificate price risk since these are traded in their own market. One attempt to reduce these

[39] Klessmann al. (2013), p. 392
[40] Klessmann et al. (2013), p. 394

risks is the use of cap and floor prices for premiums, as well as floor prices for certificates or referring to monthly or yearly average electricity prices for premiums. In addition to these methods, RES-E generators can also use a Power Purchase Agreement with an energy company to protect themselves against the market price risk; in exchange the energy company gets to keep a certain part of the profits. Another price related risk that is mentioned is the risks arising from incidents of grid congestions and system stability, curtailment and safeguarding measures need to be taken in these cases. Priority dispatch of RES-E ensures that the electricity of RES-E generators is treated with priority and not be taken off the grid in case of power congestion. Compensation payments when curtailment is necessary are another option to reduce these risks.

For group (c), technical and project specific risks, one option from the side of policy makers could be to help develop "independent risk assessment tools and ratings for the performance of RET or projects" so it is easier to rate RES projects as 'investment-grade', this and the international availability of empirical data concerning RE technology would make it easier to assess RE projects and might help them to get funded.[41] Additionally, if commercial insurance policies were open for RE technology and operational risks and provide guarantees and insurances this would be beneficial for investment. Similar ideas are "private-public efficacy insurance that covers RET regarded as too risky for conventional insurances" and "publicly backed guarantees for RET loans (…)".[42] Both of these ensure that a third party or third funding source covers part of the risk in order for higher risk technologies to have lower financing costs.

As we have established, higher costs for a project can be a reason for investors to decide against it. Some additional generic measures which could help to reduce costs in the different areas are the following: Technology related costs and project development costs could be lowered with investments into R&D and stable and transparent permit processes, good grid connection, and support policies. The most financing is needed in the early stages of commercializing RET. With the investment in R&D processes could be optimized and the learning stages can be surpassed more quickly, possibly resulting in lower overall costs for the technology. The continuous improvement of the regulatory conditions can also serve as a measure to reduce costs in the long run. Things like the duration and efficiency of administrative procedures and their transparency are important factors for investors to consider. Klessmann et al. (2013) also mention spatial planning rules and better definition of RES priority areas as important. In

[41] Klessmann et al. (2013), p. 395
[42] Klessmann et al. (2013), p. 396

combination with a guaranteed grid access for renewables and limited grid connection costs, these measures can improve the chances that investors will decide for a RE project. As mentioned above, a stable support policy framework is key to moving forward in the capacity building of Renewables. If subsidies for conventional energy sources in the following years would be reduced and prices for holding emissions permits would increase, this would potentially accelerate the growth of Renewables even further.

When we now look back to the different factors involved in RES policy and the risks associated with RE investments, we notice that one support instrument continuously appears as a very successful and safe option, this instrument is the Feed-in Tariff. In the next section, this financial support instrument will be described in more detail.

1.3 Feed-In Tariffs

The Feed-In Tariff (FIT) is a policy instrument where producers of electricity from Renewable Energies receive an increased payment, either for a certain period of time, like a certain number of years, or for a certain generated amount of Terawatt hours. It is a price-based system, under which RES-E producers also receive priority dispatch from transmission or distribution networks. It guarantees that such an operator will take the generated power and transmit it further at a particular predetermined price. The transmission and distribution operators are the ones, which then have to market the power and pass on the extra costs to the end-user. This happens either completely separated or partially separated from the free market. Several different versions of the FIT support instrument exist but the main schemes are the fixed-price model and the premium tariff model.[43] The *fixed-price* tariff guarantees that RES electricity producers can sell power to the grid at a set price, which is set above the market price. With the fixed feed-in tariff, there is usually one tariff per RE technology, which can only be changed through amendments to the respective regulation. This second type is practiced in Germany.

The next type of feed-in tariff is the *Time-dependent feed-in tariff*. Here there are two to three different tariffs that vary according to either day or nighttime, or peak and off-peak times. This exists for each technology group and can only be changed through an amendment to the regulation. For example, Spain uses these tariffs for hydropower and biomass. Then there is the

[43] Kitzing et al. (2012), p. 194

Indexed feed-in tariff, wherein the tariffs depend on certain market indicators. This can be either the exchange rate to a particular currency or the price of natural gas, for example. In general, the tariff rates cannot be known before one invests in a project, since they are not predetermined. Similar to this is the *Adjusting feed-in tariff*; these tariffs are also not predetermined before installation.

The last type of FIT is the *Target price feed-in tariff*, which consists of a guaranteed target price and is paid out with an adjustment to the market price. Either it adds an extra amount to the market price, or it is reduced to the specific amount, essentially filling the gap between the target-price that was set and the current market price. The target price is predetermined per individual technology group and according to the specific regulation or it is project-specific, for example through tenders. The reasoning behind this method is to improve market integration for RES-E under the FIT scheme while also offering the RES-E generators protection from market risks through this target price, this type of FIT is also called *Contracts of difference*.[44]

Similar to the feed-in tariffs are the feed-in premiums. A *premium-tariff* gives RES-E generators an additional bonus to the wholesale market price.

Feed-in Premiums work through a guaranteed premium that is paid out as a fixed add-on to the market price. Usually RES-E producers receive a premium per unit (MWh) that they sell, and they are selling their power on the free market. Premiums are secured either for a certain period of time or for a pre-determined production load. The *Fixed feed-in premium* is literally a fixed premium price that is predetermined by regulation for the different specific technology groups and can only be altered by amendments of the regulation. In contrast to this is the *Adjusting feed-in premium*, here the tariffs are not strictly fixed for projects and if they are changed via amendments they might affect existing projects. The premiums can vary depending on certain indicators; in Spain, for example, the premiums vary on the basis of per-hour market prices. Through this mechanism, floor and cap prices are created which apply to the RES-E producer. Such a method protects the RES-E producers from low market prices, yet it prevents them from over-compensating for high market prices.[45]

[44] Kitzing et al. (2012), p. 194
[45] Kitzing et al. (2012), p. 195

In general, the contracts for this Feed-in tariff policy instrument are set up for a certain time span, usually ranging from 10 to 25 years. The contracts vary, but a longer contract can provide a slightly lower tariff for a longer period of time as opposed to a high tariff for merely 10 years.[46] This makes feed-in tariffs a very “secure investment”, with possibilities for “fine tuning and the promotion of mid- and long-term technologies”[47] The tariff amount varies according to the generation cost, location, the system size, and the receiving party. The cost allocation works as follows: the RE electricity generator is entitled to feed the power from his utility into the grid prior to other conventional sources. The difference in price is either covered by various forms of state budget or more commonly passed along to the consumer in form of an additional premium per kWh on the end-user price. Many of these policies have a built-in digression rate, where the tariff amount is reduced gradually over time to adjust the incentive provided by FIT, mainly in order to account for the advanced level of technology and to prevent free riders from taking advantage of this policy. This is done to increase the economic viability of RES policies. Another form of controlling the costs is to either “cap the total capacity that may be installed or total tariffs that may be awarded under a FIT policy each year”.[48]

Feed-in Tariffs are the most dominant support instrument in RE policy. Reiche and Bechberger in their 2004 article published in *Energy Policy*, point out the success conditions for this particular instrument, which can be observed in countries like Germany. Here, FIT prompted a substantial increase in wind energy capacity but also for photovoltaic. First off is the long-term security for investors with guaranteed and fixed tariffs for a period of 20 years or longer on a high level. Additionally, Germany has strong financial subsidy programs for FITs. This is combined with a remuneration in a digressive style form a safety net for both the government, the grid operator, and the RE electricity producer. Increased electricity production from RES helps the government to achieve renewable energy targets, and a secure contract which regulates the long-term financial situation for the RES-E producer, increasing the willingness to expand RES-E capacity, and to make sure the technological incentive for R&D remains attractive. The digression in tariff value (for example PV installations receive 5% less payment per kWh than the previous year) accounts for the electricity production costs and internalizes future cost reductions within the fixed feed-in tariff. Furthermore, the FIT is structured differently and pays differently according to each RE technology and also the location of a

[46] S. Jenner et al. (2013), p. 386
[47] The support of electricity from renewable energy sources - Communication from the Commission (2005), p. 4
[48] S. Jenner et al. (2013), p. 386

production site. For example, on a windier location, the tariff amount will decrease quicker than on a less windy site.[49]

The development of the Feed-in Tariff has shown that it is a very successful instrument with a high growth rate. The scheme is more frequently applied to small installation sizes across all the different technologies. It is very likely to be combined with other policies such as tenders for fixed or target price feed-in tariffs or investment grants. The dominant use of this price-control instrument and its effectiveness for wind and solar power in particular, lead to the conclusion that this instrument must be very effective to boost every RE technology capacity. S. Jenner (2013) showed the effects of FIT in their work, which was specifically applied for photovoltaic and on-shore wind power, and they called for the effects of FIT to be analyzed for other technologies as well.[50] Therefore, FIT was chosen as the support policy instrument that we will analyze in the empirical part of this work.

Our working hypotheses are the following:

Hypotheses 1: FIT is the most effective instrument to boost the capacity of any RE technology.

Hypotheses 2: If FIT policy is the policy of choice for biomass in a country, the biomass capacity will increase more than with a different support policy instrument.

Before we test these preliminary hypotheses, we must first examine the key features of biomass, including what counts as biomass, how it is produced, and the relative advantages and disadvantages of biomass as a fuel source.

[49] Reiche/ Bechberger (2004), p. 848
[50] S. Jenner et al. (2013), p. 398

2. Biomass

2.1 Definition

The term biomass generates much confusion among lay people, since it is not simply a renewable form of energy from one single source like solar power. Instead it means a variety of different sources and methods that are used to extract energy, which again can be produced in several forms. A definition laid down by Article 2 (e) in the EU Directive 2009/28/EC describes biomass as "the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste." Further subsections (h) and (i) of Article 2 define the term 'bioliquids' as "liquid fuel for energy purposes other than for transport, including electricity and heating and cooling, produced from biomass", and the term 'biofuels' as "liquid or gaseous fuel for transport produced from biomass." On the basis of these rather broad definitions, one can see that biomass energy is a very diverse topic and needs to be scaled down to certain classifications of biomass to better distinguish between the different sources and methods. Vladimir Strezov's (2015) attempt to gather classifications in prevalent literature resulted in the following synthesis, which we will present in this work for a more detailed overview of what constitutes biomass. The basis of this synthesis is the sub-sectioning of the source types, thus, that biomass originates either from plant materials, of terrestrial or aquatic nature, animal waste or human sewage.

Terrestrial biomass can further be divided into the following source types:

- Wooden biomass (roots, trunks and leaves)
- Nonwoody biomass (herbaceous plants, grasses)
- Fruit (soft fruit, seeds, hard shells)

Then there is Aquatic biomass, which stems from either fresh water or saltwater, it can be either Microalgae or Macroalgea.

Biomass can also be provided by other sources, animals for example produce tallow and manure which can be used, as well as sewage from human origin. Strezov categorizes the source types further into three different categories: (1) 'Accidental wastes and residues' which include weeds, agricultural and forest wastes as well as industrial and commercial wastes; (2) 'Deliberately cultivated biomass or energy crops', divided into edible and nonedible crops which are cultivated on either agricultural land or marginal soil and degraded land; (3) 'Naturally occurring biomass', meaning harvesting of plants which later either are or are not replanted.

Next there are the different so-called generations of biofuels, which can stem from various biomass sources and can be produced via several processing technologies. The production routes for biofuels depend on the characteristics, or more explicitly, the physiochemical properties of the different types of biomass. Woody biomass is composed of cellulose, hemicellulose and lignin. Cellulose takes up the largest proportion and maintains a plant's structural integrity. Hemicellulose and lignin complete the microfibril structure of the plant as the inner and outer layers around cellulose. The proportion of those properties affects the suitability of different plants for biomass usage. For biochemical processes, like for methane and ethanol production, a low lignin content is preferable since it does not decompose very well because of its low biodegradability. High lignin content works well for the thermochemical route.[51] Nonwoody biomass has the following biochemical properties: saccharides, lipids, and proteins. Saccharides are sugars and carbohydrates, which can be converted into alcohol. Lipids can exist in various forms, ranging from fat to wax to oil; they can be used to directly produce biodiesel. Proteins or amino acids occur as a by-product in fermentation-based biofuel production and can be used as animal feed or fertilizers. The ratio of these properties affects how well a plant is suited for biodiesel production. [52] In addition to these physiochemical properties, the moisture content, mineral matter content, organic matter composition and physical properties like density and grind ability are important factors for the transformation from biomass to biofuel. Transportation costs increase with the moisture content, as well as low physical density. In conclusion this means that ideally, biomass should be grown and then processed to biofuel in close proximity to the grow site. The higher the moisture content, the better biomass can be used in biochemical production; the lower the moisture content, the more biomass is suited for thermochemical processing.[53]

One of the most important processing techniques is the Fischer-Tropsch Synthesis Route, hereafter referred to as 'FT synthesis'. Discovered in 1923 by German chemists Franz Fischer and Hans Tropsch who intended "to convert coal into liquid transportation fuel to reduce

[51] Strezov (2015), p. 12
[52] Strezov (2015), p. 16
[53] Strezov (2015), p. 21

petroleum dependence",[54] it shows that there were already concerns in the twentieth century about the increasing fossil fuel dependency.[55] It is a thermochemical process in which gas is transformed into liquid fuels. The conventional fossil fuel sources, which are commercially used for producing synthetic diesel and gasoline, are coal and natural gas. The earliest application for this method was with coal, however the 'gas to liquid' method sparked interest in the market. The 'biomass to liquid' pathway via FT synthesis roughly works as follows: second-generation biofuel materials, made up of lignocellulosic biomass (forest and agricultural waste), are gasified into and then converted via the FT synthesis into synthetic diesel and gasoline. In more technical terms, carbon monoxides and hydrogen, called synthetic gas or 'syngas', is converted into liquid hydrocarbon. The advantages of synthetic transportation fuels are that they contain fewer particles and pollutants than conventionally produced diesel and can also ignite very well. However, Strezov and Thommes (2015) point out the fact that the applications for biomass still need to be optimized.

Different types of biofuels exist and will be explained shortly in the following section. The *first generation biofuels* are sources that are high in saccharides, like sugarcane and sugar beet, and lipids such as sunflower and canola. The ethical and sustainability implications for these types of crops are the highest here, due to the inherent competition with food crops and high maintenance for growing and harvesting the plants.

Second generation biofuels are the sources that are high in lignocellulosic biomass, which usually stem from nonedible plants or are generally not meant for consumption. They can be acquired as by-products or waste from agricultural or industrial processes, such as cooking oil waste, tallow, corn stover or switchgrass. Biofuels from lignocellulosic biomass cannot be used immediately and they require intermediate technologies based on either thermochemical (Pyrolysis, Fischer-Tropsch Synthesis Route) or biochemical processes (enzymes and microorganisms processed to ethanol). A practical example for Biomass to Liquid processes can be found at the Karlsruhe Institute of Technology (KIT) in Germany. They executed a pilot project (bioliq®) with the goal to produce synthetic fuel from residual biomass. The bioliq® process uses dry biomass, e.g. straw or wood waste from agriculture and forestry, which is converted into an intermediate (biosyncrude) via fast pyrolysis to achieve a higher energy

[54] Strezov/Thommes (2015), p. 310

[55] Strezov/Thommes (2015), p. 312

densification. This intermediate can be easily transported, solving the problem of high transportation costs for dry biomass which usually has a low energy density. Via entrained-flow gasification the intermediate is turned into synthesis gas, which is cleansed and conditioned in the next step. The final step in this procedure is the conversion of synthesis gas to different fuels and chemicals with established processes like the Fischer-Tropsch Synthesis Route or the Methanol Synthesis Route. Byproducts like electricity and thermal energy are used to cover the entire process. The project has been up and running since 2014, with constant status seminars to monitor the process development. Roughly 1 ton of synthetic fuel is produced with around seven tons of dry biomass like straw.[56]

Third generation biofuels describe the conversion of microalgae, in specifically its lipid and protein, into biofuels like biodiesel. Lipids and protein are present in high amounts in microalgae, furthermore it has a fast-paced growth rate and can be cultivated using wastewater, making the process more environmentally friendly. These properties lead scientists to expect microalgae to achieve a higher production of biodiesel per acre than terrestrial crops. Since all the different processing technologies can be used to convert microalgae into biofuels, it makes this type of biomass a very prominent candidate for producing biofuels in the future.

Fourth generation biofuels are not simply another source for biodiesel or a processing technology. The general idea is to incorporate the production of these fuels into a closed life cycle, where the carbon that is being produced is bound into the next part in the process of biofuel production. The author describes this as the carbon ‘sequestration pathway’ with the goal of a negative carbon footprint. He features a ‘self-sustaining pyrolysis’ where biomass is converted into biogas, bio-oils, and biochar. These are then processed into heat, biodiesel or petrochemicals, the biochar is stored in soil to improve its quality. Following this line of thought, the “ultimate goal…is to design an industry that is founded on the principles of industrial ecology and sustainability.”[57] One idea that Strezov (2015) mentions is the development of salt-resistant energy crops which could be planted in saline soil, possibly helping to put a stop to the advance of salinization in certain areas through a reduced need for irrigation.[58]

---

[56] Renger (2010), p. 31 and KIT professor Nicolaus Dahmen 2015 – Infoblatt under www.bioliq.de
[57] Strezov (2015), p. 28
[58] Strezov (2015), p. 29

2.2 Biomass Production Techniques

There are quite a few different Biomass Production Techniques, which all differ in respect to how sustainable they are and of their utilization. The production route to convert biomass into energy of various forms depends first and foremost on the source. In the section above we explained what constitutes biomass from waste or residue, naturally existing biomass (which is removed for their energy potential), and biomass crops (which are specifically cultivated for energy usage). The latter option proves somewhat problematic in its function as a provider for energy due to the fact that the intended use of crops lies in harvesting it for food, not as a biomass source, which is a critical ethical issue. Further concerns are directed towards the lower degree of sustainability. Higher maintenance costs for cultivation, harvest and transportation also come into play here. The removal of naturally occurring biomass in the form of deforestation and algae removal prove to be problematic as well. Long-term effects on the environment such as desertification and loss of biodiversity have to be taken into the equation.

According to Strezov, the production routes fall into three basic categories:

1) Thermochemical
2) Biochemical
3) Physiochemical

We will elaborate shortly on each of these production routes and mention the underlying processes without getting into unnecessary detail. This will serve to provide a basic understanding of the input-output process of biomass conversion into energy. Further information on this topic can be found in relevant literature.

1) Thermochemical Production Techniques

The most common and most versatile production route is the thermochemical process. Different possibilities of this production route include *Combustion, Gasification, Pyrolysis* and *Hydrothermal processing.*

Simply put, all of these methods produce several different kinds of energy, such as heat, steam, electricity or biogas and bio-oil, as well as charcoal. The following overview shows the respective energy conversion methods and their possible energy outcomes:

- Combustion: heat, steam or electricity
- Gasification: heat, steam electricity, methane, hydrogen
- Pyrolysis: charcoal/ biochar, biogas, bio-oil
- Hydrothermal processing: charcoal, biogas, bio-oil

According to Strezov's research, there are advantages and drawbacks for each method. A positive aspect to note for all of them is the fast conversion rate. For the Combustion and the Gasification methods, both of which can draw on technologies that are already in use for fossil fuels, conversion efficiency lies between 20-40%. However, current trends suggest conversion rate efficiencies are higher in co-combustion techniques that utilize a mix of biomass and fossil fuels.[59]

2) Biochemical Production Techniques

The biochemical production techniques available today and the types of energy they produce are the following:

- Anaerobic Digestion: biogas, digestate
- Fermentation: ethanol fermentate

In Anaerobic Digestion, bacteria transform biomass material into a solid part and a gaseous part in the absence of air. The solid part is re-used as compost and the biogas that is developed can be recovered for energy usage. Fermentation operates on a slightly different principle. Here, the sugar in biomass material is converted to alcoholic liquid, which can serve as fuel with the help of bacteria and distillation.[60]

3) Physiochemical Processing

Physiochemical Processing describes the process of esterification, where biomass is stripped from its lipids via either mechanical or a solvent liquid. The lipid is then converted to biofuel or biodiesel through transesterification.

