WHAT IS THE IMPACT OF DIFFERENT COUNTRIES' NATIONAL POLICIES REGARDING ENERGY TRANSITION ON THESE COUNTRIES' CARBON DIOXIDE (CO2) PRODUCTION? EVIDENCE FROM THE EU.

By

Vladislav Dimitrov 3610497

Alexander Marx 3486303

Marta Scropetta 3480666

rijksuniversiteit groningen

UNIVERSITY OF GRONINGEN

Lecturer: MSc. Peter Perey

Abstract

Purpose: The aim of this research paper is to investigate the impact which different countries' national policies regarding the transition from non-renewable fossil fuels to renewable sources of energy generation has on countries' carbon dioxide (CO2) production.

Design/methodology approach: To observe the national carbon abatement policies' effect of carbon dioxide emissions, we formulated an empirical model estimating the connection between certain policies' presence in EU countries and the changes in carbon dioxide emissions per capita, and per income. We selected three different policy schemes, which were implemented to reduce the CO2 emissions of the energy sector between 2000 and 2018. The sample size used in these studies, included all 27 present-day EU-member state countries.

Findings: The main findings from the conducted study indicate that there is a clear negative relationship between the number of CO2 regulations and the emissions per capita of the energy sector.

Originality value: This research contributes to the stream of literature investigating the effect of national and supra-national policies on the total reduction of CO2 emissions. Additionally, the research paper provides some policy recommendations on what governments can do to reduce CO2 emissions.

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Table of Contents

1. Introduction

The Industrial Revolution created a great deal of positive change in society (Hudson, 2010). Starting in the middle of the 18th century, the Industrial Revolution had a plethora of positive economic and social effects such as an increase in wealth as "goods that had once been painstakingly crafted by hand started to be produced in mass quantities by machines in factories" (History, 2018). However, according to many scientists and researchers (e.g., Albritton Jonsson, 2012), the Industrial Revolution set also the beginning of a process of rising global temperatures. According to Abram, McGregor, Tierney (2016) as human society started to industrialize progressively, especially at the end of the 18th and the beginning of the 19th century, CO2 emissions started to increase due to the intensive burning of fossil fuels needed to meet the constantly increasing energy demand. The present-day evidence of rising global temperatures according to the Intergovernmental Panel on Climate Change (IPCC) which consists of more than 1,300 environmental scientists who provide regular assessments of the scientific basis of climate change are unequivocal (IPCC, 2020).

The planet's average surface temperature has risen about 0.9 degrees Celsius since the beginning of the 20th century (NASA, 2017) with 2016 being the warmest year on record based on independent analyses conducted by the two biggest climate research organizations – the National Aeronautics and Space Administration (NASA) and by the National Oceanic and Atmospheric Administration (NOAA) *(See Figure 1).*

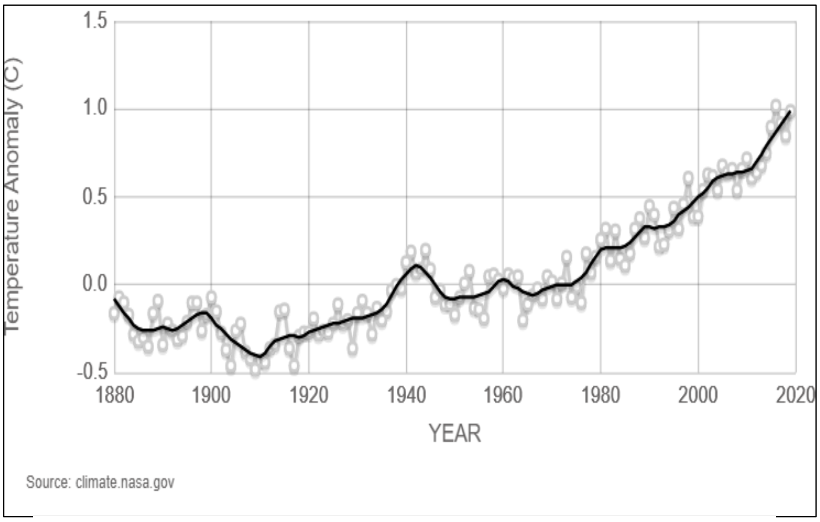


Figure 1: *Illustration of the change in global surface temperature relative to 1951-1980 average temperatures.*

What is more, the rising global sea levels and the shrinking of ice sheets in Antarctica and Greenland are unambiguous evidence for the rising of global temperatures. The higher temperatures lead to the melting of the ice from glaciers and ice sheets, which is one of the most significant contributors to the rising of global sea levels (NASA, 2020). It is estimated

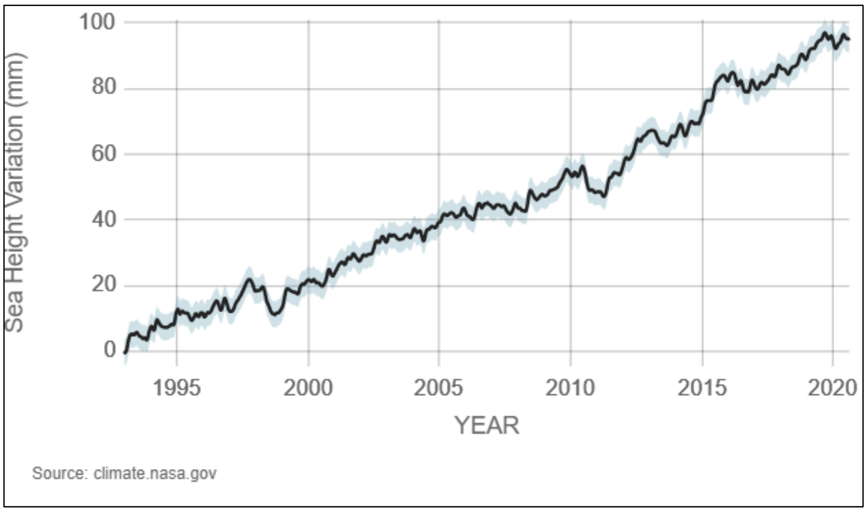


Figure 2: This graph tracks the change in sea level since 1993 as observed by satellites.

that the world sea level is rising on average by 3.3 mm every year *(See Figure 2)* resulting in a total increase of about 10 cm in the last 30 years (NASA, 2020).

Additionally, in 2019, in its annual report, the World Economic Forum identified the biggest risks to humanity's survival in the next fifty years. From nuclear war to super volcanoes and the risk of AI becoming the dominant form of intelligence on our planet, the report categorized climate change as the biggest, scientifically proven risk for humankind in the years to follow (WEF, 2019).

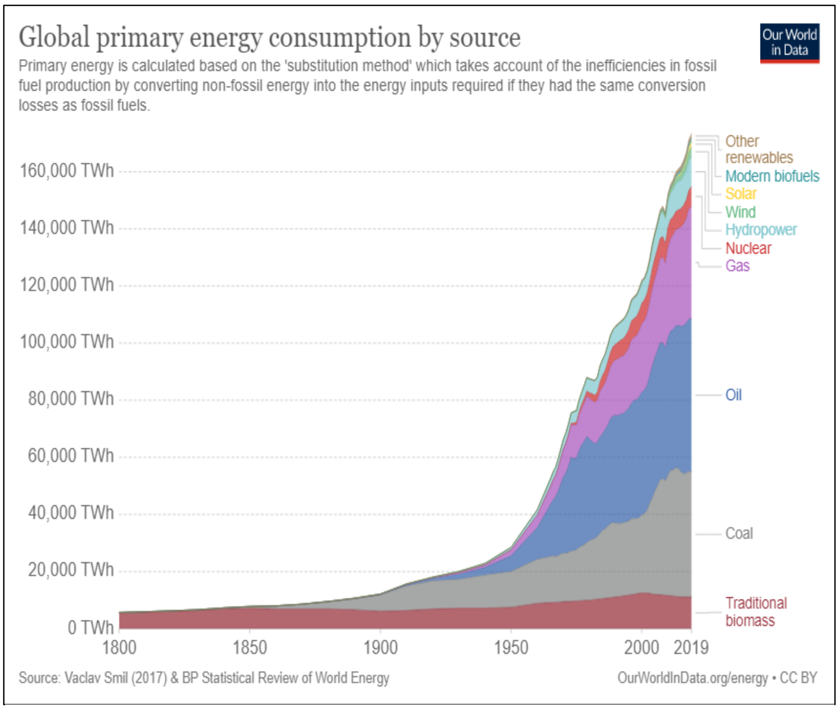


Figure 3: *Global primary energy consumption by source (1800-2019)*

Previous research has found a strong and positive relationship between energy production and economic growth (Stern, 2010; Awodumi & Adewuyi, 2020), implying that when energy is scarce it imposes strong constraints on the growth of a country's economy, but when energy supply is abundant, these constraints are significantly removed, fostering economic growth. However, the main source of energy production in the world remains oil and coal (Smil, 2017), both of which being non-renewable sources with a negative environmental impact *(See Figure 3)*.

As a result, apart from being the main driver of countries' economic growth, energy generation through non-renewable sources of energy such as coal and oil is also the underlying reason behind the rising of global temperatures due to the carbon dioxide that is released into the atmosphere during the burning of fossil fuels (Lindsey, 2020). Consequently, a vicious cycle is created as countries need energy in order to develop and run their economies, non-renewables are used as a main source of energy, carbon dioxide is released, global temperatures are increased to a critical level and a threat to countries' economic and social well-being is posed as for example air pollution is the single largest environmental cause of premature death in the urban parts of the European continent and emissions from coal plants are partly responsible for this, with around 23,000 early deaths every year because of coal burning (Jones et al., 2016)

Therefore, acknowledging the need for decreasing CO2 emissions, through energy transition from non-renewable sources of energy to renewables such as solar energy, wind energy, and hydro energy one of the key pillars of the EU's energy policy is indeed – energy transition or in other words, policies and regulations undertaken to replace non-renewable sources of energy like fossil fuels, with renewable ones (European Commission, 2016). Accordingly, in 2005, the EU set up the *European Trading System* (ETS) according to which companies can receive or buy emission allowances with the ultimate goal of reducing carbon emissions within the EU. The ETS "has proven to be an effective tool in driving emissions reductions cost-effectively" (European Commission, 2016) leading to 35% of emissions from installations covered by the ETS. However, despite the effectiveness of the ETS and the ultimate goal of the EU to increase the EU's greenhouse gas emission reduction target to at least 55% by 2030 and the goal of making Europe the first climate-neutral continent by 2050 (European Commission, 2016), at a national country level within the EU member states, the adopted policies towards energy transition and use of renewable sources of energy are contradictory. For example, European governments continue to provide subsidies to fossil fuels industries totalling 137€ billion a year, with Germany providing the biggest amount of subsidy to fossil fuels industries in absolute values (Ferguson, 2020). Consequently, the countries with the biggest subsidies to fossil fuels (Germany, the UK, Italy, and France) were also the European countries with the most CO2 equivalent air emissions in 2017 (Statista, 2019). Additionally, Germany was below the EU's 20% average share of energy from renewable sources for all EU member states in 2018 (Eurostat, 2018), indicating that despite EU policies regarding energy transition, the country's national policies were in contradiction with the EU's ones and the main source of the country's CO_2 emissions.

Consequently, inspired by the different countries' national policies regarding energy transition or in contradiction to them, the aim of this paper is to investigate the impact which national policies adopted by four EU member states, namely – Germany, Sweden, Poland, and the Netherlands have on these countries' CO_2 emissions. Accordingly, we have formulated our research question in the following way:

What is the impact of different countries' national policies regarding energy transition on these countries' carbon dioxide (CO_2) emissions?

