MASTER THESIS

Two paths for nuclear energy in Europe

9 January 2017

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MASTER OF ENVIRONMENTAL AND ENERGY MANAGEMENT PROGRAMME

UNIVERSITY OF TWENTE

ACADEMIC YEAR 2015/2016

ABSTRACT

The background of the research is difference in nuclear energy policies in European countries from active development and enlargement to strict prohibition. This research aims to identify arguments for two almost opposite paths for nuclear energy in Europe through contrasting policies held by countries with similar backgrounds: France and Germany.

The research can be regarded as a desk research, so it uses data and information gathered from official sources: policy documents, the media and energy reports. Both quantitative and qualitative data and information is used, qualitative analysis is applied. The recommendations include elaboration on the advantages and disadvantages of each path, identification of the policies' problems and description of a country's specific characteristics that are necessary for effective implementation of each of these policies.

Key words: nuclear energy policy, nuclear energy in France, nuclear energy in Germany, nuclear energy perspectives.

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CHAPTER 1. INTRODUCTION

1.1 Background

Since 1940s nuclear reaction was regarded as the future source of energy in many developed countries worldwide. And this is for a reason: even known uranium deposits are enough for 85 years, and new fast reactor technology can prolong this estimation up to 2,500 years. Besides, the IAEA reports (2005) that there are 35 million tones more available for extraction. In addition, nuclear energy production is harmless in terms of greenhouse gases emissions and air pollution, that does it especially attractive in worldwide struggle with the climate change (Welsch & Biermann, 2014).

However, there are several concerns related to the nuclear energy production.

First of all, nuclear wastes management is a headache for scientists and managers all around the globe. Although the most radioactive wastes are recycled any used in secondary fuel production, some of it is getting landfilled.

Then, there are nuclear proliferation risks. Although the enrichment degree of Uranium for nuclear weapons is 20 times higher than for nuclear fuel, radioactive material can still be used for so-called "dirty bombs". Moreover, nuclear reactors may one day become targets for terrorist attacks (for example, with planes).

Thirdly, the risk of nuclear accidents is the biggest fear related to nuclear power. Three most serious nuclear accidents became real catastrophes for nations, and the consequence management in such cases takes decades.

These can be the causes for a fact that only about 30 countries (most of them are in Europe, Northern America, East Asia and South Asia) had experienced nuclear energy production. And some of them decided not to use it in future, while others focus on the technology's development.

However, it is still hard to say why some countries decide to continue with nuclear energy while others - even the countries with almost the same geographical and economic conditions and political structures – stop.

1.2 Problem Statement

Although the Fukushima nuclear accident changed social attitude to the nuclear energy production in Europe dramatically (Wittneben, 2012), different countries are dealing with this issue and form their nuclear energy policies differently. New policies are being designed and partly implemented; however, it is still unclear what consequences this shift will bring in terms of sustainable development of each country.

Thus, it is important to describe policies referred to the nuclear energy, analyze and compare them to make recommendations for policy-makers.

1.3 Research Objective

The objective of this research is to widen the information base for policy-making in Europe on the aspects of two opposite paths for nuclear energy production (French and German) through the definition of the arguments for each strategy, their analysis and comparison.

These recommendations will give a wide base for informed decisions based on the specific features of each approach to the nuclear energy. The countries examined in the research - France and Germany - will get more information on weaknesses and strengths of different aspects of their policies. While the policy-makers of other European countries can implement the most efficacious and successful experiences of either way (or even both at the same time), manage shortcomings that existing strategies have and avoid mistakes. On a larger scale it will contribute to the achievement of highly effective, sustainable and more secure energy status of the EU countries.

1.4 Research Question

The main Research Question of this paper is:

What can EU energy policy learn from the German position to phase out nuclear energy and the French position to continue nuclear energy in electricity production, with respect to security of supply, economic competitiveness and sustainability?

Sub-Research Questions:

- What are the arguments of France to continue nuclear energy in electricity production?
- What are the arguments of Germany to phase out nuclear energy from electricity production?
- How do the German and the French position on nuclear energy score on security of supply, economic competitiveness and sustainability?

1.5Table of Contents

In line with recommendations from the book “Designing a Research Project” by P. Verschuren and H. Doorewaard (2010), a Table of Contents with chapter and subchapter titles is developed to define the most efficient way to arrange the research.

Here is the short description of each chapter and their role in the research:

Chapter 2 gives an overview of the nuclear energy concept, defines the terms used in the research and clarifies the EU criteria for energy policies development. These criteria are later used in this research for the German and French nuclear energy policies evaluation.

Chapter 3 describes the methods of answering the research question.

Chapters 4 and 5 answers the 1st and the 2nd sub-research questions based on the overview of historical background, existing policies in two examined countries, arguments and their evaluation according to the aspects defined in Chapter 2.

Chapter 6 is an answer to the 3rd sub-research question - a comparison between the French and German arguments with identification of the strongest ones and underlining main problems with each strategy.

Chapter 7 answers the main question of this research, giving account of what the EU energy policy can learn from the German and French position with respect to the three aspects.

CHAPTER 2. NUCLEAR ENERGY: TECHNOLOGY AND CURRENT EU POLICY

This chapter includes definitions of the terms, some basic information on the nuclear energy, description of the EU energy and nuclear energy policies with a focus on the main aspects the policy-makers are supposed to pay it formulates a base for arguments evaluation to answer sub-research questions 1 and 2.

2.1 Concept Definition

For the purpose of this research, the following key concepts are defined:

Nuclear energy (nuclear power, atomic energy) can be defined from two points of view.

One of them is technological and refers to the physical phenomenon itself: “the energy derived from the nuclear transformation (fission or fusion) of atoms” (United Nations, 1997). However, in this research the term is used to describe “a branch of power engineering that uses atomic energy for electricity and heat generation” (Rosatom, 2014).

National energy policy – targeted strategies and programs for the national energy sector’s development (Russian Government, 2015).

2.2 Nuclear Energy Technology

Nuclear energy is a branch of power engineering that uses atomic energy for electricity and heat generation.

Nuclear energy production is based on a self-sustaining chain reaction - a fission of nucleus of Uranium, Plutonium or Thorium in nuclear reactors. In this process, a large amount of heat is released due to a system's kinetic energy increase. This heat is warming up the water circulating in reactor. The steam from boiling water turns turbines, so the energy is produced (World Nuclear Association, 2016; Nuclear Energy Institute, 2016).