We will explain the Combustion conversion method and Gasification in a bit more detail, since these are the currently most advanced processing technologies and the most feasible.

[59] Strezov (2015) p.24
[60] Strezov (2015), p. 25

Combustion

Combustion of biomass has reached a high level of technical maturity. It is used to produce heat and power for a wide spectrum of MW with a good energy input and output ratio. The rough definition of combustion is the burning of biogenic material that is not fossil fuel or fossil fuel related. An exothermic chemical reaction happens between the biomass fuel and the oxidant. It is a very old method of producing energy; it is essentially the act of creating heat through making fire. The direct combustion of biomass is commercially available on a large scale, as well as co-combustion with coal. Issues that the technology is permanently concerned with is the optimization of the entire process, the increase of its efficiency, and the reduction of economic costs, but also the emissions that come with combustion and the attempts to reduce these emissions.

The combustion process has four main stages: *Drying, Devolatilisation, Combustion of volatiles* and *Combustion of char*.

In the *Drying process*, the biomass is deprived of its moisture content. The duration of the process depends on the level of moisture in the respective biomass material, its size and its density. First the 'free' water and then the 'bound' water evaporates. It is important that the moisture content of the material does not exceed 65% since this would make evaporation and the consecutive autothermal reaction very difficult.[61]

The *Devolatilisation process* turns dry biomass into tar, volatile gases, and solid char at temperatures between 220°C and 500°C. The devolatilisation process is essential in determining the flame position and temperature, which then in turn determines the char combustion rate and the formation of NO_x pollutants.

Next the *Combustion of volatiles* occurs in the combustor. The tars, volatile gases and air react with each other, the volatiles are ignited and combusted. This oxidation of volatiles produces heat and light. The products formed through this combustion are carbon monoxide (CO), carbon dioxide (CO_2), water (H_2O), soot, polycyclic aromatic hydrocarbons (PAHs), and other pollutants. *Combustion of Char* is the final process that occurs in the combustor. Char reacts with oxygen at the same time as the volatiles combustion is happening, in a highly exothermic

[61] Strezov/Kan (2015a), p. 53-54

reaction and forms CO, CO_2 and other pollutants. The processes all are overlapping to some extent as they happen at different places in the combustion chamber. The biomass combustion process can also be divided up into three phases: *ignition, flaming*, and *smoldering*. During the *ignition phase* the drying of biomass occurs which releases flammable hydrocarbon gases until the ignition begins. The biomass thermally decomposes, releasing volatiles, tars, and gases which mix with air and oxidize, producing flames. With sufficient air supply, biomass will burn irreversibly. In the *smoldering phase*, the combustion of char mainly happens and produces carbon monoxide.[62]

Biomass combustion systems can be evaluated using different performance indicators such as (i) combustion efficiency for assessing the completeness of combustion process, (ii) furnace efficiency which rates the extent to which the furnace is insulated and its proper design, (iii) boiler efficiency which rates heat exchangers and (iv) economic costs and pollutant emissions which involves many different parameters. The types of biomass source material that is used on a large scale for combustion fall into different categories. There are agricultural products, forestry products, domestic and municipal waste and energy crops. The various harvesting residues, animal waste, processing waste, wood, grass, and other crops require differing stages of pre-processing before they can be used for biomass combustion. This involves drying, grinding, leaching in water or diluted in acid and alkaline solutions to get rid of metal constituents in the biomass. Water content and particle size of the biomass influence the combustion performance.[63] Various technologies are available for biomass combustion; they can be grouped according to their sizes into (1) small-scale systems of up to 200 KW_{th}, (2) medium-scale systems of 200 KW_{th} to 20 MW_{th} and (3) large-scale systems of more than 20 MW_{th} and coal-fired systems which reach several hundred MW_{th}. [64]The biomass combustion systems in the first group are, for example, stoves, boilers, wood stoves and fireplaces, as well as wood log or wood pellet boilers. The primary fuel types used here are wood chips, wood pellets, and logs. The second and third group of biomass combustion systems are various heat and power supplies like district heating, process heating and cooling, and CHP production. The biomass fuel type used here are wood chips, forest residues, and straw. The fuel is added to the combustor and burned which produces hot flue gas. This can either be directly used as heat

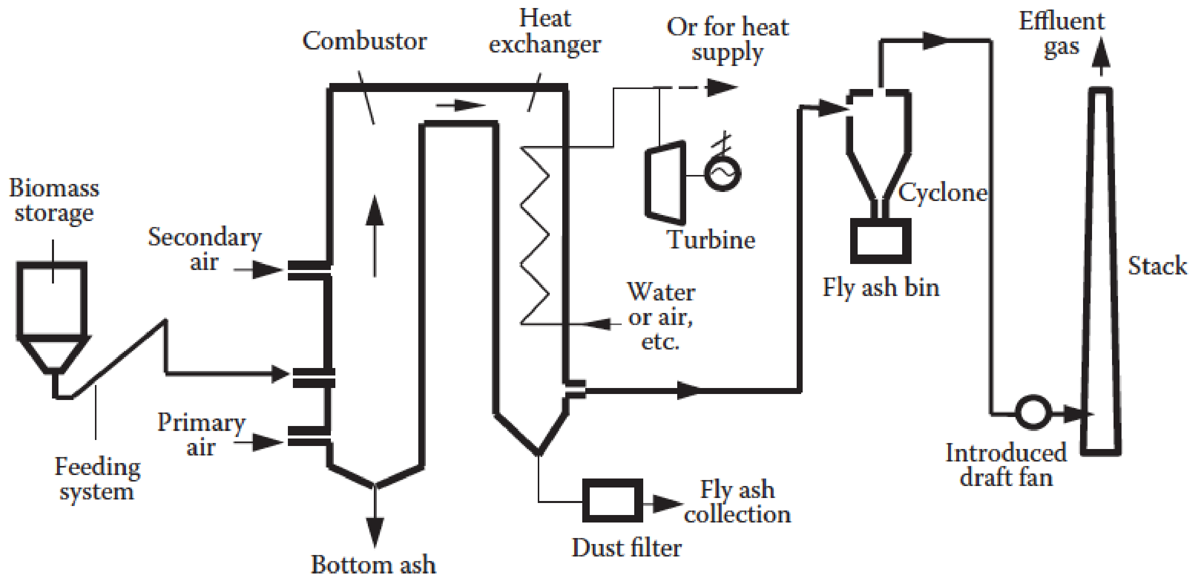
[62] Strezov/ Kan (2015a), p. 55-57
[63] Strezov/ Kan (2015a), p. 60
[64] Strezov/ Kan (2015a), p. 61

supply or the process continues and it is put into a heat exchanger (boiler) and produces steam. The steam can then be used to supply space heating or used in industrial applications, like in the food, paper, or chemical industries. It can also be used to generate electricity. For this type of energy, the steam's journey continues to a steam turbine, which is connected to a generator and produces electricity.[65] Figure 3 illustrates how a basic set-up of a biomass combustion system can look and operate.

Co-firing with coal is another and more commercialized option for biomass combustion. It was introduced in the 1980s in Europe and the United States. Co-firing can be used to generate power or for CHP production. The leading countries in the application of this technology are Finland, the US, and Germany. Benefits of co-firing include the possibility to use preexisting coal-fired plants since few changes are needed to modify it into a co-firing plant with biomass. The combination of biomass and coal releases lower SO_2 emissions since biomass has lower sulfur content than coal. It is also argued that it contributes to lower emissions in general due to the fact that biomass is considered to be CO_2-neutral. The conversion rate efficiency is higher than only biomass combustion. Another benefit is that various combustor types can be used. The three basic types of co-firing technologies are direct co-firing; here biomass is pre-mixed with coal before it is put into the combustor and then there is parallel co-firing. In this method, biomass and coal are combusted separately and the steam generated from the process is merged afterwards. The last one is indirect co-firing, whereby biomass is gasified separately and the gas is then combusted in a downstream coal boiler.[66]

[65] Strezov/ Kan (2015a), p. 60
[66] Strezov/ Kan (2015a), p. 67

Figure 3: Basic components of an integrated boiler system for biomass combustion



Source: Strezov/Kan (2015a) in *Biomass Processing Technologies*, p. 62

In general, direct biomass combustion, which generates electricity with steam turbines, achieves a conversion efficiency rate of between 15 and 35%. Power generation in co-firing systems, however, achieves a slightly higher rate of 32 to 36%.[67]

Pollutant emissions from installations like the above are a point of serious concern for research. Pollutants from biomass combustion can be either (a) from incomplete combustion (CO, NH_3, N_2O, and PM, PAHs), (b) complete combustion (CO_2, NO_x, SO_2, etc.) or c) other pollutants (hazardous heavy metals like Cadmium or Mercury). The effects of these pollutant emissions range from contributing to the greenhouse effect and acid precipitation (e.g. 'acid rain') to tropospheric ozone precursors through atmospheric reactions. It can affect human health, potentially leading to serious medical conditions that include respiratory and cardiovascular problems; it can affect and irritate the skin, and some pollutants which can be formed during combustion (dioxins) can act as carcinogens. However, the factors influencing the formation and emission of these pollutants are the type of fuel and their respective properties, as well as the specific characteristics the combustion process. The emission of pollutants can be reduced with adequate pre-processing of the biomass fuel source such as leaching out the hazardous

[67] Strezov/ Kan (2015a), p. 69

elements, such as alkaline metal or chlorine, from the fuel or through proper torrefaction to adjust the moisture content in the biomass and efficient biomass combustion.[68]

Gasification

Gasification is the process where biomass is turned into combustible gas, which is used for either heat generation or electricity production. Biomass fuel reacts with oxygen or carbon dioxides at around 800°C and turns into combustible gas. This is also called 'producer gas' and usually consists of the following elements: hydrogen (H_2), carbon monoxide (CO), methane (CH_4), carbon dioxide (CO_2), water vapor (H_2O), and nitrogen (N_2). Impurities such as tar vapors can also be found in the gas. After filtration of the impurities the result is syngas, which consists mainly of carbon monoxide and hydrogen. There are different uses for the two types of gas. Producer gas can be used in internal combustion engines or gas turbines for heat in boilers, or to produce electricity and heat. Syngas can be turned into either hydrogen, transportation fuels (gasoline, diesel), methanol, or fertilizers. [69]

The first producer gas from coal (coal gas or 'town gas') was used for heating in the nineteenth century. Biomass gasification started in the mid-1990s. The leading countries are the United States, Canada, Germany, Austria, Sweden, and Finland. The gasification process happens in a gasifier in four consecutive zones. In the *Drying Zone,* biomass fuel material is dried and its moisture content is reduced at a temperature of around 100°C to 200°C. The duration of this process depends on the moisture content and the gasifier type. Lower moisture content yields more efficient results. In the *Pyrolysis Zone* the pyrolysis of the dried biomass happens at around 200°C to 700°C, it decomposes into molecules and gases, solid char, tar and bio-oil. The *Partial Combustion Zone* is the place where exothermic reactions of char and gaseous molecules, tar and oil vapors happen with oxygen. Oxidation takes place and forms carbon monoxide and carbon dioxide. This zone also provides heat for the other zones. The *Reduction Zone* or *Gasification Zone* is where carbon dioxide and water vapor are finally turned into carbon monoxide and hydrogen to form producer gas. Some solid residue like unreacted char and ash might remain which should be removed from the gasifier. [70]

---

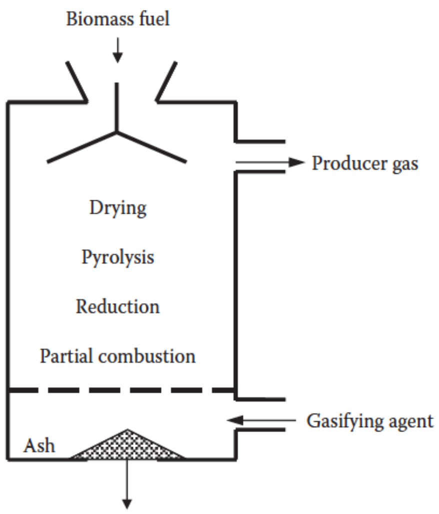
[68] Strezov/ Kan (2015a), p. 70

[69] Strezov/ Kan (2015b), p. 82

[70] Strezov/ Kan (2015b), p. 85

The different types of gasifiers in existence depend on the type of gasifying agent that is used. They can be separated between: air-blown, oxygen-blown, steam-blown, air/steam blown gasifying agent. Then there is differentiation by temperature, pressure (atmospheric/pressurized), by transport process (updraft, downdraft, fluidized bed, entrained flow) and the method of heat supply. Three main types of gasifiers are *fixed bed/ moving bed* gasifiers, *fluidized bed* gasifiers and *entrained flow* gasifiers.[71] The *fixed bed/moving* gasifier type is the oldest and simplest construction, the average work temperature is around 1000°C. They are further differentiated by transport process or direction of flow into updraft, downdraft, side draft and open core. The *fluidized bed* gasifiers resemble coal gasifiers in function. The material is fluidized. The categories of those types of gasifiers are: bubbling fluid bed gasifiers (BFB), circulating fluid bed gasifiers (CFB), and dual fluid bed gasifiers.[72] *Entrained flow* gasifiers are widely used for integrated gasification combined-cycle coal power plants, operating with high pressure and high temperatures of around 1200°C to 1600°C. The usage of biomass for this type of gasifier, however, is not recommended.[73] Figures 4 to 7 show sketches of some of the main gasification methods.

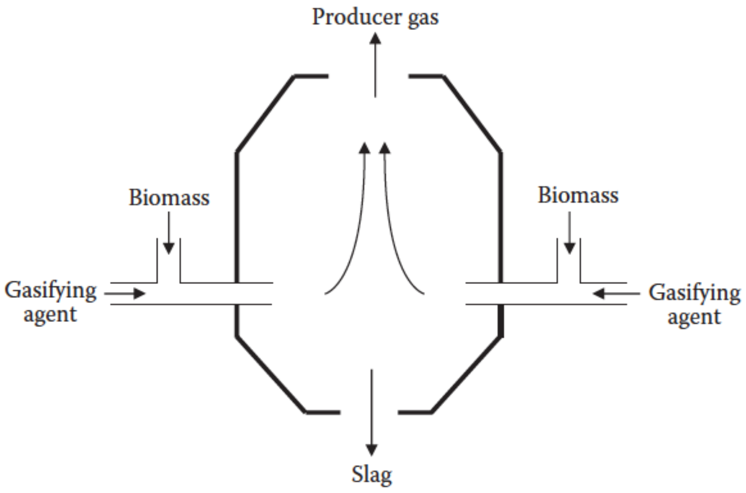
Figure 4: Schematics of Updraft Gasifier



Source: Strezov/ Kan (2015b) in *Biomass Processing Technologies*, p. 90

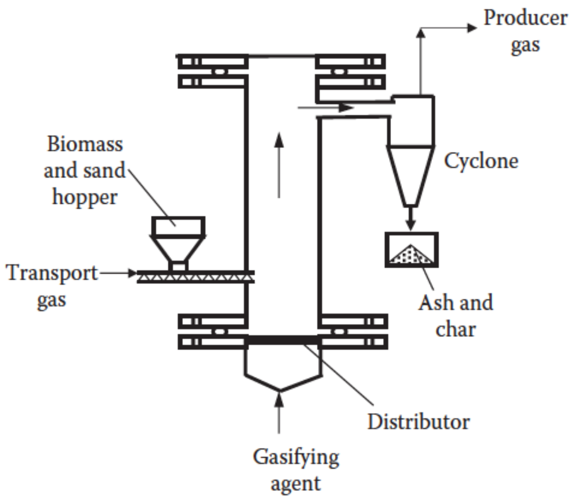
[71] Strezov/ Kan (2015b), p. 89
[72] Strezov/ Kan (2015b), p. 94
[73] Strezov/ Kan (2015b), p. 97

Figure 5: Schematics of Entrained Flow Gasifier



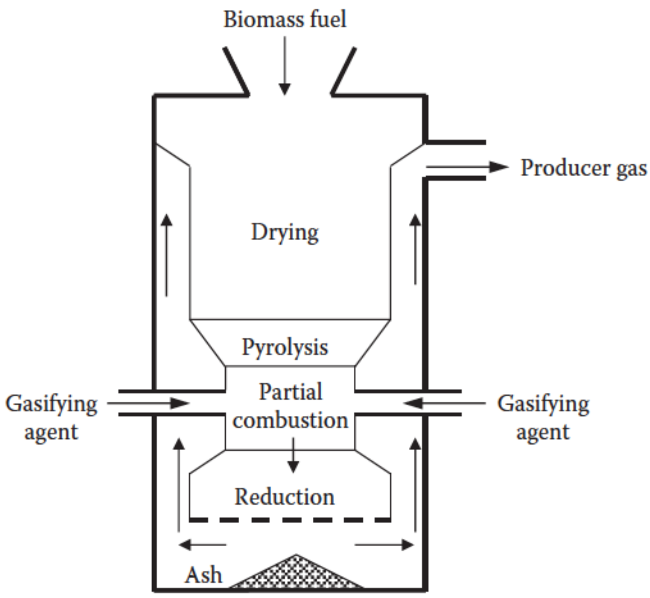
Source: Strezov/ Kan (2015b) in *Biomass Processing Technologies*, p. 97

Figure 6: Schematics of BFB Gasifier



Source: Strezov/ Kan (2015b) in *Biomass Processing Technologies*, p. 94

Figure 7: Schematics of Downdraft Gasifier



Source: Strezov/ Kan (2015b) in *Biomass Processing Technologies,* p. 91

This brief description serves to form a basic understanding of the different types of biomass conversion technologies. The methods described above are the main technologies used for turning biomass into other forms of energy. Additional technologies include *hydrothermal* gasification and *plasma* gasification, which will be mentioned but not explained in more detail here. The functionality of biomass gasification systems can be evaluated by criteria like gas properties, gas product yield, carbon conversion ability and cold-gas, thermal and exergy efficiency.[74] In summation, small-scale applications like fixed bed gasifiers with their relatively simple structure and acceptable efficiency at low cost seem to be preferred. However, when choosing a gasifying method, it is essential to choose the concrete gasification technology in conformity with the best suitable biomass for the respective technology. It is also advantageous to take into account the proximity to biomass production sites due to biomass' low energy density.[75] A closer look at the various advantages and drawbacks of biomass as a renewable energy source will follow in the next section.