Therefore, the rationale behind our research question is further supported by its relevance, practical implications, and contributions. Firstly, one of the key contributions that stems from answering this research question relates to the investigation of the reasons behind the huge variability in terms of the share of renewables used within the European Union. Answering our research question allow us to identify the reasons why despite the fact that EU regulations and directives are at a supranational level, meaning that they encompass all member states, there are still some bigger than others EU polluters. Additionally, the reported findings could potentially influence countries' policymakers to develop and implement national regulations incentivizing the production of "green energy" by imposing stringent climate policies (e.g., they could potentially increase the taxes on natural gas used for the industry sector). Nevertheless, previous research on energy transition (e.g., Fang, 2011) found that a 1% increase in renewable energy consumption leads to a 0.120% increase in real GDP, a 0.162% increase in GDP per capita, and per capita annual income increase of urban households by 0.368%. Therefore, national regulations stimulating the renewable sources of energy has the potential to increase the overall economic welfare of countries, which has the potential to become a strategic driver towards countries' further economic developing.

The remainder of this paper is organised as follows: Section 2 defines Germany, Sweden, Poland, and the Netherlands in terms of their energy mix and consumption, provided subsidies to fossil fuels, and share of renewables used. Section 3 describes the research's methodology. Empirical tests, results, and findings are discussed in Section 4. Section 5 concludes the paper.

2. Literature Review

2.1. Energy Mix

The main goal of our research is to identify the energy policy measures undertaken by Sweden, Germany, Poland and the Netherlands which contributed to a reduction in their greenhouse gas emissions. The choice of these countries has the purpose to give a wider scope to the research and to provide a clear perspective on the European situation concerning its energy transition in relation to its economic activity. Indeed, it is known that Sweden is by far one of the most advanced countries for green energy while Germany is the strongest economic power in Europe. Poland, instead, seems lagging a bit behind in terms of development and the Netherlands, even though is a quite small country, it is moderately evolved in its technological production.

The production of energy is by far not the only contribution to European greenhouse emissions, however, reducing the CO2 emitted through the production of energy is one of the main objectives of the European Energy Policy (Lenschow, 2002). The topic has been widely discussed in the literature at a country level by the International Energy Agency (IEA) annual reports, yet a cross-country comparison of different practical implications of the European Energy Policy is missing.

In order to grasp a clear idea of the European situation concerning the production of electricity, it is important to analyse both the downside of the fossil fuels reliance and the positive impact that the generation of renewable electricity has created.

As a result, the comparison of the national and European energy policies in the last decade, the carbon emissions, the change in electricity prices, and the renewable energy production follow in the next paragraphs.

2.1.1. Carbon Emissions

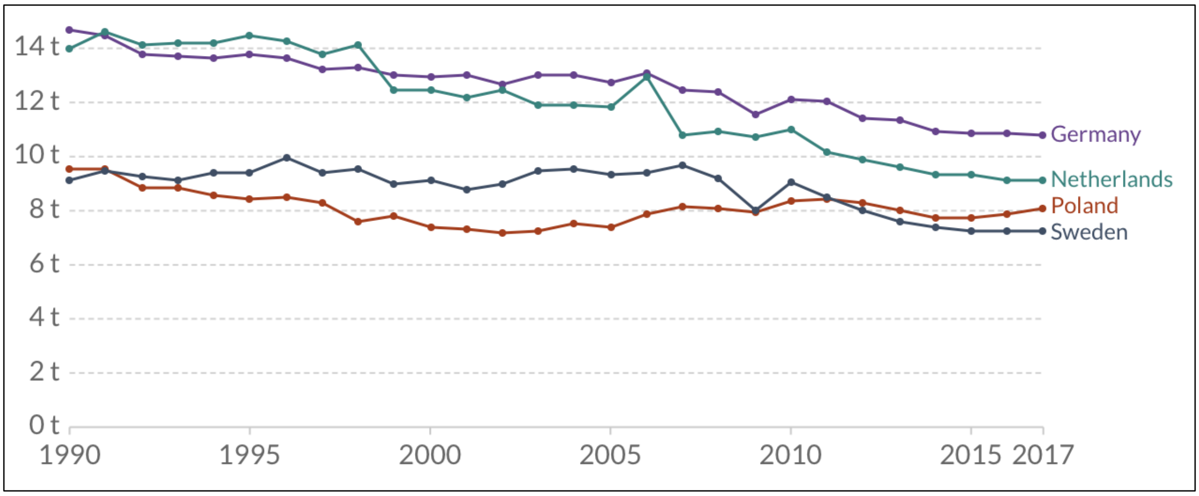


Figure 4: Annual CO2 emissions per capita per country: Germany, *Netherlands, Poland & Sweden (1990-2017). Source: OWID based on Global Carbon Project & UN Population.*

As we have outlined in the introductory part, carbon dioxide emissions are the primary driver of global climate change and they refer to the main downside of the reliance on fossil fuels for energy production. According to Our World in Data, each year there is a European production of Carbon Emissions of over 6 billion metric tons (2020). The generation of these gases is mainly caused by transportation, electricity production and by some industrial processes and activities, such as iron and steel production, machinery production, chemical production.

As shown in Figure 4, in Europe the carbon emissions are different per country, and they mainly depend on the economic structure of the nation (see appendix, Figure 5A). As it could be seen in the graph and, as Clean Energy Wire states, Germany's energy production sector is the largest generator of carbon emissions. Indeed, the country is relying on renewable energy only for 14% of its total consumption, while the rest consists in mineral oil, natural gas, hard coal and nuclear power (Clean Energy Wire, 2019). Additionally, even though Germany is striving to reduce its transportation's emissions of 55% by 2030, the country is, however, still struggling to cut emissions in the transport and heating sectors and is facing a slow-down in the roll-out of renewable energy (Clean Energy Wire). Finally, Germany is highly relying on the automotive, mechanical engineering, chemical and electrical industries to generate growth in its economy.

Sweden has a completely different situation compared to Germany. In fact, it could be seen from Graph 1 that it has been, and it currently is the lowest producer of carbon emissions.

Its policies for environmental protection have set a target to reduce transport emissions by 70% between 2010 and 2030 (IEA, 2019). This might be a quite achievable goal according to the Swedish economic structure. Indeed, its main industries concern the sectors of telecommunications, pharmaceuticals and precision equipment which do not imply a very high emissions' generation (Britannica, 2019). Additionally, Sweden is already relying for its energy consumption by 55% on renewable energy and its transportation system is quite advanced compared to the other European countries (IEA, 2019).

The Polish economy is mainly focused on the industrial sectors concerning agriculture, manufacturing, energy, and tourism industries. For this reason, it might be considered as the least developed one within the analyzed countries. Even though they do not seem highly polluting areas, the Ecologic Institute (2013) stated that emissions from industrial processes increased from 1990 to 2011 by over 30%. Additionally, its transportation system has generated a steady increase of carbon emissions across the years, therefore the electric transport may turn out to be one of the most break-through technologies in the Polish energy sector (IOS-PIB, 2018). However, its share in the energy consumption only accounts for the 5%. A larger impact might be done improving the energy mix and making it more renewable since it is still quite low. A reduced use of coal as energy sources has been observed through time, while the share of energy from renewable energy sources in final gross energy consumption has been systematically growing and in 2016 exceeded 11% (IOS-PIB, 2018).

Finally, the Netherlands is involved in another different context. Its economy is strongly based on the agri-food sector, the information technology and chemicals (Our World in Data, 2019). However, its carbon emissions production is dominated by the burning of fossil fuels for energy production, and industrial production of materials such as cement. In fact, the country relies only for 18% of its energy consumption on renewables (IEA, 2019). Even if the Netherlands does not comprise a very high generation of renewable energy, its transportation system could be defined as one of the greener among European countries (Invest in Holland, 2018). Moreover, the country is very advanced in natural gas production, which is the least polluting fossil fuel. As a result, it has a good potential for lowering even more its carbon emission production.

Overall, the carbon emissions generated in Europe are still quite high, and this does not help the countries to achieve a sustainable target in the long run. Despite the fact that reducing carbon emissions is quite challenging, policy responses have been characterized by delay and caution. Indeed, Humphreys (2007) affirmed that instead of implementing a carbon tax, popular policy options have been framed as Emissions Trading Schemes (ETS) to create a market 'price on carbon'. The negative side of these proposals is that the schemes still ensure the rights to trade carbon.

An additional point could be made on the holistic 'cap-and-trade' schemes described in the Treaty of Lisbon, signed by the European Union, which tries to enforce convergence in the consumption of energy and on CO2 emissions toward the levels in accordance with the Paris agreement (European Union, 2007). These schemes have married ambitious targets of reduced emissions with strongly enforced regulations covering and monitoring all kinds of industrial, agricultural, commercial and residential activities, even though no such ideal scheme actually exists (Gilbertson & Reyes, 2009). However, they have reduced EU emissions by 1 billion tons of CO2 between 2008 and 2016 despite being deemed to be ineffective (Bayer & Aklin, 2020; Laing et. al, 2013). Concerning the discussion of the most efficient energy policies, feed-in tariffs prove to be the most effective than the European Trading Scheme in reducing CO2 emissions (Nicolini & Tavoni, 2017). This raises the question whether the findings of Nicolini and Tavoni (2017) do also provide external validity and whether feed-in tariffs are also effective in countries like Sweden, Poland, Germany and the Netherlands.

2.2. Countries' Energy Mix and Energy Consumption

European countries differ quite a lot in their energy mix composition and consumption (see appendix, Figure 6A). Additionally, large are the differences in the development of energy consumption and therefore of CO2 emissions, which can be explained by the differences in the accumulation of human and physical capital per country (Binswanger et al. 1978, Mulder & Groot 2012). To this concern, Kounetas shows that over the period 1970 to 2010 the EU countries converged towards two distinct patterns of energy consumption and towards two different equilibria of CO2 emissions (2018). These centers of conversion differ along the dimensions of GDP per capita (see Graph 1), climatic and topographic conditions of the countries. Following this pattern, Kounetas gave scope for future and long-term convergence in energy consumption patterns as well as in CO2 emissions.

However, there are many pieces of literature against the general assumption that energy consumption rises with economic growth, indeed, we see a partial decoupling of economic growth and energy consumption in countries with a higher GDP per capita (Grubb et al., 2012). To this concern, various papers have analyzed the data within which one is written by Ozturk and Acaravci (2013) that has proved that an increase in foreign trade to GDP ratio results in an increase in per capita carbon emissions and financial development variable has no significant effect on per capita carbon emissions in the long-term. This finding means that the level of CO2 emissions initially increases with income, until it reaches its stabilization point, then it declines. Nonetheless, the efficiency improvement in CO2 emissions by European countries has been enough to ignore the joint pressure of population and economic growth on CO2 emissions. (Moutinho, Moreira & Silva, 2015).

Another perspective is taken by Liddle (2010) who shows that a country's fuel mix, its economic structure, industrial development and energy efficiency determine energy consumption behaviour. Indeed, it has been proved that the OECD and Eurasian countries have shown considerable, continued convergence, while the Sub-Saharan African countries have converged amongst themselves, but at a slower rate than the OECD and Eurasian countries; by contrast, Latin American and Caribbean and Middle East and North African countries have exhibited no convergence to divergence in energy intensity. In line with this idea, an increasing diffusion and access to more efficient technologies is crucial in inducing less developed European countries to reduce their CO2 emissions (Gonzales, Landajo & Presno, 2014). This idea has also been discussed by Li et al. (2011) who proved the importance of the carbon dioxide capture technology.