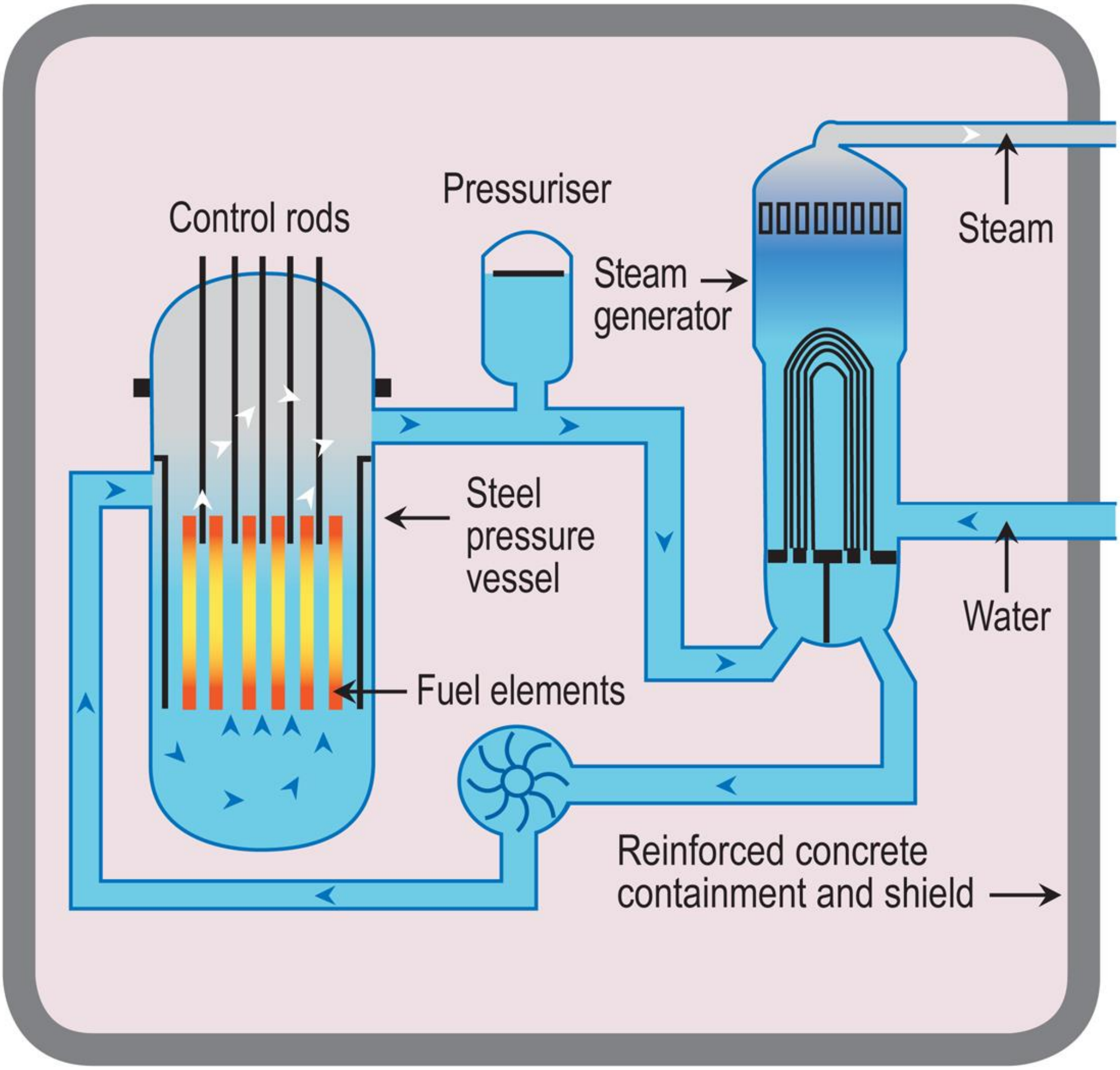


Figure 1. Diagram of pressurized water reactor (World Nuclear Association, 2016)

During the Second World War nuclear studies were held in order to create a nuclear weapon. However, some technologically developed countries also focused on a peaceful application of an atom. The first self-sustaining chain reaction was achieved in Chicago in 1942, but it took 9 years more to produce energy by this method (in Idaho on December 20, 1952) (U.S. Department of Energy, n.d.). In 1952 the USSR became the first country that connected a nuclear power plant (NPP) to the power grid. It produced 5 megawatts (MW) of power.

The USA, the USSR and the UK were the leaders in nuclear power generation in 1950s-1970s. However, after the oil crisis in 1973 other countries decided to start nuclear energy programmes in order to decrease their dependence on oil.

During more than 60-years history of nuclear power there were 3 major accidents that influenced social attitude to the nuclear energy dramatically: Three Mile Island (the USA, 1979), Chernobyl (the USSR, 1986) and Fukushima Daiichi (Japan, 2011). These catastrophes played a huge role in energy policy plans' change of many countries (Jacoby & Paltsev, 2013). For example, in June 2011 a referendum was held in Italy, and citizens decided to stop any nuclear plans in the country (Batsford, 2013; Hibbs, 2012).

An earthquake and the following tsunami in Japan caused comprehensive risk assessment of all nuclear power plants in Europe. This initiative was proposed in March 2011 by the European Council. Nuclear power plants in 17 countries were checked by national and international specialist groups on whether they can resist 3 types of events: natural disasters, man-made failures and actions and preventive and other terrorist or malevolent acts (European Commission, 2011). The results confirmed that high safety and security measures are applied, but "not all safety standards promoted by the International Atomic Energy Agency (IAEA) and not all international best practices are applied in all Member States" (European Commission, 2012), so there is a need for a further improvement.

Nowadays nuclear energy has an 11% share in world's energy production – it is around 2.4 billion KWh. The leaders in the industry are: the USA, France, Russia, South Korea and China. There are 65 reactors under construction, 173 planned and 337 projects are proposed worldwide (World Nuclear Association, 2016).

2.3 The EU Energy Policy

An effective energy production remains one of the most important challenges for the policy-makers in Europe.

Paragraph 1 of Article 194 of the Treaty on the Functioning of the European Union (2008) states:

"In the context of the establishment and functioning of the internal market and with regard for the need to preserve and improve the environment, Union policy on energy shall aim, in a spirit of solidarity between Member States, 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."

It can be seen from this fundamental document, that European governments have set 3 main objectives for their energy policies: **security of supply**, **economic competitiveness** and **sustainability** (European Commission, 2011).

Figure 2. Pillars of the EU's energy policy (Finnish Energy Industries, 2013)

In the beginning of the XXI century sustainability (especially its 'climate change mitigation' aspect) objective was the number one priority for European energy policy makers. However, the concerns about energy security and competitiveness become more and more stressing every year (IEA, 2014). Nowadays, the European energy system is vulnerable, as its dependence on imported fossil fuels – mainly oil and gas, is not only high (80% and 60%) but is predicted to increase if no measures are undertaken (European Commission, 2014).