[74] Strezov/Kan (2015b), p. 86
[75] Strezov/Kan (2015b), p. 99

2.3 Advantages and Drawbacks of Biomass

Energy from biomass can be attained via different methods, some of which have been described above. The question that we will try to answer in this section is: what are respective advantageous and disadvantages of using biomass to produce energy? There are different issues that need to be addressed here. We will begin with the biomass source material and the corresponding questions arising from using them. Considering especially the conversion of biomass to electricity through gasification and pyrolysis, the biomass that is used for this type of technology is residue, such as bagasse (the remains of used sugar cane stalks) or forest and agriculture residue such as wood waste and dedicated energy crops. Residue bagasse is an interesting biomass fuel because the bagasse can be used on-site during the production of to generate electricity and heat for the production process. In this way, transportation of the bagasse is kept to a minimum which entails lower costs for transport. The only limit here is the harvesting or production cycle of sugarcane, which depends on seasons. This is one example in which biomass can be used in a sustainable way, in a closed cycle where waste gets re-used for different processes.[76] Opposed to this, forest residue and other waste material that can be used for energy conversion have a low energy density and high transportation costs. The wastes are limited in quantity since they depend on the processes that generate these wastes and are bound to their location. Dedicated energy crops are somewhat of a larger issue. Strezov et al. (2015) argue that they are 'essential' for producing energy from biomass. Especially highlighted are short-rotation crops such as poplar, willow, and eucalyptus trees, and grasses that ideally have a rotation period of 3 to 10 years. According to the authors, Willow is the most sustainable crop. Problems arising from dedicated energy crops are, of course, soil depletion and loss of biodiversity due to the monocultural dominance of one crop. To mitigate these effects, natural vegetation should be maintained throughout the monoculture areas. Ideally, energy crops should require low maintenance, requiring almost no pesticides or fertilizers. Another problem is the unpredictable shifts of time and size of harvest due to the weather and the climate in general. One concern is that dedicated energy crops would not be as economically viable unless external costs like CO_2 tax and stationary energy prices have been increased. Other types of crops with multiple application possibilities for the future are crops grown on land which is not

[76] Strezov et al. (2015), p. 35

being used for agriculture at the moment, or at all due to soil conditions that cannot support edible crops.[77]

The authors Strezov et al. (2015) attempt to assess the sustainability of plant-based biomass regarding their conversion into electricity over the entire life cycle. They chose as indicators the price for production of electricity, efficiency of energy conversion, carbon dioxide emissions, availability, limitations, water use and social issues. In the aspect of electricity production prices, the authors found a large variation in price due to the variability in feedstock and processing technologies. Biomass has a low energy density and as such its transportation costs are fairly high. Additionally, fluctuations in harvest and demand also affect the price. Therefore, biomass feedstock that has higher energy density is preferred because it is more profitable. At an average price of 6.9 c/kWh for biomass it is only slightly more expensive than fossil fuels, which lie at around 4.2-4.8 c/kWh. If external costs are counted, including human health costs and environmental costs, then biomass can be cheaper than coal. Other renewables like photovoltaic are expensive with 24 c/kWh. Wind energy and hydropower lie at 6.6 c/kWh and 5.1 c/kWh respectively.

Investment costs for biomass plants can be quite capital intensive, especially at the beginning of the process. Direct combustion is the lowest price option here with $1.90-2.90/kW, as opposed to pyrolysis with $3.50-4.50/kW. The combustion-based technologies are more profitable over their life cycle in total.[78] It was found that the fuel costs for biomass electricity accounts for around 50% of the total costs. Here the costs are divided almost equally between cultivation or harvest and transportation, so it is important to focus on the conversion efficiencies of biomass. They are however very different across the different types of technologies. Combined cycle gasification seems to be quite efficient with as high as 43% energy conversion efficiency, as opposed to an average of around 27%.[79] The focus is on optimizing conversion processes but it should also definitely shift towards the acquisition and cultivation of biomass and finding effective ways of transport, for example through pre-processing. Regarding the topic of Greenhouse Gas Emissions, Strezov et al. (2015) report that biomass can claim to be a carbon-neutral energy source due to the carbon capture of the crop plants. They also point out however, that the whole process needs to be analyzed and certain

[77] Strezov et al. (2015), p. 36
[78] Strezov et al. (2015), p. 39
[79] Strezov et al. (2015), p. 40

carbon emissions from cultivation, fertilization, harvesting, and transportation are likely not to be counted when claims of carbon neutrality are made.[80]

Biomass does have mostly low net carbon emissions (carbon dioxide), and still it emits a great deal less than natural gas or coal; however, it needs to be produced sustainably for it to actually emit less CO_2. In order to achieve this, energy crops need to be grown with as little fertilizer and maintenance as possible. Furthermore, they need to possess a high energy density for the least amount of emission, and it is beneficial when the chosen plant has high crop yields. Larger carbon savings are achieved through the carbon storage in the soil and the crops. A study revealed that an example for greenhouse-gas friendly crop is hemp. The technology process during which the lowest amount of emissions is emitted is gasification. When it comes to the water usage, overall biomass does have a relatively high demand for water throughout the entire process chain.[81] When it comes to producing biomass sustainably, the rate of regeneration and consumption is important. Biomass energy does face resource constraints; the demand for biomass waste exceeds the supply, there is limited plant operation time since some biomass types are seasonal, and there is competition between food crops and energy crops for space. The limitations of resources and land are evident, and this is an area for improvement. Social effects from biomass use for energy are mainly focused on its competition with food crops. Energy and food prices are increasingly interconnected, which poses a threat for the part of world's population living in poverty and a threat for food security.[82] The competition with food crops for land to grow on is an important issue, with the consequence that energy crops should be cultivated on land that cannot be used for food crops due to soil conditions. Taking wood residue out of forests is another, better way of harvesting biomass source material. Implications can be that the forest grounds then lack the nutrients, which would be produced with this wood waste. Partially counteracting this and replenishing organic matter, minerals, and nitrogen, at least to some extent, can be done by spreading wood ash. Another concern however for energy crops is the loss of habitat and biodiversity through the act of taking away native wood waste from forested areas. This is a major reason behind the public perception that biomass is not environmentally friendly.[83]

[80] Strezov et al. (2015), p. 40
[81] Strezov et al. (2015), p. 41-43
[82] Renger (2010), p. 30
[83] Strezov et al. (2015), p. 46

Renger (2010) argues that in spite of the challenges biomass energy can present, it is worth expanding if the above-mentioned risks are contained and given serious attention. Different sources of biomass offer a variety of possible fuel sources, which spreads the risk of overuse of one source out over several biomass sources. The variety in technology offers options for each individual biomass fuel source and various forms of energy such as heat and electricity. Another plus is that biomass can be used for energy or for its original substance; some biomass sources, for example, can have pharmaceutical properties. In most cases though, it can only be used for either one original form, or converted into energy, but not both. The exception here might be usage through burning a wooden object. It is also beneficial to store biomass energy. Base load capacity is possible since biomass meets the requirements, it can be stored and is independent from factors of time or weather. The CO_2 balance is also important to keep in mind; as opposed to fossil fuels, which emit CO_2 that has been stored over millions of years as coal or oil or gas, CO_2 emitted from biomass was formed using the energy of the sun and water in the atmosphere. This means we have a cycle of CO_2 in which the emitted portion is always used up again through photosynthesis. So we have a form of energy, which is more-or-less CO_2 neutral. Already today many technologies to use energy from biomass are available.[84] The Renewable Energy Progress Report (EU) shows a slow progress in biofuel use and RE share in transport in 2013, around 5.4%. There is political uncertainty and awareness that some biofuel production techniques might lead to higher emissions through indirect land use changes, which are accounted for. Commercially available second-generation biofuels are still not as prevalent and more research should go into this direction. When it comes to energy security, biofuel is a good option, the Report showed that 75% of biofuel consumed in the European Union was also produced in the EU. There were almost no imports from Africa due to valid concerns about food security. A small amount of imports came mostly from the US and Brazil. Domestic feedstock makes up 60% of biodiesel (rapeseed oil) and 79% of bioethanol (wheat, maize, sugar beet). One positive factor was the introduction of the sustainability criteria for biofuels via the EU Directive, enforced also for third country feedstock producers via bilateral agreements with importing country, member state national systems or voluntary schemes.[85]

In summary, the disadvantages for biomass energy are that initial capital expenditure for building installations can be high and require the use of advanced technology. Another

[84] Renger (2010), p. 30
[85] European Commission, Renewable Energy Progress Report (2015), p. 15

disadvantage is the required space. Biomass can be generated from waste products, but energy crops, on the other hand, do need space to grow. These dedicated energy crops can be detrimental to the soil if no adequate protection measures are taken. In addition, they are in competition with food crops, although the shift of biomass being cultivated on land not suited for food crops can be noted as a positive development. The low energy density of biomass requires a lot more mass to produce a certain amount of energy and the transport costs take a large portion of the price. All this reinforces the public perception that biomass is not a sustainable energy source. The advantages and potential biomass energy can bring to the table are however undeniable and need to be taken seriously in the face of climate change and the depletion of fossil fuels. Biomass is a renewable energy source that can literally be *regrown*. It is better for the environment than fossil fuel options since it emits lower emissions and pollutants. The dependence on fossil fuels can be counteracted with increased use of biomass. Landfills and their waste can be re-used for something useful, and the energy chain can become an energy circle. Thus far, biomass energy production is not entirely carbon neutral, but it is a major improvement on the use of coal or oil. The resources are quite abundant in the sense that there are a wide variety of fuel sources that can be used. It is possible to contribute to base load capacity with biomass since its energy can be stored independent of weather and climate. And lastly, the different conversion methods provide many opportunities and have suitable pairings for biomass sources and conversion methods.

Now that we made the case for biomass as a renewable energy source that shows potential to for increased future use, we will look at the actual analysis and see whether the Feed-in tariff policy actually increases the capacity of biomass.

3. Methodology

3.1 Data

The primary dataset, which was chosen for this analysis, consisted of 18 countries, of which 10 countries have an active FIT policy and 8 countries without an active FIT policy, they use other support instruments such as quotas. The countries with FIT policy are the following: Austria, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Portugal, and Spain. Luxembourg was later excluded due to lack of sufficient data and the relatively small size of the country. Countries without FIT policy, which are used as a control group in this analysis, are Belgium, Denmark, Finland, the Netherlands, Poland, the United Kingdom, Norway, and Sweden. The collection of data is taken from a number of different sources: the BP Statistical Review of World Energy 2015, the OECD Statistics National Accounts with the Base Year 2010, Eurostat (2015/2016), the World Bank World Development Indicator Data base 2015, the CIA World Factbook, the OECD Energy Balances, and the OECD Energy Prices and Taxes. The initial tame frame of the years 2000-2015 were reduced to 2000-2013 due to lack of sufficient data for certain variables. Following the work of A.C. Marques et al. (2010) this work looks at similar, or in some cases identical variables, to investigate the question of whether FIT policy really does have a significant effect on biomass capacity growth. The dependent variable for the analysis is Contribution of Renewable Energy to Energy Supply (CRES), specifically biomass energy, measured in percent of total primary energy supply in kilotonne of oil equivalent and is taken from the OECD Energy Balances from the years 2003 – 2015.

The explanatory variables include the following:
The FIT Dummy Variable, coded as 0 for no FIT policy and 1 for FIT policy; Area in km^2; Primary Energy Consumption; Energy Import Dependency; Energy Use per capita; CO_2 per capita; Oil Prices for Households; the GDP and the Agricultural Share of GDP of a country. Excluded were the variables total primary energy supply and Gas Prices Households due to lack of data.

FIT Dummy Variable

Coded 0 for no active FIT policy and 1 for active FIT policy, this variable controls for the effect this type of policy might have in the country. Following our hypotheses, this is the main variable in the analysis, since we expect to find that FIT policy significantly improves CRES opposed to other policies. Information on which countries use FIT and which do not was taken from the Legal Sources on Renewable Energy website provided by the European Union.

Area in km²

Following Vachon and Menz (2006) and A.C. Marques et al. (2010) we include area size in the analysis. The different geographic areas in a country are an important factor when it comes to production potential for renewable energy. The thought here is, the larger a country is, the more space and possibilities there might be for growing biomass material due to more agriculture and more space for biomass conversion facilities. The data was taken from the CIA World Factbook.

Primary Energy Consumption

Primary Energy Consumption can be used as an indicator of a country's development stage (A.C. Marques et al. 2010). Measured in millions of tons equivalent to oil (mtoe), it was chosen to assess the overall energy consumption, we expect that the more energy is consumed the more a country might rely on fossil fuels, although the energy could be made up of a mix of traditional and clean energy forms. The BP Statistical Review of World Energy 2015 provided the data.

Energy Import Dependency

Measured in percent, energy import dependency shows a country's energy situation and security through its dependence on energy imports. The outcome is expected to show that a high energy dependency on for example fossil fuels like oil and gas (and thus high energy prices set by e.g. oil producing countries) might be a motivation to produce more sustainable energy in the own country. The numbers were taken from Eurostat.

Energy Use per capita

This variable, measured in kilogram of oil equivalent per capita is used in addition to the variable Primary Energy Consumption to show energy use in relation to a country's population size. This data was taken from the World Development Index provided by the World Bank.

CO_2 per capita

Measured in tons per capita, high CO_2 per capita is possibly connected to high primary energy consumption and is one of the most recognized factors of climate change. In an attempt to find quantifiable indicators for the environmental state in a country, CO_2 is used the most frequently. Higher CO_2 and thus higher environmental pollution might prove to be a driver for development of RE and a strong push to increase the contribution of RE energy capacity to the total energy supply. Eurostat provided the numbers for this variable.

Oil Prices Households

Oil Price of Light Fuel Oil for Households, measured in in $US per toe (converted using exchange rates and adjusted to 2010 dollars using the Consumer Price Index 2010). The prices of traditional energy forms like oil and natural gas shape a country's commitment to the development of clean energy. We expect the results to prove that the higher the oil price is, the more motivation and push for RE energy would exist in a country. The data used is from the OECD Energy Prices and Taxes.

GDP

The GDP is a classic economic measure which is used to describe a country's economic performance and is frequently used in literature as an effect on renewable energy (A.C. Marques et al. 2010). Measured in million $US at constant prices and exchange rates, we include this variable with the expected result that the more GDP a country has the more financial means exist to sustain RE development and the more RE capacity is produced. Also higher regulatory costs resulting from RE policies are easier to sustain if more money is free to flow towards this direction. The OECD Statistics National Accounts with the Base Year 2010 provided the data.

Agricultural Share of GDP

This variable, measured as percentage of the total GDP, was chosen to show the possible connection between a larger amount of agriculture in a country and the biomass capacity which could be produced as a result. In the variable Area in km^2 we already mentioned the possibility of a larger country having more agriculture and this variable serves as a more exact measure in support of the former. This data was also taken from the OECD Statistics National Accounts with the Base Year 2010.

3.2 Analysis

The data in this analysis was sorted in a panel data format by year and country. This created high multicollinearity. The Durbin-Watson Test revealed high values, after sorting the data by a random variable the problem was solved and the Durbin-Watson value now at an acceptable level of 2.028. The first step was to input all explanatory variables into a linear regression model. The FIT Dummy Variable and the variable Area in km² were included in the regression as time-invariant and constant factors and were kept in every regression model. Stepwise the other variables were added. The level for the significant value was capped off at 0.05%.

In the best model, we found FIT not to be significant. However, the variables Area in km², Primary Energy Consumption, Energy Import Dependency, Energy Use per capita, CO_2 per capita, and Oil Price were all found to have a significant effect on the dependent variable CRES. The variables GDP, Agricultural Share of GDP, and the year effect also proved to be not significant. The heterogeneity of the different countries prompts the question whether the results of the first regression are enough to explain the variables' effect. From the linear regression result the second step was taken to put all the relevant variables into a Linear Mixed Effects Model to test the country-fixed effects and control for country-specific characteristics. Recoding of the variable Country, a so-called reverse coding, was needed to ensure proper choosing of the reference category. The statistical analysis software SPSS chooses the highest numerical value as a reference category, reverse coding made the country number 19 the reference category, here the country of Austria was chosen. All the different countries were set in the model as fixed effects, since different countries would have different 'starting points' and thus separate constants depending on their level of energy consumption, share of renewable energy and so on. Next also the significant variables of the previous linear regression model were included as fixed effect: Primary Energy Consumption, Energy Import Dependency, Energy Use per Capita, CO_2 per capita, and Oil Prices of Households.

4. Results and Discussion

4.1 Results

The variables FIT Dummy Variable and Area in km² were included in the linear regression model at all times. Then, a stepwise addition of the remaining explanatory variables followed. The cap off for the significance level was set at 0.05%. The FIT variable becomes insignificant after introducing the first independent variable, Primary Energy Consumption. The independent variables have different effects on the contribution of RE to energy supply. The dependent variable CRES was positively influenced by these independent variables: Area in km², big energy import dependency, high energy use per capita and high oil prices for households. Negative influences on CRES were high primary energy consumption, high CO_2 per capita, with this last one having a particularly big negative effect. We see from the results that FIT policy being present in a country actually does NOT have a significant influence on CRES, it is a negative influence of -14.1%.

In the first model with just FIT and Area in km² the R-squared value is 0.060 or 6.0% and the adjusted R-squared is 0.050 or 5.0%. After that the values are increasing. The model summary below shows an R-squared of 56.7% for the model number 6, this model takes all independent variables into account and is our most important one. The dependent variables and the independent variables are correlated in a way such that the IV (independent variables) in this data can give clues for the values of the dependent variable. Of course it does not explain the model entirely. This is an average R-squared value which we might be able to improve with looking at country effects later. The many IV in our case make the model much less stable, which is taken into account by the adjusted R-squared. Model number 6 has an adjusted R-squared value of = 0.551 or 55.1%. We can see in the table below that the standard error gets smaller the more IVs are added to the model and is the lowest in (6) with 3.9647% of difference between predicted and measured values.

Table 1: Linear Regression Model Summary

Modellzusammenfassung[g]

Modell	R	R-Quadrat	Korrigiertes R-Quadrat	Standardfehler des Schätzers	Statistikwerte ändern: Änderung in R-Quadrat	Statistikwerte ändern: Änderung in F
1	,244[a]	,060	,050	5,7689%	,060	6,487
2	,575[b]	,330	,320	4,8806%	,271	82,423
3	,641[c]	,411	,400	4,5870%	,081	27,948
4	,689[d]	,475	,462	4,3421%	,064	24,540
5	,739[e]	,547	,533	4,0444%	,072	31,829
6	,753[f]	,567	,551	3,9647%	,020	9,169

Modellzusammenfassung[g]

Modell	Statistikwerte ändern: df1	df2	Sig. Änderung in F	
1	2	205	,002	
2	1	204	,000	
3	1	203	,000	
4	1	202	,000	
5	1	201	,000	
6	1	200	,003	2,028

a. Einflußvariablen: (Konstante), Area in km², FIT Dummy

b. Einflußvariablen: (Konstante), Area in km², FIT Dummy, Primary Energy Consumption

c. Einflußvariablen: (Konstante), Area in km², FIT Dummy, Primary Energy Consumption, Energy Import Dependency %

d. Einflußvariablen: (Konstante), Area in km², FIT Dummy, Primary Energy Consumption, Energy Import Dependency %, Energy Use per capita

e. Einflußvariablen: (Konstante), Area in km², FIT Dummy, Primary Energy Consumption, Energy Import Dependency %, Energy Use per capita, CO2 per capita

f. Einflußvariablen: (Konstante), Area in km², FIT Dummy, Primary Energy Consumption, Energy Import Dependency %, Energy Use per capita, CO2 per capita, Oil Prices Households

g. Abhängige Variable: CRESpercentage Contribution of RE to Energy Supply %

Linear Regression Model

In the Table below we show the results of the linear regression with all the explanatory variables, the most relevant model, model number 6 which encompasses all IVs, is in the last section of the table.

