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Poland and its Strategy to reach European Renewable Energy Targets 2020

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 11 October 2014

Affidavit

I, **MARTA KACZMAREK**, hereby declare

1. that I am the sole author of the present Master's Thesis, "POLAND AND ITS STRATEGY TO REACH EUROPEAN RENEWABLE ENERGY TARGETS 2020", 59 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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Signature

ABSTRACT

As member of the European Union, Poland has committed to the reduction of CO_2 emissions, the increase of energy efficiency and an increase of the share of energy generated from renewable sources by the year 2020, a difficult challenge for a member state traditionally relying on energy generation from out-dated coal-fired power plants. Poland must implement a comprehensive strategy to gradually diversify and modernize the energy sector, while meeting the growing energy demand and maintaining stable supply. The thesis aims to identify the challenges and opportunities for the development of a future-proof energy sector, which further complies with the commitments agreed upon within the framework of the EU 20-20-20 goals. It will look at the characteristics of the current coal based network and assess the potential to diversify the national energy mix by inclusion of renewable energy alternatives.

ACKNOWLEDGEMENTS

I would like to dedicate this thesis to the friends and family closest to me. In particular, I would like to thank my parents, who have supported me throughout my academic and professional career and have helped me become who I am today.

Equally, I would like to thank my friends, whose support and encouragement has always reminded me to believe in myself.

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LIST OF ABBREVIATIONS / ACRONYMS

BAU	Business as usual
CH_4	Methane
CHP	Combined Heat and Power
CO_2	Carbon dioxide
CCS	Carbon Capture and Storage
EBRD	European Bank for Reconstruction and Development
ECJ	European Court of Justice
ETS	Emissions Trading System
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GW	Gigawatt
HFCs	Hydrofluorocarbons
IEA	International Energy Agency
kWh	Kilowatt-hour
Mt	Megatons
NREAP	National Renewable Energy Action Plan
N_20	Nitrous oxide
NATO	North Atlantic Treaty Organisation
PFCs	Perfluorocarbons
RED	Renewable Energy Directive
RES	Renewable Energy Sources
SF_6	Sulphur hexafluoride
UN	United Nations
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework on Climate Change
UNIPCC	United Nations International Panel on Climate Change

1. INTRODUCTION

Climate change and global warming in competition with growing population and (energy) consumption levels are amongst the most pressing challenges society is confronted with. Technological advancements since industrialization in particular provided populations with the possibility to influence and shape their surroundings and ecosystems. Humans no longer have to adapt to nature, but learned to adapt it to their needs. Decades of anthropogenic activity resulted in the disturbance of natural systems, inter alia, leading to pollution and increasing greenhouse gas concentrations endangering human, plant and animal health. Population growth and increasing demand pushed consumption levels beyond the point of long-term sustainability and the planet's capability to regenerate. The energy sector (i.e. electricity, heating and transport) accounts for the largest contribution to pollution and GHG emissions. This is mainly due to the traditional focus on coal as one of the oldest, most abundant fuel source. Due to high emission of carbon dioxide and other pollutants reliance on conventional sources or fossil fuel based energy has proven detrimental to the well-being of the planet and its inhabitants. Thanks to technological advancement fossil fuels can increasingly be used in cleaner, environmentally friendlier ways, or substituted by low- or zero emission renewable energy sources altogether.

Increasingly, governments and civil society join efforts to counteract and mitigate the harm done and establish frameworks to limit future deterioration. As member of the European Union, Poland has committed to several energy and environment related objectives; inter alia, the reduction of CO_2 emissions by 14 percent, the increase of energy efficiency by 20 percent and an increase of the share of energy generated from renewable sources to 15 percent by the year 2020. Traditionally, Poland relies heavily on fossil fuel to cover its energy needs, coal accounting for 90 percent of all energy generation. Most power plants have been in operation for over 25 years, thus lacking in efficiency and contributing vastly to environmental pollution as reflected in high CO_2 concentration, lower air quality, and overall disturbance of natural ecosystems. The challenge for the years to come will be to implement a comprehensive strategy to gradually diversify and modernize the energy sector, while meeting the growing energy demand and maintaining stable supply.

The transition to a diversified energy sector is challenged by a combination of the slow implementation of necessary measures, a complex legal and investment framework and national commitment to coal as an important energy source. Fears of high reform costs versus one of the highest abundances in coal reserves worldwide explain Poland's reluctance to commit to a regenerative energy market. Often seen as an enemy of international mitigation efforts and progress in the domain the situation must also be looked at from the Polish point of view, whereas the modernization of coal based energy coupled with increased efficiency and cross-border partnerships on energy exchange may be the most effective, financially feasible and realistic approach to a forward looking energy sector.

1.1. Outline

Looking at the status quo of Poland's energy system, the thesis aims to identify the challenges and opportunities for the development of a modern, stable and secure energy sector, which further complies with the commitments agreed upon within the framework of the EU 20-20-20 goals.

The first part of the thesis will provide the theoretical basis in the form of background information on Poland and its energy market, its obligations as EU member state and the main objectives found in the National Renewable Energy Action Plan. Finally, this section aims to assess the potential for renewable energy in Poland. The second section, i.e. the technical part of the thesis focuses on the analysis of the coal power plant network currently in operation. By calculation of present efficiencies and emission levels this chapter aims to determine the potential cuts and savings linked to the modernization or diversification of the network vis a vis efforts to meet EU level targets and ensure stable and affordable energy supply in the future. Part three will briefly mention alternative and/or accompanying approaches towards a modernised sector, i.e. by focus on regional cooperation and on efficiency improvements. Finally, summarizing the key findings of the above chapters, part five intends to interpret key data and provide an outlook for the next decade in the evolution of Poland's energy sector and coal exploitation.

1.2. Research Question

In brief, the following chapters intend to answer two main questions:

- Given the dominance of energy generated from coal-fired power plants how can Poland combine its coal reliance with efforts to modernize the energy sector and comply with European environmental and energy targets 2020 and beyond?
- What are the costs and benefits of an energy sector transition and/or modernization of the existing infrastructure?

1.3. Methodology

The main findings of this thesis are derived from an internet based research of academic papers, national and EU level policy papers and legislation of past and present, as well as reports and articles of national and international interest and stakeholder groups. As result of the lack of a comprehensive database on technical specifics of existing and planned coal power plants in Poland, this thesis aims to bring together this data including direct and indirect (or external) costs and benefits of the maintenance of the current energy system (business as usual) vis-á-vis its modernization. The respective calculated efficiencies, emission levels and potentially saved emissions in case of modernization and/or decommissioning are assumptions based on average numbers taken as reference from current state of the art levels. Equally, the financial aspects and calculated values must be understood as guidelines based on the current costs of state of the art technology, financial mechanisms, tax levels, etc. and are subject to change in proportion to possible policy shifts and decreasing technological costs in the future.

2. BACKGROUND

2.1. Country Profile

The Republic of Poland, with its capital Warsaw, is located in Central Europe. A population of 38.6 million shares a territory of 312 679 square kilometres. The climate is mild with moderate winters, frequent precipitation and mild summers (CIA, 2014). Poland is abundant in natural resources, predominantly coal, sulphur, copper, natural gas, silver, lead, salt, amber and arable land. In 2013, Poland's exports, mainly machinery, transport equipment and intermediate manufactured goods, accounted for roughly 160 billion Euro. As a consequence of its heavy industry Poland has been confronted with high air, soil and water pollution and GHG concentrations.

Following World War Two Poland became a satellite state of the Soviet Union, a period also reflected in the characteristics of the underdeveloped centrally planned economy. '*A "shock therapy" program during the early 1990s enabled the country to transform its economy into one of the most robust in Central Europe*' (CIA, 2014). Continuous liberalization efforts turned it into a major economic power in Central and Eastern Europe, which, unlike other states, achieved minor economic growth of 1.9 percent during the most recent economic crisis (CIA, 2014).

> *The reasons for Poland's relatively good performance compared with regional peers are found in its comparatively small domestic and external imbalances prior to the crisis. With a large domestic sector, a relatively un-leveraged banking system and less buoyant credit and housing bubbles in recent years, Poland's resilience has been broadly based on domestic consumption, supported by both fiscal and monetary stimulus.* (European Bank for Reconstruction and Development, 2010)

Despite the growth and access to EU funds, Poland remains one of the poorest EU members. Its current GDP stands at 814 billion Euro equal to 13 334 Euro per capita or 56 percent of the EU average (European Bank for Reconstruction and Development, 2010). Unemployment remains high at 13.5 percent. Additionally,

> *Poland has among the highest levels of material deprivation in the EU-27. Although the 'at-risk-of-poverty' rate of 18 percent is only slightly higher than the EU-27 average, the vast majority of extreme poverty, including age-related poverty, is to be found in rural and agricultural areas.* (European Bank for Reconstruction and Development, 2010)

Since regaining autonomy in the early 1990s the state has been an active international actor, most prominently joining NATO in 1999 and the EU in 2004 becoming one of the largest member states. As regards the environmental domain, Poland is party to several international agreements, inter alia, the UNFCC and the subsequent Kyoto Protocol.

2.2. The Energy Market

16.7 million consumers, 90 percent of which are private households, consumed 147.67 TWh in 2011 or 3.83 MWh per capita in Poland (IEA, 2011). The use of coal as primary energy generation source is accompanied by several harmful side effects, such as high CO_2 intensity amounting to 300 Mt (or 7.79 tons per capita) in 2011 (IEA, 2011). Old installations and inefficient distribution systems frequently result in (uncontrollable) network losses amounting to 9 percent in 2009, a problem that has been acknowledged in the government's Energy Strategy 2030.

> *National legislation on the requirements for energy grids has a hierarchical structure and includes the following...: Energy Act..., regulations on detailed conditions for the electricity system functioning..., principles for defining and calculating tariffs and principles for settlements in electric energy trading..., licences for electricity transmission or distribution..., operating and maintenance instructions of the Transmission and Distribution Grids drawn up by the energy grid operators... approved by the President of the Energy Regulatory Office of Poland.* (Ministry of Economy, 2010)

Prior to 2007 the national electricity and transmission sector was fully unbundled, a status which had been reversed with the consolidation of most of the energy production and supply companies into four vertically integrated state owned groups, namely Tauron, PGE, Energa and ENEA[1], of which the first three largest ones account for nearly two thirds of all production or 70 percent of the market share (Bayer, 2014). The map below shows the distribution of the market share in 2013.

[1] ENEA has been partially privatized.

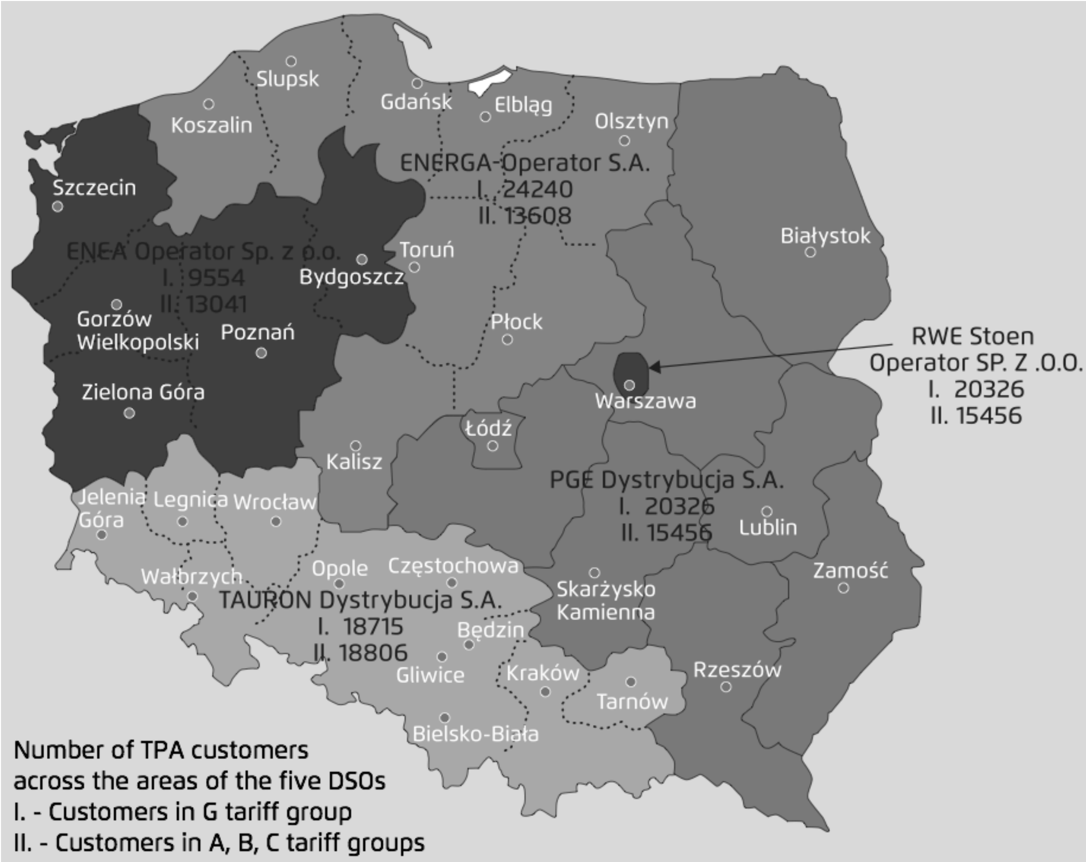

Figure 1: Market share distribution by operator and region (Bayer, 2014)

The Energy Strategy envisions a modernisation and expansion of the current transmission grid to meet the requirements of the planned RES development, as shown in the table below:

Table 1: Numbers of kilometres of planned expansion and modernisation of transmission lines, according to voltage (Ministry of Economy, 2010a)

Voltage (kV)	Type of undertaking	Length (km)	
		Route	Conductors
		938	1377
		794	1250
220	new	115	115
	modernised	961	842

'As regards the operation of the electricity distribution system...the President of ERO appointed 16 grid operators. Currently, all Distribution System Operators (DSO) have Development Plans for distribution systems in their areas' (Ministry of Economy, 2010a).

From 2007 onwards the electricity market has been fully liberalized in compliance with EU level regulations. Customers have the right to choose their supplier. Although 82 retail suppliers operated on the market as of 2012, 86 percent of the supply derived from the top four companies named above, thus not leaving much room for competition. Additionally, '*the State Treasury still hold shares in multiple natural resources companies (PGNiG, Lotos, OLPP, PKN Orlen, PERN)'* (European Bank for Reconstruction and Development, 2010).

In the past years

> *the quality of institutions has also been improved: a fully independent regulator is in place and tariffs are cost-reflective, with retail electricity prices still subject to regulatory approval. Moreover, the regulatory framework for renewables has become one of the most advanced among the EBRD countries of operation, following the introduction of a green certificates scheme in October 2005*. (European Bank for Reconstruction and Development, 2010)

Electricity is tradable on different types of markets, with most trades being based on long-term agreements. The market rules are fixed and monitored by an Independent Polish Energy Regulation Office in combination with balancing groups made up of representatives from consumer and supply side. Despite ongoing reform the sector is still flawed in terms of transparency and accountability. In particular, *'state subsidies to the mining industry remain an issue of concern'* (European Bank for Reconstruction and Development, 2010). Discussions on the introduction of reformed energy legislation and the passing of a Renewable Energy Act are overshadowed by ongoing protests of the coal mining industry and its efforts to maintain financial state support and employment.

As concerns the financial aspect the average price of electricity per kilowatt-hour has been steadily increasing. Alone in the past years the price rose from 0,098 Euro in 2004 to 0,134 Euro in 2014 (Polski Zakład Energetyczny, 2014). Notably, this lies still below the average EU price level of 0,2 Euro. However, many expect that the legal obligation on operators to supply part of its electricity from renewable sources coupled with a decline of the coal share in the national mix and natural inflation may lead to higher generation and transmission costs which will be passed on to the consumers in the form of higher electricity prices, as can be observed in Germany, where the costs of an accelerated 'Energiewende' have been redistributed to the consumer side.

2.3. International Energy Policy framework[2]

Growing awareness about the negative impact of (careless) anthropogenic activity in the past century, as well as diminishing reserves of conventional energy sources, prompted interest and discourse on the development of 'green economies' and enhanced progress in the deployment of renewable energy. In an effort to counteract climate change, slow down global warming and mitigate the impact of past activities world leaders agreed on several multilateral agreements setting out objectives, rules and measures to achieve common goals. An IEA study on Energy Technology Perspectives estimates that 32 billion Euro, or 880 million Euro annually, would have to be invested globally to decrease CO_2 emissions by 70 percent. Primary areas of investment identified are energy efficiency and renewable alternatives to conventional fuels. While the costs seem high they are low when compared to the total estimated savings of coal, oil and natural gas amounting to 115 billion Euro.

As party to the UN Kyoto Protocol[3] Poland agreed to a GHG reduction of 6 percent for the period of 2008-2012 and 20 percent for the period of 2012-2020 (not ratified), as compared to levels in the base year 1990 (Kyoto, 1998). These targets were met and even exceeded.

More importantly, Poland is also 'obliged' to comply with collective and individual targets as set within the framework of its EU membership, at the core of which lies the Energy and Climate Change Package[4]. Adopted in 2009 it is based on the Renewable Energy Directive, a revised Emissions Trading System Directive, an effort-sharing decision covering GHG emissions outside the ETS directive, a regulation on reduced CO_2 emissions from cars, a revised fuel quality directive and a directive on a regulatory framework for Carbon Capture and Storage. Most prominently the 20-20-20 targets envision the binding reduction of GHG emissions by 20 percent compared to 1990 levels, the binding increase of the share of renewable energy in the total energy consumption to 20 percent, and the non-binding reduction of energy consumption by 20 percent until the year 2020 (EC, 2008). Additionally, by the end of 2014, EU leaders aim to agree on the Energy Strategy 2030 which foremost aims to increase commitments to an overall GHG emission reduction by 40 percent, an increase of renewables to 27 percent and of

[2] Further details on the development of an international legal framework on energy and environmental aspects can be found in Annex 2.
[3] For details on the Protocol see: http://unfccc.int/kyoto_protocol/items/2830.php
[4] For details see European Commission DG Climate Action:http://ec.europa.eu/clima/policies/package/index_en.htm

efficiency to 30 percent towards the establishment of a stable, secure and independent energy sector in Europe[5].

In this context, targets according to individual capacities have been identified for each member state, which was obliged to develop and publish its respective strategy in National Renewable Energy Action Plans (NREAP) by 2010. In the words of the European Parliament and the Council of the EU:

> *It is…necessary to translate the Community 20 percent target into individual targets for each Member State, with due regard to a fair and adequate allocation taking account of Member States' different starting points and potentials, including the existing level of energy from renewable sources and the energy mix…on the basis of an equal increase in each Member State's share weighted by their GDP, modulated to reflect their starting points, and by accounting in terms of gross final consumption of energy, with account being taken of Member States' past efforts with regard to the use of energy from renewable sources.* (EP & CoEU, 2009)

Poland is obliged to reach a GHG reduction to 14 percent over 2005 levels and a 15 percent share of renewables in final consumption by 2020. As a result of Poland's failure to transpose the Directives and implement necessary measures in time, the state is subject of three infringement proceedings at EU level: the case on the failure to transpose the Renewable Energy Directive (2009/28/EC) brought to the ECJ in March 2013, two reasoned opinions by the European Commission on taking action with obligations under the Energy Performance of Buildings Directive (2010/31/EC) and on taking action to transpose the EU Emissions Trading System Directive (2009/29/EC) (Bayer, 2014). In response, Poland introduced legal changes to the Energy Act relating to electricity, natural gas and renewable energy regulations in August 2013, which helped to achieve compliance with the Third Energy Package, but not the Renewable Energy Directive (Bayer, 2014).