A quite relevant aspect that could also be analyzed concerns the change in prices of the energy sources, and its consequential change in its consumption and demand. To this concern, researchers have analyzed the situation regarding specific sources of energy. In fact, Valizadeh et al. (2017) proved that in the Iranian oil industry during the period 1994-2012 the energy prices had a significant and positive effect on energy consumption efficiency. From a similar perspective, Prasolov et al. (2020) found that the value of gas price in European countries does not depend on whether this country is its producer on its territory. However, they proved that there is an inverse relation between the production level of energy resources and the level of economic development. Additionally, Abumunshar et al. (2020) shows that oil price fluctuations have severe effects on the economic performance in Turkey, which in turn affects energy consumption and the level of carbon emissions.

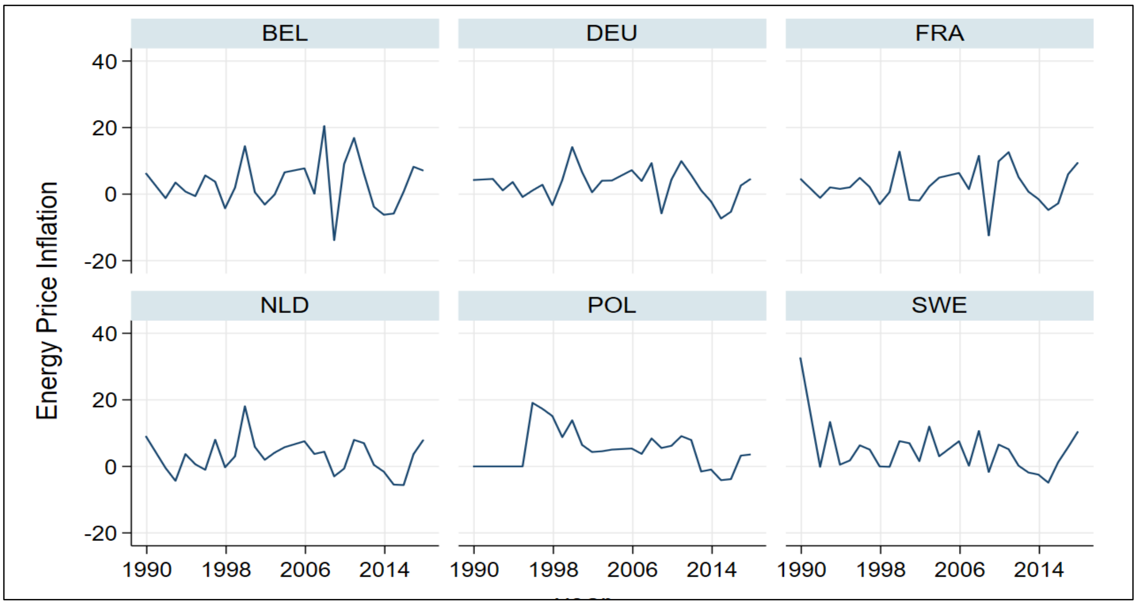


Figure 5*: Energy price in Europe, calculated with energy price inflation data (1990-2018). Source: OECD Database*

As a result, according to the different perspectives that take into account the energy mix, its consumption and price fluctuations, it might be interesting to see if there is a correlation between the change in energy prices, its consequent consumption, and the recent development of the energy policies in Europe. To this concern a study by Ugursal (2011) states that Trinidad & Tobago is further developing and implementing energy policies to reduce its energy consumption while maintaining or improving its economic and socio-economic wellbeing. Similarly, a study has been conducted in China by Sian Leng et al. (2012) who found that through the dynamic linkages between energy consumption and energy R&D, fossil fuel consumption promotes fossil fuel R&D and fossil fuel R&D in turn drives its own consumption. However, researches about this topic and concerning the European context are missing.

2.3.National and European Energy Policies

In this section of our paper, we outline the key national policies of the four countries of our interest, and compare them to the supranational EU policies in an attempt to outline the huge differences between the supranational policies towards renewable sources of energy and the actual policies adopted at a national level.

2.3.1. Germany

To begin with, Germany is the second largest energy producer in Europe only after France and it is the largest energy consumer in Europe (Eurostat, 2017; Energy Information

Administration (EIA), 2016). Despite the country's ambitious goal of generating at least 80% of its total electricity from renewable sources of energy by 2022 (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), 2016), the country still remains the biggest provider of national fossil fuels subsidies. The country has provided fiscal support (e.g., tax exemptions, price reliefs) worth 33.3€ billion (*See Table 1* at the end of this section for a summary between the four countries with regards to the amount of main subsidies provided to the fossil fuels industry) and a total of 2.4€ billion per year of private finance for the period 2014-2016. More than half of the provided subsidies support fossil fuels use in the transport sector (18.9€ billion per year between 2014 and 2016). A total of 2.7€ billion per year (substantially less than the amount of money for supporting the transport sector) between 2014-2016 went as a fiscal support for the coal mining industry, with the goal of supporting the transition away from coal. The country provided additional subsidies to the coal mining industry in terms of exemptions made on water extraction fees for lignite and hard coal which were altogether worth 52€ million in 2014 (OECD, 2015; Küchler and Wronski, 2015). Moreover, 322€ million in 2014 in the form of tax breaks for costs of intermediate inputs for manufacturers of energy products were provided, while oil in the transport sector is heavily subsidised, through tax relief on diesel (almost 8€ billion per year between 2014-2016), and tax relief for fuels used in commercial aviation (more than 7.5€ billion per year in 2016) (Zerzawy et. al., 2017). What is more, under the ETS, CO2 emission allowances have been allocated to installations in the industrial sector free of charge but allowing CO2 producers to pollute at no cost.

As a result, Germany's policies towards energy transition are in contradiction with the EU's supranational policies. For example, in 2010 the commitment to end subsidies to production of hard coal by 2018 became a European Union-wide goal, but the country continued to subsidise the consumption of fossil fuels mainly through tax exemptions. Additionally, the country's national policies are not in line with the commitment which all EU countries have made to the Sustainable Development Goals (SDGs), which highlight phasing out fossil fuel subsidies as a means of implementing Goal 12 to 'ensure sustainable production and consumption patterns' (United Nations (UN), 2015).

2.3.2. Sweden

Contrary to Germany, in Sweden, the share of fossil fuels in electricity generation is very low (about 2.2% in 2015), with fossil fuels being only 30% of the primary energy supply (Zerzawy et. al., 2017). However, despite Sweden's commitment to eliminate completely all types of fossil fuel subsidies, the government still continues to provide incentives to the usage of non-renewable sources of energy. It is noteworthy, however, that in contrast to Germany which publishes regularly a full inventory of its fossil fuel subsidies or any other incentives which are environmentally harmful, Sweden demonstrates lower transparency in terms of systematic reporting regarding the provided fossil-fuel subsidies. Despite the limited transparency, from reports published by the Swedish environmental protection agency, it can be observed that the country's government provides subsidies to fossil fuels. For example, between 2014 and 2016 about €539 million were provided to fossil fuel-base electricity. Besides, the reduced energy tax for diesel used in the transport sector in the country is the biggest subsidy worth a total of €837 million per year between 2014 and 2016. Additionally, natural gas and LPG were also subject to subsidies (e.g., 30% reduction in the CO2 tax rate). Moreover, all fuels used for domestic shipping and aviation were exempted from energy and C02 tax (OECD, 2015). Beyond the electricity and transport sectors, the mining sector together with the agricultural sectors were as also subject to fossil-fuels subsidies. For example, a 70% reduction on the energy tax rate for diesel used for stationary machinery was provided to the mining industry, for a total of €18 million, while a 53% CO2 tax reduction was provided to the agricultural sector for diesel used as a fuel for machinery in agriculture and forestry.

As a result, Sweden's national policies are partially in line with the supranational EU policies towards phasing out "inefficient: fossil fuels subsidies. However, despite the substantial effort into eliminating subsidies to fossil fuels, the Swedish government continuous to provide numerous tax breaks to the consumption of fossil fuels, mainly in the electricity, transport, industry, and agriculture sectors.

2.3.3. The Netherlands

In sharp contrast to Sweden, in the Netherlands fossil fuels continue to be the major source of energy production, with renewables contributing to only 12% of the total energy produced (Central Bureau of Statistics (CBS), 2016a). In the European Union (EU), only Luxembourg and Malta have smaller shares of renewable energy in total energy consumption (Eurostat, 2017). However, similarly to Sweden and in contrast to Germany, the Dutch government does not provide an inventory of its fossil fuel subsidies, nor of its harmful environmental subsidies. However, despite the limited transparency, and the claims of the former Dutch Minister of Economic Affairs Henk Kamp that the Netherlands does not provide any subsidies to fossil fuels, the truth is that the government continues to provide fossil fuel subsidies in the form of fiscal support such as tax breaks, and price and income support. The total amount of fossil fuel subsidies provided per year between 2014 and 2016 was €4.4 billion, with the highest amount of support going to the consumption of fossil fuels in the transport sector (about €3.5 billion per year for the same period). Additionally, fiscal support to oil and gas production worth more than €144 million per year between 2014 and 2016 was provided. Moreover, a tax exemption for the use of coal in electricity production was reintroduced in 2016, after it had been eliminated in 2012 which has been estimated to €189 million in governance revenue forgone per year since the reintroduction (Rijksoverheid, 2015). Nevertheless, the Dutch government has also introduced compensation for energy-intensive industries in order to prevent the potential negative impact which the EU Emissions Trading Scheme might impose on these industries. For the period between 2014-2016, the Dutch government spent an annual average of €50 million on this support (Oxenaar, 2017).

As a result, despite the steps taken towards phasing out fossil fuel subsidies for encouraging the development of non-renewable sources of energy, the country continues to provide substantial fiscal support to the fossil fuel industries with the highest level of budget support provided to consumption in the transport sector. Therefore, despite having made bigger progress towards the phasing out of fossil fuels subsidies compared to Germany, the subsidies provided to non-renewable sources of energy remain the main reason for the country's low share of renewables used for the production of electricity.

2.3.4. Poland

Poland is the second-largest coal producer in Europe, following Germany which is the biggest producer (EIA, 2016). As a result, of the large coal mining sector, nearly 81% of the electricity generation in the country is based on coal which ranks the country as one of the most carbon-intensive of the member countries of the Organisation for Economic Co-operation and Development (OECD, 2015a; 2015b; European Commission, n.d.). Similarly, to Sweden and the Netherlands, the Polish government does not publish an inventory of its fuel subsidies or any other environmentally harmful subsidies. However, from the available reports, it can be seen that subsidies have primarily been provided through state-owned enterprise (SOEs) investment worth a total of €4.5 billion per year for the period between 2014 and 2016. Of this total amount, €2.8 billion per year supported fossil fuel-based energy generation, and €1.4 billion supported oil and gas production. In addition, the Polish government spent €7.5 million on average a year on coal-related research and development. In the transport sector an energy tax relief for diesel is provided in which diesel is taxed at a lower rate compared to gasoline (European Environment Agency (EEA), 2016). Additionally, energy-intensive industries are given a tax exemption on the use of natural gas. Moreover, in the agriculture sector, coal is exempt from excise duty when used in agriculture, fish farming, forestry, and horticulture.