Table 2: Linear Regression: Coefficients

Koeffizienten[a]

Modell		Nicht standardisierte Koeffizienten		Standardisierte Koeffizienten	T	Sig.	Kollinearitätsstatistik	
		Regressionskoeffizient B	Standardfehler	Beta			Toleranz	VIF
1	(Konstante)	6,689	,775		8,632	,000		
	FIT Dummy	-2,527	,805	-,214	-3,138	,002	,987	1,013
	Area in km²	5,023E-6	,000	,144	2,115	,036	,987	1,013
2	(Konstante)	7,409	,660		11,220	,000		
	FIT Dummy	-1,050	,700	-,089	-1,499	,135	,934	1,071
	Areainkm²	1,634E-5	,000	,469	6,910	,000	,713	1,403
	Primary Energy Consumption	-,041	,004	-,633	-9,079	,000	,675	1,482
3	(Konstante)	7,686	,623		12,340	,000		
	FITDummy	-2,327	,701	-,197	-3,319	,001	,823	1,215
	Area in km²	1,928E-5	,000	,553	8,415	,000	,671	1,491
	Primary Energy Consumption	-,045	,004	-,699	-10,478	,000	,651	1,536
	Energy Import Dependency %	,011	,002	,316	5,287	,000	,812	1,232
4	(Konstante)	1,210	1,434		,844	,400		
	FIT Dummy	-,452	,764	-,038	-,591	,555	,621	1,611
	Area in km²	1,661E-5	,000	,477	7,432	,000	,632	1,583
	Primary Energy Consumption	-,043	,004	-,663	-10,419	,000	,642	1,557
	Energy Import Dependency %	,012	,002	,367	6,375	,000	,786	1,272
	Energy Use per capita	,001	,000	,321	4,954	,000	,617	1,620

Koeffizienten[a]

Modell		Nicht standardisierte Koeffizienten: Regressionskoeffizient B	Nicht standardisierte Koeffizienten: Standardfehler	Standardisierte Koeffizienten: Beta	T	Sig.	Kollinearitätsstatistik: Toleranz	Kollinearitätsstatistik: VIF
5	(Konstante)	8,665	1,879		4,612	,000		
	FIT Dummy	-,264	,713	-,022	-,371	,711	,619	1,614
	Area in km²	7,497E-6	,000	,215	2,846	,005	,394	2,536
	Primary Energy Consumption	-,035	,004	-,539	-8,536	,000	,565	1,769
	Energy Import Dependency %	,012	,002	,368	6,863	,000	,786	1,272
	Energy Use per capita	,002	,000	,538	7,512	,000	,440	2,270
	CO2 per capita	-1,140	,202	-,375	-5,642	,000	,509	1,963
6	(Konstante)	3,496	2,511		1,392	,165		
	FIT Dummy	-,141	,700	-,012	-,201	,841	,617	1,620
	Area in km²	9,238E-6	,000	,265	3,492	,001	,376	2,661
	Primary Energy Consumption	-,034	,004	-,531	-8,571	,000	,564	1,773
	Energy Import Dependency %	,013	,002	,387	7,322	,000	,774	1,292
	Energy Use per capita	,002	,000	,516	7,327	,000	,436	2,293
	CO2 per capita	-,851	,220	-,280	-3,867	,000	,413	2,421
	Oil Prices Households	,002	,001	,163	3,028	,003	,748	1,337

a. Abhängige Variable: CRESpercentage Contribution of RE to Energy Supply %

Every one-unit increase in the independent variable leads to an X amount of unit increase or decrease in the dependent variable, holding all other independent variables constant.

These are the results of the linear regression for model 6 in short:

- If FIT policy is present, CRES decreases by -0.141 or -14.1 %, it has no significant effect.
- The remaining variables are all significant:
- Per additional km² a country has, CRES increases by + 9.238E-6 or 0.000928%.
- Per additional million tons of oil equivalent in Primary Energy Consumption, CRES decreases by -0.034 or -3.4%

- Per additional percent of Energy Import Dependency, CRES increases by +0.013 or +1.3%
- Per additional ton of CO_2 per capita, CRES decreases by -0.851 or -85.1%
- Per additional dollar ($) of Oil Price Households, CES increases by +0.02 or 2.0%
- Per additional kgoe/cap of Energy Use per capita, CRES increases by +0.02 or 2.0%

When we look at Table 2, we see that in two of the earlier models the FIT Dummy Variable is significant. Only after the introduction of Primary Energy Consumption in model 2 and Energy Use per capita in model 4 FIT becomes insignificant at 0.135 and 0.555 respectively. Interestingly, in model 2 with the variables FIT, Area in km² and Primary Energy Consumption FIT is insignificant, yet it becomes significant after the introduction of Energy Import Dependency in model 3. The values of FIT in the significant models 1 and 3 are that, if FIT policy is present, CRES decreases by -2.527 or -252.7 % in model 1 and -2.327 or -232.7% in model 3. In every model however, the value for the FIT Dummy variable seems to always be negative. The remaining variables are around the same value in every model.

The coefficients table also gives information regarding collinearity between the independent variables with tolerance and the variance inflation factor VIF. Tolerance levels for example range between 0.376 for Area in km² and 0.774 for Energy Import Dependency in model 6. Usually tolerance levels should ideally not be under 0.25 so there is no multicollinearity, this is fulfilled here and also in the earlier models. Tolerance levels can also show us how much one IV can be explained by the remaining variables. Our FIT dummy variable for example is at 0.617 which means that 1-0.617=0.383 or 38.3% can be explained by the remaining variables. Interestingly, the tolerance levels for FIT are much higher in the earlier models, which means that the more variables are added the more the FIT variable can be explained by the other variables. The highest value in the last model is Area in km² with 1-0.376=0.624 or 62.4% that can be explained via the other IVs. Close up are Energy Use per capita and CO_2 per capita which can be explained through the other variables with 56.4% (1-0.436=0.564) and 58.7% (1-0.413=0.587) respectively. Variance inflation factors above 5.0 can already be regarded as a sign for multicollinearity. The lowest VIF in model 6 taking all IVs into account is at 1.292 and the highest is at 2.661. In the previous models the values are similarly low, we can conclude that this does not show strong signs of multicollinearity.

Table 3: Linear Regression: Residual Statistics

Residuenstatistik[a]

	Minimum	Maximum	Mittelwert	Standardabweichung	N
Nicht standardisierter vorhergesagter Wert	-2,551%	19,356%	6,643%	4,4562%	208
Nicht standardisierte Residuen	-6,6248%	8,0286%	0,0000%	3,8971%	208
Standardisierter vorhergesagter Wert	-2,063	2,853	,000	1,000	208
Standardisierte Residuen	-1,671	2,025	,000	,983	208

In the residuals statistics table, we can see that the median of the unstandardized predicted value lies at 6.643%, with a standard deviation of 4.4562%. The values themselves range from the minimum -2.551% to the maximum of 19.356%. Unstandardized residuals have a standard deviation of 3.8971%, the standardized residuals have one of 0.983.

The Anova table below in Table 4 shows that the significance of the models lies at a p-values of 0.000, so we can say that there must be a connection between the dependent variables and the IV.

Table 4: Linear Regression: ANOVA

ANOVA[a]

Modell		Quadratsumme	df	Mittel der Quadrate	F	Sig.
1	Regression	431,812	2	215,906	6,487	,002[b]
	Nicht standardisierte Residuen	6822,535	205	33,281		
	Gesamt	7254,346	207			
2	Regression	2395,103	3	798,368	33,517	,000[c]
	Nicht standardisierte Residuen	4859,244	204	23,820		
	Gesamt	7254,346	207			
3	Regression	2983,145	4	745,786	35,445	,000[d]
	Nicht standardisierte Residuen	4271,201	203	21,040		
	Gesamt	7254,346	207			

ANOVA[a]

Modell		Quadratsumme	df	Mittel der Quadrate	F	Sig.
4	Regression	3445,825	5	689,165	36,553	,000[e]
	Nicht standardisierte Residuen	3808,521	202	18,854		
	Gesamt	7254,346	207			
5	Regression	3966,476	6	661,079	40,414	,000[f]
	Nicht standardisierte Residuen	3287,870	201	16,358		
	Gesamt	7254,346	207			
6	Regression	4110,602	7	587,229	37,359	,000[g]
	Nicht standardisierte Residuen	3143,745	200	15,719		
	Gesamt	7254,346	207			

a. Abhängige Variable: CRESpercentage Contribution of RE to Energy Supply %

b. Einflußvariablen : (Konstante), ² Area in km², FIT Dummy

c. Einflußvariablen : (Konstante), Area in km², FIT Dummy, Primary Energy Consumption

d. Einflußvariablen : (Konstante), Area in km², FIT Dummy, Primary Energy Consumption, Energy Import Dependency %

e. Einflußvariablen : (Konstante), Area in km², FIT Dummy, Primary Energy Consumption, Energy Import Dependency %, Energy Use per capita

f. Einflußvariablen : (Konstante), Area in km², FIT Dummy, Primary Energy Consumption, Energy Import Dependency %, Energy Use per capita, CO2 per capita

g. Einflußvariablen : (Konstante), ² Area in km², FIT Dummy, Primary Energy Consumption, Energy Import Dependency %, Energy Use per capita, CO2 per capita, Oil Prices Households

Collinearity Diagnosis

The following diagnosis of collinearity (Table 5) aids in determining whether multicollinearity exists between different variables. In the condition number test here it is revealed that the last three independent variables; Energy Use per capita, CO_2 per capita and Oil Prices for Households especially; show condition indices of above 10. This happens in the subsequent models 4, 5 and 6. In our model 6, Oil Prices has a condition index of 26.981, showing a medium level of multicollinearity. Between levels of 10 and 30 medium multicollinearity exists which is the case here. When we look at the different parts of variance, Energy Use per capita and Oil Prices Households explain most of the variance in the model with 0.46 and 0.42 respectively and thus likely to be the cause of multicollinearity.

Table 5: Linear Regression: Collinearity Diagnosis

Kollinearitätsdiagnose[a]

Modell	Dimension	Eigenwert	Konditionsindex	Varianzanteile		
				(Konstante)	FIT Dummy	Area in km²
1	1	2,438	1,000	,04	,06	,04
	2	,393	2,491	,03	,83	,24
	3	,169	3,795	,93	,11	,72
2	1	3,187	1,000	,02	,03	,02
	2	,420	2,754	,00	,80	,10
	3	,246	3,596	,49	,05	,02
	4	,147	4,662	,48	,11	,86
3	1	3,208	1,000	,02	,03	,02
	2	1,067	1,734	,00	,02	,01
	3	,360	2,987	,01	,66	,05
	4	,222	3,798	,58	,25	,02
	5	,143	4,733	,38	,04	,90
4	1	3,966	1,000	,00	,01	,01
	2	1,130	1,874	,00	,03	,00
	3	,371	3,270	,01	,31	,00
	4	,358	3,328	,01	,29	,07
	5	,150	5,143	,01	,00	,89
	6	,025	12,539	,97	,35	,02
5	1	4,832	1,000	,00	,01	,00
	2	1,140	2,059	,00	,03	,00
	3	,458	3,248	,00	,05	,05
	4	,362	3,654	,00	,56	,02
	5	,169	5,354	,00	,00	,41
	6	,027	13,371	,25	,33	,10
	7	,013	19,620	,75	,01	,41
6	1	5,645	1,000	,00	,01	,00
	2	1,150	2,215	,00	,03	,00
	3	,501	3,355	,00	,03	,05
	4	,366	3,926	,00	,57	,01
	5	,175	5,677	,00	,00	,34
	6	,129	6,627	,00	,05	,07
	7	,025	14,951	,09	,27	,18
	8	,008	26,981	,91	,03	,34

Kollinearitätsdiagnose[a]

Modell	Dimension	Varianzanteile				
		Primary Energy Consumption	Energy Import Dependency %	Energy Use per capita	CO2 per capita	Oil Prices Households
1	1					
	2					
	3					
2	1	,02				
	2	,07				
	3	,59				
	4	,31				
3	1	,02	,00			
	2	,00	,67			
	3	,20	,16			
	4	,40	,14			
	5	,38	,03			
4	1	,01	,00	,00		
	2	,00	,57	,00		
	3	,07	,31	,04		
	4	,33	,04	,01		
	5	,56	,06	,01		
	6	,03	,02	,94		
5	1	,01	,00	,00	,00	
	2	,00	,56	,00	,00	
	3	,17	,12	,01	,01	
	4	,11	,22	,00	,00	
	5	,54	,09	,00	,01	
	6	,06	,02	,87	,06	
	7	,11	,00	,11	,92	
6	1	,01	,00	,00	,00	,00
	2	,00	,53	,00	,00	,00
	3	,19	,11	,01	,00	,02
	4	,07	,24	,00	,00	,00

Kollinearitätsdiagnose[a]

Modell	Dimension	Varianzanteile				
		Primary Energy Consumption	Energy Import Dependency %	Energy Use per capita	CO2 per capita	Oil Prices Households
	5	,36	,08	,00	,02	,06
	6	,22	,00	,04	,01	,46
	7	,12	,02	,89	,13	,04
	8	,04	,01	,05	,84	,42

a. Abhängige Variable: CRESpercentage Contribution of RE to Energy Supply %

Next we also carried out a bivariate correlation, following Pearson, to measure if there are high correlations between certain variables. The full result for the correlations can be seen in Table A1 in the Appendix. Our assumption that especially the variables for energy measurements are correlated has been confirmed in some cases.

Medium high bivariate correlations can be observed between the following variables:

- Primary Energy Consumption and CRES: -0.370**
- Energy Use per capita and FIT Dummy: -0.581**
- Energy Use per capita and CRES: +0.350**
- Energy Import Dependency and FIT Dummy: +0.369**
- Oil Prices and CRES: +0.304**
- Area km² and Primary Energy Consumption: +0.555**
- Energy Use per capita and Energy Import Dependency: -0.395**

Since CO_2 per capita had such a major negative effect on our dependent variable it is interesting to see the bivariate correlations of CO_2 with other measures of energy.

- Energy Use per capita and CO_2 per capita: +0.466**
- Oil Prices Households and CO_2 per capita: -0.367**
- CRES and CO_2 per capita: -0.159*
- FIT Dummy and CO_2 per capita: -0.333*

From these correlation values we might be able to explain the sharp drop in CRES percentage following an increase in CO2. The correlation shows that higher oil prices mean less CO_2 per capita which makes sense. Higher Energy Use per capita leads to higher CO_2 emission per capita, the two variables have a positive correlation. This possibly explains why CRES would decrease by ~85% if CO_2 increases.

Indicators for Data Fit

This histogram and the next graph, showing the normal distribution for the standardized residual depicting the normality of the model in visual form, they both show a slight deviation from perfect normality, however it is still within acceptable parameters.

Figure 8: Linear Regression: Histogram

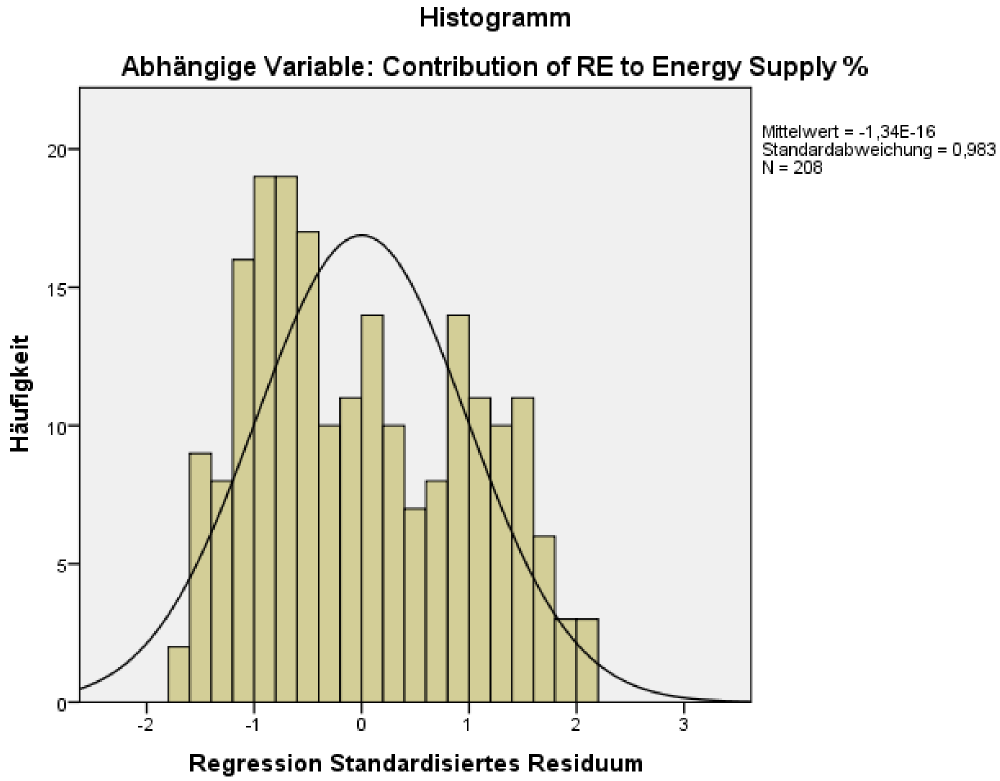
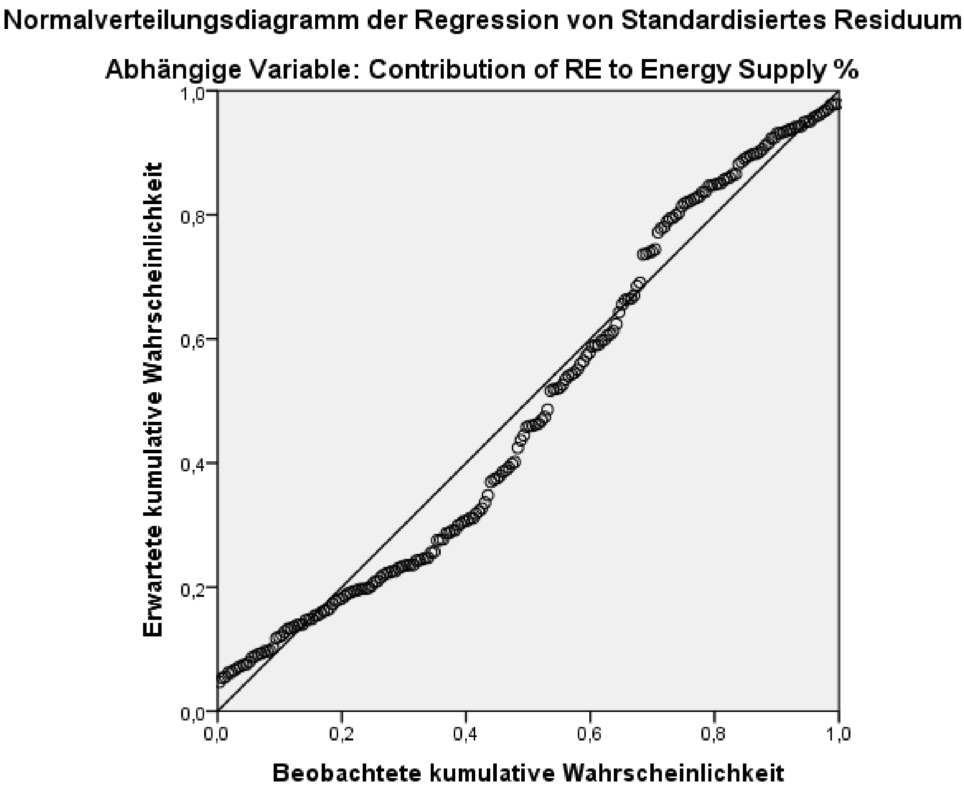
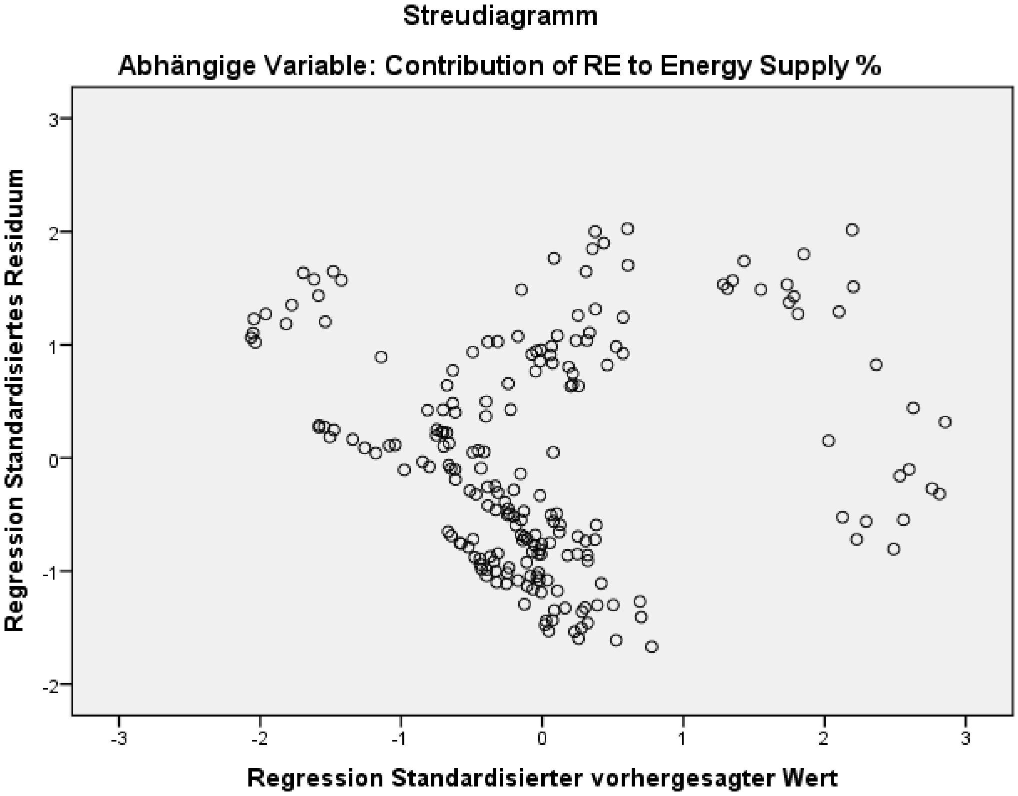