2.4. Poland's Energy Policy

2.4.1. Energy Policy until 2030

Already in the year 2000, the Polish Ministry of Economy adopted a regulation *'on the obligation to purchase electricity from unconventional and renewable sources and electricity from combined heat and electricity generation as well as heat from*

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[5] For more details see: http://ec.europa.eu/clima/policies/2030/index_en.htm

unconventional and renewable sources' (Ministry of Economy, 2010). In accordance with its provisions, the obligation to purchase renewable energy had been imposed on all electricity trading companies, which are required to ensure the relevant share of energy from RES in electricity sales volume. In 2001, this share equalled 2.4 percent, increasing slowly each year. Following a resolution on the Development Strategy for the Renewable Energy Sector in 2001, more significant amendments were made to the Energy Act in 2004 and 2005. In this context and with the adoption on an Energy Policy of Poland until 2030 and the NREAP in 2009 several measures were implemented to encourage the development of a RES sector in Poland, most importantly the

> *Obligation of energy grid operators to ensure priority to...electricity produced from RES', the 'the obligation to purchase energy from RES...on sellers of electricity', a 'reduction of the fee for connection to the grid, determined based on actual outlays incurred for installing the connection for renewable energy sources with total installed power not exceeding 5 MW and cogeneration units with power not exceeding 1 MW; special principles of wind farm balancing; additional support to small RES (below 5MW) producing electricity...,exemption of energy produced from renewable sources from excise duty that currently equals PLN 20 per 1 MWh, financial support to investments in RES provided in form of grants or borrowings and investment loans bearing low interest rate.*[6] (Ministry of Economy, 2010)

The Energy Policy of Poland until 2030 was adopted in November 2009, aiming to *'address the most important challenges that the Polish energy industry must face, both in the short and in the long run, until 2030'* (Ministry of Economy, 2010). The document foresees an increase in the final energy use by 11 percent between 2006 and 2020. The table below illustrates the projected demand for final energy by sectors in Mtoe with the largest increase in consumption expected for the industry and transport sectors.

[6] from public funds, including EU funds within financing of Operational Programme: Infrastructure and Environment and Regional Operational Programmes; from regional funds, including from the budget of the European Union, within the scope of support to investment projects pertaining to RES; from funds of the National Fund for Environmental Protection and Water Management (Narodowy Fundusz Ochrony Srodowiska i Gospodarki Wodnej); from funds of the Eco-Fund that provided co-financing for investments in solar, wind, biomass and biogas energy, and highly efficient co-generation in the years 2005-2009; from resources of the European Economic Area, including the Norwegian Financial Mechanism that provided co-financing for, inter alia, projects increasing the use of renewable energy sources in the years 2004-2009. (Ministry of Economy, 2010)

Table 2: Demand for final energy by sectors of the economy [Mtoe] (Energy Policy of Poland until 2030) (Ministry of Economy, 2010)

	2006	2010	2015	2020	2025	2030
Industry	20.9	18.2	19.0	20.9	23.0	24.0
Transport	14.2	15.5	16.5	18.7	21.2	23.3
Agriculture	4.4	5.1	4.9	5.0	4.5	4.2
Services	6.7	6.6	7.7	8.8	10.7	12.8
Households	19.3	19.0	19.1	19.4	19.9	20.1
TOTAL	65.5	64.4	67.3	72.7	79.3	84.4

The Ministry foresees a slight diversification in the national energy mix which would result in the decrease of coal consumption while *'other carriers would record a growth: oil products – by eleven percent, natural gas – also by eleven percent, renewable energy – by 40.5 percent, and electricity – by 17.9 percent'* (Ministry of Economy, 2010). The expected change in the share of renewables is rather insignificant when compared to the sum of all other fuel types combined.

Table 3: Demand for final energy by carriers [Mtoe] (Energy Policy of Poland until 2030) (Ministry of Economy, 2010)

	2006	2010	2015	2020	2025	2030
Coal	12.3	10.9	10.1	10.3	10.4	10.5
Oil products	21.9	22.4	23.1	24.3	26.3	27.9
Natural gas	10.0	9.5	10.3	11.1	12.2	12.9
Renewable energy	4.2	4.6	5.0	5.9	6.2	6.7
Electricity	9.5	9.0	9.9	11.2	13.1	14.8
District heat	7.0	7.4	8.2	9.1	10.0	10.5
Other fuels	0.6	0.5	0.6	0.8	1.0	1.2
TOTAL	65.5	64.4	67.3	72.7	79.3	84.4

With regards to the development of renewable energy, neither photovoltaics nor biofuels will play a role in the mix before 2020. This may be explained by the comparably high costs of the technologies.

Table 4: Demand for gross final energy from RES by types of energy [ktoe] (Energy Policy of Poland until 2030) (Ministry of Economy, 2010)

	2006	2010	2015	2020	2025	2030
Electricity	370.6	715.0	1,516.1	2,686.6	3,256.3	3,396.3
Solid biomass	159.2	298.5	503.2	892.3	953.0	994.9
Biogas	13.8	31.4	140.7	344.5	555.6	592.6
Wind	22.0	174.0	631.9	1,178.4	1,470.0	1,530.0
Water	175.6	211.0	240.3	271.4	276.7	276.7
Photovoltaics	0.0	0.0	0.0	0.1	1.1	2.1
Heat	4,312.7	4,481.7	5,046.3	6,255.9	7,048.7	7,618.4
Solid biomass	4,249.8	4,315.1	4,595.7	5,405.9	5,870.8	6,333.2
Biogas	27.1	72.2	256.5	503.1	750.0	800.0
Geothermal	32.2	80.1	147.5	221.5	298.5	348.1
Solar	3.6	14.2	46.7	125.4	129.4	137.1

Transport biofuels	96.9	549.0	884.1	1,444.1	1,632.6	1,881.9
Sugar and starch bioethanol	61.1	150.7	247.6	425.2	443.0	490.1
Rape biodiesel	35.8	398.3	636.5	696.8	645.9	643.5
2nd generation bioethanol	0.0	0.0	0.0	210.0	240.0	250.0
2nd generation biodiesel	0.0	0.0	0.0	112.1	213.0	250.0
Biohydrogen	0.0	0.0	0.0	0.0	90.8	248.3
TOTAL gross final energy from RES	4,780	5,746	7,447	10,387	11,938	12,897
Gross final energy	61,815	61,316	63,979	69,203	75,480	80,551
% share of renewable energy	**7.7**	**9.4**	**11.6**	**15.0**	**15.8**	**16.0**

The strategy assumes that Poland will reach a share of 25.4 percent of renewable energy in the total generation capacity by 2020, thus meeting EU level obligations. As seen in the forecast of installed capacity by fuel type nuclear power will also play a role in the national mix from 2020 onwards, despite a trend of turning away from nuclear power in many other countries such as Germany and even France.

Table 5: Generation capacity of gross electricity [MW] (Energy Policy of Poland until 2030) (Ministry of Economy, 2010)

Fuel/technology	**2006**	**2010**	**2015**	**2020**	**2025**	**2030**
Lignite – PC boiler/fluidized-bed furnace	8,819	9,177	9,024	8,184	10,344	10,884
Hard coal – PC boiler/fluidized-bed furnace	15,878	15,796	15,673	15,012	11,360	10,703
Hard coal – CHP	4,845	4,950	5,394	5,658	5,835	5,807
Natural gas – CHP	704	710	810	873	964	1,090
Natural gas – GTCC	0	0	400	600	1010	2,240
Large water	853	853	853	853	853	853
Pump water	1,406	1,406	1,406	1,406	1,406	1,406
Nuclear	0	0	0	1,600	3,200	4,800
Industrial Coal – CHP	1,516	1,411	1,416	1,447	1,514	1,555
Industrial Gas – CHP	51	50	63	79	85	92
Industrial Other – CHP	671	730	834	882	896	910
Local Gas	0	0	22	72	167	278
Small water	69	107	192	282	298	298
Wind	173	976	3,396	6,089	7,564	7,867
Solid biomass – CHP*	25	40	196	623	958	1,218
Biogas CHP	33	74	328	802	1,293	1,379
Photovoltaics	0	0	0	2	16	32
TOTAL	**35,043**	**36,280**	**40,007**	**44,464**	**47,763**	**51,412**

** – co-firing not included*

Source: Energy Policy of Poland until 2030

Moreover, despite pressure to increase the share of renewables Poland plans to invest in the construction of further coal plants in the capacity of 11 300 MW by

2020, significantly surpassing the installed renewable capacity as demonstrated in the graph below:

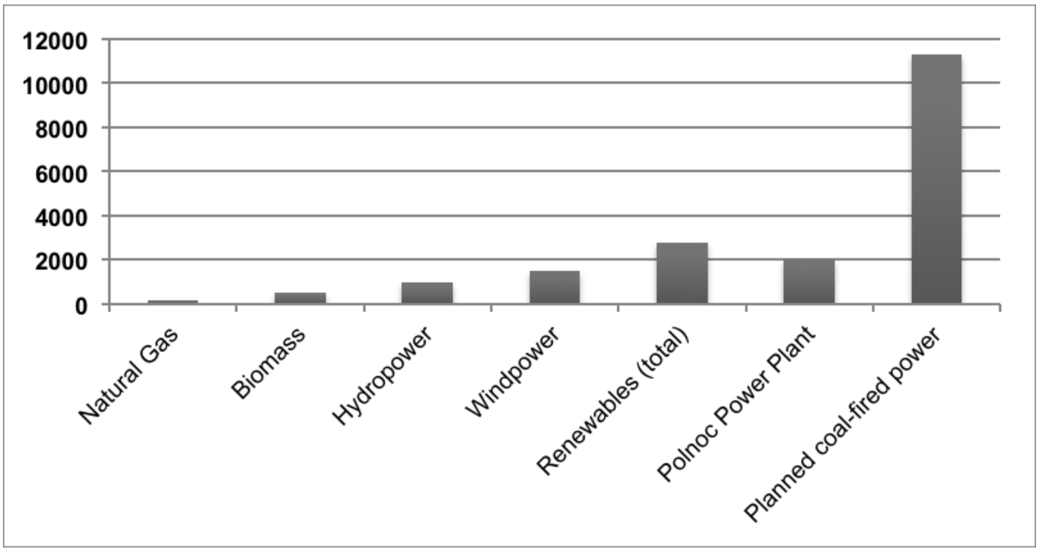


Figure 2: Installed renewable capacity versus planned coal-fired power plants in MW (Bank Watch, 2014)

2.4.2. National Renewable Energy Action Plan[7]

The National Renewable Energy Action Plan was adopted in 2009 and presented in 2010, aimed to address Poland’s commitments under Article 4(1) of Directive 2009/28/EC on the promotion of the use of energy from renewable sources. The most significant provisions in the context of this thesis will be presented and discussed below.

Table six below illustrates the adjusted expected total energy consumption in Poland. It is to note that the figures for the reference scenario are based on BAU, whereas the second scenario takes into account the expected improvements in efficiency and energy saving through measures mentioned above.

[7] For the full text of Poland’s NREAP see: http://ec.europa.eu/energy/renewables/transparency_platform/doc/dir_2009_0028_action_plan_poland.zip

Table 6: Expected gross final energy consumption of Poland in heating and cooling, electricity and transport up to 2020 taking into account the effects of energy efficiency and energy saving measures 2010-2020 [Mtoe] (Ministry of Economy, 2010)

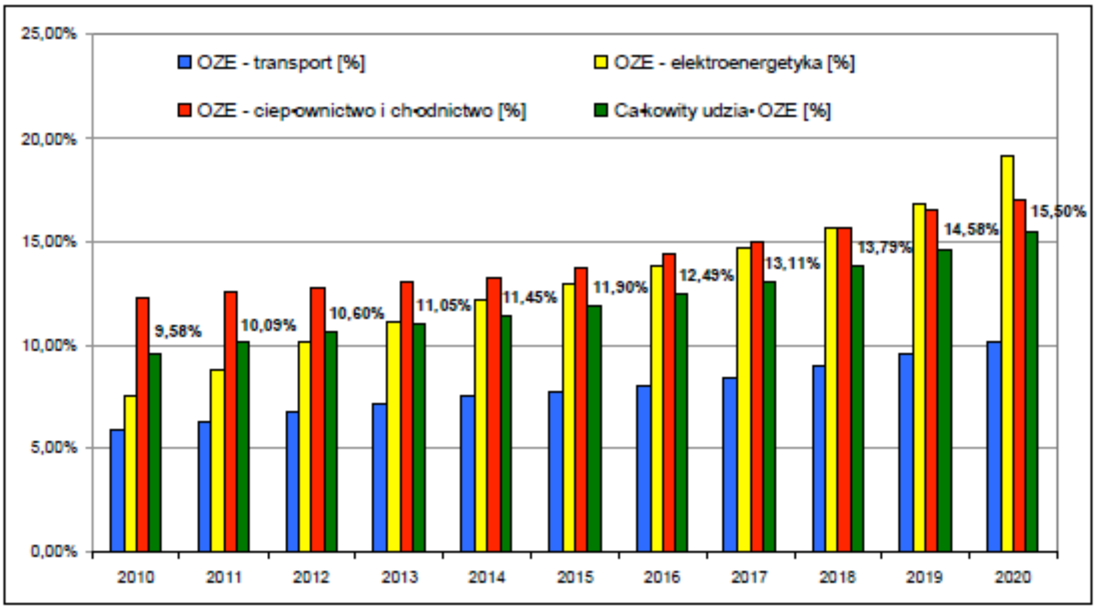
Description	2010		2011		2012		2013		2014	
	reference scenario	additional energy efficiency	reference scenario	additional energy efficiency	reference scenario	additional energy efficiency	reference scenario	additional energy efficiency	reference scenario	additional energy efficiency
(1) heating and cooling (district and non-district)	31.6	32.4	33.0	32.5	34.7	32.7	35.9	32.8	37.3	32.9
(2) electricity	12.9	12.1	13.4	12.3	14.0	12.5	14.4	12.7	14.9	12.9
(3) transport as in Article 3(4)a	16.8	16.8	17.0	17.0	17.5	17.2	17.5	17.4	17.7	17.6
(4) Gross final energy consumption	**61.3**	**61.3**	**63.4**	**61.8**	**66.2**	**62.4**	**67.8**	**62.9**	**69.9**	**63.4**

Description	2015		2016		2017		2018		2019		2020	
	reference scenario	additional energy efficiency	reference scenario	additional energy efficiency	reference scenario	additional energy efficiency	reference scenario	additional energy efficiency	reference scenario	additional energy efficiency	reference scenario	additional energy efficiency
(1) heating and cooling	38.8	33.1	40.3	33.4	41.8	33.8	43.2	34.1	44.7	34.4	46.2	34.7
(2) electricity	15.3	13.1	15.7	13.4	16.2	13.7	16.6	14.0	17.1	14.3	17.4	14.6
(3) transport as in Article 3(4)a	17.9	17.8	18.2	18.2	18.4	18.6	18.6	19.0	18.9	19.5	19.1	19.9
(4) Gross final energy consumption	**72.0**	**64.0**	**74.2**	**65.0**	**76.4**	**66.1**	**78.4**	**67.1**	**80.7**	**68.2**	**82.7**	**69.2**

Table 7: National overall target for the share of energy from renewable sources in gross final consumption of energy in 2005 and 2020 (Ministry of Economy, 2010)

(A) Share of energy from renewable sources in gross final consumption of energy in 2005 (S2005)	7.2 %
(B) Target of energy from renewable sources in gross final consumption of energy in 2020 (S2020)	15 %
(C) Expected total adjusted energy consumption in 2020	69,200 ktoe
(D) Expected amount of energy from renewable sources corresponding to the 2020 target (calculated as BxC)	10,380.5 ktoe

'Sectoral targets and trajectories ensuring that in 2020, Poland achieves the required share of energy from renewable sources by electricity, heating and cooling, and transport sectors' are presented below, and 'include...most economic solutions, also considering costs of their introduction, demonstrating the highest effectiveness of the use of renewable resource, development of the technology of their use and the best environmental effects' (Ministry of Economy, 2010).



Source: Own work based on the forecasted RES energy basket until 2020.

OZE – transport – RES – transport
OZE – elektroenergetyka – RES – electricity
OZE – ciep•ownictwo i ch•odnictwo – RES – heating and cooling
Ca•kowity udzia• OZE – Total RES share

Figure 3: National 2020 target and estimated trajectory of energy from renewable sources in heating and cooling (district and non-district systems), electricity and transport [%] (Ministry of Economy, 2010)

Table 8: National 2020 target and estimated trajectory of energy from renewable sources in heating and cooling, electricity and transport (Ministry of Economy, 2010)

Description	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
RES – heating and cooling (district and non-district systems) [%]	12.29%	12.54%	12.78%	13.05%	13.29%	13.71%	14.39%	15.02%	15.68%	16.50%	17.05%
RES – electricity [%]	7.53%	8.85%	10.19%	11.13%	12.19%	13.00%	13.85%	14.68%	15.64%	16.78%	19.13%
RES – transport [%]	5.84%	6.30%	6.76%	7.21%	7.48%	7.73%	7.99%	8.49%	9.05%	9.59%	10.14%
Overall RES share [%]	**9.58%**	**10.09%**	**10.60%**	**11.05%**	**11.45%**	**11.90%**	**12.49%**	**13.11%**	**13.79%**	**14.58%**	**15.50%**
of which from cooperation mechanism [%]		*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*		*0.0%*
surplus for cooperation mechanism [%]*		*1.31%*	*1.82%*	*1.48%*	*1.88%*	*1.16%*	*1.75%*	*0.81%*	*1.48%*		*0.50%*
In accordance with Annex I, Part B to the Directive		2011-2012		2013-2014		2015-2016		2017-2018			2020
		S_{2005}+**20%** (S_{2020}-S_{2005})		S_{2005}+**30%** (S_{2020}-S_{2005})		S_{2005}+**45%** (S_{2020}-S_{2005})		S_{2005}+**65%** (S_{2020}-S_{2005})			S_{2020}
RES minimum trajectory [%]		8.76%		9.54%		10.71%		12.27%			15.0%
RES minimum trajectory [ktoe]		5,439.96		6,024.51		6,907.95		8,171.82			10,380.5
**adjusted surplus for cooperation mechanism* [%]*		*1.58%*		*1.71%*		*1.49%*		*1.20%*			*0.50%*

** Calculated for subsequent years, taking into account estimated trajectory (two-year) in accordance with Appendix I Part B to Directive 2009/28/EC.*
Source: Own work. The table structure and headings are consistent with Decision 2009/548/EC.

The table below illustrates the projected share and distribution of RES in the electricity supply mix by 2020, as derived from Poland's NREAP.