The European Commission (2000) classifies typical risks related to energy as:

1. Physical risks, distinguishing between permanent disruption (due to stoppages in energy production or to exhaustion of energy resources) and temporary disruptions (due to geopolitical crisis or natural disasters).
2. Economic risks, caused by volatility in energy prices after imbalances between demand and supply.
3. Political risks, brought about by energy exporting countries that intend to employ energy deliveries as a political weapon.
4. Regulatory risks, due to poor regulations in the domestic markets and regulatory variability in exporting countries (both in terms of security of energy investments and of security of supply contracts).
5. Social risks, due to social conflicts that are linked to continuous increases in energy prices.
6. Environmental risks that are related to the energy sector (oil spills, nuclear accidents, etc.) and may cause significant environmental damages.

The physical and political risks refer to the security of supply objective. Economic and social are based on the economic competitiveness. Environmental risks are the main challenge for the sustainability objective.

2.4 The EU Nuclear Energy Policies

Traditionally nuclear energy played a big role in the European Union. The Treaty of Rome established the European Economic Community and the European Atomic Energy Community (EURATOM) in 1957 with the objective to "to contribute to the formation and development of Europe's nuclear industries, so that all the Member States can benefit from the development of atomic energy, and to ensure security of supply", and it is still relevant (EURATOM, 2007).

It seems that the Fukushima nuclear accident of March 2011 had impact on the European energy policies. It became one of the reasons for the European Commission's document "EU Energy, Transport and GHG Emissions: Trends to 2050. Reference scenario" update issue in 2013. However, against expectations of anti-nuclear activists all across the globe, the EU has not banned nuclear energy, but strengthened security requirements for nuclear technologies. This is reflected in detailed surveys into the possibilities of extending the lifetime of existing power plants based on their type, location and national legislation; higher requirements for new plants construction. All these changes will definitely lead to the higher costs of nuclear energy production and lower perspectives for nuclear power in future (European Commission, 2013). However, it does not mean that it will not be present in future European energy system. Environmental goals are one of the reasons for it.

The EU goal to cut greenhouse gas emissions by 80–95% by 2050 has serious implications for the energy system, but there are several tools to do so. Nuclear power is regarded as one of the most important ones together with renewables and energy efficiency improvement (Finnish Energy Industries, 2013). There are five decarbonisation scenarios described in the Energy Roadmap 2050 issued by the European Union:

- High energy efficiency (high energy savings that lead to a decrease in energy demand)
- Diversified supply technologies
- High renewable energy sources (RES) (strong support measures for RES)
- Delayed carbon capture and storage (CCS) (similar to the diversified supply technologies scenario but assuming that CCS is delayed, leading to higher shares for nuclear energy)
- Low nuclear (similar to the diversified supply technologies scenario but assuming that no new nuclear (besides reactors currently under construction) is being built).

It is easily seen that all five scenarios assume that the nuclear power will be produced in future. European researchers assume that nuclear energy remains "a key source of low carbon electricity generation". Besides, the scenarios with the highest level of nuclear power – delayed CCS (18%) and diversified supply technologies (15%) would give the lowest energy costs and electricity prices.

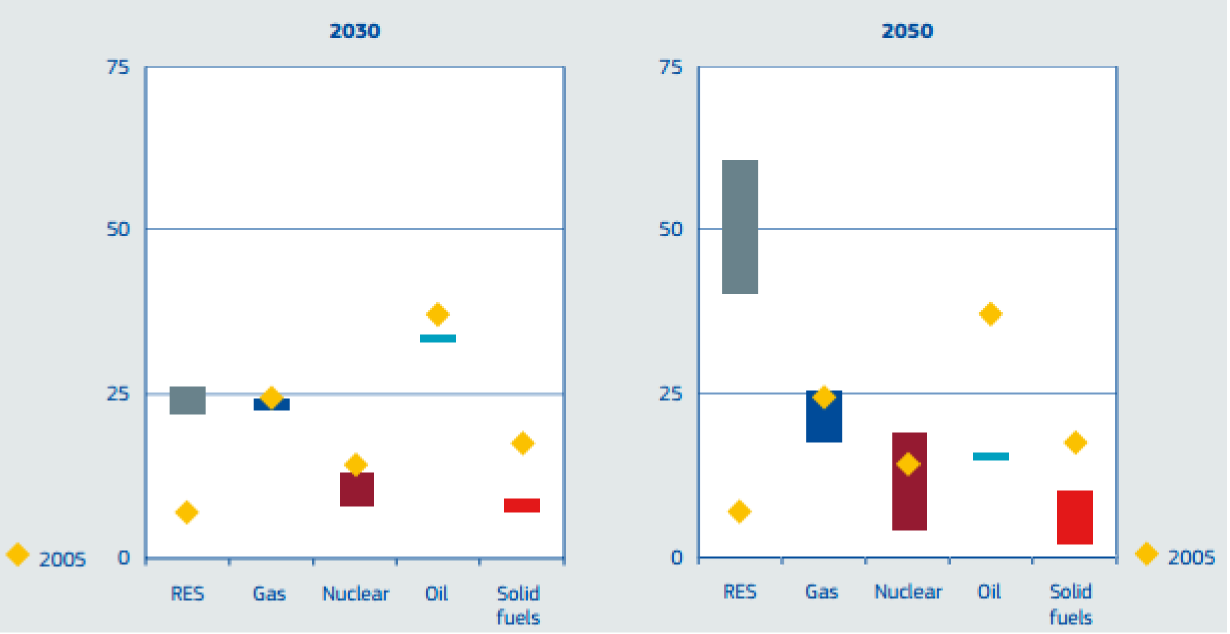


Figure 3. EU decarbonisation scenarios - 2030and 2050 range of fuel shares in primary energy consumption compared with 2005 outcome (%) (European Commission, 2012)

Moreover, in the 2015 EU Nuclear energy forecast FORATOM calls nuclear energy “a competitive, reliable and base-load source of energy that will continue to make a major contribution to all three pillars of EU's energy policy” (FORATOM, 2015).

However, the EU treats with respect all national approaches to the nuclear power: it takes into consideration both the ban (Austria, Italy...) or phase-out (Belgium, Germany) and prolongation or development of nuclear use (for example, in Spain and Sweden), and it is also reflected in the strategy (European Commission, 2013).

2.5. The EU objectives for energy policies

2.5.1 Security of Supply

Security of supply means constant availability of sufficient energy supplies at affordable prices from different sources to all users (European Commission, 2014; IEA, 2011).

Energy security has gained increasing importance in the EU discussion since 2000s. And this is for a good reason: security of supply can be affected not only by economic and technical, but also by political conditions. Nowadays it has a frightening confirmation due to situation in Ukraine and strained relations between the EU and Russian Federation (Jonsson at al., 2015). The EU imports 53% of the energy it consumes. Energy import dependency is the highest on crude oil, natural gas and nuclear fuel. It is especially applied to the Eastern Europe.