Figure 9: Linear Regression: Diagram of Normal Distribution of Standardized Residual



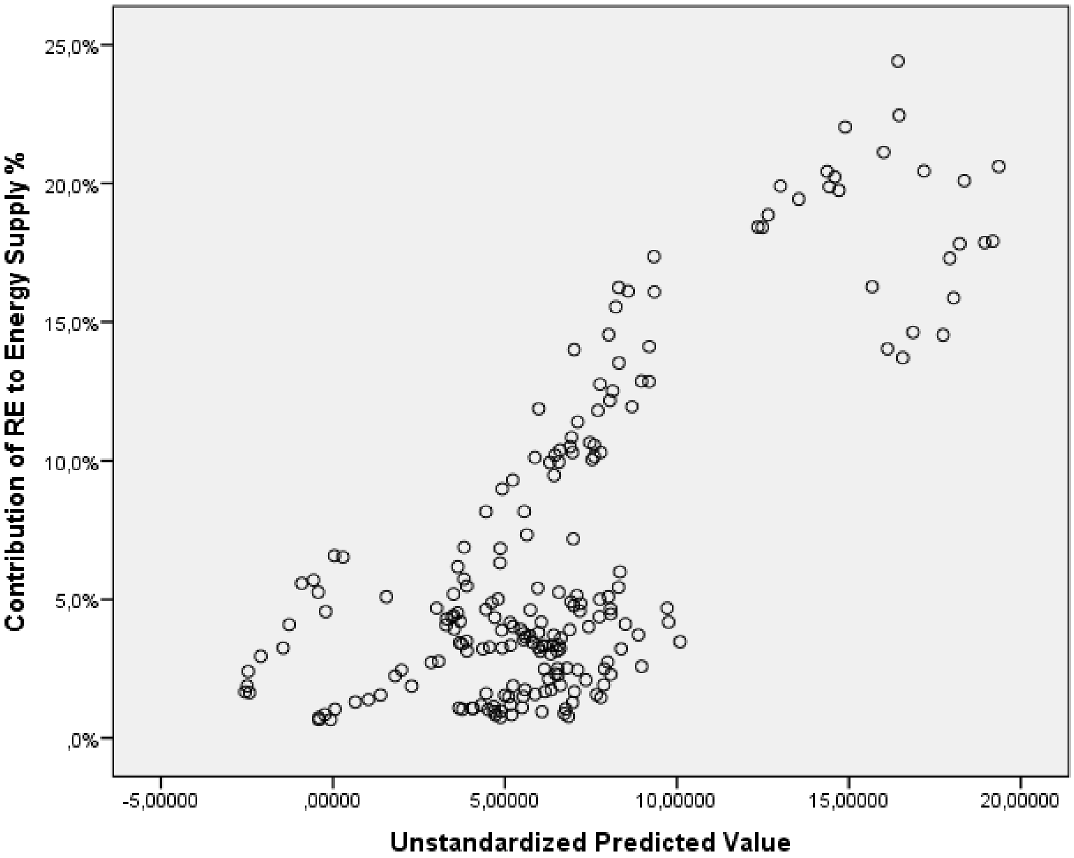
We can see that the normal distribution is meandering around the regression line, so it does not match it perfectly, yet it is certainly close enough to still represent a good result.

Figure 10: Linear Regression: Scatter Plot of standardized residual



This Scatter Plot of the Residuals above from our model number 6 shows the standardized residuals with the standardized predicted value. We can not see a discernable pattern, so there is no correlation, which is the ideal situation. The Scatter Plot of earlier models did not show any patterns either, confirming the validity of the Linear Regression.

Figure 11: Linear Regression: Residual Scatter Plot of Predicted CRES values



This next graph above (Figure 11) shows how the prediction of our model holds up versus reality; it shows how well the model predicts the CRES values. The data points are centered around the same area where the regression equation should be. This is not the best possible outcome, yet it shows potential to be optimized by taking into account the country differences.

<u>Linear Mixed Model with Country Effects</u>

Country-Fixed Regression follows, since the linear regression model does not explain all of the variability around the response data mean we follow up by first looking at the difference between the countries in general. We see that the mean for the dependent variable CRES percentage varies a lot between the different countries. This can and most likely is to be connected to the size, economic power and energy consumption patterns in these countries.

Table 6: Linear Mixed Model with Country Effects: Kruskal-Wallis-Test of CRES percentage mean

Ränge

	Country Country	N	Mittlerer Rang
CRESpercentage_mean	1 Austria	14	203,50
	2 France	14	119,50
	3 Germany	14	133,50
	4 Greece	14	77,50
	5 Hungary	14	147,50
	6 Ireland	14	35,50
	7 Italy	14	63,50
	9 Portugal	14	189,50
	10 Spain	14	91,50
	11 Belgium	14	49,50
	12 Denmark	14	175,50
	13 Finland	14	231,50
	14 Netherlands	14	7,50
	15 Poland	14	161,50
	16 United Kingdom	14	21,50
	17 Norway	14	105,50
	18 Sweden	14	217,50
	Gesamt	238	

Statistik für Test[a,b]

	CRESpercentage_mean
Chi-Quadrat	237,000
df	16
Asymptotische Signifikanz	,000

a. Kruskal-Wallis-Test

b. Gruppenvariable: Country Country

The Kruskal-Wallis-Test as an initial test for country effects shows if the countries differ in general when looking at the CRES percentage. We use the mean here to be better able to do comparisons. As is evident from the table, the countries differ quite significantly. The highest CRES percentages, when looking at the mean of the 14 years we cover, are the countries of

Finland, Sweden and Portugal. The medium level is dominated by France, Germany and Austria. The lowest mean across the years are by the countries of the Netherlands, Italy and the UK. The next step was to fully examine the effects these differences among the countries have on our model we carry out a linear mixed effect model with 'country' as a fixed factor together with the other significant variables that we have examined in our linear regression. There are 16 countries, 5 variables, and one constant in this model which leads to a total of 22 parameters to examine.

Linear Mixed Effects Model

Table 7: Linear Mixed Model with Country Effects: Model dimensions

Modelldimension[a]

		Anzahl Ausprägungen	Anzahl Parameter
Feste Effekte	Konstanter Term	1	1
	Country	16	15
	PrimaryEnergyConsumption	1	1
	CO2percapita	1	1
	EnergyUsepercapita	1	1
	EnergyImportDependency	1	1
	OilPricesHouseholds	1	1
Residuum			1
Gesamt		22	22

a. Abhängige Variable: CRESpercentage Contribution of RE to Energy Supply %.

Table 8: Linear Mixed Model with Country Effects: Information Criteria

Information Criteria[a]

Eingeschränkte -2 Log Likelihood	648,443
Akaike-Informationskriterium (AIC)	650,443
Hurvich und Tsai (IC)	650,465
Bozdogan-Kriterium (CAIC)	654,675
Bayes-Kriterium von Schwarz (BIC)	653,675

Die Informationskriterien werden in einem möglichst kleinen Format angezeigt.[a]

a. Abhängige Variable: CRESpercentage Contribution of RE to Energy Supply %.

The table for Information Criteria shows fit indices for the model, we use the Bayesian Information Criterion (BIC), the lower the value the better the model fits[86], and the value is a little high but seems fine for our purpose.

The next section shows the results of the country fixed effects regression. The Test on Fixed Effects presents the F-Values for all variables and their significance. A small significance value of smaller than 0.05 means the effect is noticeable in the model. In our model all variables are significant and thus have in influence on the result.

[86] Schendera (2014)

Fixed Effects

Table 9: Linear Mixed Model with Country Effects: Fixed Effects Test

Tests auf feste Effekte, Typ III[a]

Quelle	Zähler-Freiheitsgrade	Nenner-Freiheitsgrade	F-Wert	Signifikanz
Konstanter Term	1	187,000	29,972	,000
Country	15	187	186,718	,000
PrimaryEnergyConsumption	1	187,000	5,644	,019
CO2percapita	1	187,000	36,113	,000
EnergyUsepercapita	1	187,000	9,001	,003
EnergyImportDependency	1	187	13,956	,000
OilPricesHouseholds	1	187	66,022	,000

a. Abhängige Variable: CRESpercentage Contribution of RE to Energy Supply %.

The linear mixed model does not automatically give us a value for R or R-squared, so we did a simple correlation first to determine the value of R and then calculated R-squared and the adjusted R-squared. We get the value for R from the table below, R = 0.956 thus $R^2 = 0.913936$ and the adjusted $R^2 = 0.90417903$. This is a much higher value than in the linear regression. Of course R-squared increases the more variables are added,[87] in total however it points to a better fit of the model altogether.

Table 10: Linear Mixed Model with Country Effects: Correlations

Korrelationen

		Contribution of RE to Energy Supply %	Feste vorhergesagte Werte	Vorhergesagte Werte
Contribution of RE to Energy Supply %	Pearson-Korrelation	1	,956**	,956**
	Sig. (2-seitig)		,000	,000
	N	238	224	224
Feste vorhergesagte Werte	Pearson-Korrelation	,956**	1	1,000**
	Sig. (2-seitig)	,000		,000
	N	224	224	224
Vorhergesagte Werte	Pearson-Korrelation	,956**	1,000**	1
	Sig. (2-seitig)	,000	,000	
	N	224	224	224

[87] Brosius (2010)

The next table, Table 11, with the estimates for the fixed parameters tells us the effect of each individual fixed factor, the constant is significant as well as most other countries and the independent variables. Only significant parameters should be taken into account as well as the ones where the confidence interval excludes the value 1. It is important to note that the estimates in the linear mixed model procedure are not standardized which means they can be misleading. One has to be careful with interpreting them. The constant term is the intercept of the regression line, an estimated average thereof.[88]

All the independent variables are significant at the 0.05 level as well as some countries, namely Greece, Ireland, Portugal, Belgium, Denmark, Finland, the Netherlands, Norway, and Sweden. The country regression result also shows us different values for the independent variables than the linear regression.

- Primary Energy Consumption: -0.040791 or -4.0791% decrease of CRES per additional million tons of oil equivalent.
- CO_2 per capita: -1.189508 or -118.9508% decrease of CRES per additional ton of CO_2 per capita
- Energy Use per capita: +0.002231 or +0.2231% increase of CRES per additional kgoe/cap
- Energy Import Dependency: -0.013934 or -1.3934% decrease of CRES per additional percent
- Oil Prices Households: +0.002045 or +0.2045% increase of CRES per additional $

All of these variables are significant and with a confidence interval that excludes 1. Especially the value for CO2 is surprisingly high, even higher than in the linear regression. The correlation matrix table, Table A2 which can be found in the Appendix, might be able to tell us more about this result. We compiled the most interesting correlations below. Indeed, we can observe several high correlations between CO2 per capita and other variables:

- CO_2 per capita/ Energy Use per capita: -0.758
- CO_2 per capita / Energy Import Dependency: 0.238
- CO_2 per capita/ Oil Prices Households: 0.465
- CO_2 per capita/ Primary Energy Consumption: 0.030

[88] Schendera (2014)

Additionally, the correlations between the independent variables and countries were quite high. Below are the tables with the results of the country fixed regression; the independent variables are in the last part of the first table.

Table 11: Linear Mixed Model with country effects: Fixed Parameter Estimates

Schätzungen fester Parameter[a]

Parameter	Schätzung	Standard Fehler	Freiheitsgrade	T-Statistik	Signifikanz
Konstanter Term	14,728108	1,726484	187	8,531	,000
[Country=2 France]	-2,906221	3,786260	187	-,768	,444
[Country=3 Germany]	5,116097	5,029813	187,000	1,017	,310
[Country=4 Greece]	-5,647133	1,160056	187,000	-4,868	,000
[Country=6 Ireland]	-8,333733	,850430	187,000	-9,799	,000
[Country=7 Italy]	-4,766066	2,783137	187	-1,712	,088
[Country=9 Portugal]	-2,233638	,867351	187,000	-2,575	,011
[Country=10 Spain]	-3,925557	2,240872	187,000	-1,752	,081
[Country=11 Belgium]	-9,550687	,840723	187,000	-11,360	,000
[Country=12 Denmark]	-3,180110	,691760	187,000	-4,597	,000
[Country=13 Finland]	4,567382	1,753350	187,000	2,605	,010
[Country=14 Netherlands]	-9,338209	,940069	187	-9,934	,000
[Country=15 Poland]	-2,996176	1,692061	187,000	-1,771	,078
[Country=16 UK]	-3,231174	3,268524	187,000	-,989	,324
[Country=17 Norway]	-22,710401	3,519485	187,000	-6,453	,000
[Country=18 Sweden]	-3,679577	1,683616	187,000	-2,186	,030
[Country=19 Austria]	0[b]	0	.	.	.
PrimaryEnergyConsumption	-,040791	,017169	187,000	-2,376	,019
CO2percapita	-1,189508	,197942	187,000	-6,009	,000
EnergyUsepercapita	,002231	,000743	187,000	3,000	,003
EnergyImportDependency	-,013934	,003730	187	-3,736	,000
OilPricesHouseholds	,002045	,000252	187	8,125	,000

Schätzungen fester Parameter[a]

Parameter	Konfidenzintervall 95% Untergrenze	Konfidenzintervall 95% Obergrenze
Konstanter Term	11,322219	18,133997
[Country=2]	-10,375492	4,563051
[Country=3]	-4,806372	15,038566
[Country=4]	-7,935612	-3,358654
[Country=6]	-10,011402	-6,656064
[Country=7]	-10,256447	,724315
[Country=9]	-3,944687	-,522589
[Country=10]	-8,346195	,495081
[Country=11]	-11,209208	-7,892167
[Country=12]	-4,544766	-1,815454
[Country=13]	1,108493	8,026270
[Country=14]	-11,192712	-7,483707
[Country=15]	-6,334158	,341805
[Country=16]	-9,679093	3,216745
[Country=17]	-29,653399	-15,767404
[Country=18]	-7,000898	-,358255
[Country=19]	.	.
PrimaryEnergyConsumption	-,074662	-,006920
CO2percapita	-1,579995	-,799021
EnergyUsepercapita	,000764	,003697
EnergyImportDependency	-,021291	-,006576
OilPricesHouseholds	,001549	,002542

a. Abhängige Variable: CRESpercentage Contribution of RE to Energy Supply %.

b. Dieser redundante Parameter wird auf null gesetzt.

Table 12: Linear Mixed Model with country effects: Covariance parameter estimates

Schätzungen von Kovarianzparametern[a]

Parameter	Schätzung	Std.-Fehler	Wald Z	Sig.	Konfidenzintervall 95%	
					Untergrenze	Obergrenze
Residuum	1,116851	,115502	9,670	,000	,911939	1,367805

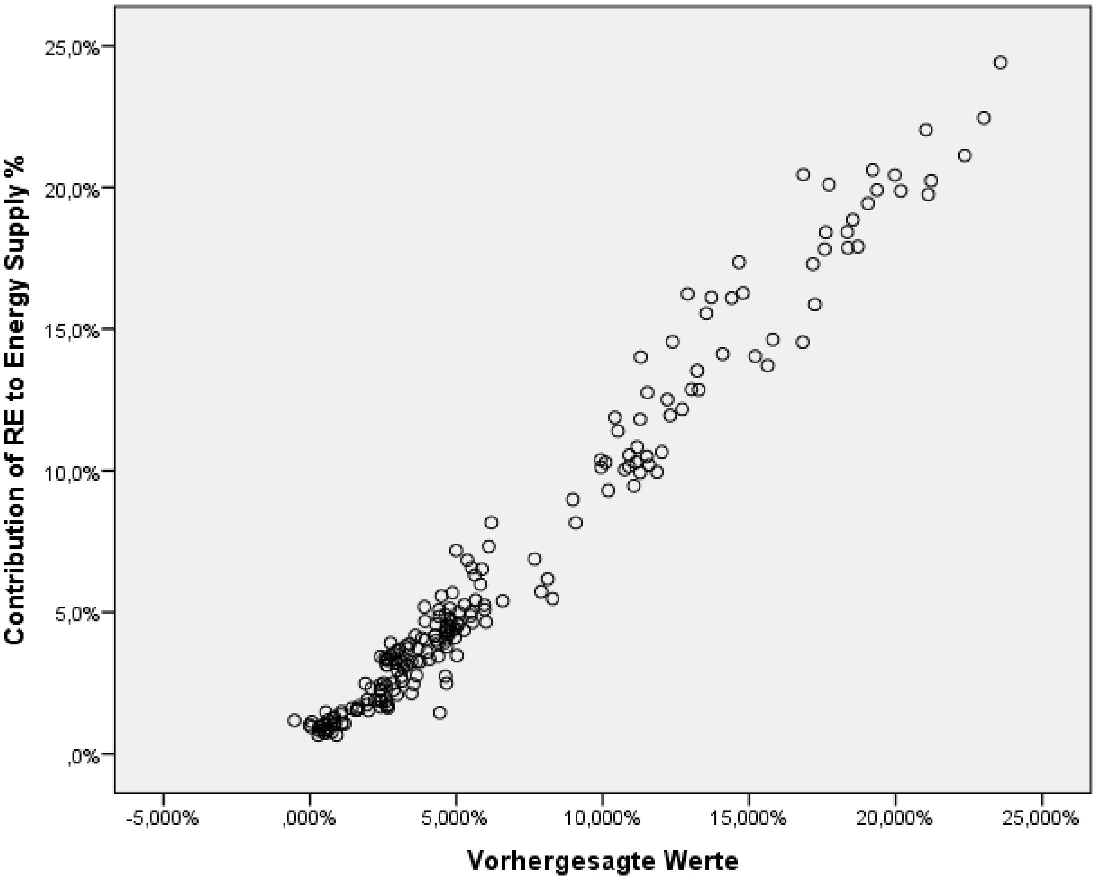
Korrelationsmatrix für Schätzungen von Kovarianzparametern[a]

Parameter	Residuum
Residuum	1

a. Abhängige Variable: CRESpercentage Contribution of RE to Energy Supply %.