Therefore, despite gradually phasing out some of its coal mining in line with EU commitments, the country continues to subsidise the coal mining industry through investment by state-owned enterprises, mainly in fossil fuel-based power generation and gas production. Energy tax breaks are also provided for fuel consumption by the industry, agriculture, and transport sectors, as well as households.

Table 1: Summary of the main fossil fuels subsidies provided per year for the period 2014-2016

	Germany	**Sweden**	**Netherlands**	**Poland**
Total subsidies	€33.3billion	No data	€4.4 billion	€4.5 billion
Subs. to the transfer sector	€18.9 billion	€837 million	€3.5 billion	€1.2 billion
Coal and mining industry	€2.7 billion	€18 million	No data	€7.5 million
Fossil fuel base electricity	€4.5 billion	€539 million	No data	€2.8 billion
Oil and gas production	€8 billion	€539 million	€144 million	€1.4 billion

2.4. Renewables in Germany, Sweden, Poland and the Netherlands

According to the UNEP, renewable energy is divided in some broad categories, namely the solar, wind, hydro, biomass and geothermal energy. However, biomass got some critics concerning its consideration as a real renewable energy source. The worldwide overall production of renewables has steadily increased in the last five years, according to the International Renewable Energy Agency (IRENA). In fact, as it could be seen in the graph below, there has been a very large growth especially in the solar and wind power respectively of 28.3% and 11.4%. However, a closer look at the European data, shows that the production of renewables is ranked second between the continents with an annual amount of 1298 TWh (IRENA, 2018). The largest share is given by the hydro (578 TWh) and wind energy (384 TWh).

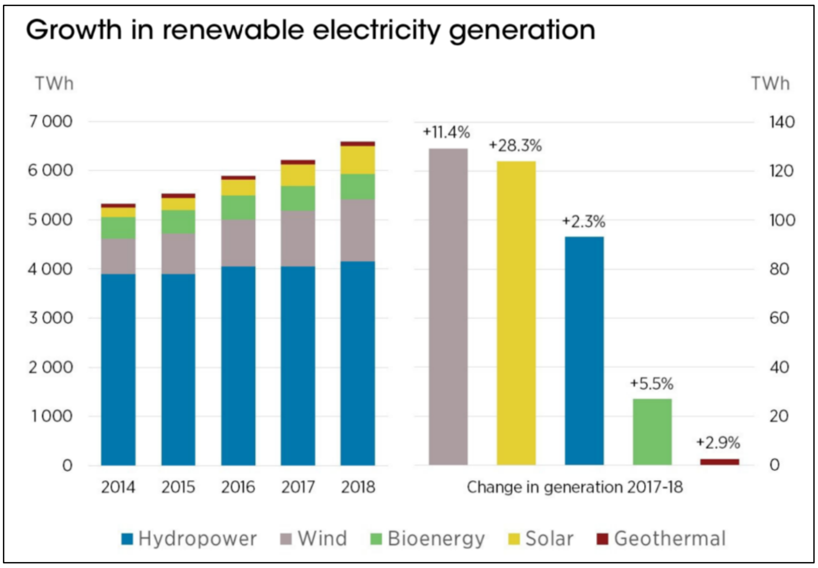


Figure ?: Growth in renewable energy generation (2014-2018). Source: Renewable Energy Statistics 2020, IRENA.

In order to get a more detailed idea of the annual production per country, some additional data are retrieved from the "Renewable Energy Statistics 2020" by IRENA. As it is described in this paper Germany produced more than half of its electricity with renewable power in the first three months of 2020, the first full quarter in which renewables covered the majority of the country's electricity needs. The numbers were driven by record wind and high solar production in February and March and a dip in overall energy use tied to the coronavirus pandemic. As a result, it could be argued that these values might not be considered as a benchmark to look at for future periods.

The scenario in Poland is different. According to Flanders Investments and Trade, Poland is a coal country: over 80% of its electricity comes from either coal or lignite. By 2017, renewables accounted for 14% of electricity generation, mostly from wind energy. The total energy consumption from renewables in 2016 was 11.3%, mostly from biomass.

Sweden with its low carbon economy, instead, is considered the leader in the energy transition by the International Energy Agency (IEA, 2019). IRENA explored the country's four tailor-made solutions to integrate high shares of renewables into the national power system. This complex process, in a few words, consists of combining key innovations in four broad dimensions – enabling technologies, business models, market design and system operation – to tackle different challenges in the power system value chain. In this way, Sweden has been able to generate a power system almost entirely decarbonised, that is based on extensive hydropower resources and nuclear power, as well as biomass energy. In 2017, its electricity production included around 40% hydropower, 39% nuclear, 11% wind power and 10% combined heat and power fueled predominantly by renewable sources (IRENA, 2020).

Finally, the energy scenario in the Netherlands is even more different from the ones already described. In fact, the Netherlands today is currently far behind most other EU countries in the production of energy from renewable sources according to EU Observer (2020). IEA has stated in its analysis that "Natural gas and oil are the most important fuels in the Dutch energy supply. In 2018, TPES came from natural gas (42%), oil (37%), coal (11%), biofuels and waste (5%), and small shares from nuclear, wind, solar, hydropower and geothermal".

Overall, it could be stated that even though there is a large gap in the production of renewables between European countries, the continent is still well positioned worldwide. The different use of the renewable energy in the mentioned countries might affect the carbon emissions production as well as the implementation of the energy policies. In fact, energy efficiency and the use of renewable could be complementary. Lenard (2009) notes that in principle one could achieve a given reduction in fossil fuel use at least cost by allowing electricity suppliers to use energy use reductions to meet RPS requirements. Additionally, Baslalobre-Lorente et. al show that increasing the electricity production from renewable energy sources decreases the CO2 emissions (2018).

3. Empirical Analysis

3.1. Method

To observe the national carbon abatement policies’ effect of carbon dioxide emissions, we formulate an empirical model estimating the connection between certain policies' presence in EU countries and the changes in carbon dioxide emissions per capita, and per income. As described earlier in this report, one of the main goals of the European Union’s energy and policy is to decrease greenhouse gas emissions in electricity generation to mitigate climate change. A key tool for this pursuit is increasing the share of electricity generated from renewable sources and replacing carbon intensive fossil fuels. Liddle & Sadorsky (2017) provided empirical evidence on the significant connection between the increase in the share of electricity generated via renewable sources and greenhouse gas emission reduction using panel data estimation on 93 country samples. Looking at only developed countries (OECD average) they found a long-run displacement elasticity of 0.54 for non-fossil fuel consumption per capita on reducing the subsequent carbon dioxide emissions, and on average higher values for developing and more carbon intensive countries. Nicolini & Tavoni (2017) investigated the effectiveness of different renewable energy subsidies to increase the share of renewable energy sources in electricity generation on a panel data set including the five biggest European countries, by observing the connection between different monetary incentives for renewables and the production of incentivised energy. They classified the policies adopted by these countries into two groups: feed-in tariff and feed-in premium, and tradable green certificates. They find a significantly positive relationship – on average 1% increase in the incentive leads to an increase in renewable generation of 0.4–1%, feed-in tariffs outperforming tradable green certificates. Based on this model, and by assuming a strong connection between the share of non-fossil sources electricity generation and carbon dioxide emissions, we tested the direct connection between national policies aiming at increasing the share electricity generated from renewable sources and changes by time in greenhouse gas emission in the corresponding countries in a country fixed effects model. Our dataset consists of panel data on all the European Union member countries plus Switzerland and Norway between years 2000 and 2018.

In our estimation procedure we apply a simple Difference in Difference Estimation strategy. Which looks as following:

$$\text{Ln Emissions} = \beta_0 + \beta_1 \text{ g(GDP/Capita)} + \beta_2 \text{ GDP/Capita} + \beta_3 \text{Subsidies} + \beta_4 \text{ Sub. Loan \& Debt} + \beta_5 \text{ Emissions Regulation} + \beta_6 \text{ CO2 Price} + \beta_k \text{ Control}_k$$

In our model, the dependent variable of interest *Ln Emissions* is the natural logarithm of per capita carbon dioxide emissions of the energy sector, obtained from using emissions data from OECD and population data from the World Bank.

The first group of dependent variables *g(GDP/Capita)* and *GDP/Capita* denote the environmental Kuznets curve. The environmental Kuznets predicts that low-income countries with higher growth rates may devote less attention to environmental protection than richer countries with a higher GDP (Sun, 1999). This Kuznets curve has been especially evident across Western and Easter European countries (Atici, 2009). Additionally, we expect that even high-income countries emissions are dependent on economic growth (Ali & Ozturk, 2010). Therefore, we include both variables in our equation to derive the extent to which extend differences in GDP and economic growth explain the deviations in emissions per capita.

Our main variable of interest is the impact of different subsidy schemes on emissions per capita.We selected three different policy schemes, which were implemented to reduce the CO2 emissions of the energy sector between 2000 and 2018. Feed-in tariffs, which we denote as Subsidies, are the subsidies paid to the energy sector to induce the adoption of renewable energy sources. The level of the subsidies is scalded by the GDP per capita of each country and normalized. The dummy variable Sub. Loan & Debt are policies support the financing of new renewable energy sources with below market interest rates. The dummy variable *Emissions Regulation* obligates the energy sector to either increase the share of renewable energy sources or reduce emissions (NewClimate Institute, 2020). To capture the possibility that multiple policies of the same type could be in place at the same time, the dummy variables represent the number of the respective policies in place in a given year.

There are also a wide range of determinants of CO2, which are included in our regression as control variables. We add the CO2 emissions price, which has been proven to reduce emissions emitted by firms but is inherently inefficient due to its low price on carbon dioxide (Abrell, Ndoye Faye & Zachmann, 2011). The energy intensity measures the amount of total electricity consumed relative to the GDP and is positively associated with higher emissions (Liaskas et. al., 2000). Furthermore, negative supply side shocks which increase the price of electricity usually reduce the emissions in any given year (Marrero, 2010). By including *Hydro Power Prod,* we include the amount of energy produced by hydropower stations. For countries like Sweden, Norway, Austria and Switzerland hydropower is one of the biggest energy sources without producing any CO2 emissions (Lehner, Czisch & Vassolo, 2005). However, the amount of electricity that can be produced with hydropower fluctuates depending on the rain and snowfall and decreases with rising temperatures (Koch et al, 2011; Hamududu & Killingtveit, 2012). *Prod Cost Windpower* controls for the falling levelized costs of onshore wind power generation, which allows for larger scale up of windmills at the same cost and has been shown to be a major contributor of rising renewable energy production (Sims, Rogner & Gregory, 2003). Finally, *oil* captures the global oil price, which is a substitute for renewable energies and thus a decreasing oil price raises each country's CO2 emissions (Sadorsky, 2009).

The final control variables model the country's economic structure and fiscal conditions. *GFCF/ Capita,* the Gross Fixed Capital Accumulation per Capita, represents the investment in fixed capital in the overall economy. This variable often identifies the investment in new technologies. Alqaralleh shows that higher investment in new technologies is associated with lower CO2 emissions (2020). *VA Agriculture/GDP* and *VA Manufacturing/GDP* indicate the share of value added produced in the agricultural sector and manufacturing sector. Crop production as well as live-stock farming and manufacturing activities are both related to higher CO2 emissions while service while the direct emissions stemming from the service is sector is relatively low (Diakoulaki & Mandaraka, 2007; Alcántara & Padilla, 2009; Garnett, 2009; Bennetzen, Smith & Porter, 2016). Therefore, countries with a larger service sector may emit less CO2 due their economic structure. Finally, countries with higher public debt may pay lower subsidies and have less CO2 regulations in place than other countries. To control for an omitted correlation between the two variables we also include the level of public debt relative to GDP in our data.