The EU actions to deal with this issue requires a thorough study on the best practices of member states and other countries. Nowadays, the strategy towards security of energy supply includes strengthening of the internal energy market with increased interconnections, a balanced energy mix that is based on resources available creation, demand management, energy production increase and external supplies diversification (European Commission, 2014).

That is why the criteria used to evaluate energy policies in terms of its security of supply in this research are:

- Availability of resources
- Dependence on import

2.5.2 Economic competitiveness

Economic competitiveness is the criterion used to ensure the competitiveness of European economies and the availability of affordable energy.

Additional financial pressure on households and industries as a consequence of the energy prices increase makes economic competitiveness one of the main political concerns related to a national energy policy.

Besides, states need to keep balance between supply and demand at all times. This is called flexibility of operation and it can characterize a power system from the economic competitiveness perspective. Flexibility is system specific. For example, systems with many fuel options will be more flexible than ones dominated by one source. Inflexibility of energy production can be detected by the following signs: difficulty in balancing demand and supply, energy curtailments (mostly for renewable energy sources), deviations from the schedule of the area power balance, price volatility, negative market prices. (Clean Energy Ministerial, 2014)

Thus, in this paper Economic competitiveness objective is regarded from two points:

- Energy prices
- Flexibility of energy production (Energinet.DK, 2015; European Commission, 2014)

2.5.3 Sustainability

“We want our energy consumption to be sustainable, through the lowering of greenhouse gas emissions, pollution, and fossil fuel dependence” the policy-makers of the European Commission say in the Energy Strategy documents (European Commission, 2016).

Besides, sustainability criteria involves social aspect. "Social sustainability occurs when the formal and informal processes; systems; structures; and relationships actively support the capacity of current and future generations to create healthy and liveable communities. Socially sustainable communities are equitable, diverse, connected and democratic and provide a good quality of life" (Adams, W.M., 2006).

That is why sustainability will be evaluated based on the following criteria:

- Effect on greenhouse gases emissions
- Pollution caused
- Positive impact on society

Nuclear industry became one of the alternatives while switching to sustainable energy production in Europe in the 20th century (Elzen, B. et al., 2004). And it still plays a big role in policy documents prepared by European Commission. Although several countries decided not to use nuclear in their energy mix, new generation of nuclear power plants is still perceived by European policy-makers as one of the most sustainable energy sources for base-load, as it is carbon-dioxide free, relatively cheap and stable (European Commission, 2007).

This chapter gives an understanding of what do the goals developed by European politicians mean and what criteria they include. These criteria are used in this research to evaluate each strategy arguments in line with the EU energy policy goals and are necessary to answer sub-research question 3.

CHAPTER 3. RESEARCH METHODS

The chapter describes research units, boundaries, data sources, their analysis methods and the way the research question is answered.

3.1 Research Framework

The research aims to analyze and compare two opposite paths for nuclear energy production – French and German in terms of their advantages, problems and future impact on energy system development with regard to giving recommendations for energy policy makers of European countries.

The research objects are nuclear energy policies in France (development) and Germany (phase-out). The research observes its objects from the European Energy policy goals perspective complemented by the qualitative data analysis. The research will compare two objects and identify their special features to give recommendations for future policies. That is why the research can be regarded as an evaluation research.

3.2 Research Strategy

The research is based on the “desk research” strategy, mostly its “secondary research” variant. This strategy aims to use existing articles and data from official sources to make conclusions on the research question and does not include any direct contact with the research object.

3.2.1 Research Unit

The research units are the national nuclear energy policies in Europe, particularly those of France and Germany.

3.2.2 Selection of Research Unit

The reason for selecting French and German policies for the research is their opposite attitude to the nuclear energy development under their comparatively similar geographical, economic and technological status.

3.2.3 Research Boundary

In order to achieve the study goal within the defined time, several boundaries are set:

- each nuclear energy path’s analysis will not include political, social, technological and international aspects;
- recommendations made as the outcome of this research are general and do not regard specific features of countries that can make use of it.

3.3 Research Material and Assessing Method

Information and data required to conduct the research is extracted from the following sources:

- Documents
- Literature

- The Media

Documents are the main source of data for this research. They involve governmental and companies reports on the national energy issues of France and Germany, official strategies and other policy documents.

Media data source is applied to get a broader overview of the countries' plans, as some of the decisions are not documented yet and are subject to discussion on different levels. Besides, the media helps to trace back the development of the policies to reveal their backgrounds.

The literature used involves mostly scientific papers on the nuclear energy history and analytical reports on the energy forecasts.

3.4 Data Analysis

The research uses both qualitative and quantitative methods within a *secondary research* strategy. Empirical data (mostly quantitative) on the specific topics produced by public authorities, companies, media and experts will be gathered, analyzed and interpreted from the perspective of their feasibility and effectiveness. The conclusions on advantages and disadvantages of each path will be made. That information will be used to answer the main research question.

For a valid qualitative data analysis, findings from the quantitative data analysis and conclusions from the official documents and public statements are confronted with the relevant scientific literature.

3.5 Research Planning

Activities in this Research are to be performed subsequently as it is shown in Appendix 1.

CHAPTER 4. ANALYSIS OF FRENCH NUCLEAR ENERGY PATH

Chapter 4 includes description of the French nuclear energy policies in the past, present and plans for the future development. It extracts and evaluates arguments for the policies according to the EU energy policy objectives to answer the 1st sub-research question.

4.1 Nuclear Energy in France

4.1.1 Historical background

Although the nuclear research was held in France before the World War II, and the first nuclear power plant was opened in 1962, the nuclear energy development started on a large scale after the 1973 oil crisis and understanding of relatively low natural resources reserves (Petit, 2013) when the Prime Minister Pierre Messmer initiated a huge nuclear programme that aimed to reduce the country's dependency on imported fuel. There was a huge anti-nuclear social movement in 70s, but it was suppressed by the police (Batsford, 2013).

In 1999 during the debate on a higher level it was concluded that neither gas nor alternative sources can replace nuclear energy in the country.

4.1.2 Current situation

Nowadays nuclear energy makes more than 76% of energy produced in France which is around 418 TWh (in 2014) (Réseau de transport d'électricité, 2016; World Nuclear Association, 2016). It makes the country the most relying on nuclear energy in the world.