Next we see a graph in Figure 12, which again tests how well prediction holds up versus reality regarding the CRES values, it shows a much higher concentration of the data points around the line of the regression equation, proving our assumption stated earlier that taking into account the country effects will lead to an optimized predictability rate of our model.

Figure 12: Linear Mixed Model with Country Effects: Residual Scatter Plot of Predicted CRES values



Linear Mixed Effects Model with Standardized Z-Scores

The final step in our overall analysis was to repeat the country fixed regression with standardized z-scores to better compare between the independent variables, their units are now equalized. This way it is possible to see which ones have the largest effect in the model. The z-scores have a mean of 0 and a standard deviation of 1. When we look at the information criteria table, the Bayes Criterion is already much smaller with standardized values and lies at -56.987, this suggests a better model fit.

Table 13: Linear Mixed Model with standardized z-scores: Information Criteria

Informationskriterien[a]

Eingeschränkte -2 Log Likelihood	-62,218
Akaike-Informationskriterium (AIC)	-60,218
Hurvich und Tsai (IC)	-60,197
Bozdogan-Kriterium (CAIC)	-55,987
Bayes-Kriterium von Schwarz (BIC)	-56,987

Die Informationskriterien werden in einem möglichst kleinen Format angezeigt.[a]
a. Abhängige Variable: ZCRESpercentage z-Faktorwert: Contribution of RE to Energy Supply %.

For this regression we again calculated the value of R-squared to better compare this regression to the previous ones. We get the value for R from the table below, R = 0.985 thus $R^2 = 0.970225$ and the adjusted $R^2 = 0.96685774$. This value is again a little bit higher than the R-squared from the previous regression.

Table 14: Linear Mixed Model with standardized z-scores: Correlations

Korrelationen

		z-Faktorwert: Contribution of RE to Energy Supply %	Feste vorhergesagte Werte	Vorhergesagte Werte
z-Faktorwert: Contribution of RE to Energy Supply %	Pearson-Korrelation	1	,985**	,985**
	Sig. (2-seitig)		,000	,000
	N	238	208	208
Feste vorhergesagte Werte	Pearson-Korrelation	,985**	1	1,000**
	Sig. (2-seitig)	,000		,000
	N	208	208	208
Vorhergesagte Werte	Pearson-Korrelation	,985**	1,000**	1
	Sig. (2-seitig)	,000	,000	
	N	208	208	208

The z-scores for our independent variables are again all significant and exclude the value 1 in the confidence interval, this can be seen in Table 15. Specifically, the results for our independent variables are:

- Z Primary Energy Consumption: -0.6295 or -62.95%
- Z CO2 per capita: -0.4141 or -41.41%
- Z Energy Use per capita: +0.4911 or +49.11%
- Z Energy Import Dependency: -0.399 or -39.9 %
- Z Oil Prices Households: 0.1678 or +16.78%

Obviously, Primary Energy Consumption has the biggest effect on our dependent variable in this model with a decrease of -62.95% if it is increased by one unit. Almost as large is the effect Energy Use per capita and CO2 per capita have on the model with 49.11% and -41.41% respectively. Energy Import Dependency follows with -39.9% and it is surprising to find that oil prices seem to have the lowest effect with only 16.78%.

Table 15: Linear Mixed Model with standardized z-scores: Fixed Parameter Estimates

Schätzungen fester Parameter[a]

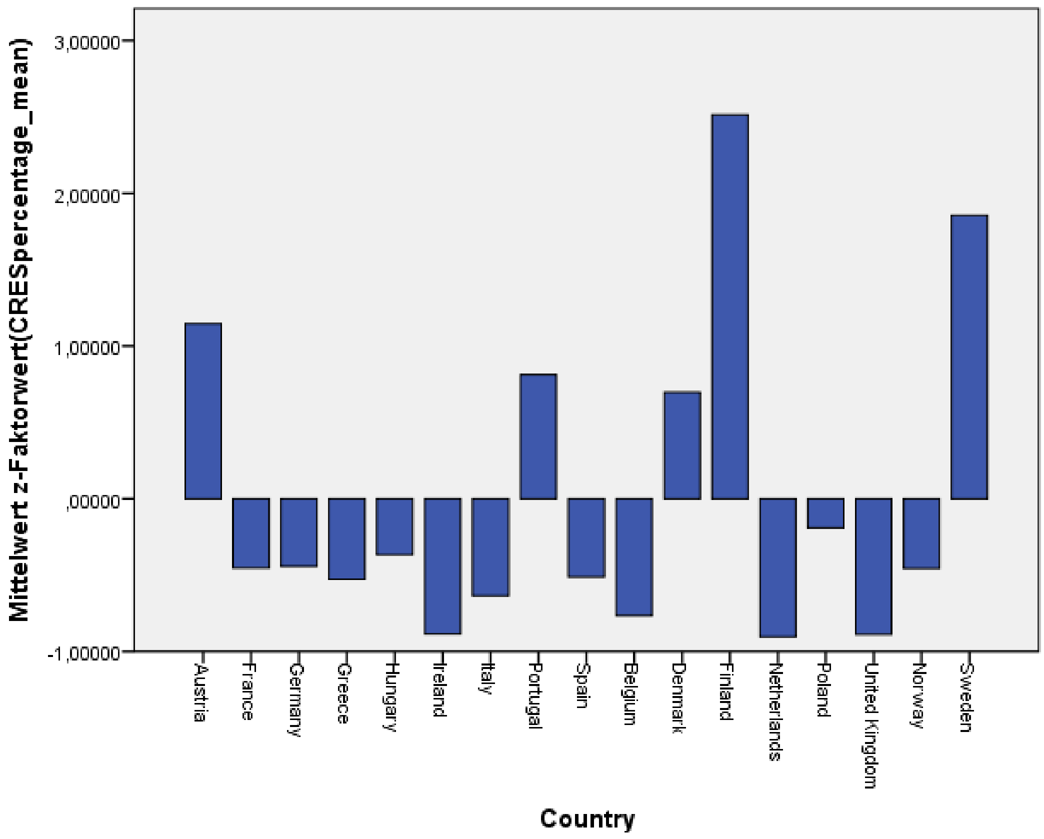
Parameter	Schätzung	Standard Fehler	Freiheitsgrade	T-Statistik	Signifikanz
Konstanter Term	,801434	,188229	187,000	4,258	,000
[Country=2]	-,493348	,642740	187	-,768	,444
[Country=3]	,868487	,853840	187	1,017	,310
[Country=4]	-,958634	,196926	187,000	-4,868	,000
[Country=6]	-1,414700	,144365	187	-9,799	,000
[Country=7]	-,809068	,472454	187,000	-1,712	,088
[Country=9]	-,379173	,147238	187	-2,575	,011
[Country=10]	-,666386	,380401	187	-1,752	,081
[Country=11]	-1,621285	,142718	187	-11,360	,000
[Country=12]	-,539842	,117430	187	-4,597	,000
[Country=13]	,775340	,297641	187	2,605	,010
[Country=14]	-1,585216	,159582	187	-9,934	,000
[Country=15]	-,508618	,287237	187,000	-1,771	,078
[Country=16]	-,548511	,554851	187	-,989	,324
[Country=17]	-3,855224	,597453	187	-6,453	,000
[Country=18]	-,624630	,285804	187	-2,186	,030
[Country=19]	0[b]	0	.	.	.

Schätzungen fester Parameter[a]

Parameter	Schätzung	Standard Fehler	Freiheitsgrade	T-Statistik	Signifikanz
ZPrimaryEnergyConsumption	-,629576	,264997	187,000	-2,376	,019
ZCO2percapita	-,414109	,068910	187,000	-6,009	,000
ZEnergyUsepercapita	,491101	,163694	187	3,000	,003
ZEnergyImportDependency	-,399493	,106937	187,000	-3,736	,000
ZOilPricesHouseholds	,167829	,020655	187	8,125	,000

This next graph, Figure 13, aids in illustrating the results as it shows how the CRES percentage mean looks like for all the different countries with standardized z-scores.

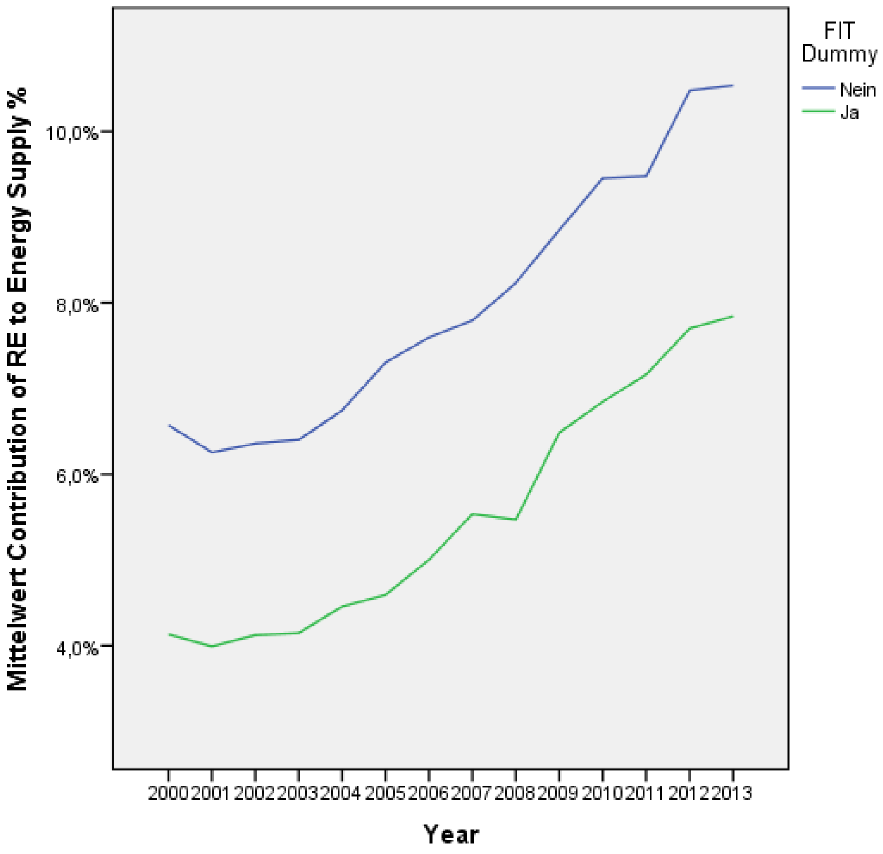
Figure 13: Linear Mixed Model with standardized z-scores: centered CRES percentage mean values by country



4.2 Discussion

Overall the results show an increase of the percentage of Renewable Energy, with or without FIT policy in place. This suggests that the type of RE promotion policy doesn't matter as much, but that instead it rather comes down to the predisposition for RE, economic activity and energy consumption patterns of a country. The models did well with the prediction for the expected values, however, adding the country differences into the equation made it more accurate. The most important conclusion we can draw from our result that includes all independent variables is, that the FIT policy seemingly does not have a significant effect on increasing CRES for Biomass. The linear regression model 1 with the FIT dummy variable and only Area in km^2 as additional variable and model 3 with FIT and the IVs Area in km^2, Primary Energy Consumption and Energy Import Dependency were significant. However, they both showed very negative effects for FIT with values of -2.527 and -2.327 respectively. In addition to that, the R^2 for model 1 is very low with 0.060 or 6.0% and the standard error is at 5.7%. For model 3 the R^2 is better but still not very good with a R^2 of 0.411 or 41.1% and a standard error of 4.6%. This shows that despite their significance they are not as precise and useable as the one that encompasses all the independent variables. What we can observe is, that the FIT policy seems to have a negative effect on the percentage of biomass in every model, the linear regression including all IVs gives the result of -0.141 for the regression coefficient of the FIT dummy variable and a significance value of 0.841 which is high above the 0.05 cut off value. The former can be translated as a -14.1% decrease in CRES if FIT policy is present in a country. When we look closer at the data and visualize them in a graph (Figure 14) we notice that the countries without FIT policy have on average a higher mean percentage value of CRES.

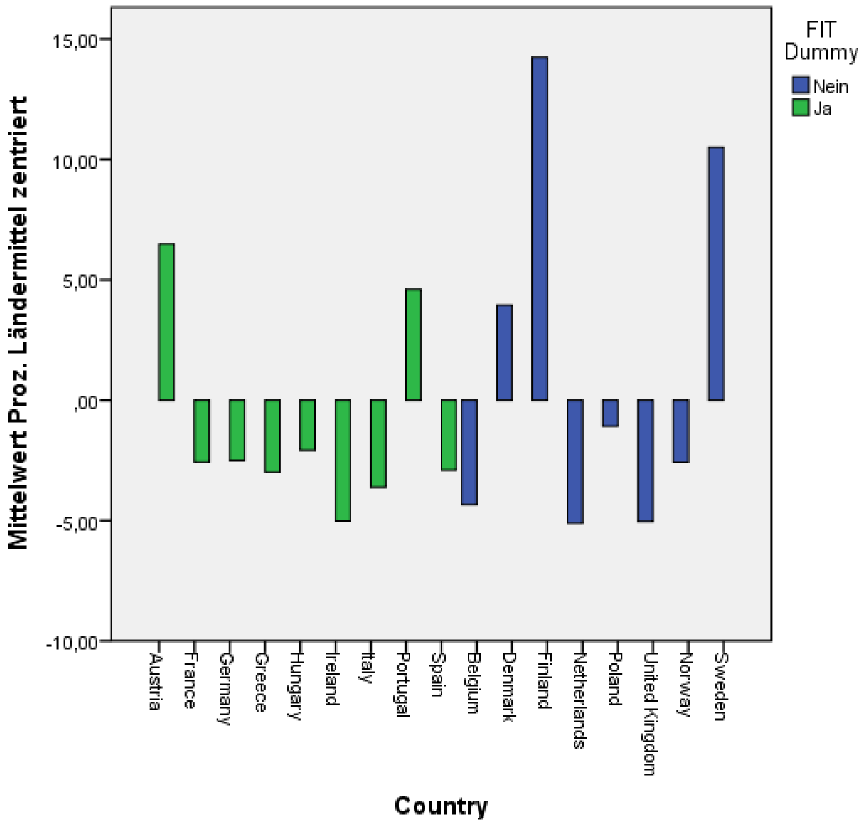
Figure 14: Yearly CRES percentage mean growth differentiated by FIT Dummy variable (Yes=green/No=blue)



Our findings suggest that countries without FIT perform better with CRES for Biomass. The graph below, Figure 15, illustrates this particular point. We see the standardized CRES mean values for all countries, and notice that more of the FIT countries have a negative mean percentage than non-FIT countries.

This might suggest that other policies are better or more effective for promoting the increase of biomass in the overall energy mix. However, as we have noted before the country effects do play a major role in the linear mixed model, so this result can’t be looked upon as 100% conclusive.

Figure 15: centered CRES percentage mean growth differentiated by country FIT Dummy variable (Yes=green/No=blue)

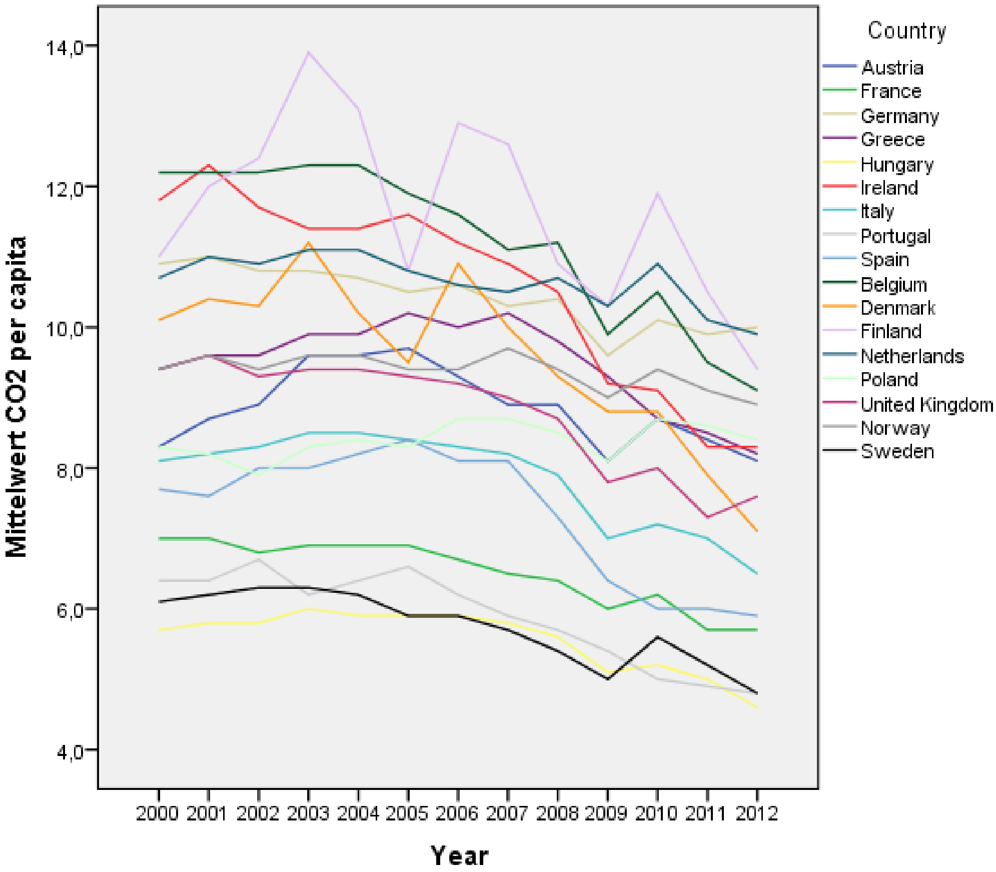


CRES in our case only includes renewable energy from biomass, hence the result can be different for other forms of energy as we have seen in the S. Jenner et. al. 2013 article on electricity feed-in tariffs from PV and wind energy. The question arises from the results, why is FIT not significant in this analysis for biomass? The variables with negative effects on CRES were high primary energy consumption and high CO_2 per capita. The linear mixed effect model with standardized z-scores revealed that these variables and also Energy Use per capita have had the biggest effect on the model, so maybe there is a connection there. Also, when we look at the countries that have active FIT policy, one notes that they are countries with bigger economic powers than the ones without FIT and thus in turn probably have higher Primary Energy Consumption and CO_2 per capita.

Regardless of the policies that are in place, it appears to be the case that as long as there is any form of active RE promotion mechanism the percentage of biomass is increasing. Certainly it is safe to assume that part of this increase is also a compiled effect of better conversion technology, increased awareness for the need for RE and simply time itself which allowed existing biomass plants to grow and expand.