3.2. Data

As our independent variables we used the carbon dioxide emission prices in the ETS, accessed from the site of the European Environmental Agency, and dummy variables on four types of policies promoting the use of renewable energy. The dummy variables indicate, whether a subsidy and loan policy or an environmental regulation promoting the use of renewable energies is in place. Each dummy represents how many policies are in place at a given year. The data on these dummy variables were obtained from the NewClimate policy database by the NewClimate Institute, with the typology of policy instruments based on the IEA policies and measures database. In this typology, the four dummy variables represent the following. Feed-in tariffs refer to policies, where governments guarantee access to the electricity grid, and offer a either a fixed price or premium over the market price for electricity produced via renewable sources.

The data provided by the OECD on RES tariffs shows the large variation in subsidy schemes and regulations in place albeit the common EU target to reduce emissions. Belgium, Germany and France and the Netherlands introduced a subsidy scheme very early, Sweden at a later stage and Poland has until now not introduced any subsidy scheme. Additionally, we can see that Germany and Belgium pay the highest subsidy while Sweden pays the lowest subsidy in terms of cents per kilo-watt.

According to the data from the Climate Change policy database, France has the most regulations on emission in place at any given moment, followed by Germany and Belgium, while the Netherlands, Poland and Sweden have avoided putting strict regulations into place. Furthermore, in Belgium, France and Germany regulations have been put in place over the entire time-frame of our analysis.

	BEL	DEU	FRA	NLD	POL	SWE
Emissions per 100000 habitants	435.38	435.38	85.87	395.59	452.17	111.08
Subsidies	17.78	17.78	14.44	12.50	0.00	1.83
Years Subsidy is in place	16.00	16.00	13.00	15.00	0.00	3.00
Emissions Regulation	5.72	5.72	6.72	0.00	0.00	0.00
Years Regulation in place	18.00	18.00	18.00	0.00	0.00	0.00
Sub. Loan & Debt	6.61	6.61	3.56	0.00	0.00	0.72
Years of Loan & Debt Finance	18.00	18.00	17.00	0.00	0.00	13.00
Observations	18	18	18	18	18	18

The table shows the emissions per 100.000 habitants, the average value of subsidies, their duration, the average number of regulation and loan & debt policies in place at a given moment in time and their average duration.
All calculations are done by the author.
Data retrieved from the World Bank, OECD, IMF, Climate Change Policy Database, IRENA Rewnewable Energy Database & IEA.

Figure 6: Overview of Policies relevant policies targeting the Energy Industr**y** according to the New Climate Policy Database.

Moreover, those countries, which put emission regulation in place, supported these regulations with additional subsidies for loan and debt financing. Unfortunately, the exact amount of support in loan and debt financing is unobservable and therefore we only measured the number of loan and debt financing policies in place at a given amount of time.

4. Results

The regression results indicate that there is a clear negative relationship between the number of CO2 regulations and the emissions per capita of the energy sector. This relationship is robust to the random effects estimation, however, its significance weakens when we allow for random intercepts. Technically speaking, if we add one more regulation in any given year to the energy sector, we could reduce the emissions per capita by 2% with about a 95% level of confidence.

Furthermore, over the period of observation a reduction in cost of offshore wind turbines reduce the emissions per capita. Likewise, the effect of emission regulations on emissions, this effect is significant and robust to the introduction of random effects. Therefore, a reduction in the production costs of the levelized costs of onshore wind turbines by about leads approximately to a decrease of emissions by 0.1%. The ceteris paribus relationship between Emissions and regulation and subsidies is pictured in Figure 8.

Remarkably, is that the introduction of feed-in tariffs and the subsidizing loans and debts for the investment in renewable energy sources have yet not reduce the emissions per capita. This may be due to either low value, their short duration, which leaves the investor with a lot of uncertain or because they are mostly used for long-term investment productions which have yet not been built and set up.

Figure 7: Regression Results of Ln Emissions per capita on different Policies

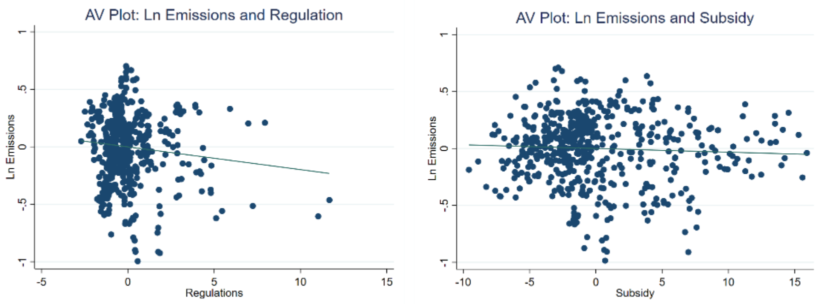
	OLS	OLS	RE
Gowth GDP/Capita	-0.296	6.178	5.319
	(29.232)	(12.824)	(6.543)
GDP/Capita	-11.861***	-6.114***	-3.712
	(2.891)	(1.632)	(2.885)
Subsidies	-0.001	-0.006***	-0.001
	(0.004)	(0.002)	(0.001)
Sub. Loan & Debt	0.096***	0.069***	0.016
	(0.033)	(0.015)	(0.014)
Emissions Regulation	-0.095***	-0.054***	-0.020**
	(0.027)	(0.012)	(0.008)
CO2 Price	-0.003	-0.002	-0.003*
	(0.006)	(0.003)	(0.001)
Energy Intensity		-1.858***	-0.666*
		(0.503)	(0.359)
Electricity Price		0.001	0.000
		(0.002)	(0.001)
Hydro. Power Prod.		0.000	-0.000**
		(0.000)	(0.000)
Prod. Cost Wind Power		0.001***	0.001***
		(0.000)	(0.000)
Oil Price		-0.000	0.000
		(0.001)	(0.000)
GFCF/Capita		0.000***	0.000**
		(0.000)	(0.000)
VA Agriculture/GDP		0.000	-0.000
		(0.000)	(0.000)
VA Manufacturing/GDP		-0.000***	-0.000
		(0.000)	(0.000)
Public Debt/GDP		0.002***	-0.002***
		(0.001)	(0.001)
Emissions in 1999		355.193***	299.543***
		(10.227)	(38.142)
Adjusted R^2	0.067	0.852	
Observations	391	391	391

levels of significance * 0.1 ** 0.05 *** 0.01

All calculations are done by the author.

Data retrieved from the World Bank, OECD, IMF, Climate Change Policy Database, IRENA Rewnewable Energy Database & IEA

Figure 8: Overview of Policies relevant policies targeting the Energy Industr**y** according to the New Climate Policy Database.



5. Conclusion

So, having outlined the results and limitations of our paper, in the lines that follow, we provide some applicable recommendations towards policy makers on what policies they can adapt and support in order to achieve the goal of decreasing CO2 emissions further. To begin with, based on the results from the conducted analysis, we found that emissions regulation is a significant way of reducing carbon dioxide emission, so based on this finding we recommend policy-makers to focus their attention on the development of more stringent regulations towards CO2 emission. On the other hand, we also found that subsidies to renewable source of energy proved to be significantly inefficient way of reducing emissions, so based on this finding we recommend policy makers to reduce the total amount of money spend for subsidizing the renewables energy sector, and to relocate this money on the development of emissions regulations as we outlined above. Finally, a bit of more of a specific recommendation is that policy makers should take actions towards the reduction of the total cost of energy produced through wind turbines, as we found that cost reduction in wind production has the biggest positive effect on decreasing the total amount of emissions. Therefore, we firmly believe that by implementing these three key recommendations stemming from our research, countries will be able to decrease the total amount of CO2 emissions released in the atmosphere by reducing their environmental footprint, and by aligning their national policies with the EU's supranational policies and goals.

6. References

Abrell, J., Ndoye Faye, A., & Zachmann, G. (2011). *Assessing the impact of the EU ETS using firm level data* (No. 2011/08). Bruegel working paper.

Abumunshar, M., Aga, M. & Samour, A. (2020). Oil Price, Energy Consumption, and CO2 Emissions in Turkey. New Evidence from a Bootstrap ARDL Test. Department of Accounting and Finance, Faculty of Economics and Administrative Sciences

Acaravci, A., & Ozturk, I. (2010). On the relationship between energy consumption, CO2 emissions and economic growth in Europe. *Energy*, *35*(12), 5412-5420.

Alcántara, V., & Padilla, E. (2009). Input–output subsystems and pollution: An application to the service sector and CO2 emissions in Spain. *Ecological Economics*, *68*(3), 905-914.

Alqaralleh, H. (2020). On the nexus of CO2 emissions and renewable and nonrenewable energy consumption in Europe: A new insight from panel smooth transition. *Energy & Environment*, 0958305X20937687.

Atici, C. (2009). Carbon emissions in Central and Eastern Europe: environmental Kuznets curve and implications for sustainable development. *Sustainable Development*, *17*(3), 155-160.

Bennetzen, E. H., Smith, P., & Porter, J. R. (2016). Decoupling of greenhouse gas emissions from global agricultural production: 1970–2050. *Global change biology*, *22*(2), 763-781.

Bayer, P., & Aklin, M. (2020). The European Union emissions trading system reduced CO2 emissions despite low prices. *Proceedings of the National Academy of Sciences*, *117*(16), 8804-8812.

Binswanger, H. 164418P.; Ruttan, V. W.; Ben-Zion, U.; Janvry, A. de; Evenson, R. E. (1978): Induced innovation; technology, institutions, and development: Baltimore, Md. (USA) Johns Hopkins Univ. Press.

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., & Farhani, S. (2018). How economic growth, renewable electricity and natural resources contribute to CO2 emissions?. *Energy Policy*, *113*, 356-367.

Britannica (2019). Sweden. Retrieved from: https://www.britannica.com/place/Sweden/Economy

Buchholz, K. February 2020. *Rising Sea Levels Will Threaten 200 Million People by 2100*, Retrieved from: https://www.statista.com

Clean Energy Wire (2019). Germany's greenhouse gas emissions and energy transition targets. Retrieved from: https://www.cleanenergywire.org/factsheets/germanys-greenhouse-gas-emissions-and-climate-targets

Diakoulaki, D., & Mandaraka, M. (2007). Decomposition analysis for assessing the progress in decoupling industrial growth from CO2 emissions in the EU manufacturing sector. *Energy Economics*, *29*(4), 636-664.

Ecologic Institute (2013). Assessment of climate change policies in the context of the European Semester - Country Report: Poland. Retrieved from: https://ec.europa.eu/clima/sites/clima/files/strategies/progress/reporting/docs/pl_2014_en.pdf

European Union (2007). Consolidated versions of the Treaty on European Union and the Treaty on the functioning of the European Union. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:12016ME/TXT&from=EN

Flanders Investments & Trade (2019). Renewable Energy in Poland. Retrieved from: https://www.flandersinvestmentandtrade.com/export/sites/trade/files/market_studies/2019-Poland-Renewable_Energy.pdf

Garnett, T. (2009). Livestock-related greenhouse gas emissions: impacts and options for policy makers. *Environmental science & policy*, *12*(4), 491-503.