Table 9: RES-Electricity 2020 Projection (European Renewable Energy Council, 2011)

RES-E 2020 Projections	National RES industry Roadmap			NREAP		
	MW Installed	RES Electricity Generation (GWh)	% in Electricity Consumption	MW Installed	RES Electricity Generation (GWh)	% in Electricity Consumption
Large Hydro	689.1	1,400	0.8	772	1,758	1
Hydro (below or equal to 10 MW)	889(1)	1,211(1)	0.7	380	1,211	0.7
Geothermal	110(2)	858(2)	0.5	0	0	0
Photovoltaic	786	650	0.4	3	3	0
Tidal, Wave, Ocean	0	0	0	0	0	0
Wind Onshore	10,000	23,600	13.9	6,150	13,710	8.1
Wind Offshore	500	1,800	1.1	500	1,500	0.9
Biomass (solid, biowaste, bioliquid)	1,550(3)	10,200(3)	6	1,550	10,200	6
Biogas	980(3)	4,018(3)	2.4	980	4,018	2.4
Total RES-E	15,504.1	43,737	25.8	10,335	32,400	19.1

Equally projections were made for the Heating sector, although no specific measures are planned within the current NREAP. Although:

> *The Energy Act also provides for imposing the obligation to include the potential use of heat from renewable sources...no specific annual obligation levels or annual targets for the use of renewable energy in the transmission and distribution system or heat trading have been set in case of heat. These targets were set only indirectly, in provisions referring to "the quantity not larger than the demand of the customers" connected to the heating grid.* (Ministry of Economy, 2010)

Table 10: RES-Heating Projections (European Renewable Energy Council, 2011)

RES-H 2020 Projections (ktoe)	National RES industry Roadmap		NREAP	
	RES Heat Consumption	% in Heat Consumption	RES Heat Consumption	% in Heat Consumption
Biomass (solid, biowaste, bioliquid)	6,677	19.2	4,636	13.4
Biogas	92.4	0.3	453	1.3
RE from Heat Pumps:	239	0.7	148	0.4
Geothermal Heat Pumps	*104(1)*	*0.3*	*NA*	*NA*
Aerothermal & Hydrothermal Heat Pumps	*135*	*0.4*	*NA*	*NA*
Solar Thermal	319	0.9	506	1.5
Geothermal	330(1)	1	178	0.5
Total RES-H	7,657.4	22.1	5,921	17.1

(1) Source: EGEC

A possible incentive to increase the share of RES could also be the adoption of requirements for new buildings and constructions. As mentioned in the NREAP:

> *there is no national legislation that would require installing and using RES in newly built or modernised buildings. In order to promote the use of RES, the legislator has introduced the system of incentives and premiums. Main incentives in this area include the thermo-modernisation premium and the renovation premium that the investor can obtain...for reducing an annual demand for energy, reducing annual energy losses, reducing annual costs of heat production, replacement of an energy source with a renewable energy source or using highly efficient co-generation...The system of assessment of energy performance of buildings...is another legal instrument promoting the use of renewable energy sources and improvement of the effectiveness of renewable sources used in the building sector.* (Ministry of Economy, 2010)

The most important policy and financial measures to encourage the development of the RES sector have already been mentioned within the discussion of the Energy Strategy 2030. A detailed listing of national legislative acts, as well as an overview of policies and measures can be found in Annex 3. It is to note, however, that stakeholders blame an uncertain and complex legal environment for a lack of investment in renewable energy installations, as the subsidy system in place failed to offer long-term guarantees (Goettig & Kahn, 2014).

In April 2014, Poland's government approved a draft law on Renewable Energy which aims to correct this by laying 'out new long-term subsidies for renewable energy, aiming to cut costs to consumers' and further introduces changes to the financial support framework in the form of auctions which guarantee a fixed price for 15 years for producers of renewable energy (Goettig & Kahn, 2014). Contracts or agreements under the current subsidy system may be continued or replaced by auctions. '*The government has calculated that the cost of its current subsidy system would rise to 7.5-11.5 billion zlotys a year by 2020'* (Goettig & Kahn, 2014). This equals between 1.8-2.7 billion Euro.

2.5. The potential of renewable energy generation in Poland

Renewable energy constitutes '*energy derived from natural processes that are replenished at a faster rate than they are consumed'* (IEA, 2014). In the EU's understanding 'energy from renewable sources' means energy from renewable non-fossil sources (EP & CoEU, 2009).

The IEA defines three generations of renewable energy development:

> *First-generation technologies emerged from the industrial revolution at the end of the 19th century and include hydropower, biomass combustion, geothermal power and heat…Second-generation technologies include solar heating and cooling, wind power, modern forms of bio-energy, and solar photovoltaic… Third-generation technologies are still under development and include advanced biomass gasification, bio-refinery technologies, concentrating solar thermal power, hot-dry-rock geothermal power, and ocean energy.* (IEA, 2007)

In general, such energy is low or lacks in GHG emissions (i.e. CO_2, CH_4, N_20, HFCs, PFCs, SF_6), thus contributing to climate change mitigation through the reduction of emission concentrations in the atmosphere. This characteristic coupled with growing interest in non-fossil fuel energy and fast improving cost competitiveness of the new technologies leads to estimates of a 25 percent share of RES in the global power mix by the year 2018 (IEA, 2011).

According to Poland's Energy Act:

> *Renewable energy source is a source which uses wind power, solar power, geothermal energy, sea wave, sea current and tidal energy, or energy obtained from the fall of rivers and biomass energy, energy from landfill biogas as well as biogas produced in the process of sewage disposal and treatment or decomposition of plant and animal remains.* (Ministry of Economy, 2010)[8]

In Poland, renewable energy production and supply remain an infant industry. Merely 8.7 percent of all electricity produced in 2012 was regenerative. The graph below illustrates the current distribution of renewable energy generation in Poland. In the year 2012 6.5GW of electricity originated from regenerative sources, 3.08GW of which from wind power, 2.3GW from hydropower, 0.97 from biomass and 0.15 from biogas (Bayer, 2014). These figures lie significantly under the estimates for the national potential, which will be elaborated on in more detail below.

The scope of this thesis does not allow for a thorough technical description of the respective technologies. The subchapters below will solely discuss their potential to become part of Poland's national energy mix.

[8] At the same time, in accordance with the regulation of the Minister of Economy of 14 August 2008 on detailed scope of obligations in respect to obtaining certificates of origin and submitting them for cancellation, payment of a substitution fee, purchase of electricity and heat from renewable energy sources, as well as the obligation to confirm the data on the amount of electricity produced from a renewable energy source, energy produced from renewable energy sources includes, irrespective of the source power: 1) electricity or heat produced in particular from: a) hydropower plants or wind power plants, b) sources generating energy from biomass and biogas, c) solar photovoltaic cells and heat-producing collectors, d) geothermal sources, e) co-generation systems, f) hybrid RES technology systems; 2) part of energy recovered from thermal processing of municipal waste in accordance with legislation issued based on Article 44(8) and 9 of the Act of 27 April 2001 on waste (Journal of Laws of 2007 No 39, item 251 as amended). (Ministry of Economy, 2010)

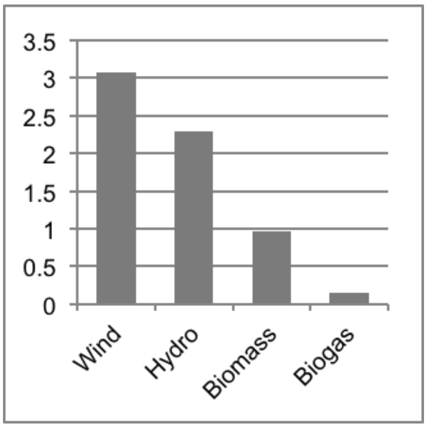


Figure 4: Make-up of renewable energies in Poland in GW as of 2011 (MoE, 2010)

2.5.1. Photovoltaic

The sun is the most powerful renewable energy source producing six thousand times more energy daily than is consumed. Consequently, energy generation from solar power is also subject to the most rapid technological development. According to a study by the European Commission '*approximately 69 GW of installations provide(d) already about 2.4 percent of Europe's electricity needs*' in 2012, subject to increase in order to reach the RED goal of 84 GW by 2020 (Ossenbrink, Huld, Jäger Waldau, & Taylor, 2013). Rapidly falling costs should encourage this development, comparable to a fall of approximately 20 percent every time the efficiency or output doubles. '*The costs of electric energy at the output of a PV module have dropped to less than 0.05 EUR/kWh, making it currently the lowest cost new technology for electricity generation'* (Ossenbrink, Huld, Jäger Waldau, & Taylor, 2013). However, application of PV remains limited due to the currently insecure supply and the costs involved in the installation of the necessary transmission and supply infrastructure, in particular, an argument also used in Poland.

Supply is highly dependent on the frequency or length of solar radiation, which is rather uneven and does not surpass more than five to six months a year in Poland due to its northern location. The graph below illustrates the distribution, intensity and length of radiation across the country and the amount of kilowatt-hours that could be potentially generated in Poland.

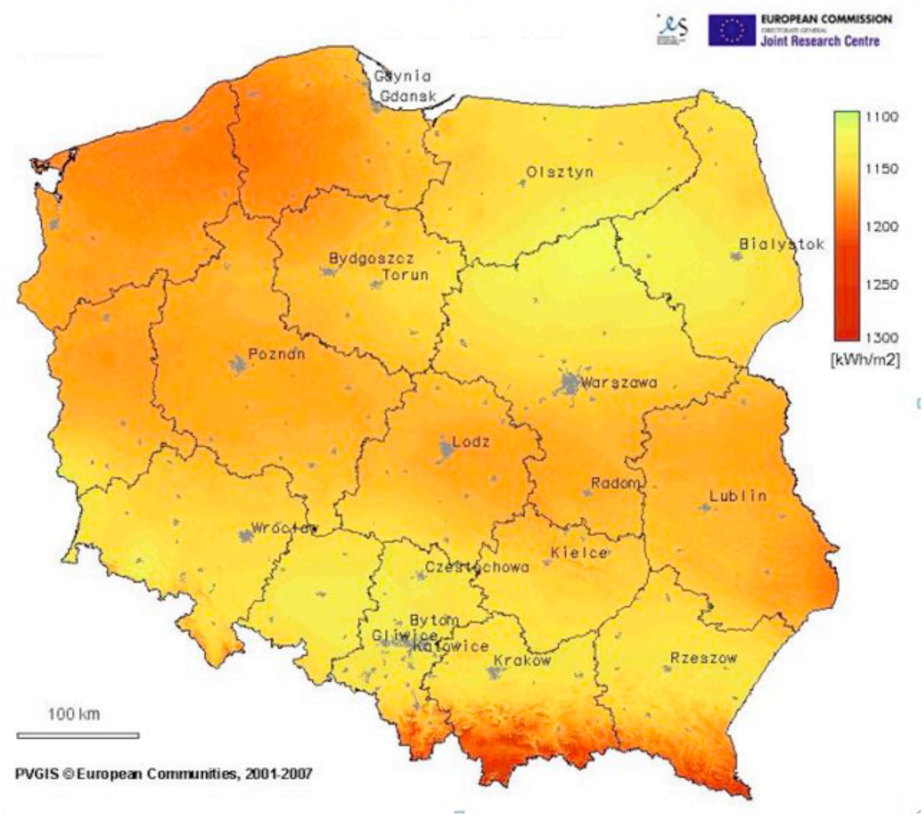


Figure 5: Yearly sum of irradiation in Poland in kWh/m2 (JRC, 2005)

Energy generated from PV is not yet integrated into Poland's central electricity supply system. Whereas the total annual potential is estimated at 83,312.2 TJ, the NREAP does not foresee the integration before 2025, the main reason being the investment and construction costs when compared to other technologies. Encouragement of investments in small-scale, private or local installations could prove a beneficial step towards energy diversification and secure supply to rural less developed areas, however. Small-scale installations could be used to secure the needs of a private household, village or smaller region on the one hand and allow for additional income through the feed-in on surplus energy into the national grid on the other. Such small-scale installations for private non-commercial use are indeed on the rise, but do not feed into the national energy mix yet.

2.5.2. Wind power

According to IRENA wind power is set to overtake hydropower as largest renewable energy source by 2030. The generation of electricity from wind can be both onshore and offshore. Whereas the development stage of onshore installations progresses quickly, offshore wind power generation is in an early commercialization stage. The onshore sector is one of the highest developed of the regenerative sectors in Poland, currently accounting for 3.7GW of installed power. Given the current state of the art it also remains the sector with the highest development potential, with many onshore projects in planning stage and the vast area off the Baltic Sea still unexploited. Due to the early stage of offshore technology the degree of environmental and marine life impact beyond operational and construction noise and changes to the seabed are yet unknown (European Parliament Directorate General for Internal Policies - Policy Department A Economic and Scientific Policy - Industry, Research and Energy, 2010).

The map below illustrates that the majority of Poland's territory lies in an advantageous to highly advantageous area for the installation of and generation of energy from wind farms.

Figure 6: Wind distribution in Poland in MW (Polish Wind Energy Association, 2014)

The graph below shows the distribution of the most significant wind farms and installations to date. While several projects are currently in construction or in process of passing the EIA, the majority of (planned) farms are located in the North and West of the country, within proximity of the Baltic Sea and the border with Germany:

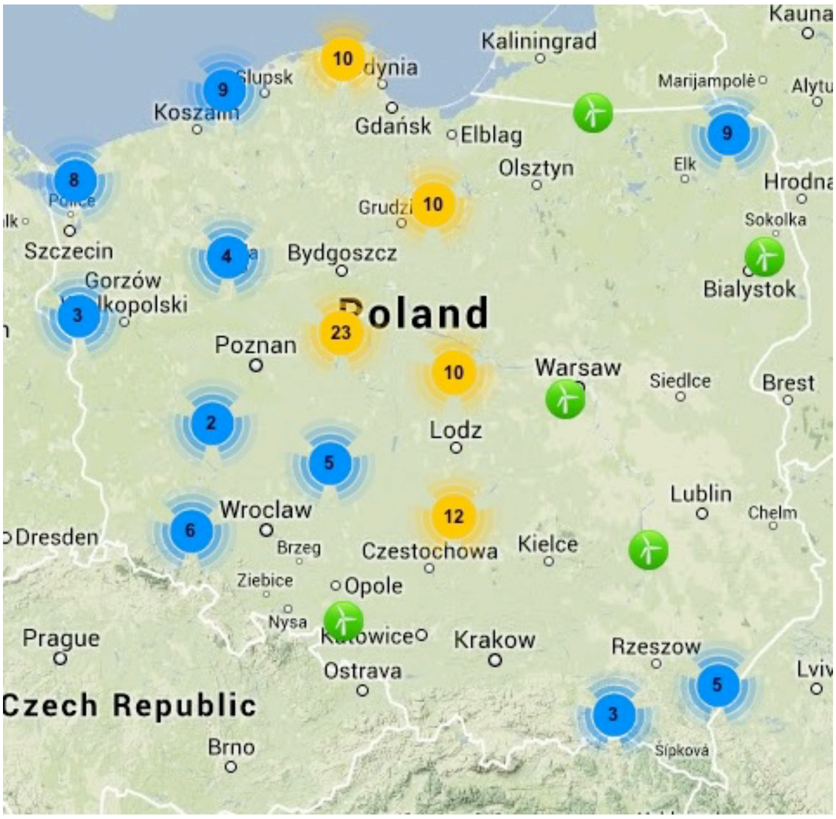


Figure 7: Distribution of wind farms in Poland as of 2013

The average investment costs for a small wind farm with a capacity of 1 MW amount to 1.5 Million Euro. Considering the average wind conditions in Poland such a small farm has the capacity to produce an annual 2 500 MWh, powering around 400 homes. As is the case with PV, wind turbines present an opportunity to deliver electricity to rural areas with limited connection to the national grid.

2.5.3. Hydropower

Energy generation from water sources represents one of the highest developed RES sectors in Poland. With a current production of 2.3GW, its potential has been largely exploited, however. Thus funds allocated for investment into the expansion of hydropower generation remain negligible in the current energy strategy. This might change once ocean current power technology leaves the research stage[9].

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[9] Power extracted from currents, tides and waves 'generate(s) electricity by converting water's kinetic or thermal energy into mechanical energy to drive a turbine or pump' (European Parliament Directorate General for Internal Policies - Policy Department A Economic and Scientific Policy - Industry, Research and Energy, 2010)

2.5.4. Biomass

In its RED the EU encourages the inclusion of biomass into the national energy mix. As economy in transition Poland remains highly focussed on its industrial and agricultural sectors with a slowly growing service sector. The large size of the agricultural sector increases the potential of biomass as source for energy generation, with the theoretical potential amounting to 739 TWh, as compared to 167 TWh of economic potential (Zielona Energia, 2014). 0.97 GW are currently fed into the national grid from biomass sources, a number subject to increase to 6 300 if installations continue to be built as planned in the NREAP. Sources of biomass in Poland originate in forestry, agriculture, fisheries and waste. In 2013 the world's largest 100 percent biomass-fuelled power plant started its operation in Polaniec, in the southeast of Poland[10]. Running on 80 percent tree farming and 20 percent agricultural by-products the plant has a capacity of 205 MW providing *'the equivalent of the annual electricity consumption of 600 000 households, and avoiding 1.2 million tonnes of CO_2 emissions a year'*[11] (RET, 2013).

Despite favourable conditions due to Poland's large agricultural sector energy production from biomass may not be the solution in the context of climate change mitigation. With its own contribution to GHG emissions during transport and production, the risk of substituting land use for food production with use for fuel purposes and the relatively high technological costs, this alternative fails to solve the problem of high emission concentrations and secure energy generation. As observed in other states, biomass-powered power plants require an immense amount of organic fuel, such as wood, hay etc., an amount which may surpass the local availability and must be purchased elsewhere and transported over longer distances. Biomass should thus be regarded with caution. Although it can be categorised as a renewable source in the broader sense, the flora necessary to fuel plants would not regenerate or grow at a speed proportionate to the needs. Equally its advantages are countered by the impact on pollution from transport and water and fertiliser use in the cultivation. A study commissioned by the European Parliament concludes, that *'the potential for electricity from wind and solar power is far higher than the potential for renewable electricity from biomass.'* (European Parliament Directorate General for Internal Policies - Policy Department A Economic and Scientific Policy - Industry, Research and Energy, 2010). It remains unclear

[10] For details see power plant website: http://www.gdfsuez-energia.pl/artykul/335253/O-NAS/Profil-firmy (in Polish)
[11] This does not include the indirect emissions originating in transport of fuel etc.

whether the study took the above aspects into account, but Poland should consider plans to expand biomass power in a long-term context including direct and indirect costs and benefits vis-à-vis other alternatives.

The map below shows the distribution of biomass-powered plants currently in operation. It is to note that within the framework of the modernisation of the coal-centred energy sector two co-generation plants are planned for construction. Operated by Energa SA they will be located in Rybnik and Ostroleka as part of existing plants, with power generation based on 900 MW blocs with a mix of 810 MW of coal and 90 MW of biomass.[12] Their profitability, however, remains unknown.

2.5.5. Biofuels

Bioenergy is based on second-generation bio fuel technologies producing biogas upgraded to natural gas transmitted through the conventional gas grid; synthetic gasoline and diesel through biomass to liquid; lignocellulosic ethanol and gas from lignocellulosic biomass through integrated gasification and combined cycle power plants (European Parliament Directorate General for Internal Policies - Policy Department A Economic and Scientific Policy - Industry, Research and Energy, 2010). These technologies have become largely mature and recycle nutrients, certain components and their by-products. However, as is the case with biomass technology, their application is contested due to the risks linked to land use change and the replacement of land and resources for food production with fuel generation. Moreover, their potential to make up a significant part of the future energy mix is more limited than for the alternatives discussed above due to the capital and labour extensive nature of production. According to NREAP projections biogas will make up around 848Mtoe both in heat and electricity supply by 2020.

[12] For details see next chapter.