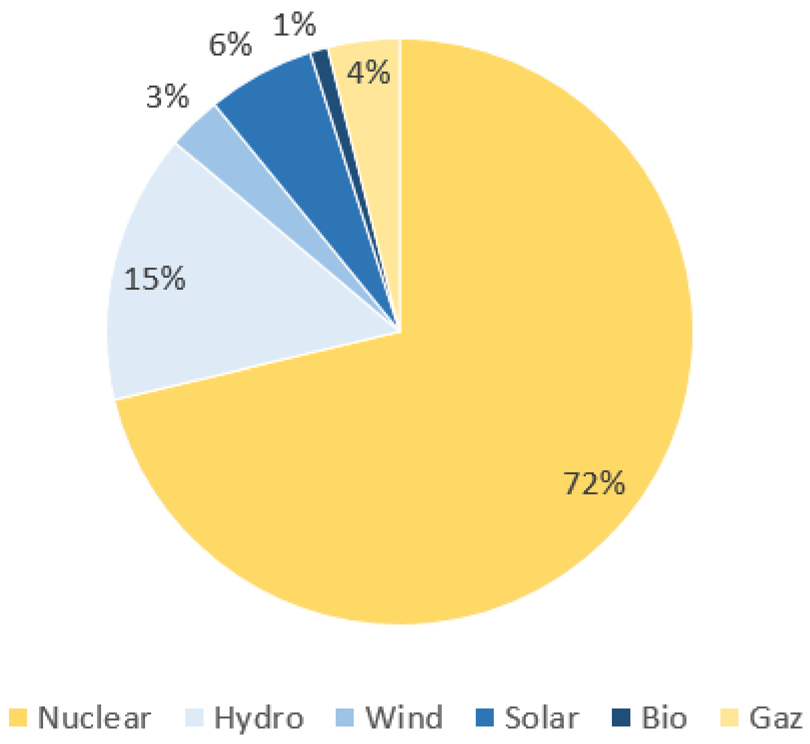


Figure 4. Energy production share in France on 20.05.2016 (Réseau de transport d'électricité, 2016)

In France there are 58 reactors in operation. They have a total capacity of 62.3 GW, that made 418 TWh in 2014. One reactor is under construction (IAEA, 2016).

The energy production in France exceeds its demand on 20%, so the country profits from export about €3 billion every year. The energy is exported mostly to Italy, Belgium, Switzerland, the UK and Spain (World Nuclear Association, 2016).

Besides, before the Fukushima tragedy the public support of nuclear energy was more than 70% due to its positive impact on greenhouse gases emission and relatively low energy prices (Petit, 2013). Though, the polls held in 2011 have shown the reduction of support: about 33% of population are for nuclear energy, while 40% are “hesitant” (Patel, 2011).

4.1.3 Plans for future

In 2012 a new president Francois Hollande came to the power and that brought some changes to the vision of nuclear future. Thus, a goal of reduction of nuclear share in energy production down to 50% was set. The debate held in all regions of the country have shown a major concern about energy prices increase as the most possible consequence of this measure. Nicolas Sarkozy commented that this measure will also lead to thousands of job losses and the industry’s decay (Patel, 2011). Moreover, according to the polls conducted in 2016, only 20% of French citizens support Hollande’s policies (Melander, 2016). That is why the question about nuclear future of the country stays open.

4.2 French nuclear policy description

The main legal instruments on the nuclear power issues are: Act No. 2006-686 of 13 June 2006 on Transparency and Security in the Nuclear Field; Code of Environment (Article L. 124-1 …); Act No. 78-753 of 17 July 1978 on the relationships between the administration and the public. In the field of radioactive waste and spent fuel management, the Act No 2006-739 of 28 June 2006 provides for the publication every 3 year of a National Plan for the Management of Radioactive Materials and Waste, and for the publication every 3 year of an inventory of radioactive materials and waste present in France (ENSREG, 2016).

The Energy Transition for Green Growth law (*la LOI n° 2015-992 du 17 août 2015 relative à la transition énergétique pour la croissance verte*) was adopted right before the 2015 United Nations Climate Change Conference in Paris. It was created in order to regulate all aspects of energy transition process in compliance with European standards. The main goals of this regulations are:

- to reduce greenhouse emissions by 40% till 2030 (compared to 1990);
- to reduce final energy consumption by 50% till 2050 (compared to 2012);
- to increase the RES share in energy production and final consumption by 40% and 32% respectively in 2030;
- to reduce wastes amount in landfill by 50% by 2025;
- to diversify electricity production and reduce the share of nuclear power to 50% by 2025.

One chapter (Titre VI – “Renforcer la sûrete nucléaire et l’information des citoyens” – “Nuclear safety strengthening and informing citizens”, articles 123-132) of this document is fully dedicated to the nuclear energy issues (Journal Officiel de la République Française, 2015).

The document identifies several basic principles for nuclear energy regulations:

1. One of the main goals of this law is to make nuclear energy production as transparent as possible. All the people living close to NPPs (does not matter whether they are French or citizens of neighboring states living near NPPs of France) will be informed timely about risks, safety and security measures, plan of actions in case of emergency. Any changes in such a plan are subject to discussion with the committee for local information.
2. The Nuclear Safety Authority (Autorité de sûreté nucléaire (ASN) is an independent administrative authority. Set up by law 2006-686 of 13 June 2006 concerning nuclear transparency and safety, ASN is tasked, on behalf of the State, with regulating nuclear safety and radiation protection) has its supervisory and punitive powers extended. Its revision is needed for any changes in NPP operations that may affect safety of the plant.
3. A stricter framework for the NPP's operations continuation after 35 years is created. These cases will be thoroughly checked by the Nuclear Safety Authority.
4. A definitive shutdown of nuclear facilities under a new regulation is supposed to be carried out as soon as possible in existing conditions after their permanent shutdown (Ministry of Ecology, Sustainable Development and Energy, 2015).

As it was already mentioned, France plans to reduce the nuclear share of electricity production to 50% by 2050 with a nuclear power capacity cap at the present level of 63.2 GWe. However, it is neither the main point nor the most realistic one. This means that an older plant will need to be closed to allow Flamanville 3 to come on line in 2017.

4.3 Arguments for the French policy

Argument for France using nuclear power in future are:

4.3.1 High safety levels

The EU has the most advanced legal framework for nuclear safety, and all the member states share the same view on ensuring the highest possible standards for safety, security, waste management and non-proliferation. The stress tests held on NPPs all across Europe after the Fukushima Daiichi accident had shown that safety standards were high, however, further improvements were recommended. France is no exception (European Commission, 2016).

The ASN (National Safety Authority of France) pays high attention to the nuclear energy industry. In 2015, the inspections were carried out daily: there were 1,882. The results and statistics on the nuclear objects safety were reported to the Parliament. The ASN is reacting to all even minor concerns provided by staff operating in NPPs (ASN, 2015).

4.3.2 Economically profitable

Already high percentage of energy produced by NPPs (76%) and a big amount of existing plants makes it economically unprofitable to stop nuclear programme. “Meeting the 50 per cent target by 2025 will likely be hugely expensive,” says François Lévêque, economics professor at l'Ecole des Mines in Paris. "If power demand continues to decrease it could mean shutting down as many as a dozen profitable and safe reactors — it's just money down the drain," he says (Stothard, M., 2015).