González, P. F., Landajo, M., & Presno, M. J. (2014). The driving forces behind changes in CO2 emission levels in EU-27. Differences between member states. *Environmental science & policy*, *38*, 11-16.

Grubb, M., Muller, B. & Butler, L. (2012). The relationship between carbon dioxide emissions and economic growth. Department of Applied Economics, Cambridge University.

Hamududu, B., & Killingtveit, A. (2012). Assessing climate change impacts on global hydropower. *Energies*, *5*(2), 305-322.

Humphreys, John (2007) Exploring a Carbon Tax for Australia, CIS Policy Monograph 80 — Perspectives on Tax Reform (14), St Leonards: The Centre for Independent Studies.

International Energy Agency (IEA) (2019). Climate change: The energy sector is central to efforts to combat climate change. Retrieved from: https://www.iea.org/topics/climate-change

Institute of Environmental Protection & National Research Institute (IOS-PIB) (2018). Actions and challenges for climate protection in Poland – brief overview. Retrieved from: https://cop24.gov.pl/fileadmin/user_upload/files/2._Brief_overview.pdf

Intergovernmental Panel on Climate Change (IPCC), 2019. Retrieved from: https://www.ipcc.ch

International Renewable Energy Agency (IRENA), 2020. Renewable energy highlights

International Renewable Energy Agency (IRENA), 2020. INNOVATIVE SOLUTIONS FOR 100% RENEWABLE POWER IN SWEDEN. Retrieved from: https://www.irena.org/-

/media/Files/IRENA/Agency/Publication/2020/Jan/IRENA_Sweden_Innovative_power_2020.pdf

Invest in Holland (2018). How the Dutch lead in Sustainability: Transportation, energy and buildings are all greener in the Netherlands. Retrieved from: https://investinholland.com/news/dutch-lead-sustainability/

Koch, F., Prasch, M., Bach, H., Mauser, W., Appel, F., & Weber, M. (2011). How will hydroelectric power generation develop under climate change scenarios? A case study in the Upper Danube basin. *Energies*, *4*(10), 1508-1541.

Laing, T., Sato, M., Grubb, M., & Comberti, C. (2013). *Assessing the effectiveness of the EU Emissions Trading System* (Vol. 126). London, UK: Grantham Research Institute on Climate Change and the Environment.

Lehner, B., Czisch, G., & Vassolo, S. (2005). The impact of global change on the hydropower potential of Europe: a model-based analysis. *Energy Policy*, *33*(7), 839-855.

Lenard, Thomas. 2009. Renewable electricity standards, energy efficiency, and cost-effective climate-change policy. Technology Policy Institute. Available at: http://www.techpolicyinstitute.org/files/renewableej.pdfS

Lenschow, Andrea (Hg.) (2002): Environmental policy integration. Greening sectoral policies in Europe. London, Sterling, VA: Earthscan Publications.

Li et al. (2011). Carbon Dioxide Capture Technology. Journal of Applied Economics

Liaskas, K., Mavrotas, G., Mandaraka, M., & Diakoulaki, D. (2000). Decomposition of industrial CO2 emissions:: The case of European Union. *Energy Economics*, *22*(4), 383-394.

Liddle, Brantley (2010): Revisiting world energy intensity convergence for regional differences. In: *Applied Energy* 87 (10), S. 3218–3225. DOI: 10.1016/j.apenergy.2010.03.030

Liddle, Brantley; Perry Sadorsky (2017): “How Much Does Increasing Non-Fossil Fuels in Electricity Generation Reduce Carbon Dioxide Emissions?” Applied Energy 197 (2017): 212–21

Lindsey, R. (2020, August 14). Climate Change: Atmospheric Carbon Dioxide | NOAA Climate.gov. Retrieved from Climate.gov website: https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

Kounetas, Konstantinos Elias (2018): Energy consumption and CO2 emissions convergence in European Union member countries. A tonneau des Danaides? In: *Energy Economics* 69, S. 111–127. DOI: 10.1016/j.eneco.2017.11.015.

Marrero, G. A. (2010). Greenhouse gases emissions, growth and the energy mix in Europe. *Energy Economics*, *32*(6), 1356-1363.

Moutinho, V., Moreira, A. C., & Silva, P. M. (2015). The driving forces of change in energy-related CO2 emissions in Eastern, Western, Northern and Southern Europe: The LMDI approach to decomposition analysis. *Renewable and Sustainable Energy Reviews*, *50*, 1485-1499.

Mulder, Peter; Groot, Henri L.F. de (2012): Structural change and convergence of energy intensity across OECD countries, 1970–2005. In: *Energy Economics* 34 (6), S. 1910–1921. DOI: 10.1016/j.eneco.2012.07.023.

National Aeronautics and Space Administration (NASA). 2017. *NASA Global Warming from 1880 to 2019*. Retrieved from: https://climate.nasa.gov

National Aeronautics and Space Administration (NASA). 2020. *NASA Sea Level Change*. Retrieved from: https://climate.nasa.gov

National Geographic (January, 2019) *Causes and Effects of Climate Change.* Retrieved from: https://www.nationalgeographic.com

National Oceanic and Atmospheric Administration (NOAA). January 2018. *Costliest U.S. tropical cyclones tables updated*, Retrieved from: https://www.nhc.noaa.gov

New Climate– Institute for Climate Policy and Global Sustainability (2020). New Climate Database. Retrieved from: http://climatepolicydatabase.org/index.php/Download_policies (01.12.2020).

Nicolini, Marcella; Tavoni, Massimo (2017): Are renewable energy subsidies effective? Evidence from Europe. In: *Renewable and Sustainable Energy Reviews* 74, S. 412–423. DOI: 10.1016/j.rser.2016.12.032.

Prasolov, V., Bezpalov, V., Dokuchaeva, S. & Rougulin, R. (2020). Energy Price Formation and Energy Consumption by Households as a Factor of Ensuring Energy Safety. International Journal of Energy Economics and Policy. 2020;10(5):82-93

Sadorsky, P. (2009). Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. *Energy Economics*, *31*(3), 456-462.

Sian Leng, W., Wai-Mun, C. & Youngho, C. (2012). Energy consumption and energy R&D in OECD: Perspectives from oil prices and economic growth. Division of Economics, School of Humanities and Social Sciences, Nanyang Technological University. Energy Policy 62 (2013) 1581–1590

Sims, R. E., Rogner, H. H., & Gregory, K. (2003). Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation. *Energy policy*, *31*(13), 1315-1326.

Sun, J. (1999). The nature of CO2 emission Kuznets curve. *Energy policy*, *27*(12), 691-694.

Ugursal, V. I. (2011). Energy use and changing energy policies of Trinidad and Tobago. Journals & Books. Volume 39, Issue 10, October 2011, Pages 5791-5794

Valizadeh, J., Habibollah, E. S. & Hanieh Davodi, E. (2017). The effect of energy prices on energy consumption efficiency in the petrochemical industry in Iran. Alexandria Engineering Journal. Alexandria University.

World Economic Forum (WEF), 2019. Retrieved from: http://www3.weforum.org

Albritton Jonsson, F. (2012). The Industrial Revolution in the Anthropocene. The Journal of Modern History, 84(3), 679–696. https://doi.org/10.1086/666049

Hudson. (2010). The British industrial revolution in global perspective - By Robert C. Allen. The Economic History Review, 63(1), 242–245. https://doi.org/10.1111/j.1468-0289.2009.00511_7.x

CBS (2016a). Elektriciteitsproductie uit steenkool opnieuw hoger. The Hague: Central Bureau forStatistics.(https://www.cbs.nl/nl-nl/nieuws/2016/26/elektriciteitsproductie-uit-steenkool-opw-hoger).

Rijksoverheid (2015) 'Belastingplan 2016'. The Hague: Rijksoverheid. (https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/kamerstukken/2015/09/15/belastingplan-2016/bp-2016-wetsvoorstel.pdf)

Oxenaar, S. (2017) Mapping the financial and organizational interdependencies between the Dutch State and the fossil fuel industry. Rotterdam: DRIFT. (https://www.drift.eur.nl/publications/interdepencencies-government-fossil-fuel-industry/)

7. Appendix

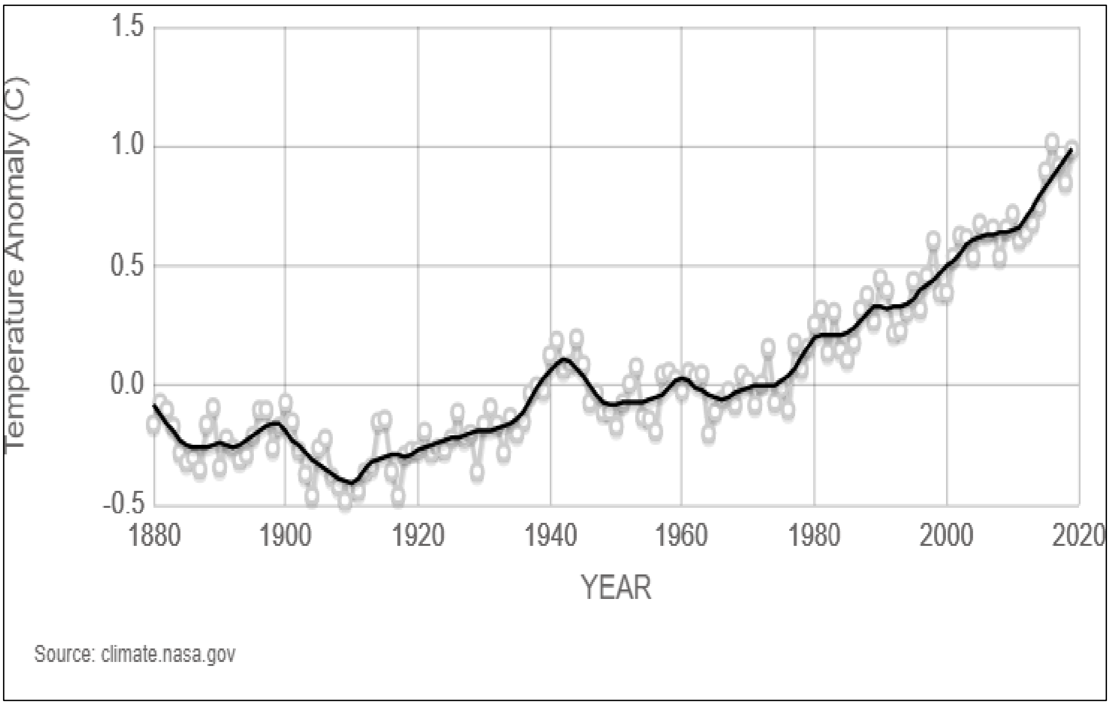


Figure 6A: Illustration of the change in global surface temperature relative to 1951-1980 average temperatures