3. COAL FIRED POWER PLANTS

3.1. Coal as important global (energy) commodity

As the world's most abundant fossil fuel source coal has traditionally played a major role in the heat and electricity production. In less- and non-industrialised states, in particular, coal remains an important and comparably cheap energy resource. Moreover, it is an important factor in the steel production, 70 percent of which is dependent on coal. According to the World Coal Association *'coal provides 29.9 percent of global primary energy needs and generates 41 percent of the world's electricity'* [resulting in the emission of over 14 billion tonnes of CO_2 annually] (WCA, 2013). 'The IEA expects a 43 percent increase in its use from 2000 to 2020' [despite the trend of growing use of RES] (WNA, 2014). *'In 2012 coal production reached a record high of 7 830 million tonnes, accounting for a 2.9 percent annual growth'* (WCA, 2013). According to an assessment by the German Federal Institute for Geosciences and Natural Resources global coal reserves of 1 038 billion tonnes could last for 132 years as compared to the global output in 2012 (WCA, 2013). The graph below illustrates the dominance of coal in the make-up of global electricity generation by source in 2009:

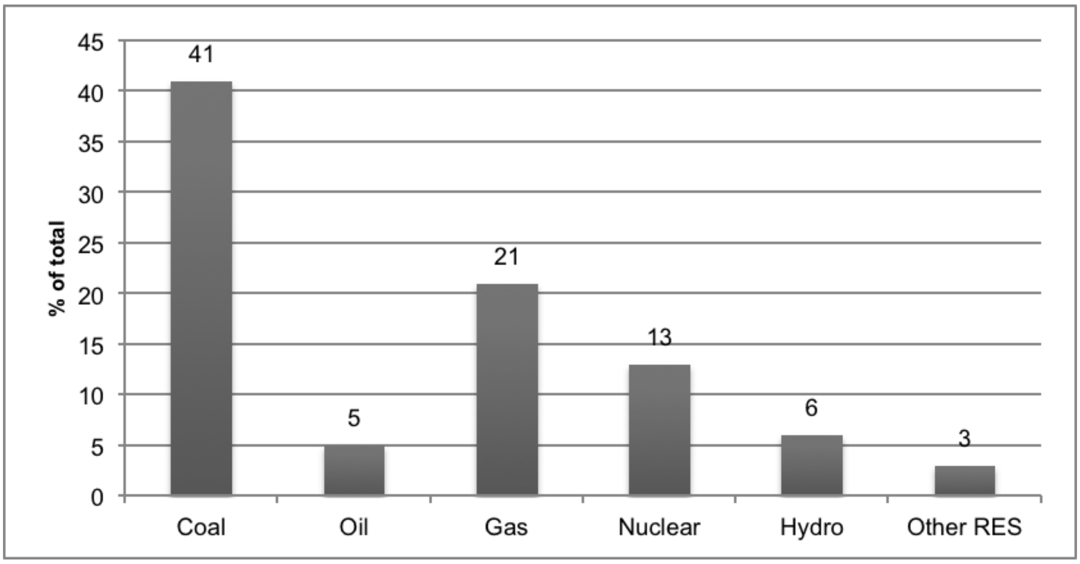

Figure 8: Global electricity generation by source in 2009 (%) (IEA, 2011)

The use of coal is linked to negative side effects and environmental concerns. According to the UN IPCC coal contributes significantly to global warming due to the emission of many polluting substances. As illustrated below, it has the highest carbon footprint of all energy sources, emitting 900 grams of CO_2 per kWh produced. Provided that a comprehensive approach is taken, a focus on the reduction of coal use or the cleansing of coal-related processes offers the highest potential in emissions reductions in terms of national emission levels and objectives.

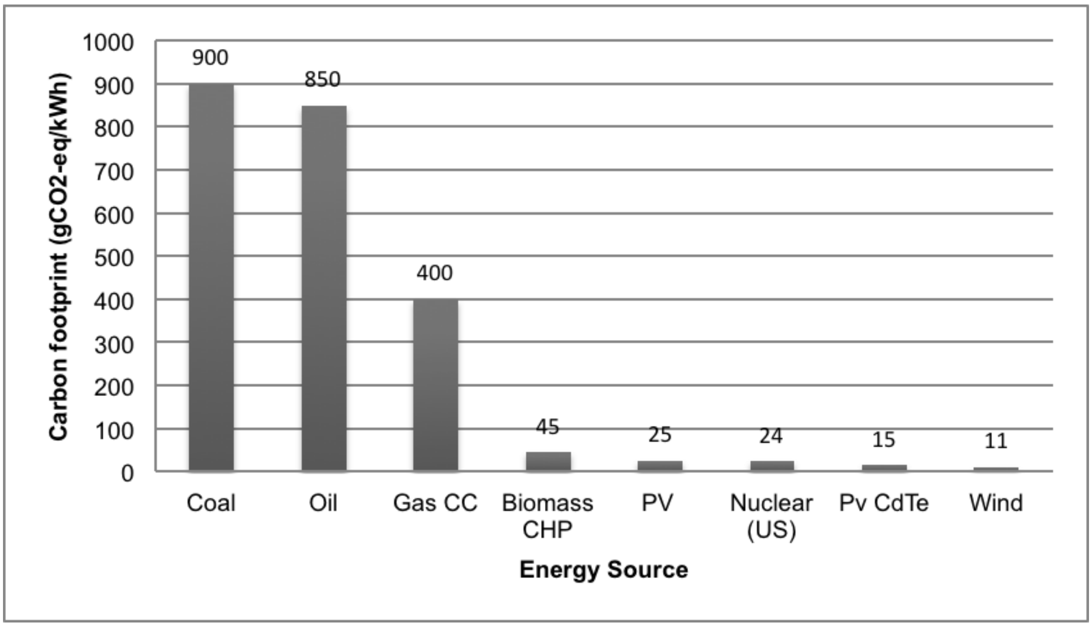

Figure 9: Carbon footprint of various energy sources

Coal is likely to remain a prominent source of energy, in less developed economies in particular. Thus there is great interest and research effort to develop a clean coal technology, which reduces the amount of harmful substance release. Carbon capture and storage is currently the only technology to cut GHG emissions, by *'capturing carbon dioxide that would otherwise be emitted to the atmosphere and injecting it to be stored in deep geological formations'* (WCA, 2014).

> *In its 2014 Energy Technology Perspectives the IEA notes that "CCS is advancing slowly, due to high costs and lack of political and financial commitment. Few major developments were seen in 2013, and policies necessary to facilitate the transition from demonstration to deployment are still largely missing." For its low-carbon 2DS scenario, "the rate of capture and storage must increase by two orders of magnitude" by 2025.* (WNA, 2014)

Optimism is high nevertheless, as reflected in the EU condition to assess and ensure that every newly built power plant is CSS ready, thus in line with expectations for future technological evolution. Currently, there are around ten coal fired and co-generation plants planned in Poland, some of which fail to comply with the above condition, thus running risk to face legal consequences.

> *Coal cleaning by 'washing' has been standard practice in developed countries for some time. It reduces emissions of ash and sulphur dioxide when the coal is*

burned. Electrostatic precipitators and fabric filters can remove 99 percent of the fly ash from the flue gases…Flue gas desulfurization reduces the output of sulphur dioxide to the atmosphere by up to 97 percent, the task depending on the level of sulphur in the coal and the extent of the reduction…Low-NOx burners allow coal-fired plants to reduce nitrogen oxide emissions by up to 40 percent. Coupled with re-burning techniques NOx can be reduced 70percent and selective catalytic reduction can clean up 90 percent of NOx emissions. Increased efficiency of plants – up to 46 percent thermal efficiency now (and 50 percent expected in future) means that newer plants create fewer emissions per kWh than older ones. Advanced technologies such as Integrated Gasification Combined Cycle (IGCC) and Pressurised Fluidised Bed Combustion (PFBC) enable higher thermal efficiencies still – up to 50 percent in the future. (WNA, 2014)

3.2. Coal in the Polish context

Poland’s energy sector is rather one-sided, concentrating on its most abundant local resources, namely hard coal and brown coal/lignite, origin of roughly 90 percent of Poland's electricity in 2012; a percentage which reflects the *‘highest national dependence (on a sole resource) in the world’* (Bayer, 2014). The graph below illustrates the distribution of sources for energy generation as of 2008.

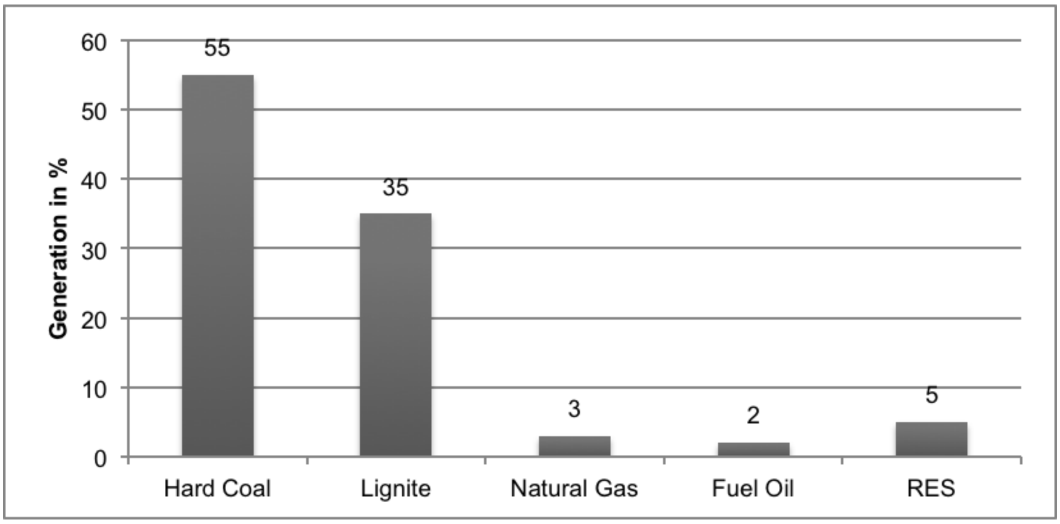

Figure 10: Energy generation by source (MoE, 2013)

According to the Ministry of Economy Poland ‘owns’ proven reserves amounting to 45 billion tonnes of hard coal and 20 billion tonnes of lignite, which at an annual average output rate of 69 million tonnes of hard coal and 56 million tonnes of lignite would last for 600 and 300 years respectively (Poland's Ministry of Economy, 2013). These numbers make Poland’s coal sector one of the most competitive industries in Europe, and Poland Europe’s largest coal producer and the ninth largest in the world. *‘Within the country hard coal goes to a range of market sectors and industrial users that include power generation, CHP, coke making, manufacturing and residential heating’* (IEA, 2007). A large part is also exported to other economies. As illustrated in the map below Poland has a widely distributed net of reserves with hard coal (black) concentrated in the South and South East, lignite or brown coal (brown) in the West and centre of the country and smaller gas and oil reserves (green) in the West and South. When compared to the territorial distribution of already existing coal fired plants it can be observed that the rather short or limited transport distances create favourable conditions for the exploitation of coal as an energy resource.

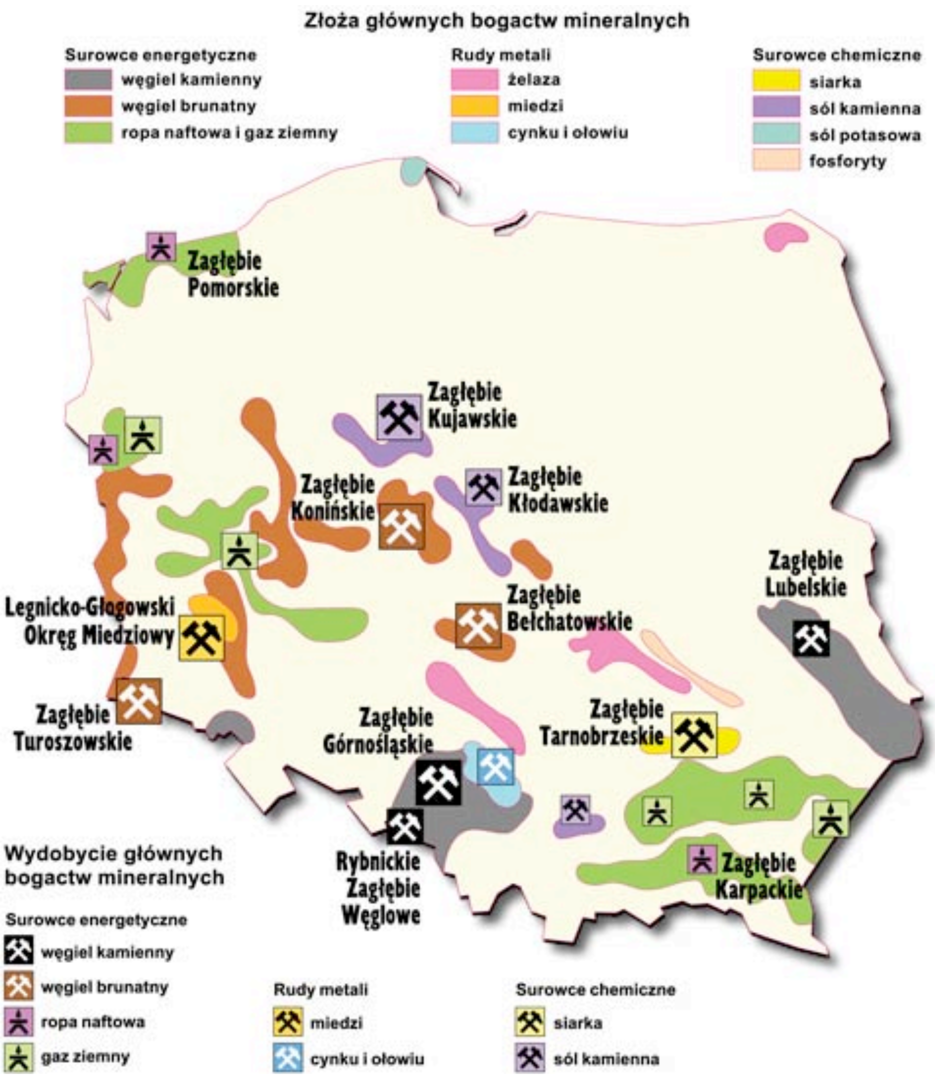

Figure 11: Location of main mineral reserves in Poland (Wiking EDU, 2014)

To date Poland's coal reserves ensured that it remained a net exporter of energy, however, growing demand is likely to result in capacity shortages as early as 2016 in a business-as-usual scenario (Bayer, 2014). Depending on the degree and speed of modernisation the deficit will either have to be imported at risk of growing reliance on external actors, or met through the exploitation of regenerative alternatives.

Four million households depend on coal as the primary or only heat source, which may prove an obstacle to a diversification of the energy mix. Additionally, the coal industry is a significant employer, particularly in rural areas, providing for over 100 000 jobs directly linked to coal extraction and processing. As a result a strong lobby and worker's representation is in place ensuring the protection of the sector and reacting critical to any mentioning of a possible shift to energy alternatives. A decline of the coal industry would thus have to be met with appropriate social policies ensuring employment or support to the workers likely to lose employment in the process.

Current national energy production is accompanied by negative side effects due to the out-dated (operational) infrastructure. Around 40 percent of conventional coal fired plants are over 40 years old, 55 percent over 30 years old, with an average efficiency of around 33 percent[13]. Consequently they lack modern end of pipe technology, i.e. technologies responsible for several cleaning processes during and after energy generation to reduce or completely eliminate the emission of polluting substances from plant stacks into the atmosphere, emitting vast amounts of CO_2 and other polluting GHGs into the atmosphere. According to estimates the introduction of end-of-pipe technology could reduce current pollutants concentration by 47 percent, thus providing a viable option or strategy to significantly decrease emissions and approach national GHG targets. End of pipe technology has become a major contributor to lower emission concentrations in all newly erected power and incineration plants in industrialised states.

With many plants to retire by 2030 a decision needs to be made on whether to decommission existing plants, replace them with modern state-of-the art models or substitute them with cleaner regenerative alternatives. Either way, investment is unavoidable, and with a combination of modernisation, higher efficiency, introduction of RES and thus overall diversification, Poland has the opportunity to reduce its emissions by 40 percent by 2030. The NREAP reconfirmed the importance of coal for the stability of Polish energy supply whereby 'it has been assumed that domestic resources of hard coal and lignite would remain important

[13] A table of specifications of plants currently in operation can be found in the next sub-chapter.

stabilisers of Poland’s energy security. It has been assumed that coal energy sources which are being withdrawn from use would be reconstructed on the basis of the same fuel by 2017 and that a part of baseload CHP plants to be built will be fired with hard coal’ (Ministry of Economy, 2010).

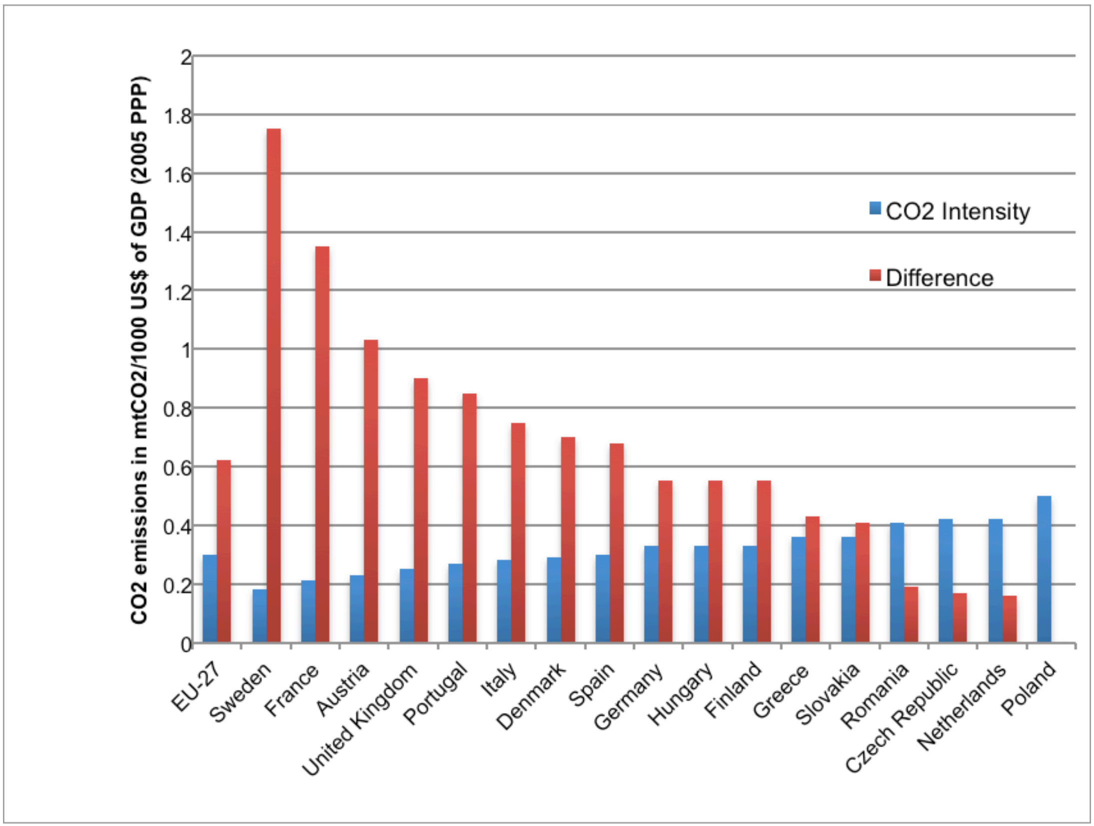

Figure 12: CO_2 emissions intensity and Poland’s difference to selected countries and regions (EIA International Energy Statistics 2008)

3.3. Overview and specifics of existing plants in operation

‘The backbone of the Polish electricity generating fleet comprises more than 50 pulverized coal fired power plants, operating with subcritical steam conditions. More than 30 of these operate as CHP facilities’ (IEA CCC, 2007). The map below illustrates the distribution of the most important hard coal and lignite fired power plants in Poland. The size of the orange circles reflects the capacity of the respective plants in GWh. The larger concentration in the South reflects both the rural industrial character, as well as the larger reserves in the region.