Climate change concerns, which are often forgotten by politicians and industrialists alike when it comes to financing profitable industry sectors, find their only reliable proof in rising CO_2 emissions. Measured in CO_2 per capita, this particular variable seems to have had a reverse effect on RE, the higher the emissions per capita are, the lower is the share of biomass. This is a surprising and unexpected result, as one might assume that higher CO_2 should lead to increased commitment to produce sustainable energy and higher RE shares. The reality of the situation seems to be that CO_2 per capita is correlated with high economic activity; we see that in its positive correlation with Energy Use per capita. Similar findings were obtained by A.C. Marques et. al. (2010), wherein they found that higher CO_2 emissions yield lower RE commitment. The very sharp negative influence of CO_2 per capita on CRES (-85.1% in the linear regression) might be traced back to the fact that the unit of one metric ton is a massive increase per capita, which might be the reason for this extremely high negative result. As is clear from the graph below, CO_2 per capita on the whole has been going down over the years. There is a noticeable drop in the year 2009 after the 2008 Financial Crisis, with an immediate up in the year 2010. After this it continues to decrease.

Figure 16: Yearly CO2 per capita mean growth differentiated by country



The main factor responsible for CO_2 emissions is, of course, Primary Energy Consumption. This variable has the largest effect on CRES in our model; it influences RE negatively, as would be expected. The result shows that higher consumption of fossil fuels has a decreasing effect on the percentage of renewable energy. The consumption of fossil fuels has been relatively stable over the years and has not changed much except for a short decrease in 2009. Energy Import Dependency does have a small positive effect for CRES in our linear regression model, but this was expected since it becomes increasingly important to be self-sufficient in this economy. However, the influence was slightly negative in our model including country effects. In case of oil prices, we can see that as expected the variable Oil Prices Households does have a small positive effect on CRES in both models. Higher oil prices lead to an increase in CRES. When we look closer at the graphs below, we notice that during the years of the Financial Crisis the oil price first has a very sharp increase and then an immediate drop in the year 2009. In the same time span, CRES starts to increase slightly in all countries, in some very much like in Denmark for example.

Figure 17: Yearly Oil Price Households mean growth differentiated by country

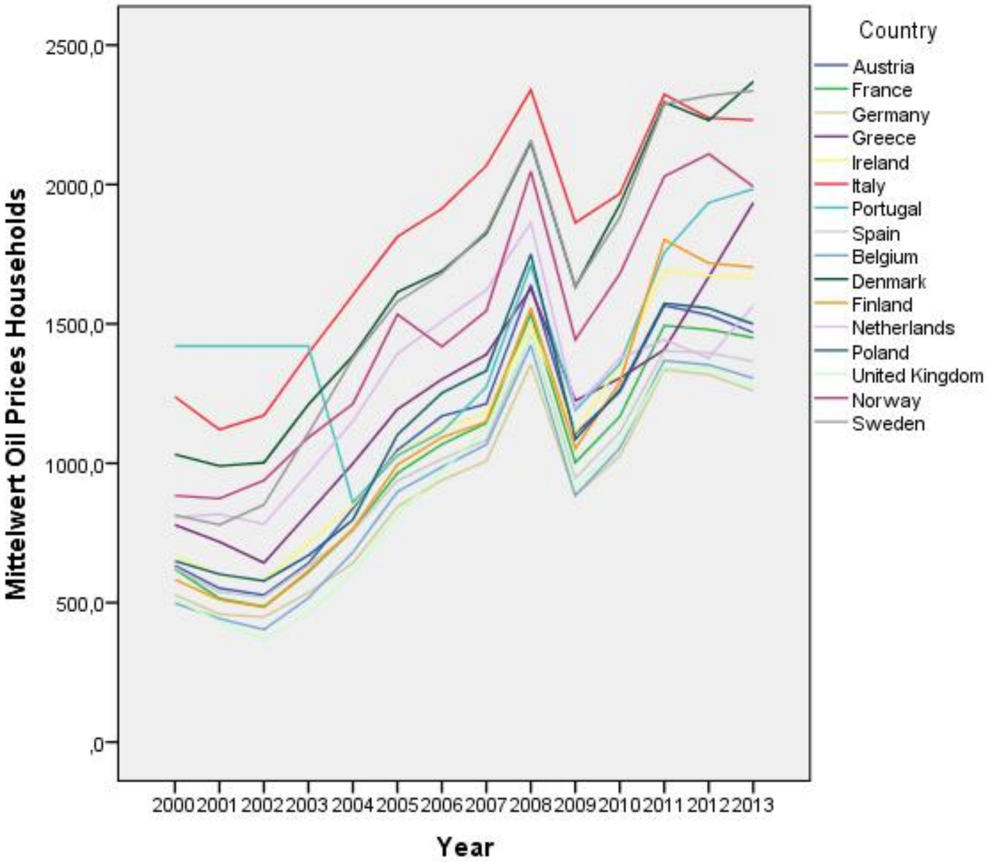
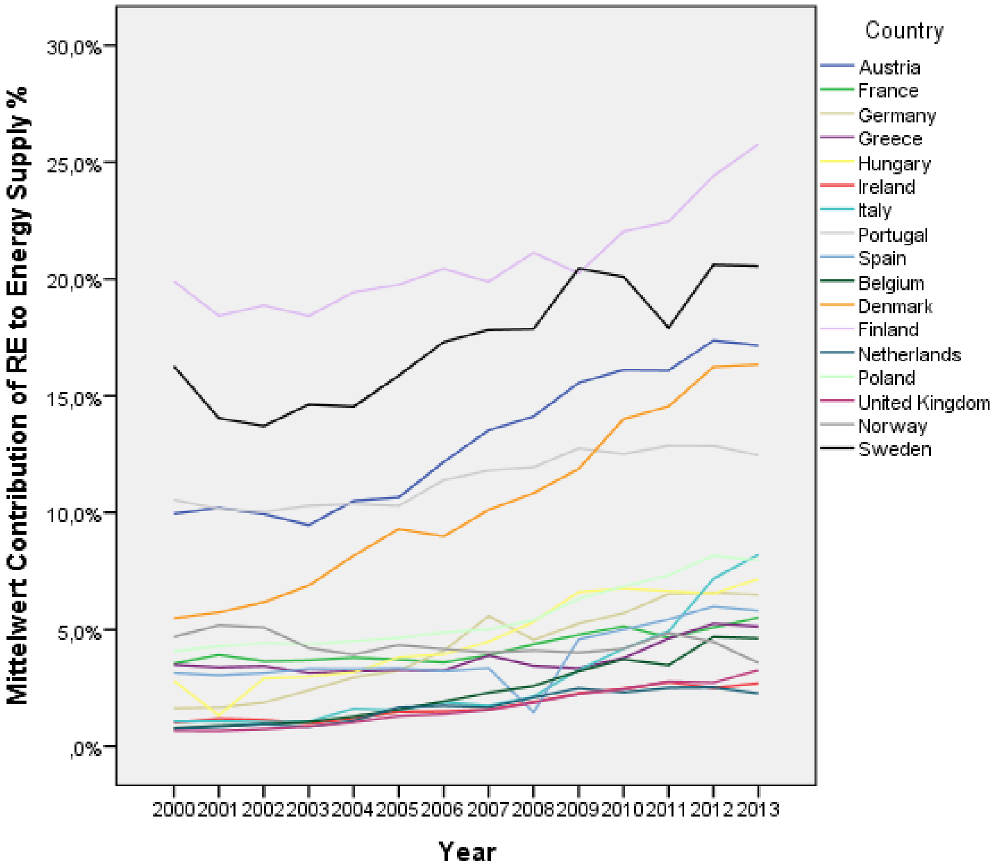


Figure 18: Yearly CRES percentage mean growth differentiated by country



When we look at the graph above (Figure 18), it shows the mean of the CRES percentage for all the countries in our analysis; we see that especially Finland, Sweden, Austria, Norway, and Denmark have very high CRES percentages, only one of these countries (Austria) is a FIT country. The remainder of the countries meander around the same values, all of them show slight increases over the years. Now this certainly means that the country effects cannot be ignored, and it is very important to consider the major differences between the countries regarding their size, energy consumption patterns, different frameworks which are in place for RE policies etc., comparisons cannot be generalized or drawn very easily without significant research. We can see very different starting points for all countries when we look at the biomass development over time.

Looking back to our hypotheses, we had our first hypothesis which was:

<u>Hypothesis 1:</u> FIT is the most effective instrument to boost the capacity of any RE technology.

According to the literature review we conducted and the empirical analysis, this hypothesis can be neither confirmed nor disconfirmed and would need more research.

Our second hypothesis is stated below:

<u>Hypothesis 2:</u> If FIT policy is the policy of choice for biomass in a country, the biomass capacity will increase more than with a different support policy instrument.

This hypothesis can be disproven due to the results we received from our empirical analysis.

Possible reasons for the fact that FIT seems to not help in increasing biomass capacity can have to do with:

a) The mechanics of this analysis: It could be that for example, sample size was too small or that more countries would be needed. Similarly, one might need to incorporate more variables and look for more detailed data for the variables. One could maybe use monthly instead of yearly data, this might increase the model accuracy, although this type of data might be hard to find for certain variables.

b) The result could also have come about because of socio-political factors, which are hard to measure in an empirical analysis like this. Monetary policies and interest rates concerning the lending from central banks and financial institutions and also credit availability, all of these influence investment and makes it more or less attractive; especially after 2008 this whole sector has seen increasing fluctuations. Reasons for these shifts can be political but also military crises, including the continuing instability in the Middle East which occurred during the analyzed period.

c) The way FIT is used in each country could have also influenced the results. This leads back to the problem of heterogeneity of the countries and their unchangeable differences. Each country needs to work with what serves them best; therefore, it is difficult to say if one particular policy works well across the board. Biomass is used for many different forms of energy, and therefore electricity is just one part of the total picture. It could be the case that the FIT tariff just is not effective for this type of green electricity. One would have to test for all the different forms of energy that biomass can produce (electricity, heat, combined heat and electricity…) together with all the different forms of subsidies and support (FIT, Tenders, Quotas...) to find out what works best for certain types of biomass sourced energy. It would be interesting to carry out a comparative study that looks at the effectiveness of other RE support policies for biomass, this might give a more comprehensive overview and reveal more information concerning the effectiveness of FIT and other policies relative to one another.

5. Conclusion and Outlook for Further Research

In this work, we have explored the different factors which influence Renewable Energy Policy, from international obligations over European regulations down to examples from national policy. We then looked more closely at the financial policy support instrument known as Feed-in Tariffs, and at biomass as a source for renewable energy with their respective benefits and possible risks. Finally, we brought together the theoretical framework and methodology, and conducted a panel data analysis with data from 18 different European nations for the period 2000 to 2013.

The main factors that influence Renewable Energy policies have been identified in the first part of this work. Geographic conditions are unique for every country and determine natural resources and meteorologically, rainfall, and sunshine hours are also specific to each country. Socioeconomic elements and context include public awareness and the inclusion of the people in RE projects. A strong resistance by local populations to large projects (the NIMBY aspect) is detrimental to new RE installations, and should be counteracted by including local people in certain aspects of the projects. Technical aspects such as the energy infrastructure are also important. Financial aspects focus mainly on investment stability for RE projects. Increased investment is needed in Renewable Energy to advance the development of RE capacity; in part, the liberalization of the energy market might prove to be helpful. Important influences on energy policy are the particular political elements of a given context. International obligations like the Kyoto Protocol or the Paris Agreement require countries to commit to certain emission targets. The European Directive 2009/28/EC is a legal instrument which all EU member countries need to adhere to. It requires each nation to implement the requirements into respective national law. Investment risks for RE projects, which were identified, showed that the 'regulatory risk' is a main concern for investors, since they want reliable, long-term, secure regulations to guarantee a return on investments. Feed-in Tariffs are such a secure investment instrument with their long contracts and risk abatement structure, making them a seemingly effective RE support instrument. The green energy form, which was chosen for this analysis, was biomass. Biomass shows potential since it can be drawn from various source materials available at different stages of production, and with several conversion methods available. Combustion and gasification are the most advanced processing technologies.

The analysis then set out to examine whether the FIT support instrument would be effective in boosting the capacity of biomass. With a linear regression and a mixed linear model, which included country effects to level out the effects of heterogeneity, we looked at one group of countries applying the FIT policy instrument and controlled with a group of countries that do not use FIT policy.

The analysis set out to analyze whether or not biomass capacity increases when a nation applies the FIT support instrument. In the analysis, we saw a noticeable country effect which did possibly influence the result. The main result of the analysis was not expected, as the FIT policy does not appear to be significant. Results suggest that countries without active FIT policy have a higher biomass capacity than countries with FIT policies in place, therefore suggesting that it is better for biomass to be supported by support policies other than the FIT. Area in km^2, Primary Energy Consumption, Energy Use per capita, Energy Import Dependency, Oil Prices for Households, and CO_2 per capita are all significant and have effects on the model. In particular Primary Energy Consumption and Energy Use per Capita and CO_2 per capita have a meaningful influence on the model. Positive influences on the dependent variable CRES (Contribution of Renewables to Energy Supply) include the variables Area size, Energy Import Dependency, Energy Use per capita, and Oil Prices. Negative influences are the variables FIT policy, Primary Energy Consumption, while the largest negative influence is CO_2 per capita. Possible reasons for these results can have to do with (i) either the framework of this particular analysis (ii) or the characteristics of biomass use for energy and the way that FIT is used in each country. Possible further research areas would therefore be to expand the data to include also the most recent years and to use more detailed explanatory variables. It would also be interesting to individually analyze all of the different energy forms that biomass can produce with all the various support policies available to see what works best to boost biomass capacity. A more in-depth analysis is needed to find out the reasons why FIT seems not to be effective for boosting biomass capacity. The exact reasons why are beyond the scope of this thesis, but they offer a number of potential research projects of their own to be conducted by future researchers.

Appendix

Table A 1: Linear Regression: Bivariate Correlations between variables

Korrelationen

		Primary Energy Consumption	CO2 per capita	Energy Use per capita
Primary Energy Consumption	Pearson-Korrelation	1	-,022	-,074
	Sig. (2-seitig)		,742	,253
	N	238	221	238
CO2 per capita	Pearson-Korrelation	-,022	1	,466**
	Sig. (2-seitig)	,742		,000
	N	221	221	221
Energy Use per capita	Pearson-Korrelation	-,074	,466**	1
	Sig. (2-seitig)	,253	,000	
	N	238	221	238
Area in km^2	Pearson-Korrelation	,555**	-,313**	,186**
	Sig. (2-seitig)	,000	,000	,004
	N	238	221	238
Energy Import Dependency %	Pearson-Korrelation	,136*	-,092	-,395**
	Sig. (2-seitig)	,037	,175	,000
	N	238	221	238
Oil Prices Households	Pearson-Korrelation	-,211**	-,367**	-,073
	Sig. (2-seitig)	,002	,000	,276
	N	224	208	224
Contribution of RE to Energy Supply %	Pearson-Korrelation	-,370**	-,159*	,350**
	Sig. (2-seitig)	,000	,018	,000
	N	238	221	238
FIT Dummy	Pearson-Korrelation	,195**	-,333**	-,581**
	Sig. (2-seitig)	,003	,000	,000
	N	238	221	238

Korrelationen

		Area in km²	Energy Import Dependency %	Oil Prices Households
Primary Energy Consumption	Pearson-Korrelation	,555**	,136*	-,211**
	Sig. (2-seitig)	,000	,037	,002
	N	238	238	224
CO2 per capita	Pearson-Korrelation	-,313**	-,092	-,367**
	Sig. (2-seitig)	,000	,175	,000
	N	221	221	208
Energy Use per capita	Pearson-Korrelation	,186**	-,395**	-,073
	Sig. (2-seitig)	,004	,000	,276
	N	238	238	224
Area in km²	Pearson-Korrelation	1	-,128*	-,053
	Sig. (2-seitig)		,048	,429
	N	238	238	224
Energy Import Dependency %	Pearson-Korrelation	-,128*	1	-,119
	Sig. (2-seitig)	,048		,075
	N	238	238	224
Oil Prices Households	Pearson-Korrelation	-,053	-,119	1
	Sig. (2-seitig)	,429	,075	
	N	224	224	224
Contribution of RE to Energy Supply %	Pearson-Korrelation	,132*	,072	,304**
	Sig. (2-seitig)	,042	,268	,000
	N	238	238	224
FIT Dummy	Pearson-Korrelation	,059	,369**	-,069
	Sig. (2-seitig)	,362	,000	,302
	N	238	238	224

Korrelationen

		Contribution of RE to Energy Supply %	FIT Dummy
Primary Energy Consumption	Pearson-Korrelation	-,370**	,195**
	Sig. (2-seitig)	,000	,003
	N	238	238
CO2 per capita	Pearson-Korrelation	-,159*	-,333**
	Sig. (2-seitig)	,018	,000
	N	221	221
Energy Use per capita	Pearson-Korrelation	,350**	-,581**
	Sig. (2-seitig)	,000	,000
	N	238	238
Area in km²	Pearson-Korrelation	,132*	,059
	Sig. (2-seitig)	,042	,362
	N	238	238
Energy Import Dependency %	Pearson-Korrelation	,072	,369**
	Sig. (2-seitig)	,268	,000
	N	238	238
Oil Prices Households	Pearson-Korrelation	,304**	-,069
	Sig. (2-seitig)	,000	,302
	N	224	224
Contribution of RE to Energy Supply %	Pearson-Korrelation	1	-,210**
	Sig. (2-seitig)		,001
	N	238	238
FIT Dummy	Pearson-Korrelation	-,210**	1
	Sig. (2-seitig)	,001	
	N	238	238

**. Korrelation ist bei Niveau 0,01 signifikant (zweiseitig).

*. Korrelation ist bei Niveau 0,05 signifikant (zweiseitig).