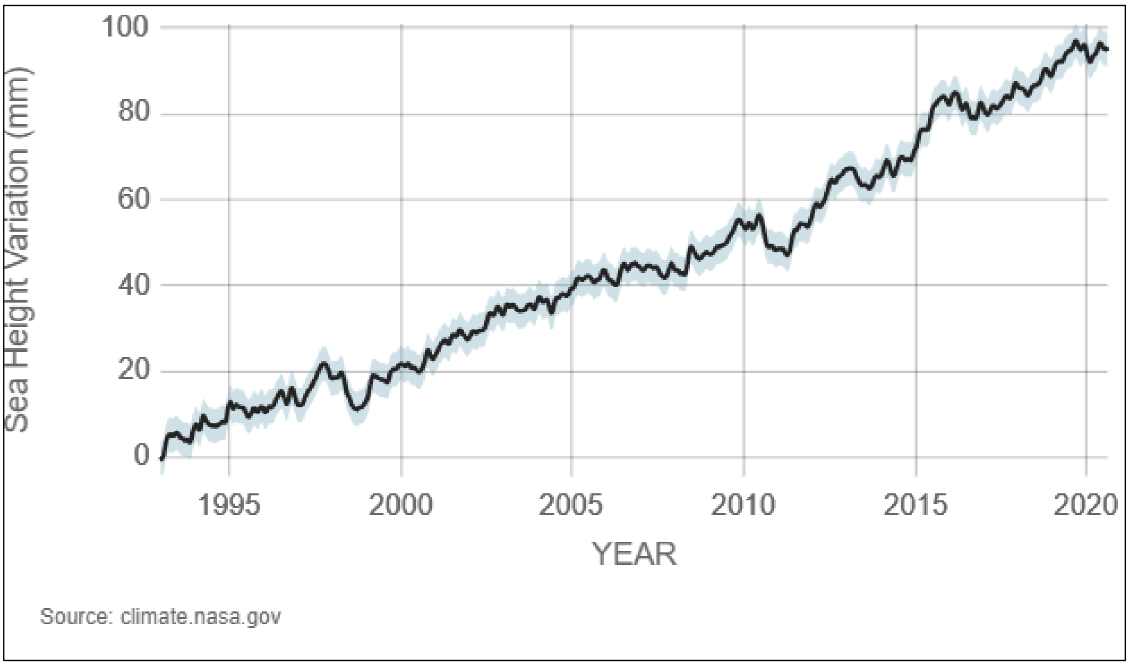


Figure 7A: This graph tracks the change in sea level since 1993 as observed by satellites.

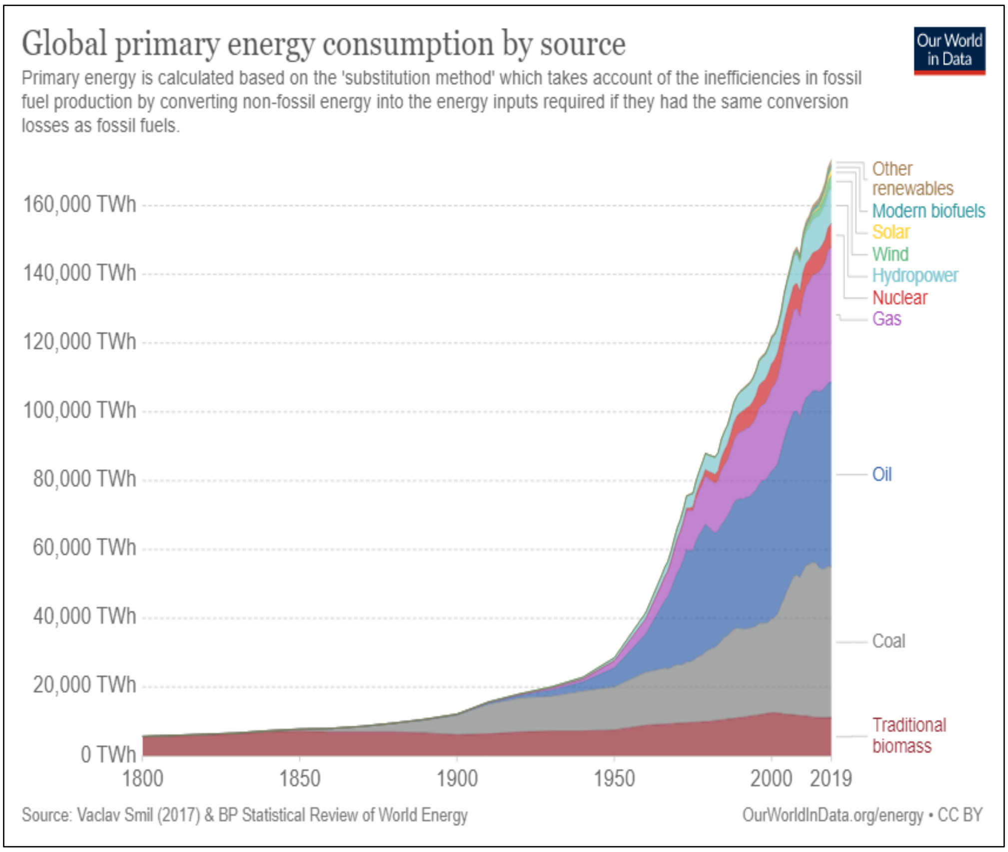


Figure 8A: Global primary energy consumption by source (1800-2019)

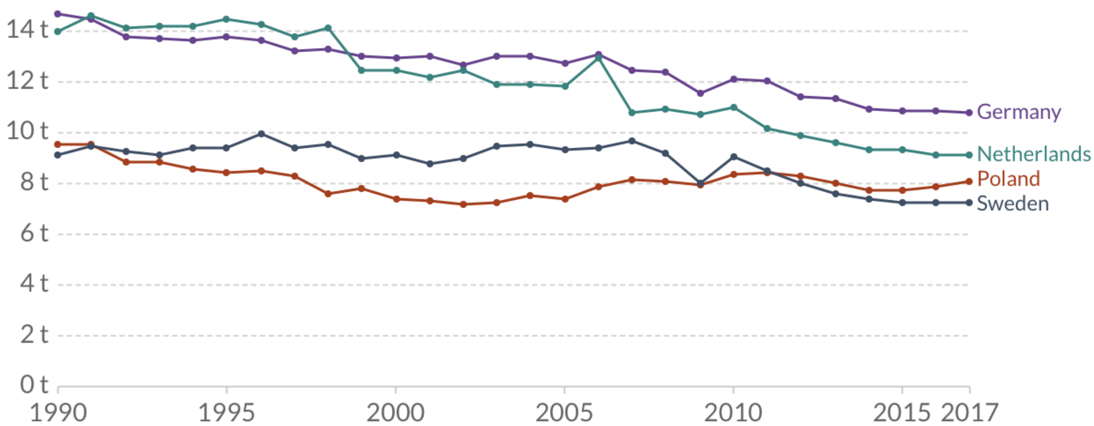
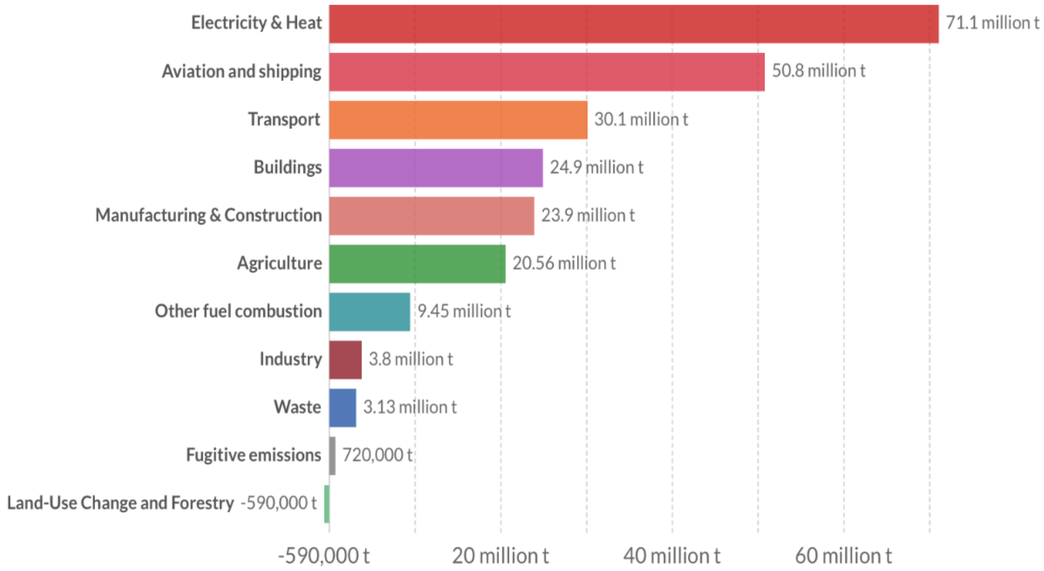
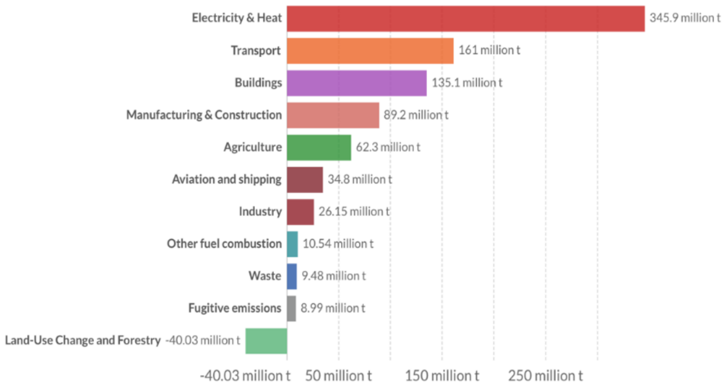


Figure 9A: Annual CO2 emissions per capita per country: Germany, Netherlands, Poland & Sweden (1990-2017). Source: OWID based on Global Carbon Project & UN Population.