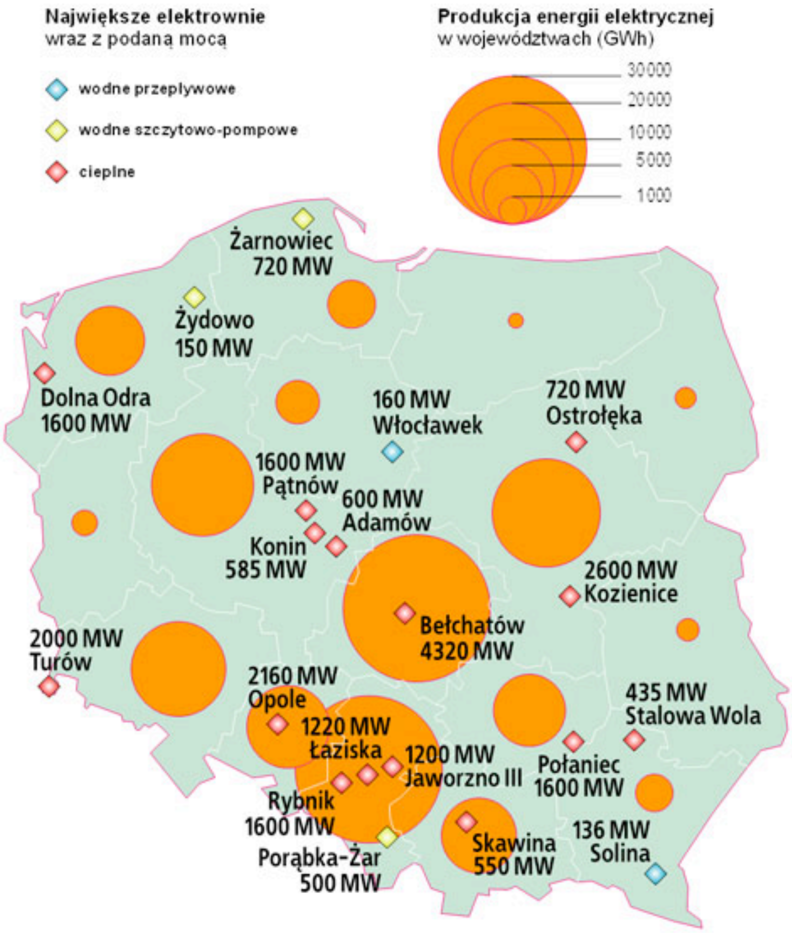

Figure 13: Major coal fired power plants in Poland and their capacity in MW (Wiking EDU, 2014)

The table below illustrates existing coal fired power plants on Polish territory according to their location, age, capacity, fuel type and ownership. It is to note that the data is based on personal research. Due to the lack of a comprehensive database on the number and type of power plants in Poland the list below is both subject to change and possibly incomplete. Respective efficiencies and CO_2 emissions have been assumed based on the year of construction and fuel type used in operation.[14]

[14] L = Lignite, HC = Hard Coal, B = Bituminous Coal, BM = Biomass, CHP = Combined Heat and Power, Y = Yes

Table 11: Overview of coal-fired power plants in Poland

Facility Name	Operator	Operation since	Location	CHP	Fuel	Installed Power	Efficiency (assumed)	CO2 (tons/year)
Elektrownia Turów	PGE	1962	Bogatynia	Y	L	5 298	35	10800000
Elektrociepłownia Czechnica	EdF	1961	Siechnice	Y	BC	132	33	425000
Elektrociepłownia Wrocław	EdF	1972	Wrocław			255	33	1190000
Elektrociepłownia Lublin Wrotków	PGE		Lublin					584000
Elektrociepłownia Lublin Megatem	Megatem-Lublin EC sp. z oo		Lublin					202000
Elektrownia Belchatów	PGE	1982	Rogowiec		L	4440	39	34400000
Elektrociepłownia Łódź 3	Dalkia	1969	Łódź	Y	BC	199	33	796000
Elektrociepłownia Łódź 2	Dalkia	1958	Łódź	Y	BC	181	31	493000
Elektrociepłownia Łódź 4	Dalkia	1969	Łódź	Y	BC	215	33	839000
Elektrociepłownia Kraków	EdF	1977	Kraków	Y	BC	460	37	2090000
Elektrownia Skawina	CEZ	1958	Skawina	Y	BC	490	31	1270000
Elektrownia Siersza	TAURON	1962	Trzebinia	Y	BC	796	33	2310000
Elektrownia Kozienice	ENEA	1972	Świerże Górne	Y	BC	2600	37	10700000

Elektrociepłownia Siekierki	PGNiG	1962	Warszawa	Y	BC	490	33	3220000
Elektrociepłownia Żerań	PGNiG	1954	Warszawa	Y	BC	250	31	2420000
Elektrownie Ostrołęka A	ENERGA	1958	Ostrołęka	Y	BC	75	31	3190000
Elektrownie Ostrołęka B	ENERGA	1972	Ostrołęka	Y	BC	652	37	
Elektrownia Opole	PGE	1993	Brzezie		BC	2160		6770000
Elektrownia Blachownia	TAURON	1957	Kędzierzyn Koźle	Y	BC	165	31	324000
Elektrociepłownia Mielec	EC Mielec sp. z oo.		Mielec					153000
Elektrociepłownia Rzeszów	PGE		Rzeszów					308000
Elektrownia Stalowa Wola	TAURON	1954	Stalowa Wola	Y	BC	350	31	1330000
Elektrociepłownia Białystok	ENEA	1978	Białystok	Y	BC	173	37	766000
Elektrociepłownia Będzin	EC Będzin SA	1978	Będzin	Y	BC	80	37	493000
Elektrociepłownia Chorzów	CEZ		Chorzów					921000
Elektrociepłownia Tychy	TAURON		Tychy					339000
Elektrociepłownia Zabrze	Fortum	1953	Zabrze	Y	BC	103	31	260000

Elektrownia Rybnik	EdF	1972	Rybnik	Y	BC	1720	37	8250000
Elektrociepłownia Częstochowa	Fortum	2010	Częstochowa	Y	C/BM	(coal) 64	46	119000 (2010 figs)
Elektrownia Halemba	TAURON	1962	Ruda Śląska	Y	BC	100	33	187000
Elektrownia Łagisza	TAURON	1963	Będzin	Y	BC	1060	33	3830000
Elektrownia Jaworzno 3 - Elektrownia 2	TAURON	1954	Jaworzno		BC	190	31	6230000
Elektrownia Łaziska Górne	TAURON	1967	Łaziska Górne	Y	BC	1155	33	5100000
Elektrociepłowna Bielsko-Biała EC1	TAURON		Bielsko-Biała					184000
Elektrociepłowna Bielsko-Północ EC2	TAURON		Czechowice-Dziedzice					395000
Elektrownia Jaworzno III - Elektrownia III	TAURON	1977	Jaworzno	Y	BC	1345	37	6230000
Elektrociepłownia Katowice	TAURON	2000	Katowice	Y	BC/WC	135	45	827000
Elektrociepłownia Zofiówka	Jastrzębska Spółka Węglowa		Jastrzębie Zdrój					414000 (2010)
Elektrociepłownia Moszczenica	Jastrzębska Spółka Węglowa		Jastrzębie Zdrój					137000
Elektrociepłownia Bytom-Miechowice	Fortum		Bytom					248000

Elektrociepłownia Kielce	PGE		Kielce					201000
Elektrownia Połaniec	GDF Suez	1979	Zawada	Y	BC/BM	1800	37	7070000
Elektrociepłownia Elbląg	ENERGA	1955	Elbląg	Y	BC	49	31	276000
Elektrociepłownia Poznań-Karolin	Dalkia	1984	Poznań	Y	BC	155	40	1380000
Elektrownia Adamów	ZE PAK	1964	Turek	Y	L/BM	600	35	4340000
Elektrownia Konin	ZE PAK	1958	Konin	Y	L/BM	193	33	746000
Elektrownia Pątnów	ZE PAK	1967	Konin		L	800	35	5840000
Elektrownia Szczecin	PGE		Szczecin					129000
Elektrownia Pomorzany	PGE	1960	Szczecin	Y	BC	120	31	750000
Elektrownia Dolna Odra	PGE	1974	Nowe Czarnowo	Y	BC	1600	37	5830000
Elektociepłownia Nowa	TAURON		Dąbrowa Górnicza	Y	BC			2860000
Elektrociepłownia Gdańska	EdF	1971	Gdańsk	Y	BC		37	1200000
Elektrociepłownia Gdyńska	EdF	1990	Gdynia					726000
Elektrociepłownia Zgierz	PGE		Zgierz					103000
Elektrociepłownia Bydgoszcz	PGE	1971	Bydgoszcz	Y	BC		37	1070000

Elektrociepłownia Toruń	EdF		Toruń					201000
Elektrownia Pątnów II	ZE PAK	2008	Konin		L	464	45	2280000
Elektrociepłownia Gorzów	PGE	1958	Gorzów Wlkp.	Y	BC	73	31	444000
Elektrownia Gubin	PGE	planned/ 2018	Lubuskie		L	2000	45	27312816,22
Elektrownia Legnica	Tauron	planned						27312816,22
Elektrownia Polnoc	Kulczyk Investments	planned			BC	2000		11655705,6
Elektrownia Opole 5 & 6	PGE	planned						9328000
Elektrownia Ostroleka (eb)	Energa Ostroleka	planned/ 2015		Y	C/BM	1000	46	5983000
Elektrownia Kozienice (eb)	ENEA	planned/ 2015		Y	BC	2000	46	5404100
Elektrownia Belchatow (eb)	PGE	2011			L	858	45	5094433,983
Elektrownia Wola (Silesia)	RWE & Kompania Weglowa	planned						4995302,4
Elektrownia Jaworzno 3	Tauron	planned			BC	855		4737864
Elektrownia Rybnik (eb)	EDF	planned		Y	BC	800	46	4737864

Elektrownia Łęczna (Stara Wieś-Stasin)	GDF Suez	planned			BC	800		4670000
Elektrownia Turow (eb)	PGE	planned/ 2016		Y	L	460	45	2867760
Elektrownia Zabrze CHP	Fortum	planned						1942617,6
Elektrownia Tychy	Tauron	planned						666040,32
Elektrownia Siechnice	Kogeneracja S.A.	planned						666040,32

3.4. Potential of an energy sector modernisation

The following sub-chapters aim to evaluate the potential, costs and benefits of different scenarios of an energy sector transition, keeping in mind their prospective contribution towards the achievement of the 20-20-20 goals, i.e. the modernization of coal-fired power plants, the replacement with a renewable energy infrastructure and the combination of energy production from coal and RES.

3.4.1. Scenario 1: Replacement of existing infrastructure with state-of-the-art technology

To determine the feasibility and potential of the replacement of current installations with state-of-the art coal-fired plants it is necessary to compare current efficiency levels, CO_2 emissions and overall costs with the levels of state-of-the art technology.

Considering technological advancements versus ‘wear and tear’, any product throughout its life cycle, in this case a power plant, loses in efficiency the longer it is in operation. Consequently, younger plants operate with higher efficiency and cleaner technologies. The table below illustrates the average efficiencies of coal-fired power plants depending on their age and operational period:

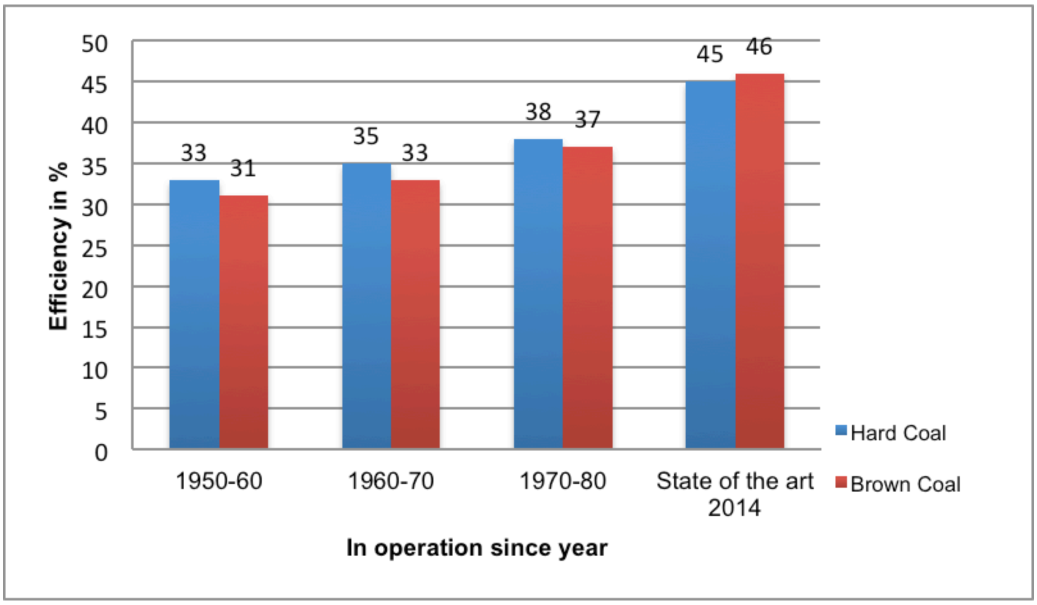

Figure 14: Average efficiencies of coal-fired power plants (Own research)

It can be concluded that a replacement of outdated technology by state-of-the-art installations would contribute towards higher efficiency, and consequently the consumption of less fuel. At the same time, thanks to the introduction of end-of-pipe technologies, CO_2 emissions would decrease significantly. Poland has the opportunity to achieve a crucial part of their 20-20-20 goals through the modernisation of the existing coal-fire system alone.

CO_2 emissions differ depending on the type of fuel used to fire the plant as listed below. Kilograms of CO_2 / kilowatt hour thermal (specific emissions) by fuel type:

Hard coal	0,343 kg
Lignite	0,419 kg
Natural gas	0,198 kg

The actual emissions of a power plant can thus be derived as follows:

eCO_2 = e-specific / efficiency (kg CO_2 / kWh)

Example: Typical Hard Coal fired plant, most of which started operating in the late 1950s / early 1960s, thus assuming an efficiency of 33 and 35 percent respectively:

$eCO_2 = 0{,}343 / 0{,}33 = 1{,}04$ kg CO_2/kWh

$eCO_2 = 0{,}343 / 0{,}35 = 0{,}98$ kg CO_2/kWh

as compared to state of the art emission levels:

$eCO_2 = 0{,}343 / 0{,}45 = 0{,}76$ kg CO_2/kWh

The modernisation of a power plant built in the 1950s can thus contribute to a reduction of CO_2 emissions by 26,9 percent or 0,28 kg per kilowatt-hour produced.

The same equation can be made for lignite fired plants, most of which began operating in the late 1950s / early 1960s with an efficiency of 31 and 33 percent respectively:

$eCO_2 = 0{,}419 / 0{,}31 = 1{,}35$ kg CO_2/kWh

$eCO_2 = 0{,}419 / 0{,}33 = 1{,}27$ kg CO_2/kWh as compared to the state of the art in 2014:

$eCO2 = 0,419 / 0,46 = 0,91$ kg CO_2/kWh

An update to state of the art levels can thus contribute to a reduction of CO_2 emissions by 67 percent or 0,44 kg per kilowatt-hour produced.

Another important factor to determine the feasibility of a modernisation is the financial aspect, i.e. how high would the investment need to be to build a modern state-of-the-art plant?

The average investment costs or the annuity factor a for a new power plant in Euro per kilowatt by fuel type equal to:

Hard Coal	a = 1500 – 2000 Euro/kW
Lignite / Brown Coal	a = 1200 – 1500 Euro/kW

These costs assume the inclusion of all typical costs linked to operation, repair, labour etc. over an average operation and life time (approximately 20 years). The separate calculation of all specific factors, tax, labour, insurance costs etc. would be complex and would not serve or contribute to the purpose of this thesis. Although, price and cost fluctuations over the years can be assumed the changes would only be minor due to the natural adaptation of the market and can thus be ignored.

Specific costs of electricity:

$k = alpha\ a + c / Tm + (b+d)$

whereas

$alpha = (q – 1)\ qn / qn – 1 = 0,087645 / 1,191123 = 0,0736$

average lifetime n = 20 years

q = 1 + p = 1,04

interest rate p = 0,04 (4%)

b = cost of coal in Eurocent / kg

c = Wear and Tear over lifetime 1,5% x a = 0,015 a

Hard coal:

a = 1500 Euro/kW

b = 1,8 Eurocent / kg = 0,018 Euro/kWh

d = 0,4 Eurocent / kWh

Lignite / brown coal:

a = 1700 Euro/kW

b = 1,5 Eurocent / kg = 0,015 Euro/kWh

d = 0,5 eurocent / kWh

Fuel type	Heat rate	Import price (Prognos)
Hard coal	7-8 kWh/kg	4,5 – 6,0 Eurocent/kWh
Brown Coal	2,2 kWh/kg	1,0 – 1,2 Eurocent/kWh
Brown coal dust	6,0 kWh/kg	

According to the NREAP Poland's total energy demand will amount to an annual 72.7 MtoE in 2020. This equals 845.5 TWh. Considering an average operation time of 24 hours per day, i.e. 8 760 hours per year this would amount to 96 518 378.995 kW. A replacement of all existing plants with state-of-the-art technology with the capacity to meet this demand would thus cost:

Hard coal powered plants only :	144.8 billion	- 193.0 billion Euro
Lignite powered plants only:	115.8 billion	- 144.8 billion Euro

when taking into account the reference investment costs above.

Maintaining the current ratio of the number of lignite to hard coal power plants (1:2) the costs would amount to between:

38.6 billion (L)	+ 96.5 billion (HC)	= 135.1 billion Euro
and		
48.3 billion (L)	+ 128.7 billion (HC)	= 177.0 billion Euro

3.4.2. Scenario 2: Replacement of existing coal-fired plants with renewable energy alternatives

To determine the potential emission reduction and costs of a total replacement of the existing system with renewable energy alternatives it is necessary to take the average investment and construction costs for RES installations and multiply them with the expected total energy demand for 2020. To avoid a complication of the matter the calculation will be based on a reference or average price for new wind powered installations, rather than a listing and separate calculation of all different types of RES. Wind turbines have been chosen due to their high potential, flexible construction and already existing stakeholder interest from both national and international actors and investors.

At 11 grams of CO2 emitted per kWh produced energy generated by wind power is technically CO2 emission free. The minor emissions across the life cycle are negligible and thus need not be calculated. This is, of course, only the case when considering the net emissions resulting from direct energy production, not the emissions set free during the production of the necessary parts, transport and construction of wind farms. Albeit important, they will not be considered in the context of this thesis, since they do not fall under the emissions measured within the framework of the EU 20-20-20 goals. Consequently, one can assume that the transition to a 100 percent renewable energy sector would offset the majority of CO2 and other polluting substances currently produced during conventional energy generation.

If the assumed energy demand for 2020 were produced by wind energy, 9.3 million tons of CO2 would be emitted annually as compared to 769 million tons from state-of-the art technology under Scenario 1.

The average investment costs for a small wind farm with a capacity of 1 MW amount to 1.5 Million Euro. Considering the average wind conditions in Poland such a small farm has the capacity to produce an annual 2 500 MWh, powering around 400 homes. 338 200.4 installations of 1 MW capacity would be needed, costing around 507 billion Euro.

After deducting the amount of already existing wind farms (3.08 GW) investment costs of 502.7 billion Euro would remain. This is 367.55 billion Euro more expensive than the cheapest combination of state of the art lignite and hard coal fired power plants. Already high, these costs do not take into account the requirement to plan and build a new infrastructure which incorporates, transmits and distributes energy generated from renewable sources.

The above calculations show that Scenario 2 would be prioritized if a significant reduction in CO2 emissions was the sole policy objective. Financially, however, this scenario is not feasible and lower emissions alone would neither persuade nor justify such high investment.

3.4.3. Scenario 3: Diversification through the combination of coal-fired power plants and renewable energy

This scenario allows for a variety of assumptions. Clear estimates or forecasts can thus not be made, as any possible make-up or mix of the energy mix depends on several factors, such as policy objectives, stakeholder interest, investment frameworks and environments, costs of technologies, to name a few. The following calculation will be based on a model which reflects Poland's national requirements for efficiency, emissions and renewable energy share as set by the EU's 20-20-20 goals and focuses on the minimum of changes necessary to achieve these objectives. It is to note that such a model should be regarded as short-term approach, considering that EU leaders are likely to increase European and national targets continuously, a trend which can already be observed in the Strategy 2030 and the aspired Roadmap 2050.