4.3.3 Low electricity bills

Most experts agree that the nuclear reactors closure will not only lead to huge immediate expenses, but will also lead to higher electricity prices (Stothard, M., 2015). A report published in September 2013 by OPECST, a scientific commission of senators and MPs from the upper and lower houses of Parliament said France risks being exposed to a power price shock if it pursues a speedy reduction of nuclear power and there is insufficient replacement through renewable energy and energy efficiency measures (European Commission, 2016).

Nowadays, electricity prices in France are among the lowest in Western Europe. In 2016 French households paid around EUR 0.169 per kWh, industries - EUR 0.099 per kWh, while, for instance, in Belgium the figures are 0.254 and 0.112 relatively, (0.297 and 0.151 for Germany) (Eurostat, 2016).

4.3.3 Easy risk management and experience exchange

All operating in France plants today are PWRs (pressurized water reactors) with three design variations (900 MWe, 1300 MWe, 1450 MWe). The sodium-cooled fast breeder reactor technology development reactors and UNGG reactors (gas cooled) have been shut down. The PWR plants were developed from initial Westinghouse design (World Nuclear Association, 2016).

It makes management of safety issues much easier: the lessons from any incident at one plant could be quickly learned by managers of the other plants (Palfreman, J., n.d.).

4.3.4 High social acceptance level

Before the Fukushima Daiichi nuclear accident, the public support of nuclear energy in France was more than 70% due to its positive impact on greenhouse gases emission and relatively low energy prices (Petit, 2013). Though, the polls held in 2011 have shown the reduction of support: about 33% of population are for nuclear energy, while 40% are "hesitant" (Patel, 2011). Which is still much higher than average in Europe (European Commission, 2007).

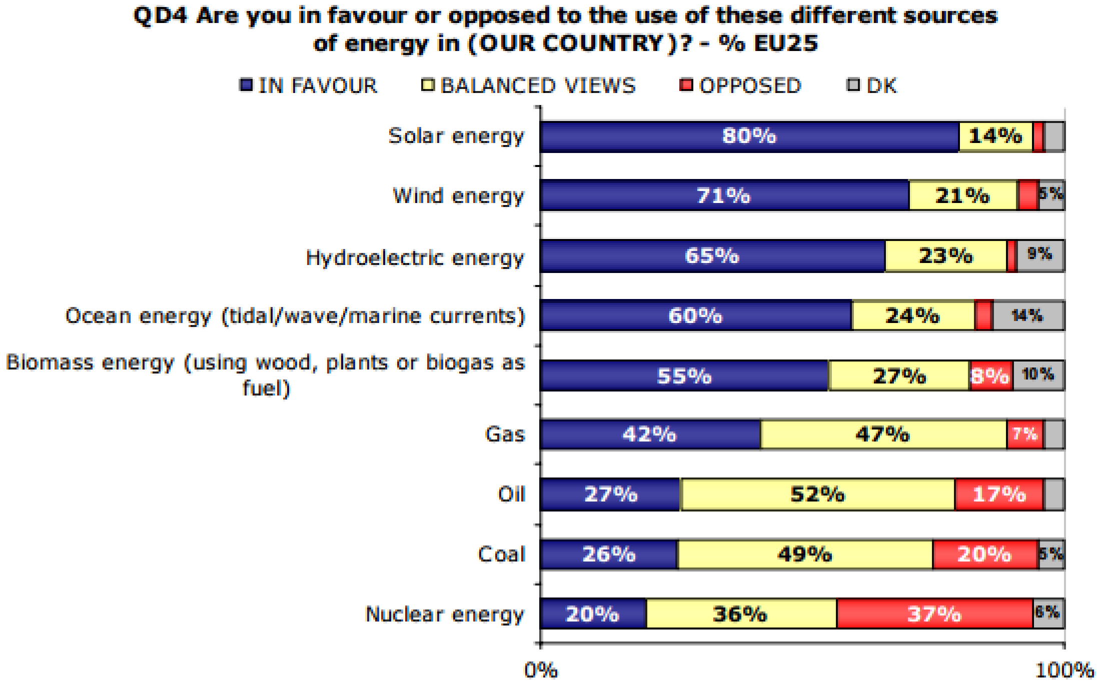


Figure 5. Attitude to different sources of energy (European Commission, 2007)

There are several possible explanations for this phenomenon.

Nuclear power has several features that are perceived especially positive by the French. First of all, French people are disturbed by the idea of energy import. They want to see themselves independent. So, when in condition of relatively small gas and oil deposits the question “Should we export resources (most probably, from Middle East) or create something ourselves” arose, the second option looked much more attractive – and nuclear power was the answer to such concerns.

Secondly, French like huge technological projects as they want to see France as a technologically advanced country. That is why professions like scientist and industrial engineer are so popular and prestigious.

Thirdly, the French authorities held advertising campaigns in favor of nuclear power and made legislation taking into account transparency issues: people get informed about NPPs. And many plants even make excursions for citizens (Palfreman, J., n.d.).

Besides, the Eurobarometer Special Report on Energy Technology has shown that energy topic is not regarded as a main one by most Europeans: only 14% mentioned "Energy prices and shortages" answering the question: "What are the most important issues facing your country today?" (European Commission, 2007).

4.3.5 Jobs creation

Unemployment is regarded as the most important issue by the EU citizens – 64% of those polled "What are the most important issues facing your country today?" mentioned unemployment – it is the highest rate (European Commission, 2007).

Nuclear energy makes a great contribution to European prosperity. It directly supports 500,000 jobs and underpins 400,000 more (European Commission, 2013).

In France around 100,000 people are employed in the nuclear industry. These are attractive, qualified and well-paid jobs. They also offer excellent career opportunities and are secure, as NPPs operate for up to 60 years (FORATOM, 2010).

4.3.6 Low carbon emissions

The Nuclear Illustrative Programme (PINC) developped in 2015 (and published in 2016) by the European Commission stresses that nuclear power (27% in electricity production) together with renewable sources (27%) is the major contributor to the Europe generating more than half of the electricity without greenhouse gases emissions (European Commission, 2016; Eurostat, 2016).

Nuclear power's environmental effects and greenhouse gas emissions are very small. The most significant environmental impact of nuclear power plants operating normally is the thermal load on the local waters near the plants as a result of discharges of warm cooling waters (Finnish Energy Industries, 2013).