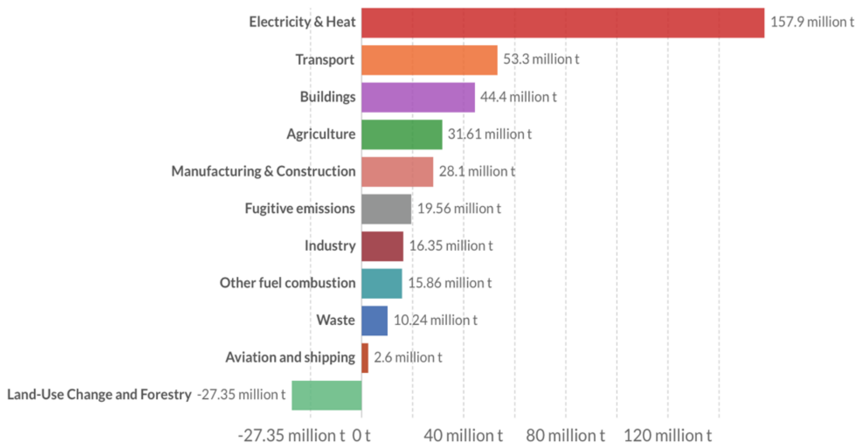
Netherlands



Germany



Poland



Sweden

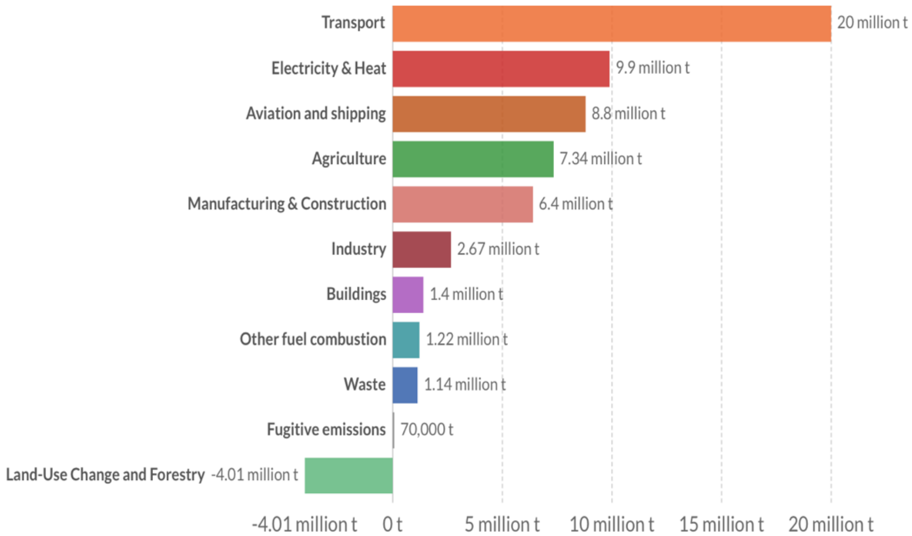
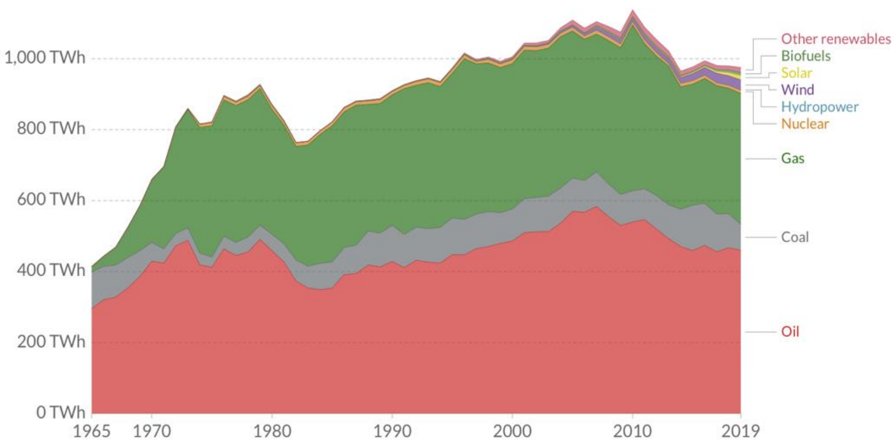
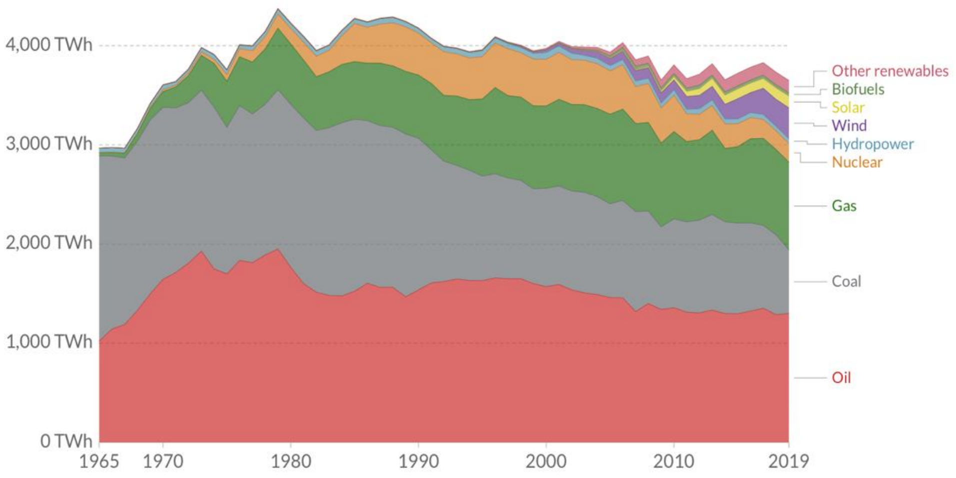


Figure 5A: Gas Emission by sector per country: Netherlands, Germany, Poland, Sweden (2017). Source: Climate Data Explorer via. Climate Watch.

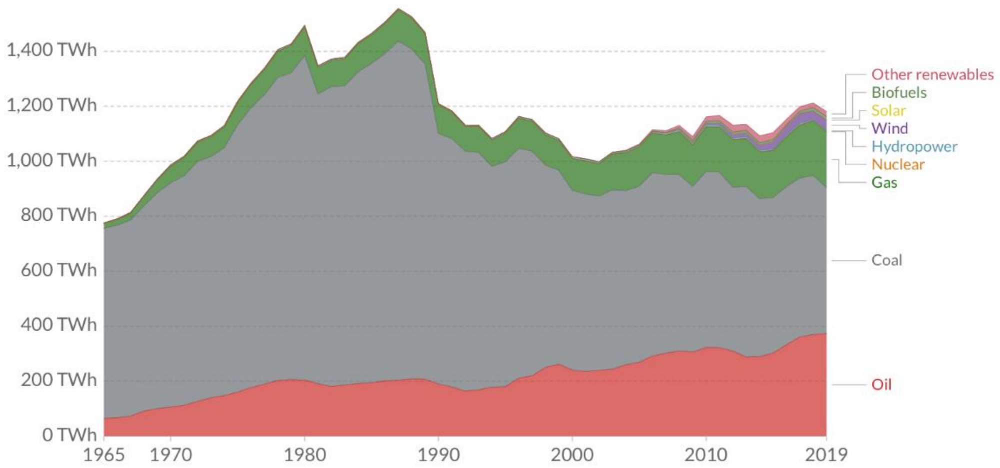
Netherlands



Germany



Poland



Sweden

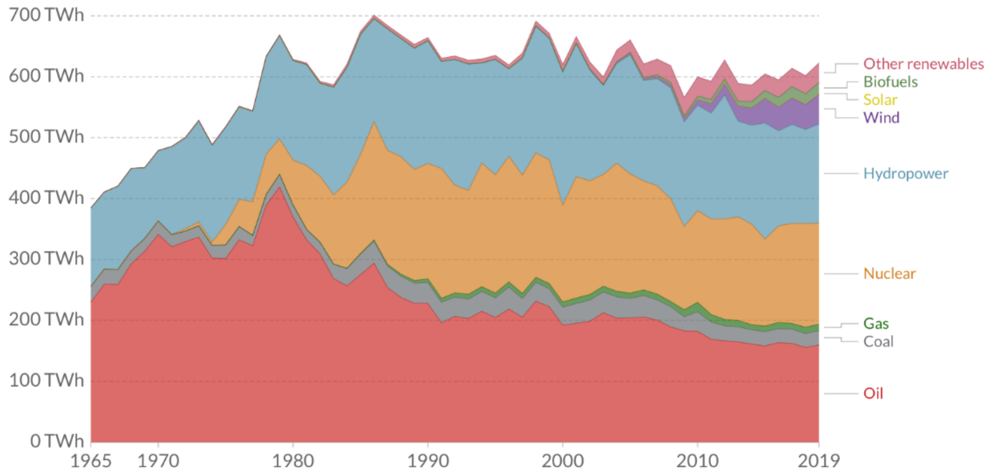


Figure 6A*:* Energy consumption by source per country: Netherlands, Germany, Poland, Sweden (1965-2009). Source: BP Statistical Review of World Energy.

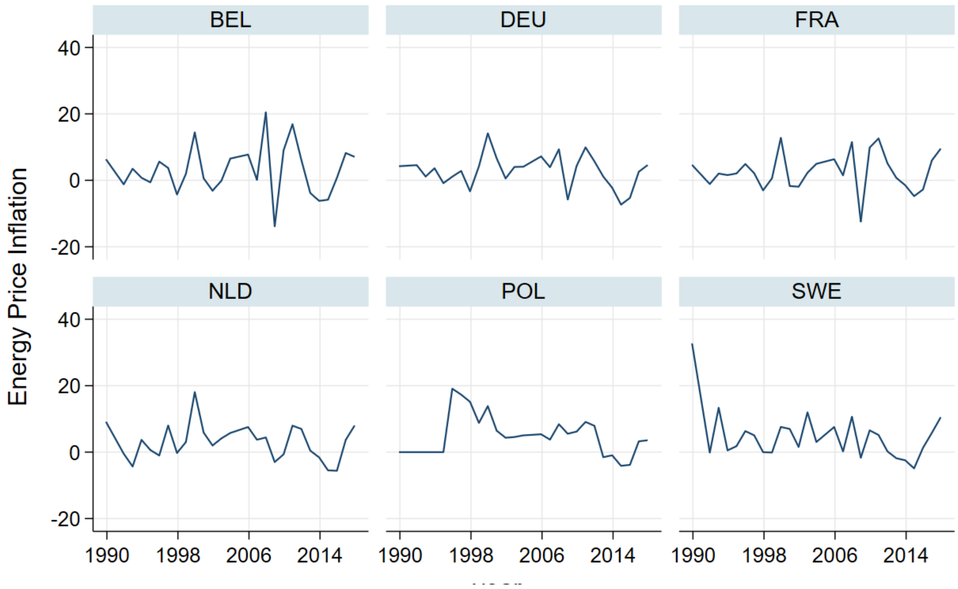


Figure 7A: Energy price in Europe, calculated with energy price inflation data (1990-2018). Source: OECD Database.

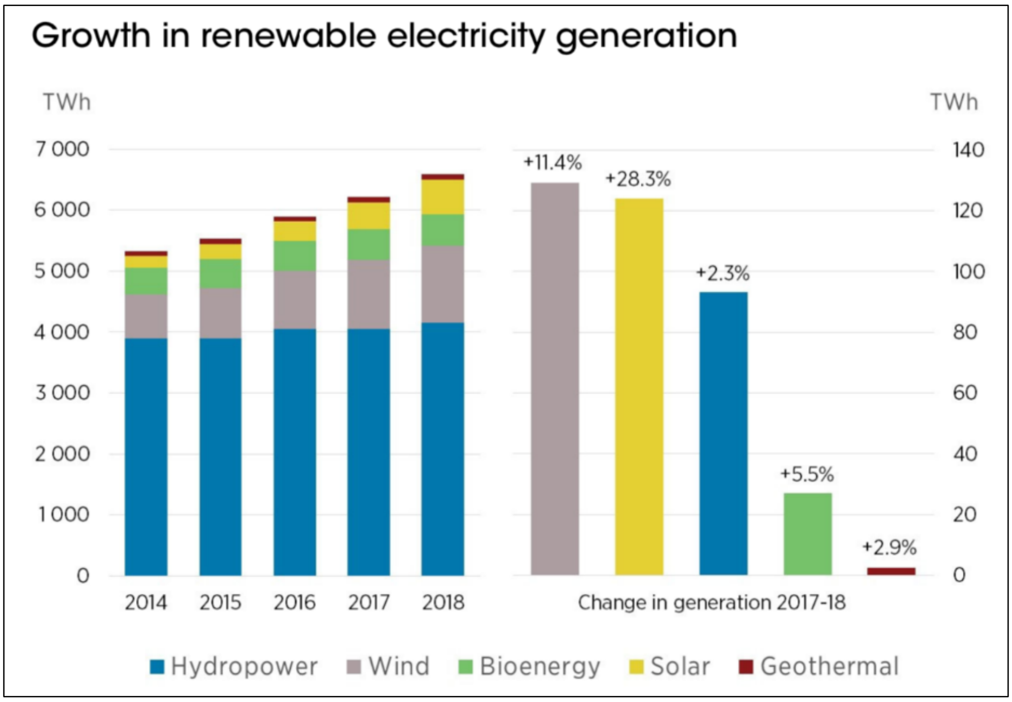


Figure 5: Growth in renewable energy generation (2014-2018). Source: Renewable Energy Statistics 2020, IRENA.