As a reminder, Poland is obliged to deliver 15 percent of its total energy from RES by 2020, equally increasing efficiency by 20 percent and reducing CO2 emissions by 14 percent. Assuming that the current share of RES lies at around 9 percent this would account for 76 TWh of the projected energy demand for 2020 of 845 TWh. This means that an additional 50 TWh would need to be produced from RES by 2020.

For simplification the calculation will be once more based on off-shore wind turbines as model for RES in general:

20 292,024 x 1.5 million Euro = 30.4 billion Euro

Equally the installation of additional RES will offset CO2 emissions amounting to approximately 15.7 Mt of CO2 produced in BAU old power plants minus 0,558 Mt of CO2 produced by wind farms = 15 Mt CO2 annually.

Additionally, it becomes inevitable to modernize or replace the outdated coal-based infrastructure. Under this scenario it can thus be assumed that the remaining 85 percent of energy will be produced by new state-of the-art technology. Deriving from the costs calculated in scenario 1, the replacement of 85 percent of coal-fired plants would cost at least 114 billion Euro. Combined with the costs for new RES installations this amounts to 145 billion Euro.

Equally emissions from the 85 percent coal fired energy generation would amount to 700 Mt of CO_2 under state-of-the-art technology. Combined with the emissions from RES the sum equals roughly 700 Mt.

(BAU: RES 9 percent: 837 Mt + CPs 91 percent: 1 007 Mt = 1 840 Mt)

The table below aims to summarise the above findings and allow for a direct comparison of all three scenarios:

Table 12: Summary of Scenarios

Scenario:	Costs in Euro:	CO_2 emissions in Mt:	Potentially saved CO_2 as compared to BAU in %
BAU:	-	1 008	
1:	135 billion	769	- 23,7
2:	502 billion	9	- 99,1
3:	145 billion	700	- 30,5

3.5. Efficiency

Efficiency is an important measure of an energy supply system. It plays a crucial role in the effective flow of energy supply and has a high impact on energy use and exploitation. The higher the efficiency of energy production, transmission, distribution and storage, the lower the actual necessary input and consumption of energy needed. In Poland it is below the European average, not only due to outdated production processes, but even more so due to flaws in the infrastructure, the transmission and distribution grid, resulting in, partially uncontrolled, losses and the use of more electricity than necessary. Losses and incidents of power outages have been linked to the high ratio of overhead installations in the electricity transport. The level in the System Average Interruption Duration Index is around eight times higher than in Germany for example (Bayer, 2014), where the majority of transmission cables run underground. Recent rain, storms and floods across the South of Poland have once again led to disruptions and power outages due to the destruction of overhead installations. An additional factor concerns the insulation of private and public buildings. Many apartment buildings, in particular older ones and prefabricated community houses, common for former socialist landscapes, lack modern insulation and double-glazed windows resulting in high losses of heat and consequently higher heat and energy consumption. This problem is not necessarily limited to Poland and can be observed across Europe. Refurbishments of decade-old buildings are on the rise and a higher investment in thermal insulation would provide for lower energy demand and consumption in return.

A study by McKinsey argues that

> *If all the energy efficiency opportunities…identified were captured, annual growth in electricity demand in Poland from 2005 to 2030 would drop from 1.5 percent per year in the BAU scenario to 0.9 percent per year – a difference of 29 Terawatt-hours by 2030. The most important opportunities…are in the buildings sector, where implementing stricter efficiency controls for new buildings and better insulating existing ones could abate almost 30 MtCO2e by 2030 – roughly 13 percent of the total potential.* (McKinsey&Company, 2009)

The opportunities linked to increased efficiency efforts have been acknowledged by international actors. The IEA estimates that both energy demand and efficiency will increase significantly by 2050, with the positive impact of efficiency increase contributing to less, or controlled consumption. Equally, the EU notes that *'to reduce greenhouse gas emissions within the Community and reduce its dependence on energy imports, the development of energy from renewable sources should be closely linked to increased energy efficiency'* (EP & CoEU, 2009). Increased efficiency in all stages and processes from energy production to consumption will decrease fuel input levels and demand in general, equally reducing pollutant emission levels as a side effect.

Poland acknowledged the importance of efficiency in its NREAP aiming for

> *Zero-energy economic growth, i.e. economic growth with no extra demand for primary energy; [and a reduction of] the energy intensity of Polish economy to the EU-15 level, consistently...[by means of]... inter alia: extension of the application of energy audits; introduction of energy management systems in industry;...introduction of energy efficiency standards for public utility buildings and facilities; intensification of replacing lighting systems with energy-saving ones; introduction of the white certificates system.* (Ministry of Economy, 2010)

Seeing as the Polish grid is based on decade old transmission lines and production technologies, numerous private and public buildings are yet to be modernised and insulated, a focus on efficiency measures combined with end-of-pipe technology will already contribute significantly to national efforts towards the 20-20-20 targets.

According to the World Coal Association:

> *Efficiency gains in electricity generation from coal-fired power stations will play*

a crucial part in reducing CO_2 emissions at a global level. Efficiency improvements include the most cost-effective and shortest lead-time actions for reducing emissions from coal-fired power generation. This is particularly the case in developing countries where existing power plant efficiencies are generally lower and coal use in electricity generation is increasing. Not only do higher efficiency coal-fired power plants emit less carbon dioxide per megawatt (MW), they are also more suited to retrofitting with CO_2 capture systems. Improving the efficiency of pulverised coal-fired power plants has been the focus of considerable efforts by the coal industry. There is huge scope for achieving significant efficiency improvements as the existing fleet of power plants are replaced over the next 10-20 years with new, higher efficiency supercritical and ultra-supercritical plants and through the wider use of Integrated Gasification Combined Cycle (IGCC) systems for power generation. A one percentage point improvement in the efficiency of a conventional pulverised coal combustion plant results in a 2-3 percent reduction in CO_2 emissions. (WCA, 2013)

The graph below illustrates the '*CO_2 reduction potential of coal-fired power plants by increased efficiency*'. It further shows that the replacement of out-dated plant technology with state-of-the-art technology increases the efficiency from Poland's current average of 33 percent to 45 percent, resulting in lower fuel consumption for the production of the same amount of energy, more specifically from previously 460 grams of coal per kilowatt-hour to 320 grams. More importantly, from an EU level point of view, the efficiency increase will further reduce the rate of CO_2 emissions from 1 116 grams of CO_2 per kilowatt-hour to 743 grams at least, amounting to a reduction by over 66 percent. In other words, the efficiency increase to current state-of-the-art levels alone can contribute to the compliance with EU emission reduction obligations.

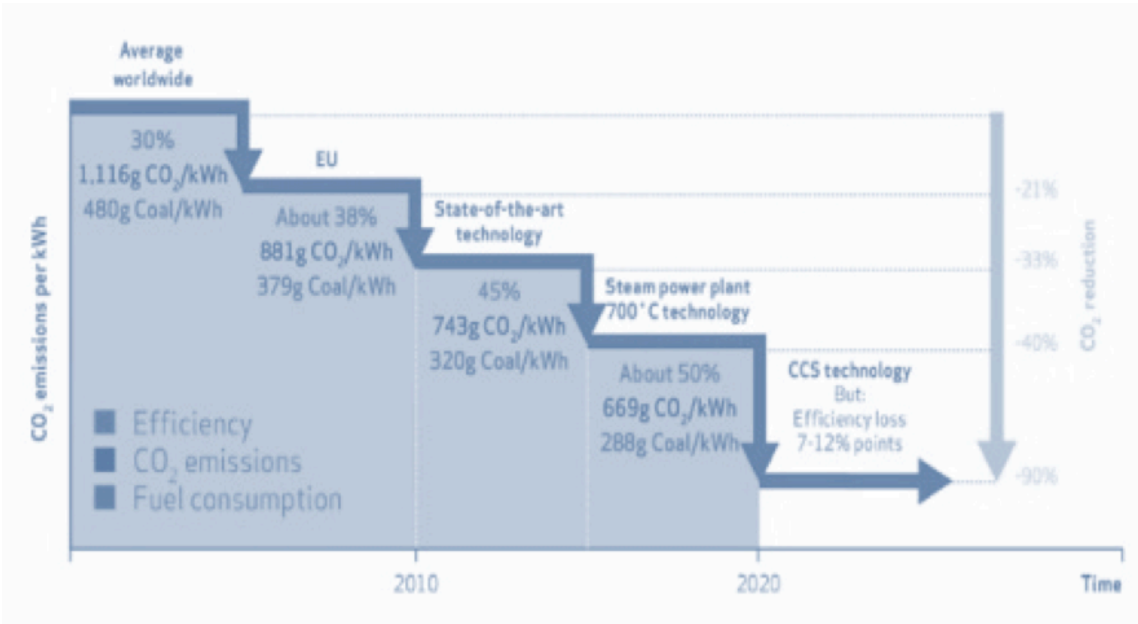

Figure 15: Impact of efficiency of a coal-fired power plant on its levels of CO2 emissions and fuel consumption (VGB PowerTech, 2010)

4. OTHER MEASURES AND IMPLICATIONS OF MODERNISATION

4.1. An Energy Cooperation with Germany

The above sub-chapters focused on the potential of national policy initiatives and modifications to the current energy market and energy mix. However, several arguments support an approach that looks beyond borders and a go-it-alone policy as currently favoured by Poland's government towards transnational partnerships.

Firstly, Poland is increasingly becoming an integral part of a greater structure. Its membership in the EU and other institutions imply an ever more cooperative approach to national, regional and global problems. Issues such as climate change mitigation and decarbonisation require common concerted action and must not be tackled in isolation. In its forecast report published in January 2010 the Ministry of Economic Affairs estimated that Poland will be able to not only meet periodical targets for renewable energy, but even surpass them by 0.5 percentage points by 2020, further arguing that the use of RES from abroad would not be necessary to satisfy domestic targets (Poland's Ministry for Economy, 2010). Considering repeated commitment to the coal industry, the forecast might have looked rather different if published in 2014 implying necessary RES imports after all.

In this context, one idea might be a partnership with another state based on the exchange of energy produced from the respective abundant sources. Due to a shared border and its frontrunner position in know-how and energy generation from RES Germany appears to be viable candidate. In a recent record, Germany produced 74 percent of its national energy demand from RES becoming one of the countries with the most prominent RES sector (Kroh, 2014). Further development may, however, be undermined by the lack of effective long-term storage solutions for renewables to date, which is also a danger for Germany's supply safety and stability. The amount of energy produced fluctuates with changing weather conditions, implying a continued necessity for a back-up of conventional fuel. A partnership between the two states could help both sides and would be focussed on the sale of energy generated from Polish coal-fired plants in exchange for energy supplies from RES. Germany would find a new market to sell its excess energy produced and avoid losing it to the lack of long-term storage while stabilising supply in times of fluctuations. Equally, Poland would secure the survival of its coal industry and work towards achieving its national 20-20-20 goals. Although such a partnership implies renewed interdependence on third actors the EU membership may contribute to trust and confidence building and additionally be protected by an EU level agreement incorporating safety principles. Naturally this concept should be treated as a temporary or transitioning solution, being contradictory to the overall objective of decreasing reliance on conventional fuels. It could offer a realistic, feasible and economic chance to transition from coal and fossil fuel to RES and allow for adaptation until long-term storage technology reaches a mature state.

In its next steps the concept could be further expanded to incorporate other states allowing for cooperation based on individual potentials and abundances eventually leading to the EU's goal of an integrated energy market across EU territory. Article 176 of the Treaty on the EU already sets out the idea of such an interconnected market. This could be extended further to include regional cooperation and the trade of RES. Equally, whereas each member state is obliged to meet its respective percentage or share of green energy in its energy mix nothing speaks against trans-border cooperation to achieve these goals towards overall EU progress. The 20-20-20 target applies to the EU in total, and might be achieved faster and more efficiently through an exchange of energy supply based on individual member state potential and capacity. Poland, a coal rich state with a long coastal line could focus its production on clean coal and future off-shore wind energy generation and obtain the remaining share of necessary alternative energy from other partners.

The EU RED offers the possibility for states to join efforts and cooperate in the generation of renewable energy, as stated in article seven, whereby *'Two or more Member States may cooperate on all types of joint projects relating to the production of electricity, heating or cooling from renewable energy sources. That cooperation may involve private operators*' (EP & CoEU, 2009). Moreover, states may

> *Decide, on a voluntary basis, to join or partly coordinate their national support schemes. In such cases, a certain amount of energy from renewable sources produced in the territory of one participating Member State may count towards the national overall target of another participating Member State if the Member States concerned' as lined out in article eleven.* (EP & CoEU, 2009)

Article six even allows for altruistic action:

> *1. Member States may agree on and may make arrangements for the statistical transfer of a specified amount of energy from renewable sources from one Member State to another Member State. The transferred quantity shall be:*
>
> *(a) deducted from the amount of energy from renewable sources that is taken into account in measuring compliance by the Member State*

making the transfer with the requirements of Article 3(1) and (2); and

(b) added to the amount of energy from renewable sources that is taken into account in measuring compliance by another Member State accepting the transfer with the requirements of Article 3(1) and (2).

A statistical transfer shall not affect the achievement of the national target of the Member State making the transfer.

4.2. Possible implications of modernization and/or replacement of existing power plants

In November 2013 Poland's chancellery published a report in which it reconfirmed the importance of coal as main energy source for the next 60 years (at least). This was justified by the vast, yet unexploited national reserves as well as financial estimates identifying it as the cheapest resource. The report fails to take into consideration the (in)direct or external both positive and negative effects of a diversification of the current energy mix. These are manifold in their social, political, economic and environmental characteristics, as will be elaborated upon in the paragraphs below:

4.2.1. Political implications

Albeit its political and legal obligation to comply with EU level benchmarks and regulations Poland has been a firm opponent of further (and stricter) obligations in past climate and environment related negotiations at EU and UN level. Most recently it earned criticism for simultaneously hosting the COP19 UN climate change conference and the International Coal and Climate Summit as contradicting events (Neslen, 2013). Whereas Polish pressure might achieve a slightly weaker consensus and negotiation outcome on common policies in the field of climate mitigation, the country does not have the political and economic power as some older member states to resist the introduction of reforms completely, and further risks to undermine its status and image in the international community. By no means should a state give into external pressure and agree to all policy decisions and suggestions made at international level. It should, however, feel encouraged to do so when it concerns initiatives likely to benefit the greater good in the long term.

In a BAU scenario, Poland risks missing the opportunity to become a frontrunner on sustainable and environmental awareness in Central and Eastern Europe. Modernisation would not only decrease political dependence on (imports of) (conventional) energy resources by third actors, but potentially establish Poland, as the largest state, as leader in alternative energy expertise in the Eastern European region, a know-how which would not only earn respect by the international community but one it could export to other states further East, where industries are yet to be modernised. The involvement of Poland as a culturally closer actor may be met with greater acceptance in former socialist states than the same efforts of interference from Western partners. Poland should thus see a rapid transition as a possibility to become the EU's partner and mediator in new and prospective member states. Common history, links to the USSR regime and geographic location would encourage it.

Additionally, sufficient (expert) proof on the reality of climate change and the need for urgent concerted action has been presented. If Poland continues down the reluctant path, it will fall behind other modernising and future-oriented economies, possibly widening the gap to more industrialised states. With decreasing costs of (renewable) energy alternatives technology, costs seize to be a valid argument for failure of adaptation. A recent report by the IPCC even shows that measures would not cost as much or have as strong an economic impact as previously feared, but lead to greatest benefit when implemented in coordinated cross-border action. Poland cannot stand-by and merely benefit from mitigation measures of its international partners. After all, a strategy is only as strong and effective as its weakest link.

4.2.2. Economic Implications

Thanks to growing analysis and scientific evidence policy-makers have become aware of the implications of anthropogenic activity and unsustainable practice. Unfortunately this awareness is not yet substantially reflected in national and international policy-making, at least not to an equal level across states. According to UNEP, however, substantial 'investments in renewable energy can be part of an integrated strategy to green the oath of global economic development' and the *'increased use of renewable energy sources could contribute more than one-third of the total reduction in greenhouse gas emissions of 60 percent achieved by 2050'* (United Nations Environment Programme, 2011).

UNEP has introduced the concept of a Green Economy, defined:

> *as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities...A green economy can be thought of as one, which is low carbon, resource efficient and socially inclusive. Practically speaking, a green economy is one whose growth in income and employment is driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services. These investments need to be catalysed and supported by targeted public expenditure, policy reforms and regulation changes. This development path should maintain, enhance and, where necessary, rebuild natural capital as a critical economic asset and source of public benefits, especially for poor people whose livelihoods and security depend strongly on nature.* (United Nations Environment Programme, 2013)

A transition to a regenerative energy sector could thus support the achievement of all the above objectives, i.e. the improvement of human well-being through new economic and employment opportunities, eventual energy security and self-efficiency, the reduction of carbon emissions and general pollution, as well as legal and institutional reform.

One obstacle to greener economies lies in the fact that the financial and banking sector fails to put the long-term common good over its focus on monetary profit. Despite growing environmental awareness many (inter)national financial institutions remain highly involved in the fossil fuel business, offering huge loans and investments in the coal industry in particular. However, according to an analysis by Bloomberg New Energy Finance the costs for meeting the national renewable energy targets would account for 0.32 percent of Poland's GDP or 724 million Euros annually, leading to a benefit (total net saving) of 97 to 338 million Euros in 2020 for the Polish economy (Bloomberg New energy Finance, 2012).

As mentioned above, the gradual development of know-how on alternative energy sources can eventually translate into an additional new service sector for the region, i.e. 'green consulting' or the export of clean energy knowledge to other less developed neighbours in the region who will increasingly become dependent on a shift to cleaner resources themselves.

Economic or energy sector reform at national level would also (in)directly lead to improved political and institutional structures. The existence of a viable economic sector presumes the creation of an environment conducive to economic growth, i.e. a system based on legitimate rules, regulations, institutions and the rule of law, which guarantees legal certainty and protection for entrepreneurs and stakeholders. An enabling business environment is, inter alia, one of the crucial conditions to attract both national and foreign investors. The potential of new income opportunities and consequently economic growth may act as incentive to increase national efforts towards more rapid reform. Thus, one might speak of the likelihood of a positive spill-over from economic to political reform, however, in particular at national level, institutional reform must precede economic one due to the arguments mentioned above.

4.2.3. Environmental Implications

The coal industry is currently experiencing a renaissance due to rather low CO_2 emission trade prices and cheap import prices (Winterer & Sempelmann, 2014), an attractive combination in the aftermath of the recent economic crisis and a phenomenon Poland could try to benefit from. What is not taken into account or largely ignored, however, are the direct and indirect effects on health and environment. At the current annual rate of coal related energy production, Poland's practice leads to the emission of 1 008 Megatons of CO_2, which is also felt beyond Poland's borders. *'A dozen large coal fired power plants are currently in the planning stages. They will potentially add over 100 million tonnes of CO_2 emissions, thus increasing Poland's annual carbon footprint by a third'* (Greenpeace, 2013).

> *Additionally the coal industry is responsible for the emission of other polluting substances such as SO_2, NO, fine particles and mercury. A recent study by Global 2000 and the Health and Environment Alliance reconfirms that emissions set free during the burning of coal lead to detrimental health effects, such as breathing problems, asthma, decreased life expectancy and even premature deaths (Winterer & Sempelmann, 2014).*

The global annual costs of treatment of related health problems amount to 194 million Euros.

Health implications are not the sole issue, however. Industrial activity is responsible for enormous environmental pollution leading to a loss in biodiversity, loss of natural habitats of animals, decreased soil quality and nutritiousness, as well as air quality. Belchatow, as the largest coal fired power plant in Poland, affects the surrounding environment, leading to lower water levels and air quality for example. The situation is even more alarming in the cities within the vicinity of industrial activity. Two Polish cities, namely Katowice and Cracow are among the top 20 most polluted cities in the EU, with 76 and 68 points on the Numbeo pollution index respectively (Numbeo, 2014). Comprehensive environmental impact assessments on BAU effects, as well as accompanying costs of counteraction, mitigation, medical treatment etc. are necessary and must be taken note of for informed action by policy-makers to prevent further deterioration.