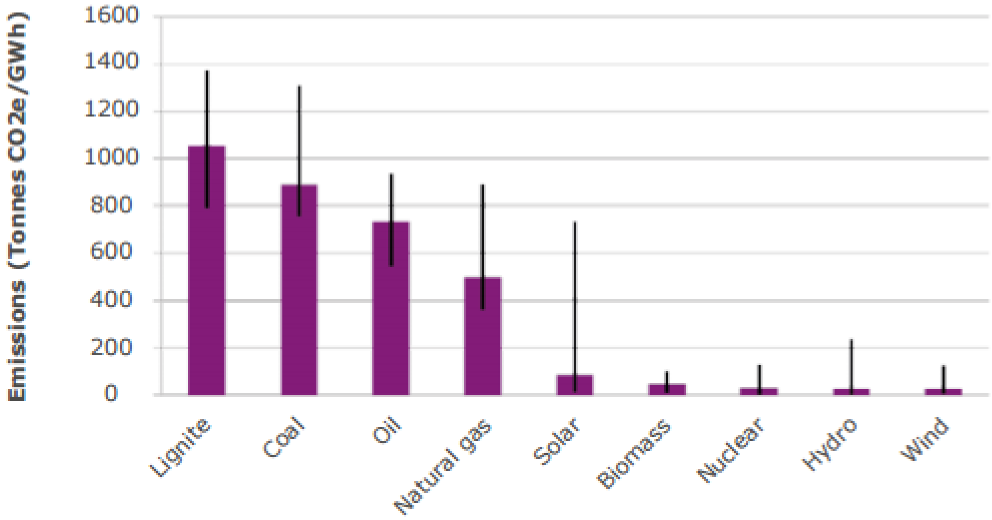


Figure 6. Life-cycle emissions of electricity production forms according to the WNA report; violet bar shows the average of the studies and the black bar the range (Finnish Energy Industries, 2013)

The statistics of the EC confirm it with figures: in 2013 France produced 36669 thousand tonnes of CO2 equivalents through its energy production and distribution. The results of other countries are not so optimistic: 364,500 thousand tonnes in Germany, 104,848 thousand tonnes in Italy (Eurostat, 2016).

4.3.7 High energy independence

In the 1970s France chose to develop nuclear as its base load electricity source as a response to the oil crisis and assure its energy independence (France in the United States, 2015).

Since the beginning of the 1990s, nuclear power fulfilled the goal: it provides 3/4 of the electricity demand in the country. France has attained self-sufficiency in terms of energy production (OECD NEA, 2008).

However, when we speak about security of supply, we cannot think only about energy production. Front end aspect (providing raw materials for the industry) and technology creation are also important.

France uses about 10,500 tonnes of Uranium per year. Much of this comes from mines (owned by Areva, a company whose major stockholder is the French government) in Canada (4500 tU/yr - 45%) and Niger (3200 tU/yr - 32%). But some amount is imported from Australia, Kazakhstan and Russia under long-term contracts. Considering both plutonium and uranium, EdF estimates that about 20% of its electricity is produced from recycled materials (Areva's estimate is 17%). Thus, the imported Uranium accounts for less than 20%. (World Nuclear Association, 2016)

France is one of the forerunners in the world nuclear reactor industry. The next generation design for French reactors is the EPR. The first French EPR is under construction at the Flamanville Nuclear Power Plant, its completion is now scheduled for 2017. The reactor design was developed by Areva (French) together with Siemens (German).

France is an active member of the The Generation IV International Forum (GIF) - a forum which goal is to design the next generation (IV) nuclear energy systems (GIF, 2016). Areva and CEA (French Alternative Energies and Atomic Energy Commission) have signed an agreement on initial design studies for a prototype of the sodium-cooled fast reactor known as ASTRID. It will be built in Marcoule, France, starting around 2020 (ENS News, 2016).

4.3.8 Additional profit from energy export

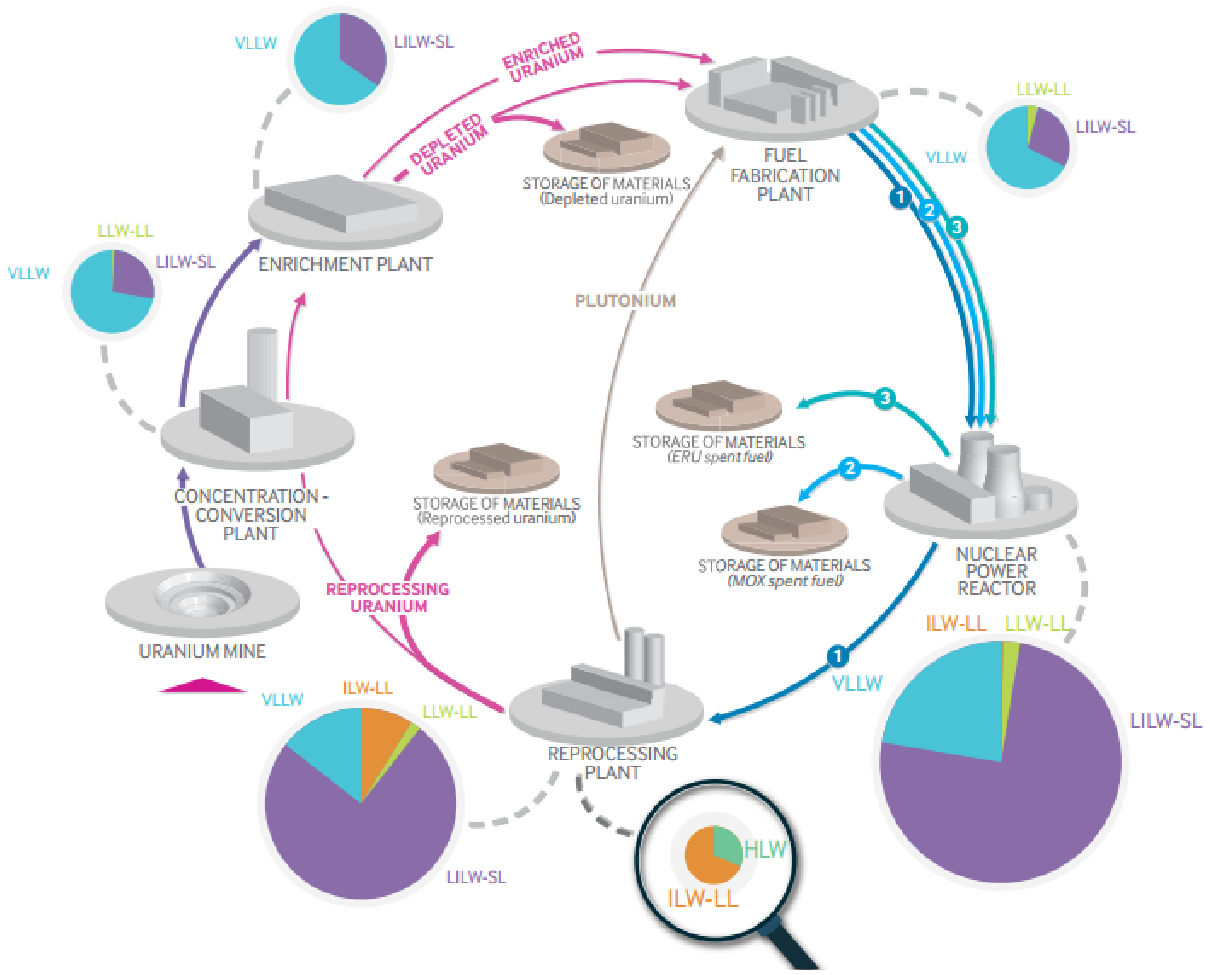
France is world's largest net exporter of electricity due to very low cost of generation, generating this amount per year. Its energy import brings the country around £3 billion (The Teleghaph, 2011).