Table A 2: Linear Mixed Model with Country effects: Correlation Matrix for Fixed Effects

Korrelationsmatrix für feste Effekte[a]

Parameter	Konstanter Term	[Country=2]	[Country=3]	[Country=4]	[Country=6]
Konstanter Term	1	-,240	-,284	-,651	-,379
[Country=2]	-,240	1	,975	,188	-,292
[Country=3]	-,284	,975	1	,347	-,135
[Country=4]	-,651	,188	,347	1	,765
[Country=6]	-,379	-,292	-,135	,765	1
[Country=7]	-,408	,932	,976	,490	,009
[Country=9]	-,848	,248	,337	,805	,585
[Country=10]	-,459	,935	,969	,475	-,011
[Country=11]	,644	,208	,094	-,577	-,487
[Country=12]	-,278	,224	,320	,604	,482
[Country=13]	,764	-,368	-,500	-,811	-,474
[Country=14]	,126	,815	,787	,035	-,266
[Country=15]	-,608	,750	,843	,738	,306
[Country=16]	-,339	,968	,991	,381	-,107
[Country=17]	,485	-,165	-,277	-,611	-,471
[Country=18]	,511	,035	-,151	-,834	-,729
[Country=19]	.[b]	.[b]	.[b]	.[b]	.[b]
PrimaryEnergyConsumption	,274	-,981	-,996	-,303	,190
CO2percapita	,150	,127	-,075	-,766	-,791
EnergyUsepercapita	-,710	,253	,418	,929	,678
EnergyImportDependency	,269	-,129	-,194	-,367	-,309
OilPricesHouseholds	-,362	,197	,116	-,168	-,283

Korrelationsmatrix für feste Effekte[a]

Parameter	[Country=7]	[Country=9]	[Country=10]	[Country=11]	[Country=12]
Konstanter Term	-,408	-,848	-,459	,644	-,278
[Country=2]	,932	,248	,935	,208	,224
[Country=3]	,976	,337	,969	,094	,320
[Country=4]	,490	,805	,475	-,577	,604
[Country=6]	,009	,585	-,011	-,487	,482
[Country=7]	1	,482	,981	-,035	,397
[Country=9]	,482	1	,501	-,559	,447
[Country=10]	,981	,501	1	-,035	,361
[Country=11]	-,035	-,559	-,035	1	-,137
[Country=12]	,397	,447	,361	-,137	1
[Country=13]	-,618	-,766	-,613	,729	-,357

[Country=14]	,717	-,004	,700	,524	,343
[Country=15]	,911	,689	,903	-,287	,566
[Country=16]	,979	,382	,974	,063	,361
[Country=17]	-,377	-,588	-,383	,515	,077
[Country=18]	-,281	-,617	-,254	,758	-,376
[Country=19]	.[b]	.[b]	.[b]	.[b]	.[b]
PrimaryEnergyConsumption	-,969	-,306	-,962	-,091	-,272
CO2percapita	-,181	-,404	-,123	,482	-,536
EnergyUsepercapita	,555	,801	,539	-,712	,515
EnergyImportDependency	-,258	-,394	-,271	,258	,283
OilPricesHouseholds	,065	,062	,157	,031	-,439

Korrelationsmatrix für feste Effekte[a]

Parameter	[Country=13]	[Country=14]	[Country=15]	[Country=16]
Konstanter Term	,764	,126	-,608	-,339
[Country=2]	-,368	,815	,750	,968
[Country=3]	-,500	,787	,843	,991
[Country=4]	-,811	,035	,738	,381
[Country=6]	-,474	-,266	,306	-,107
[Country=7]	-,618	,717	,911	,979
[Country=9]	-,766	-,004	,689	,382
[Country=10]	-,613	,700	,903	,974
[Country=11]	,729	,524	-,287	,063
[Country=12]	-,357	,343	,566	,361
[Country=13]	1	,002	-,789	-,525
[Country=14]	,002	1	,525	,776
[Country=15]	-,789	,525	1	,866
[Country=16]	-,525	,776	,866	1
[Country=17]	,706	,159	-,464	-,263
[Country=18]	,830	,246	-,540	-,168
[Country=19]	.[b]	.[b]	.[b]	.[b]
PrimaryEnergyConsumption	,492	-,775	-,821	-,988
CO2percapita	,566	,097	-,425	-,082
EnergyUsepercapita	-,943	-,012	,787	,447
EnergyImportDependency	,433	,125	-,255	-,163
OilPricesHouseholds	-,035	-,047	,007	,120

Korrelationsmatrix für feste Effekte[a]

Parameter	[Country=17]	[Country=18]	[Country=19]	PrimaryEnergyConsumption
Konstanter Term	,485	,511	.[b]	,274
[Country=2]	-,165	,035	.[b]	-,981
[Country=3]	-,277	-,151	.[b]	-,996
[Country=4]	-,611	-,834	.[b]	-,303
[Country=6]	-,471	-,729	.[b]	,190
[Country=7]	-,377	-,281	.[b]	-,969
[Country=9]	-,588	-,617	.[b]	-,306
[Country=10]	-,383	-,254	.[b]	-,962
[Country=11]	,515	,758	.[b]	-,091
[Country=12]	,077	-,376	.[b]	-,272
[Country=13]	,706	,830	.[b]	,492
[Country=14]	,159	,246	.[b]	-,775
[Country=15]	-,464	-,540	.[b]	-,821
[Country=16]	-,263	-,168	.[b]	-,988
[Country=17]	1	,686	.[b]	,268
[Country=18]	,686	1	.[b]	,125
[Country=19]	.[b]	.[b]	.[b]	.[b]
PrimaryEnergyConsumption	,268	,125	.[b]	1
CO2percapita	,458	,864	.[b]	,030
EnergyUsepercapita	-,690	-,916	.[b]	-,389
EnergyImportDependency	,931	,420	.[b]	,189
OilPricesHouseholds	-,168	,177	.[b]	-,135

Korrelationsmatrix für feste Effekte[a]

Parameter	CO2percapita	EnergyUsepercapita	EnergyImportDependency	OilPricesHouseholds
Konstanter Term	,150	-,710	,269	-,362
[Country=2]	,127	,253	-,129	,197
[Country=3]	-,075	,418	-,194	,116
[Country=4]	-,766	,929	-,367	-,168
[Country=6]	-,791	,678	-,309	-,283
[Country=7]	-,181	,555	-,258	,065
[Country=9]	-,404	,801	-,394	,062
[Country=10]	-,123	,539	-,271	,157
[Country=11]	,482	-,712	,258	,031
[Country=12]	-,536	,515	,283	-,439
[Country=13]	,566	-,943	,433	-,035
[Country=14]	,097	-,012	,125	-,047
[Country=15]	-,425	,787	-,255	,007
[Country=16]	-,082	,447	-,163	,120
[Country=17]	,458	-,690	,931	-,168
[Country=18]	,864	-,916	,420	,177
[Country=19]	.[b]	.[b]	.[b]	.[b]
PrimaryEnergyConsumption	,030	-,389	,189	-,135
CO2percapita	1	-,758	,238	,465
EnergyUsepercapita	-,758	1	-,407	-,108
EnergyImportDependency	,238	-,407	1	-,231
OilPricesHouseholds	,465	-,108	-,231	1

a. Abhängige Variable: CRESpercentage Contribution of RE to Energy Supply %.

b. Die Korrelation ist systemdefiniert fehlend, da sie mit einem redundanten Parameter verbunden ist.

Bibliography

Academic Publications:

Barrett, E. (2016). A case of: who will tell the emperor he has no clothes? —market liberalization, regulatory capture and the need for further improved electricity market unbundling through a fourth energy package. *The Journal of World Energy Law & Business*, *9*(1), 1–16.

Bühl, A. (2014). *SPSS 22: Einführung in die moderne Datenanalyse.* Hallbergmoss: Pearson Deutschland GmbH.

Brosius, F. (2010). *SPSS 18 für Dummies*. Weinheim: Wiley-VCH-Verlag GmbH & Co. KGaA.

Carley, S. (2009). State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy*, *37*(8), 3071–3081.

Evans, A., Strezov, V., & Evans, T. J. (2015). Sustainability Considerations for Electricity Generation from Biomass. In V. Strezov & T. J. Evans (Eds.), *Biomass processing technologies* (pp. 33–52). Boca Raton, FL: CRC Press.

Haas, R., Resch, G., Panzer, C., Busch, S., Ragwitz, M., & Held, A. (2011). Efficiency and effectiveness of promotion systems for electricity generation from renewable energy sources – Lessons from EU countries. *Energy*, *36*(4), 2186–2193.

Harmelink, M., Voogt, M., & Cremer, C. (2006). Analysing the effectiveness of renewable energy supporting policies in the European Union. *Energy Policy*, *34*(3), 343–351.

Jacobsson, S., Bergek, A., Finon, D., Lauber, V., Mitchell, C., Toke, D., & Verbruggen, A. (2009). EU renewable energy support policy: Faith or facts? *Energy Policy*, *37*(6), 2143–2146.

Jamasb, T., & Pollitt, M. (2005). Electricity market reform in the European Union: review of progress toward liberalization & integration. *The Energy Journal*, 11–41.

Jenner, S., Groba, F., & Indvik, J. (2013). Assessing the strength and effectiveness of renewable electricity feed-in tariffs in European Union countries. *Energy Policy*, *52*, 385–401.

Kan, T., & Strezov, V. (2015a). Combustion of Biomass. In V. Strezov & T. J. Evans (Eds.), *Biomass processing technologies* (pp. 53–79). Boca Raton, FL: CRC Press.

Kitzing, L., Mitchell, C., & Morthorst, P. E. (2012a). Renewable energy policies in Europe: Converging or diverging? *Energy Policy*, *51*, 192–201.

Kitzing, L., Mitchell, C., & Morthorst, P. E. (2012b). Renewable energy policies in Europe: Converging or diverging? *Energy Policy*, *51*, 192–201.

Klessmann, C., Held, A., Rathmann, M., & Ragwitz, M. (2011). Status and perspectives of renewable energy policy and deployment in the European Union—What is needed to reach the 2020 targets? *Energy Policy*, *39*(12), 7637–7657.

Klessmann, C., Rathmann, M., de Jager, D., Gazzo, A., Resch, G., Busch, S., & Ragwitz, M. (2013). Policy options for reducing the costs of reaching the European renewables target. *Renewable Energy*, *57*, 390–403.

Marques, A. C., Fuinhas, J. A., & Pires Manso, J. R. (2010). Motivations driving renewable energy in European countries: A panel data approach. *Energy Policy*, *38*(11), 6877–6885.

Menz, F. C., & Vachon, S. (2006). The effectiveness of different policy regimes for promoting wind power: Experiences from the states. *Energy Policy*, *34*(14), 1786–1796.

Reiche, D., & Bechberger, M. (2004). Policy differences in the promotion of renewable energies in the EU member states. *Energy Policy*, *32*(7), 843–849.

Reiche, D. T. (Ed.). (2002). *Handbook of renewable energies in the European Union: case studies of all member states*. Frankfurt am Main/New York: Peter Lang.

Renger, P. (2010). *Biomasse als grundlastfähige erneuerbare Energie: Wirtschaftlichkeit und Marktentwicklung*. Hamburg: Diplomica Verlag.

Schendera, C. FG, (2014). *Regressionsanalyse mit SPSS*. München: De Gruyter Oldenbourg, Oldenbourg Wissenschaftsverlag GmbH.

Strezov, V. (2015). Properties of Biomass Fuels. In V. Strezov & T. J. Evans (Eds.), *Biomass processing technologies* (pp. 1–31). Boca Raton, FL: CRC Press.

Strezov, V., & Evans, T. J. (Eds.). (2015). *Biomass processing technologies*. Boca Raton, FL: CRC Press.

Strezov, V., & Kan, T. (2015b). Gasification of Biomass. In V. Strezov & T. J. Evans (Eds.), *Biomass processing technologies* (pp. 81–121). Boca Raton, FL: CRC Press.

Strezov, V., & Thommes, K. (2015). Fischer–Tropsch Synthesis from Biosyngas. In V. Strezov & T. J. Evans (Eds.), *Biomass processing technologies* (pp. 309–355). Boca Raton, FL: CRC Press.

van Asselt, H., & Biermann, F. (2007). European emissions trading and the international competitiveness of energy-intensive industries: a legal and political evaluation of possible supporting measures. *Energy Policy*, *35*(1), 497–506.

Legal Documents:

Bundesministerium für Wirtschaft und Energie (BMWiBerlin) der Bundesrepublik Deutschland, *3. Nationaler Energieeffizienz-Aktionsplan (NEEAP) 2014 der Bundesrepublik Deutschland gemäß der Richtlinie des Europäischen Parlaments und des Rates vom 25. Oktober 2012 zur Energieeffizienz (2012/27/EU)*, Retrieved from: http://www.bmwi.de/BMWi/Redaktion/PDF/M-O/nationaler-energieeffizienz-aktionsplan-2014,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

Bundesministerium für Wissenschaft, Forschung und Wirtschaft der Republik Österreich, *Erster Nationaler Energieeffizienzaktionsplan der Republik Österreich 2014 gemäß Energieeffizienzrichtlinie 2012/27/EU*, Retrieved from: http://www.bmwfw.gv.at/EnergieUndBergbau/SicherheitImBergbau/Documents/NEEAP%2030042014.pdf

European Union, European Commission. (2009). *Directive 2009/28/EC of the European Parliament and of the Council: on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*. Retrieved from: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=de

European Union, European Commission. (2015). *Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Renewable Energy Progress Report.* Retrieved from: http://eur-lex.europa.eu/resource.html?uri=cellar:4f8722ce-1347-11e5-8817-01aa75ed71a1.0001.02/DOC_1&format=PDF

European Union, European Commission (2005), *Communication from the Commission: The support of electricity from renewable energy sources.* Retrieved from: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52005DC0627&from=EN

European Union, European Commission. (2014). Commission Staff Working Document: *State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU*. Retrieved from: http://ec.europa.eu/energy/sites/ener/files/2014_biomass_state_of_play_.pdf

UNFCCC (1997) *Kyoto Protocol to the United Nations Framework Convention on Climate Change*. Dec. 11, 1997, Kyoto. United Nations Treaty Series, vol. 2303, No. 3282, Retrieved from: https://unfccc.int/resource/docs/convkp/kpeng.pdf

UNFCCC (1997) *Paris Agreement to the United Nations Framework Convention on Climate Change.* Dec. 12, 2015, Paris. Retrieved from: http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

UNECD (1992) *Rio Declaration on Environment and Development of the United Nations Conference on Environment and Development*, June 13, 1992. Retrieved from: http://www.unep.org/documents.multilingual/default.asp?documentid=78&articleid=1163

UNEP (1987) *The Montreal Protocol on Substances that Deplete the Ozone Layer*, Sept. 16, 1987. United Nations Environment Programme – Ozone Secretariat. United Nations Treaty Series, vol. 1522, No. 26369 Retrieved from: http://ozone.unep.org/pdfs/Montreal-Protocol2000.pdf

Internet Sources:

United Nations Framework Convention on Climate Change (2014), on the *Kyoto Protocol* Retrieved from: http://unfccc.int/kyoto_protocol/items/2830.php, on 26 October, 2016

United Nations Framework Convention on Climate Change (2014), on the *Paris Agreement*, Retrieved from: http://unfccc.int/paris_agreement/items/9485.php on 27 October, 2016

Data Sources:

These include all of the sources which were used for the panel data base and the subsequent empirical analysis.

BP plc., *BP Statistical Review of World Energy 2015*, Retrieved from:
https://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-full-report.pdf

Organization for Economic Co-operation and Development, *OECD Statistics National Accounts with the Base Year 2010*, Retrieved from:
https://stats.oecd.org/index.aspx?queryid=60702

European Commission, *Eurostat* (2015/2016), Retrieved from:
http://ec.europa.eu/eurostat/data/database

European Commission, *RES Legal Europe: Legal Sources on Renewable Energy*, Retrieved from:
http://www.res-legal.eu/search-by-country/

The World Bank Group, *World Bank World Development Indicator Data base 2015*, Retrieved from:
http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators

United States Central Intelligence Agency, *the CIA World Factbook*, Retrieved from:
https://www.cia.gov/library/publications/the-world-factbook/

Organization for Economic Co-operation and Development/ International Energy Agency, OECDiLibrary, *OECD Energy Balances*, Editions used from the years 2003 – 2015 Retrieved from:
http://www.oecd-ilibrary.org/energy/energy-balances-of-oecd-countries_19962835

Organization for Economic Co-operation and Development/ International Energy Agency, OECDiLibrary, *OECD Energy Prices and Taxes*, Editions used from the years 2005 – 2016 Retrieved from: http://www.oecd-ilibrary.org/energy/energy-prices-and-taxes_16096835

Abstract

Feed-in Tariffs are one of the most if not the most popular policy to support electricity produced from renewable energy. Various studies have analyzed the effectiveness of this instrument in different EU countries and US states, with the main technologies in focus being wind and solar photovoltaic. This work is an attempt to expand the analysis to other technologies and to evaluate the effectiveness of Feed-in Tariffs for biomass energy by looking at different EU countries. Following the work and methodology of A.C. Marques et al., we conduct a panel data analysis of European countries. Panel data is used from 2000-2013.

Part one of this thesis is built on the work of relevant authors in the field, and it looks at the influencing factors of Renewable energy policy. Risks for investment into renewable energy projects are identified in the next part and subsequently Feed-in Tariffs are introduced as an effective and reliable support instrument. The empirical analysis then set out to examine whether the FIT support instrument would be effective in increasing biomass capacity. We examined one group of countries applying the FIT policy instrument with a linear regression and a mixed linear model, which included country effects to level out the effects of heterogeneity, and with a second group of countries that does not use FIT policy as a control.

The influencing factor analysis in the beginning revealed that geographic and meteorological conditions are unique for every country and also determine the availability of natural resources. Furthermore, socioeconomic elements and context are important factors, as are as technical aspects such as energy infrastructure. It becomes clear that increased investment is needed in Renewable Energy to advance the development of RE capacity. Some important influences on energy policy are the particular political elements of a given context. This includes international obligations and in particular EU regulation.

In the following empirical analysis, we see a noticeable country effect which did possibly influence the result. The main result of the analysis was not expected, as the FIT policy does not appear to be significant. Results suggest that countries without active FIT policy have a higher biomass capacity than countries with FIT policies in place, therefore suggesting that it is better for biomass to be aided by support policies other than the FIT. We suggest a more in-depth analysis of the topic to determine the exact reasons why FIT does not seem to be effective to stimulate an increase in biomass capacity.

Zusammenfassung

Die Einspeisevergütung ist eine der am weitesten verbreiteten politischen Förderinstrumente für Erneuerbare Energien. Verschiedene Studien haben bereits die Effizienz dieses Förderinstruments in unterschiedlichen EU Ländern und US Staaten analysiert. Der Fokus wurde dabei immer auf Technologien wie Wind- und Solarenergie gelegt. Die vorliegende Arbeit ist ein Versuch, diese Analyse um andere Technologien zu erweitern; und zu beurteilen ob die Einspeisevergütung auch für Energie aus Biomasse funktionieren würde. Hierfür werden mehrere unterschiedliche EU Länder untersucht. In Anlehnung an die Arbeiten und die Methodik von A.C. Marques et. al. wird eine Paneldatenanalyse verschiedener EU Länder durchgeführt, die dabei genutzten Daten stammen aus den Jahren 2000-2013.

Diese Arbeit ist aufgebaut auf vorangegangenen Studien relevanter Autoren dieser Fachrichtung. Im ersten Teil der Thesis werden die Faktoren betrachtet, die die Erneuerbare Energien Politik beeinflussen. Im nächsten Teil werden Risiken identifiziert die bei der Investition in Erneuerbare Energie Projekte auftreten können. Anschließend wird die Einspeisevergütung als effizientes und sicheres Förderinstrument vorgestellt. Im Folgenden untersucht die empirische Analyse ob die Einspeisevergütung eine effektive Möglichkeit ist um die Kapazitäten für Biomasse zu erhöhen. Eine lineare Regression und ein gemischtes lineares Modell, welches den Effekt der Heterogenität aufgrund der Länderunterschiede mit einbezieht, werden durchgeführt. Es wird eine Ländergruppe, die Einspeisevergütung anwendet, mit einer Kontrollgruppe verglichen die dieses Instrument nicht nutzt.

Die Analyse der beeinflussenden Faktoren zu Beginn zeigte, dass geographische und meteorologische Verhältnisse für jedes Land einzigartig sind, sie bestimmen ebenfalls das Vorkommen natürlicher Rohstoffe. Des Weiteren sind der sozioökonomische Kontext und technische Aspekte, wie beispielsweise die Energie Infrastruktur, wirkende Faktoren in diesem Bereich. Es wird ebenfalls deutlich, dass mehr Investitionen in Erneuerbare Energien benötigt werden um die Kapazität erneuerbarer Energien voranzutreiben. Ein besonders wichtiger Einfluss, der sich auf die Erneuerbare Energien Politik auswirkt, sind die politischen Elemente im gegebenen Kontext. Dies beinhaltet internationale Verpflichtungen und insbesondere EU Regelungen.

In der danach folgenden empirischen Analyse stellen wir fest, dass die Länderunterschiede vermutlich einen großen Einfluss auf das Ergebnis hatten. Das wichtigste Resultat der Analyse war, dass die Einspeisevergütung wohl keinen signifikanten Einfluss auf die Biomassekapazität hat. Länder ohne aktive Einspeisevergütung, zeigten demnach eine höhere Kapazität als solche mit aktiver Einspeisevergütung. Dies suggeriert, dass ein anderes politisches Förderinstrument möglicherweise besser geeignet wäre den Anteil an Biomasseenergie zu erhöhen. Wir schlagen eine tiefergehende Analyse vor um die genauen Gründe herauszufinden weshalb die Einspeisevergütung für diese Form Erneuerbarer Energie nicht effektiv zu sein scheint.