The transfer to an increased use of green energy would thus mitigate effects of climate change and environmental degradation mitigation. Even though emissions cannot be fully avoided, renewable alternatives are proven to produce significantly less than conventional non-renewable sources. The table below compares the life cycle of CO_2 emissions of power generating-technologies. Hydropower is considered to contribute most to reductions, followed by wind and geothermal energy technologies (Müller, Braun, & Ölz, 2011).

Although a move from a carbon-reliant to a green industry will contribute to environmental mitigation in the long term, the development assumes some environmental implications in the short to medium term. After all, the construction of the necessary infrastructure requires extensive use of machinery, transport, transit, etc. and is likely to impact on the development of previously unused spaces. Comprehensive studies and environmental impact assessment must be incorporated into the planning of new plant locations, etc. to avoid ecological destruction and contradictory effects in the process towards greener energy.

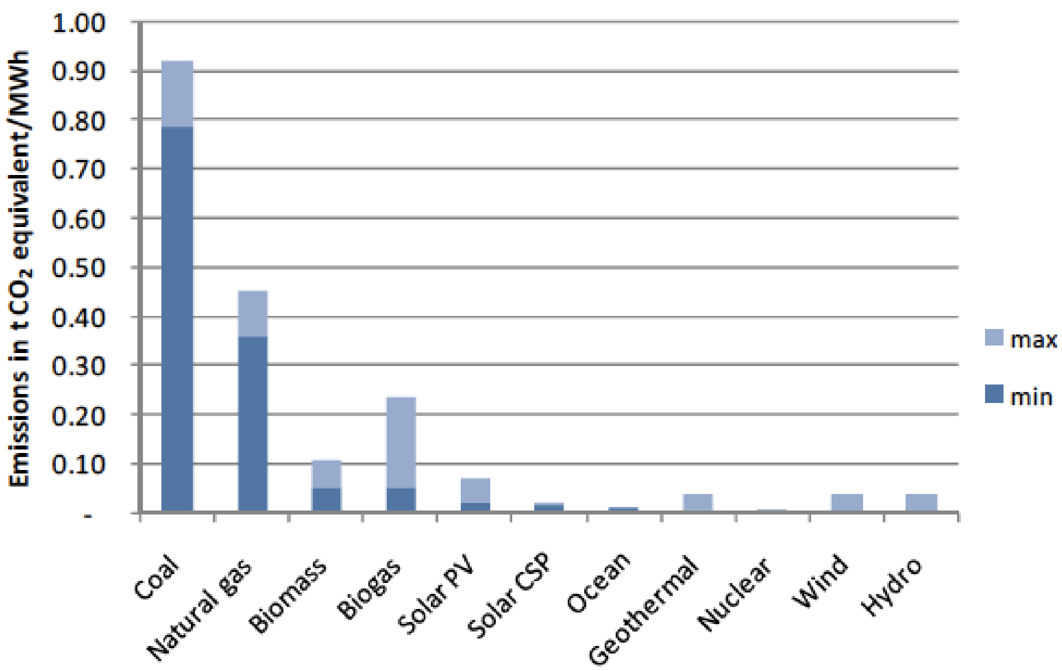

Figure 16: Emissions of CO2 by energy source (Müller, Braun, & Ölz, 2011)

4.2.4. Social implications

The social benefits in relation to health and environmental aspects, i.e. a decrease of pollution, improved air, soil and water quality, improved health and living standards to name a few, have been discussed above.

The benefits in social terms lie predominantly in the newly arising employment opportunities. The renewable energy sector is increasingly turning into an important source for employment opportunities from low to high skilled jobs. In 2010 3.5 million people were (in)directly employed in the sector (United Nations Environment Programme, 2011). According to UNEP *'compared to fossil fuel power plants, renewable energy generates more jobs per unit of installed capacity, per unit of power generated and per dollar invested'* (Müller, Braun, & Ölz, 2011).

> *Initially, economic restructuring means that jobs are both created and destroyed. As countries further integrate into the global economy, restructure enterprises, improve conditions for doing business, and modernize labour markets, job creation outpaces job destruction and this then translates into higher aggregate employment.* (World Bank, 2013)

The move towards a green economy can thus help reduce unemployment, halt the brain drain of skilled workers and rural exodus to more prosperous economies, a trend Poland as a country of emigration has been forced to fight with for several generations. According to a Greenpeace report the shift to renewables could potentially create 108 600 direct jobs, which is equal to Poland's workforce currently employed in the coal industry (Greenpeace, 2013). Equally, the NREAP assumes the creation of several thousand jobs annually from a shift to RES development: i.e. 8 557 in 2014, 9 834 in 2015, 7 882 in 2016, 8 566 in 2017, 8 781 in 2018, 10 405 in 2019 and 16 371 in 2020 respectively.

Traditional economic models show the interrelation between employment, growth and development. Higher employment rates would result in increased spending power of households, a benefit not only to the individual, but also effectively to rising demand and eventually economic growth itself.

Another positive implication lies in the opportunity to tackle the challenge of energy poverty. Even today over two billion people remain without access to electricity. Renewable energy offers the most favourable option to improve energy supply, environmental and living conditions (European Renewable Energy Council, 2011). According to the Global Energy Assessment Report

> *Access to modern forms of energy is an essential pre-requisite for overcoming poverty, promoting economic growth, expanding employment opportunities,*

supporting provision of social services, and, in general, promoting human development', whereby 'countries with the highest levels of poverty and underemployment tend to be those that also lack access to adequate levels of energy services and the modern conveniences they provide' (Karekezi & McDade, 2012).

The provision of more efficient, diversified and secure energy structures will both decrease the price of energy for private households and allow for a diversion of income to other areas of personal development, e.g. education.

The expansion of energy services through the modernisation and construction of new (plant) infrastructure implies a gradual urbanisation process, which may improve the integration of rural areas through the creation of new transport routes and infrastructure, allowing for the connection of isolated regions. Higher integration with the remaining urban territory enables rural populations to improve their living conditions by means of access to better health and education services, but also to cultural offers, which will eventually lead to higher living standards, social development and more homogenous societies. While economic growth will always remain a key policy objective, the improvement of social conditions should not be underestimated. Social development is a prerequisite to a modern society; higher education levels have a positive correlation to improved rule of law, innovation and efficiency.

The positive contribution of a market transition has also been confirmed by the European Union in its RED:

> *When favouring the development of the market for renewable energy sources, it is necessary to take into account the positive impact on regional and local development opportunities, export prospects, social cohesion and employment opportunities, in particular as concerns SMEs and independent energy producers.* (EP & CoEU, 2009)

The Directive further states that:

> *It is appropriate to support the demonstration and commercialisation phase of decentralised renewable energy technologies. The move towards decentralised energy production has many benefits, including the utilisation of local energy sources, increased local security of energy supply, shorter transport distances and reduced energy transmission losses. Such decentralisation also fosters community development and cohesion by providing income sources and creating jobs locally.* (EP & CoEU, 2009)

5. CONCLUSION

5.1. Summary of findings

The aim of this thesis was to look at the situation and characteristics of Poland's energy sector, by determining the importance of the coal industry as part of the national energy mix, as well as by looking at the national strategy to modernise the energy sector towards increased diversification and incorporation of cleaner, sustainable, and foremost renewable energy resources in the context of the obligations imposed upon Poland within the framework of EU Climate and Energy Policy and the 20-20-20 goals.

The first part of the thesis presented the theoretical background outlining the general situation and structure of Poland's energy market, as well as the national potential and development of national and international energy policy on the way towards environmentally friendly energy generation.

The second part discussed the importance of coal as a crucial energy resource and tried to bring together data on Poland's coal power plant network. To determine the possible investment costs three possible scenarios for Poland's future energy sector were assumed, i.e. a full reliance on modernised coal-fired power plants, a full replacement of coal-based energy generation by RES, and finally, a combination of the two alternatives, concluding that a either a share of energy generation between coal and renewable sources or a modernisation of the existing infrastructure present themselves as viable options. Either way, both a focus on increased efficiency and cross-border cooperation on energy exchange would contribute significantly to a modernisation of the energy supply system, as well as the achievement of the EU 20-20-20 goals.

Finally, the last chapters were devoted to the implications, both positive and negative, of the maintenance of the status quo or the gradual transition towards greater diversification respectively, concluding that Poland could benefit from an honest commitment to a greener energy sector in financial, political and social terms. However, stakeholders would have to be aware that the process requires long-term involvement with most benefits materialising only after an initial period where greater investments and efforts would be necessary.

A comparison of the financial components of different scenarios and their potential to contribute to decarbonisation, emission reduction and stable supply shows that despite popular belief Poland is not yet prepared or capable to opt for a predominantly regenerative economy. Abundant coal reserves, existing infrastructure and government and industry support for coal as the leading energy resource speak in favour of the modernization of coal powered plants, which, given current and expected improvements in the state of the art technology, can indeed contribute to the production of affordable energy at significantly reduced emission and pollution rates. Coupled with trans-border cooperation on the transfer of respective energy supplies between Germany and Poland and an overall increase in efficiency in coal exploitation, energy production and distribution, improved isolation of buildings and prevention of network and heat losses, Poland will benefit most from a cooperative and efficient clean coal approach towards a gradual and pragmatic transformation of its energy sector.

5.2. The future of Poland’s energy sector

Climate change and the decrease of conventional (fossil fuel) sources have become an undeniable fact. (Publicly at least) a global trend towards the exploitation of renewable alternatives can be observed, putting traditional coal-based energy production under pressure. Albeit continued (financial) support for and trust in the coal industry, production will have to meet several expectations and criteria to become sustainable and future-proof. Efficiency and low emissions of CO2 and other polluting substances have been discussed at length in the chapters above. Another important characteristic will be the flexibility of the overall energy sector and supply system. With an exponential growth of the RES share in the national and global energy mix traditional processes will have to be adapted to complement a fluctuating generation from renewables. Coal-fired plants will gradually stop running on full-load hours and remain efficient with lower loads. Additionally the time required to fire-up a plant and generate energy will have to be decreased in order to allow for rapid take-up of operations to ensure stable and sufficient supply during periods where the output of RES installations is hampered by unfavourable (weather) conditions. Poland, just as the rest of the global community, will have to develop and adopt a strategy to establish a well-oiled interaction between new and conventional means of energy production towards a future-proof energy sector.

As already mentioned Poland received the opportunity to give more weight to its interests through the appointment of (former) Prime Minister Tusk to one of the top posts in the European Union, namely the position of President of the European

Council. For the first time, one of the new CEE members assumes a powerful position, an opportunity Mr Tusk is likely to exploit by all means. Considering previous attitudes and positions on issues of international nature, his appointment will likely lead to enforced negotiations on energy independence from Russia, thus greater European cooperation, as well as less stringent climate and environmental regulations. Equally it could also be an opportunity for Poland to take the lead in integrating states with less developed, coal and gas reliant energy sectors and guide them on their way towards energy independence and cleaner energy, as suggested in the chapters above.

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Annex 1: OUTLINE OF A TYPICAL COAL FIRED POWER PLANT

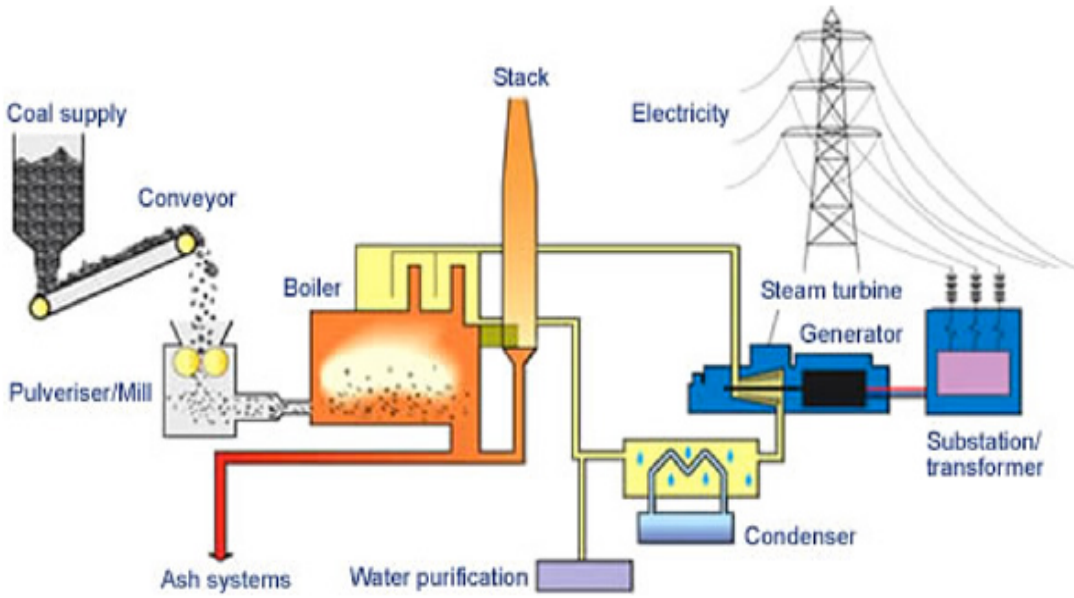

Figure 17: Energy production from a coal-fired power plant (WCA 2014)

Annex 2: INTERNATIONAL LEGAL FRAMEWORK

Growing awareness about the negative impact of (careless) anthropogenic activity in the past century, as well as diminishing traditional energy sources, prompted interest and discourse on the development of 'green economies' and progress in the deployment of renewable energy. In an effort to counteract climate change, slow down global warming and mitigate the impact of past activities leaders agreed on several multilateral directives and agreements setting out objectives, rules and measures to achieve common goals.

A.2.1. United Nations Framework

Awareness and consideration of the impact of anthropogenic activity on the planet and its environment, as well as consensus on common responsibility for the tackling of accompanied challenges increasingly gained prominence at EU level from the 1970s onwards. It, inter alia, resulted in the formation of the United Nations Environment Programme in 1972 with the mission to act *'as a catalyst, advocate, educator and facilitator to promote the wise use and sustainable development of the global environment'* (United Nations Environment Programme, 2014). In the context of this thesis three important agreements should be mentioned, if only, because they are regarded as models or precursors for policies and efforts at EU level:

As a result of the conference in Stockholm in 1972, the declaration of the UN Conference on the Human Environment firstly acknowledges common responsibility for the protection of the environment and the sustainable use of natural resources, proclaiming

> *Growing evidence of man-made harm in many regions of the earth: dangerous levels of pollution in water, air, earth and living beings; major and undesirable disturbances to the ecological balance of the biosphere; destruction and depletion of irreplaceable resources; and gross deficiencies, harmful to the physical, mental and social health of man, in the man-made environment, particularly in the living and working environment.* (United Nations Environment Programme, 1972)

More prominently, the Rio Declaration on Sustainable Development 1992 set out guidelines for concerted action on sustainable development and mitigation of harmful anthropogenic activity. Under principles seven and eight states agreed to:

> *Cooperate in a spirit of global partnership to conserve, protect and restore the*

> *health and integrity of the Earth's ecosystem...and reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies.* (United Nations Conference on Environment and Development, 1992).

Unsustainable or non-environmental economic activity was to be discouraged, which could also be expanded to polluting energy generation.

Aside from the Rio Declaration, the UN Framework on Climate Change is the second important document drafted at the United Nations Conference on Environment and Development in 1992. A non-binding treaty it entered into force in 1994 aimed to address climate change issues and provide a framework towards the negotiation of binding limits on GHGs. The main objective, as stated in Article two is:

> *The stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.* (United Nations Framework Convention on Climate Change, 1992)[15]

Although adopted in 1997, the Kyoto Protocol to the UNFCC, as the result of state negotiations on binding GHG emission obligations, did not enter into force until 2005[16]. Its success is contested due to the lack of ratification by important states, such as the United States or China, who are simultaneously part of the biggest emitters in the world. Article two of the Protocol calls for the introduction of policies which, inter alia, enhance energy efficiency, reduce GHG emissions and promote increasing use of renewable forms of '*new and renewable forms of energy, of carbon dioxide sequestration technologies and of advanced and innovative environmentally sound technologies'* (Kyoto, 1998).

Poland, for example, committed to a GHG reduction of 6 percent for the period of 2008-2012 and 20 percent for the period of 2012-2020 (not ratified), as compared to levels in the base year 1990 (Kyoto, 1998). The targets have indeed been met and even exceeded. Additionally the Protocol introduces three mechanisms, by which states can cooperate in their efforts to reduce emissions and achieve national targets: Emissions trading, the Clean Development Mechanism and Joint Implementation of Projects.

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[15] For a full text of the Framework see: https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf

[16] For a full text of the Protocol see: http://unfccc.int/resource/docs/convkp/kpeng.pdf

A.2.2. European Union Framework

Major developments at EU level can be observed from the early 2000s, although energy had already played an indirect part in the formation of the precursor of the Union in the form of the European Coal and steel Community. In the spirit of UN level agreement leaders of the EU committed to a low consumption economy based on more secure, more competitive and more sustainable energy. Priority energy objectives involve ensuring the 'smooth functioning of the internal market in energy, security of strategic supply, concrete reductions in greenhouse gas emissions caused by the production or consumption of energy and the EU's ability to speak with a single voice on the international stage'. With the entry into force of the Lisbon Treaty energy became one of the core foci, provided with a previously lacking legal basis in the form of article 194 of the Treaty on the Functioning of the European Union, whereby

> *Union policy on energy shall aim...to: (a) ensure the functioning of the energy market; (b) ensure security of energy supply in the Union; (c) promote energy efficiency and energy saving and the development of new and renewable forms of energy; and (d) promote the interconnection of energy networks'* (European Union, 2010).

The EU regulatory framework has been discussed in more details in chapter 2.3. above. Its success depends on the will and cooperation of the individual member states and stakeholders, as well as the implementation of the right national regulatory frameworks and investment environments. The EU is now the least energy intensive region in the world.

According to the Renewable Energy Directive:

> *The control of European energy consumption and the increased use of energy from renewable sources, together with energy savings and increased energy efficiency, constitute important parts of the package of measures needed to reduce greenhouse gas emissions and 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. Those factors also have an important part to play in promoting the security of energy supply, promoting technological development and innovation and providing opportunities for employment and regional development, especially in rural and isolated areas.* (European Parliament and Council of the European Union, 2009)

A progress report on the development of renewable energy in the European

Union shows that there is an overall upwards trend in the share of renewable in the gross energy consumption. *'In fact, the 2010 renewable energy shares of 20 Member States and the EU as a whole were at the level of or above 2010 commitments set out in their national plans and above the first interim target for 2011/2012'* (European Commission, 2013). However, the level of progress differs between member states, with many having failed to reach their 2010 targets, thus leading to a bleaker outlook towards the 2020 goals. The report further concludes that

> *Overall, by sector and across technology, there has been a strong initial start in EU renewables growth under the new regime of the Renewable Energy Directive. However, as we look at their future evolution, it seems that the economic crisis is now affecting the renewable energy sector, particularly its cost of capital, as it has all other sectors of the economy. This, combined with ongoing administrative barriers, delayed investment in infrastructure and disruptive changes to support schemes, means further efforts are needed to achieve the 2020 targets.* (European Commission, 2013)

The Commission suggests a strengthening of cross-border cooperation to reach targets, as well as of support and guidance on effective implementation of measures (European Commission, 2013).

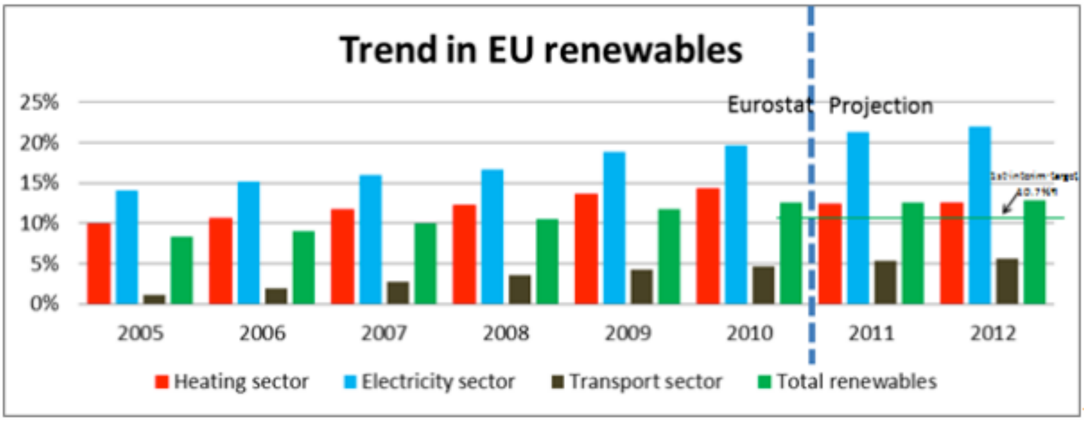

Figure 18: Trend in EU renewables (Eurostat)

The Third legislative Energy Package focuses on the smooth operation of electricity and gas supply markets in Europe towards the eventual formation of a single European energy market. According to the preamble of the electricity directive 2009/72/EC *'A well-functioning internal market in electricity should provide producers with the appropriate incentives for investing in new power generation, including in electricity from renewable energy sources'* (European Parliament Directorate General for Internal Policies - Policy Department A Economic and

Scientific Policy - Industry, Research and Energy, 2010). In the context of this thesis the third package is of importance in so far, as it encourages the unbundling of production, supply and transmission of energy. *'Proponents of unbundling claim that vertically integrated companies…have little incentive to invest in networks due to the fact that congestion revenues outweigh possible profits from building interconnections'* (European Parliament Directorate General for Internal Policies - Policy Department A Economic and Scientific Policy - Industry, Research and Energy, 2010). This is also the case in Poland, where it results in limited or blocked access of new and renewable energy operators to the national grid. It further calls for more flexible and adaptable networks:

> *The integration of the main large scale renewable energy sources (wind, solar and tidal) often located far from the point of consumption, with CHP and small renewable energy sources normally located very close to the point of consumption will require (i) increased long-distance transmission capacity, (ii) more load flexibility by means of demand side management, and (iii) active distribution networks managed similar to the transmission network.(EC 2007) The 3rd internal market package aims to facilitate the transition towards such a renewables proof electricity grid.* (European Parliament Directorate General for Internal Policies - Policy Department A Economic and Scientific Policy - Industry, Research and Energy, 2010)

Other important factors for smooth operation and climate change mitigation are the introduction or expansion of smart grid systems and other energy efficiency measures.

Annex 3: OVERVIEW OF POLICIES AND MEASURES TO PROMOTE RES[17]

Polish legislation that supports implementation of the national policy to promote the use of energy from renewable sources includes mainly:

1. Energy Act of 10 April 1997 (Journal of Laws of 2006 No 89, item 625, as amended).

2. Act of 2 July 2004 on freedom of economic activity (Journal of Laws of 2007 No 155, item 1095, as amended).

3. Act of 6 December 2008 on excise duty (Journal of Laws of 2009 No 3, item 11, as amended).

4. Environmental Act of 27 April 2001 (Journal of Laws of 2008 No 25, item 150, as amended).

5. Regulation of the Minister of Economy of 14 August 2008 on detailed scope of obligations in respect to obtaining certificates of origin and submitting them for cancellation, payment of a substitution fee, purchase of electricity and heat from renewable energy sources, as well as the obligation to confirm the data on the amount of electricity produced from a renewable energy source (Journal of Laws No 156, item 969, as amended).

6. Regulation of the Minister of Economy of 4 May 2007 on detailed conditions for the electricity system functioning (Journal of Laws No 93, item 623, as amended).

7. Regulation of the Minister of Economy of 2 July 2007 on detailed principles for defining and calculating tariffs and principles for settlements in electric energy trading (Journal of Laws No 128, item 895, as amended).

8. Regulation of the Minister of Economy of 3 February 2009 on granting public aid for investments involving construction or extension of units producing electricity or heat from renewable energy sources (Journal of Laws No 21, item 112).

9. Energy Policy of Poland until 2030 (with appendices) adopted by the Council of Ministers on 10 November 2009 and announced by the announcement of the Minister of Economy of 21 December 2009 on the national energy policy until 2030 (M.P. of 2010, No 21, item 11).

10. Act of 26 October 2000 on commodity exchanges (Journal of Laws of 2010 No 48, item 284, as amended) together with the Act of 29 July 2005 on public offer and the conditions for introducing financial instruments to the organized trading system and on public companies (Journal of Laws of 2009 No 185, item 1439, as amended), as well as regulation of the Council of Ministers of 22 December 2009 on

[17] The information in Annex 3 has is a direct reference from the NREAP.

special procedure and conditions for introducing property rights to trading on the exchange (Journal of Laws of 2010 No 6, item 30) issued based thereon.

11. Regulation of the Minister of the Environment of 2 June 2010 on detailed technical conditions for qualifying a part of energy recovered from heat treatment of municipal waste (Journal of Laws of 2010 No 117, item 788).

12. Regulations of the Commodity Energy Exchange (Towarowa Gielda Energii S.A.) and the related document Conditions of trading of property rights to certificates of origin for energy produced from renewable energy sources issued by the Commodity Energy Exchange S.A.

13. Regulations of the Register of Certificates of Origin kept by the Commodity Energy Exchange S.A., issued by the Commodity Energy Exchange S.A.

14. Operating and Maintenance Instructions of the Transmission Grid drawn up and published by PSE Operator S.A.

15. Financial priority programme of the National Fund for Environmental Protection and Water Management (Narodowy Fundusz Ochrony Srodowiska i Gospodarki Wodnej, NFO•iGW) titled Energy use of geothermal resources (Energetyczne wykorzystanie zasobów geotermalnych).

Table 13: Overview of all policies and measures (Ministry of Economy, 2010)

Name and reference of the measure	Type of measure	Expected result	Target group or activity	Existing or planned	Start and end dates of the measure
1. The obligation to obtain certificates of origin and submit them for cancellation or to pay the substitution fee imposed on energy companies selling electricity to end users	Regulatory	Increase in the installed power in renewable sources	Producers of energy from renewable sources, investors in generating installations using renewable energy sources, President of the Energy Regulatory Office of Poland, company selling energy to end users	Existing	Since 24 February 2007
2. Obligation to purchase energy produced from renewable sources imposed *ex officio* on sellers	Regulatory	Increase in the installed power in renewable sources	Producers of energy from renewable sources, investors in generating installations using renewable energy sources, sellers *ex officio*, President of the Energy Regulatory Office of Poland	Existing	Since 4 March 2005
3. Obligation of energy grid operators to ensure priority to all entities in the provision of services involving transmission or distribution of electricity produced from renewable energy sources	Regulatory	Increase in the installed power in renewable sources	Energy grid operators, investors in generating installations using renewable energy sources, producers of energy from renewable sources	Existing	Since 1 July 2007
4. 50% reduction of the fee for connection to the grid, determined based on actual outlays incurred for installing the connection for renewable energy sources with total installed power not exceeding 5 MW	Financial	Increase in the installed power in renewable sources	Energy grid operators, producers of energy from renewable sources, investors in generating installations using renewable energy sources	Existing	Since 4 March 2005 for sources with installed power not exceeding 5 MW – since 31 December 2010
5. Exemption of energy produced from renewable sources from excise duty in case of its sale to end users	Financial	Reduction of costs of production of renewable energy	Producers of energy from renewable sources, investors in generating installations using renewable energy sources, President of the Energy Regulatory Office of Poland, Heads of Customs Offices	Existing	Since 26 April 2004
6. Special principles of wind farm balancing	Financial	Reduction of costs of production of renewable energy	Transmission System Operator, producers of energy from renewable sources	Existing	2007
7. Exemption from stamp duty for issuing the licence (in case of power < 5 MW)	Financial	Reduction of costs of production of renewable energy	President of the Energy Regulatory Office of Poland, producers of energy from renewable sources, investors in generating installations using renewable energy sources	Existing	Since 4 March 2005
8. Exemption from stamp duty for issuing the certificate of origin (in case of power < 5 MW)	Financial	Reduction of costs of production of renewable energy	President of the Energy Regulatory Office of Poland, producers of energy from renewable sources	Existing	Since 4 March 2005
9. Exemption from the duty to pay annual fee to the state budget for obtaining the licence for energy generation (in case of the producer's power < 5 MW)	Financial	Reduction of costs of production of renewable energy	President of the Energy Regulatory Office of Poland, producers of energy from renewable sources	Existing	Since 4 March 2005
10. Exemption from the fee for recording certificates of origin in the Register of the Commodity Energy Exchange (in case of power < 5 MW)	Financial	Reduction of costs of production of renewable energy	Commodity Energy Exchange, producers of energy from renewable sources	Existing	Since 4 March 2005

11. Exemption from the fee for making changes in the Register of certificates as a result of selling the property rights (in case of power < 5 MW)	Financial	Reduction of costs of production of renewable energy	Commodity Energy Exchange, producers of energy from renewable sources	Existing	Since 4 March 2005
12. NFO•iGW programme for projects regarding renewable energy sources and highly efficient cogeneration – part 1	Financial	Increase in the installed power in renewable sources by 300 MW and energy amount by 1,000 GWh	Investors in generating installations using renewable energy sources	Existing	2009-2012
13. NFO•iGW programme for projects regarding renewable energy sources and highly efficient cogeneration – part 2	Financial	Increase in the installed power in renewable sources by 120 MW and energy amount by 330 GWh	Investors in generating installations using renewable energy sources	Existing	2009-2012
14. NFO•iGW programme for projects regarding renewable energy sources and highly efficient cogeneration – part 3	Financial	Installation of solar collectors with the floor area of 200 thousand m^2, which would result in an increase in renewable energy production by 100 thousand MWh per year	Natural persons and housing cooperatives	Existing	2010-2014
15. Measure 9.1 *High-efficiency energy generation* Operational Programme Infrastructure and Environment	Financial	Alteration and construction of electricity and heat co-generation units	Entrepreneurs, local governmental units and their unions and associations, entities providing public services based on the agreement concluded with local government units	Existing	2007-2015
16. Measure 9.2 *Efficient distribution of energy* Operational Programme Infrastructure and Environment	Financial	Construction and extension of: – energy distribution grid aimed at limiting network losses – heat distribution network involving application of energy-saving technologies and solutions	Energy companies	Existing	2007-2015
17. Measure 9.4 *Production of energy from renewable sources* Operational Programme Infrastructure and Environment	Financial	increase in generation of electricity and heat from renewable sources	Entrepreneurs, local governmental units, entities providing public services, churches	Existing	2007-2013
18. Measure 9.5 *Production of biofuels from renewable sources* Operational Programme Infrastructure and Environment	Financial	Projects involving production of biocomponents and biofuels, including second-generation biofuels	Entities listed in the Detailed description of the priorities of OPI&E, point 17 , which in case of measure 9.5 include entities having the status of an entrepreneur	Existing	2010
19. Measure 9.6 *Networks facilitating reception of energy from renewable sources* Operational Programme Infrastructure and Environment	Financial	Construction and modernisation of grids allowing for connecting units generating electricity from renewable sources to the National Energy System	Entrepreneurs, local governmental units, entities providing public services	Existing	2007-2013
20. Measure 10.3 *Development of industry based on RES* Operational Programme Infrastructure and Environment	Financial	Construction of plants manufacturing equipment for the production of: – electricity from wind, water in small hydro power plants up to 10 MW, biogas and biomass; – heat using biomass and geothermal and solar energy; – electricity and heat from co-generation using only biomass or geothermal energy; – biocomponents and biofuels which are fuels in its own right, excluding equipment used for the purposes of production of biofuels blended with petroleum-derivative fuels, pure vegetable oil, as well as for the production of bioethanol from agricultural products	Entrepreneurs	Existing	2007-2013

21. List of priority projects of the Voivodship Fund for Environmental Protection and Water Management (*Wojewódzki Funduszu Ochrony •rodowiska i Gospodarki Wodnej*) in Wroc•aw, planned to be co-financed in 2010	General (indicting the direction)	Within point 3 (Air protection), item 3.4. Energy management rationalisation and item 3.5. Use of renewable energy sources, including biofuels. (no detailed results)	Entities listed in *Principles for granting and redeeming the loans, providing grants and co-financing interest on preferential loans and borrowings* (see resolution of the Supervisory Board of the Fund) No 34/2009	Planned	2010
22. Funds from the Voivodship Fund for Environmental Protection and Water Management in •od•	Financial	Purchase and assembly of solar systems, heat pumps, photovoltaic cells and equipment used in the energy recuperation process	Buildings of public administration authorities and their units, used for the purposes of fulfilment of tasks entrusted to these authorities and units	Existing	Applications are examined in the calendar year of their filing
23. List of priority projects of the Voivodship Fund for Environmental Protection and Water Management in Warsaw for 2010	General (indicting the direction)	Tasks and programmes concerning the use of renewable energy sources	Application examined on an individual basis	Existing	2010
24. Granting and redeeming loans, providing grants and co-financing interest on preferential loans and borrowings from funds of the Voivodship Fund for Environmental Protection and Water Management in Opole	Financial	Limiting emission of pollution to the environment and increasing the share of energy produced from unconventional and renewable sources	Application examined on an individual basis	Existing	2010
25. Financial aid from funds of the National Fund for Environmental Protection and Water Management in Bia•ystok	Financial	Liquidation of low emission using renewable energy sources	Application examined on an individual basis	Existing	2010
26. List of priority projects of the Voivodship Fund for Environmental Protection and Water Management in Gda•sk for 2010	General (indicting the direction)	Support to the use of renewable energy sources	Application examined on an individual basis	Existing	2010
27. Loan or grant from funds of the Voivodship Fund for Environmental Protection and Water Management in Kielce	Financial	Facilities and infrastructure related to investments in electricity, heat and gas supply	Application examined on an individual basis	Existing	2010
28. Aid from funds of the Voivodship Fund for Environmental Protection and Water Management in Olsztyn	Financial	Use of renewable energy sources	Application examined on an individual basis	Existing	2010
29. List of priority projects of the Voivodship Fund for Environmental Protection and Water Management in Pozna• for 2010	General (indicting the direction)	Increased use of energy from renewable sources	Application examined on an individual basis	Existing	2010
30. Aid from funds of the Voivodship Fund for Environmental Protection and Water Management in Zielona Góra	Financial	Use of renewable energy sources	Co-financing provided to natural persons, natural persons carrying out business activities, housing cooperatives, state budget units	Existing	2010
31. Swiss-Polish Cooperation Programme	Financial	Use of energy from renewable sources	Co-financing from 60 to 100% of eligible costs of a project/ programme	Existing	2007-2017
32. NFO•iGW programme: Energy use of geothermal resources	Financial	Use of thermal water for energy production	Beneficiaries – entities entitled to implement projects involving exploration and examination of deposits of mineral based on provisions of the *Geological and Mining Act*	Existing	31 December 2013

The NREAP further foresees the introduction of legislative amendments to existing acts, as well as the adoption of the Renewable Energy Act to facilitate the achievement of planned policies and objectives.

Annex 4: NREAP ASSESSMENT OF IMPACT OF RES DEVELOPMENT

The table below illustrates the summary or assessment of the impact of the RES development in Poland according to the objectives in the NREAP:

Table 14: Assessment of the impacts of the method of RES support applied in Poland (according to NREAP) (Ministry of Economy, 2010)

Description	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Expected renewable energy use	ktoe	5,873	6,233	6,614	6,949	7,262	7,617	8,117	8,668	9,255	9,944	10,725
Expected renewable electricity use	ktoe	913	1,090	1,276	1,417	1,577	1,709	1,858	2,010	2,185	2,393	2,786
Expected renewable electricity use	GWh	10,618.0	12,678.0	14,845.0	16,478.0	18,337.5	19,875.0	21,605.0	23,373.5	25,416.0	27,828.0	32,400.0
Expected indexation of the substitution fee	PLN/ MWh	268.0	275.2	282.6	290.2	298.1	306.1	314.4	322.9	331.6	340.6	349.8
Expected balance of resources resulting from the support scheme in form of certificates of origin	PLN million	2,845.1	3,488.8	4,195.4	4,782.7	5,466.1	6,084.3	6,792.5	7,546.9	8,428.0	9,477.0	11,331.9
Expected cumulative balance of resources resulting from the support scheme in form of certificates of origin	PLN million	2,845.1	6,333.9	10,529.3	15,312.0	20,778.0	26,862.4	33,654.9	41,201.8	49,629.8	59,106.8	70,438.7
Expected CO_2 emission reduction	thousand Mg/year	7,432.6	8,874.6	10,391.5	11,534.6	12,836.3	13,912.5	15,123.5	16,361.5	17,791.2	19,479.6	22,680.0
Expected savings resulting from CO2 emission reduction	PLN million	914.2	1,091.6	1,278.2	1,418.8	1,578.9	1,711.2	1,860.2	2,012.5	2,188.3	2,396.0	2,789.6
Expected SO_2 emission reduction	tonnes/year	4.6	5.5	6.4	7.1	7.9	8.5	9.3	10.1	10.9	12.0	13.9
Expected NO_x emission reduction	tonnes/year	4.6	5.5	6.4	7.1	7.9	8.5	9.3	10.1	10.9	12.0	13.9
Expected job creation	number of jobs		5,748	7,891	8,127	8,557	9,834	7,882	8,566	8,781	10,405	16,371

Annex 5: POLAND'S INTEREST IN NUCLEAR POWER

To date nuclear power is not part of the national energy mix, although plans for the erection of a nuclear power plant on Polish territory have been manifold over the past decades. The Polish government has, however, emphasised its interest in nuclear power as an important alternative to conventional coal and gas plants, as well as opportunity to reduce dependence on imports.

> *A 2009 report to the Ministry of the Economy identified nuclear as the most cost effective method of CO2 abatement of the major generating options. A resolution by the council of ministers then called for the construction of at least two plants in Poland, or at least 4.6 GWe out of a predicted 52 GWe total capacity – to provide 15 percent of power, with coal's share falling to 60 percent by 2030.* (World Nuclear Association, 2014)

Nuclear power is thus part of Poland's Energy Strategy 2030. The planning and impact assessment for the construction of the first plant, expected to be in operation in 2025, is currently underway. *'PGE…plans to build two nuclear power plants, each with a capacity of 3 000 MWe.'* (World Nuclear Association, 2014)

> *PGE estimates that the cost would be EUR 2500-3000/kW for a modern plant, hence total project cost of up to EUR 10.5 billion. It estimates the levelized cost of generating electricity from nuclear power plants is between Euro 6.5 and Euro 6.8 cents per kWh, which "justifies construction of plants under most scenarios.* (World Nuclear Association, 2014)

The majority of ownership would remain in Polish hands, whereas foreign investors are also invited to take minority stakes. Inter alia, France signed an agreement to assist Poland in terms of construction know-how.

> *The government approved legislation amending the country's Nuclear Energy Law to "provide for the establishment of a transparent and stable regulatory framework covering the entire investment process" by the National Atomic Energy Agency (Panstwowa Agencja Atomistyki), which will oversee construction of the plants.* (World Nuclear Association, 2014)

Poland's interest in nuclear energy diverts from current prominent caution, rising criticism and resistance due to the high environmental, health and security impact in case of an accident. On the other hand the benefits with regards to efficiency, costs and the contribution to decarbonisation and climate change mitigation, provided that no accident occurs, cannot be denied. Taking into account current plans and projects the potential for nuclear power generation stands at 15 percent of the total national energy production.