4.3.9 Radioactive wastes recycling

The main principles of radioactive wastes management have been written in the 1991 Waste Act ("Loi Bataille") and improved by the 2006 Planning Act on the sustainable management of radioactive materials and waste.

From the beginning the French had been recycling their nuclear waste, reclaiming the plutonium and unused uranium and fabricating new fuel elements. This reduced dramatically the volume of radioactive wastes.

In France at La Hague, reprocessing of oxide fuels has been done since 1976, and two 800 t/yr plants are now operating, with an overall capacity of 1700 t/yr. French utility EDF has made provision to store reprocessed uranium (RepU) for up to 250 years as a strategic reserve. Currently, reprocessing of 1150 tonnes of EDF used fuel per year produces 8.5 tonnes of plutonium (immediately recycled as MOX fuel) and 815 tonnes of RepU. Of this about 650 tonnes is converted into stable oxide form for storage. EDF has demonstrated the use of RepU in its 900 MWe power plants, but it is currently uneconomic.



LEGENDS

1	Nuclear fuel made from natural enriched uranium oxide (UOX)
2	Plutonium and uranium mixed oxide fuel (MOX)
3	Nuclear fuel made from re-enriched uranium oxide from reprocessing (ERU)
▬ ▬ ▬ (light)	Operation and dismantling waste
▬ ▬ ▬ (dark)	Waste from spent fuel reprocessing

NOTE

Most of the waste produced by facility operation is short-lived waste. It is sent to the Aube industrial disposal facilities run by Andra (French National Radioactive Waste Management Agency). Intermediate level long-lived waste (ILW-LL) is stored at its production site.

Dismantling of all facilities also produces waste, most of which is very low level waste (VLLW).

Radioactive materials are currently reused, or stored until reuse is possible. Research is being conducted on a cycle with 4th generation fast breeder reactors, aimed at improving the recycling of materials, specifically MOX and ERU fuels as well as depleted uranium.

Figure 7. Current management of radioactive materials and waste in France (ANDRA, 2015)

Arguments against the French nuclear energy policy

In this research there is a focus on the positive arguments for each energy way. However, it is worth mentioning the negative points of the strategy.

Radioactive wastes still stored. The French nuclear policy related to the nuclear wastes management does not solve the problem completely – a part of radioactive wastes is being stored with regard of finding new recycling technologies in future.

But the problem is not as huge as it is often described. First of all, nuclear power is the only industry that takes care of wastes it produces. Moreover, the amounts of wastes from nuclear power are very small in comparison with the wastes from fossil fuel use (radioactive wastes count for 1% of all toxic wastes).

The radioactivity of nuclear wastes goes down over time. The elements with long half-life emit alpha- and beta- rays that are easy to shield. The elements that emit gamma-rays are more dangerous, however, their half-life is quite short. There are several types of wastes: Very low level wastes (VLLW) are not considered dangerous. Most countries utilize them together with household waste, however, France is now looking for storage options for this type. Low-level waste (LLW) accounts for 90% of all nuclear wastes volume, however, its radioactivity is 1% of all radioactive wastes. This type does not require any special protection during transportation and reprocessing. It is often pressed or incinerated before landfilling to reduce the volume. Intermediate-level wastes (ILW) are mostly the details of decommissioned reactors (7% of volume, 4% of radioactivity). These wastes are often solidified for storage. High-level wastes (HLW) – mostly used nuclear fuel – are highly radioactive and account for 95% of the total radioactivity produced in the process of electricity generation. In France HLW are reprocessed to extract elements for new fuel, the rest is vitrified and stored (World Nuclear Association, 2016).

Possibility of nuclear accidents. Currently, with routine checks carried out timely by nuclear safety specialists and strict regulations of the NPPs' operations make a possibility of nuclear accidents very low. However, it may happen that these measures are not enough.

4.4 Evaluation of the arguments

The arguments described in 4.3 were confronted to the criteria defined in 2.5 to find which of them relate to (or contradict) energy policy goals set by the European Union. The evaluation is based on the evidence presented in 4.3. The results are shown in a table below.

"+" under a criterion means that an argument contributes to this aspect positively

"-" means that an argument has a downside (while it can be used as an argument as it contributes to one or several criteria, it also has a negative impact on another criterion)

Table 1. Evaluation of the arguments for French nuclear policy

	Security of Supply		**Economic competitiveness**		**Sustainability**		
Arguments for French nuclear policy	Availability of resources	Independence from import	Low energy prices	Flexibility of energy production	No negative effect on GHG emissions	No other pollution caused	Positive impact on society
High safety levels						+	
Economically profitable		+	+	+			
Low electricity bills		+	+				+

High social acceptance level							+
Jobs creation							+
Low carbon emissions					+		
High energy independence		+					+
Additional profit from energy export			+				
Radioactive wastes recycling	+					-	

High safety levels. Strict regulations imposed of the industry provides safe operations during all nuclear cycle.

Economically profitable. Nuclear energy is relatively cheap and while produced on a large scale can be imported to get more profit. Moreover, it can be used as a base load providing country with stable energy supply.

Low electricity bills. Cheap energy has positive impact on society and economy both.

High social acceptance level. People trusting in financial well-being of their country feel more secure. And nuclear power is regarded as one of the main sources of its prosperity.

Jobs creation. Citizens are happy to get opportunity to work for good money in one of the most technologically advanced spheres.

Low carbon emissions. Nuclear energy production does not cause any additional CO_2 emissions to the atmosphere. It is another positive point in terms of environmental sustainability.

High energy independence. Big percentage of energy produced by NPPs allows the country to cover its demand and be independent from import. This also has positive impact on society.

Additional profit from energy export. Due to low costs, French nuclear energy is very competitive on European market.

Radioactive wastes recycling. It can be easily seen from the table above that only one of the arguments has negative impact on the sustainability criteria – radioactive wastes cannot be 100% recycled and reused, and any type of storage – interim or temporary – cannot be considered as a sustainable way.

CHAPTER 5. ANALYSIS OF GERMAN NUCLEAR ENERGY PATH

Chapter 5 includes description of the German nuclear energy policies in the past, present and plans for the future development. It extracts and evaluates arguments for the policies according to the EU energy policy objectives to answer the 2nd sub-research question.

5.1 Nuclear Energy in Germany

5.1.1 Historical background

German nuclear energy history started in 1950s with research and experimental reactors. From the beginning West Germany government regarded nuclear energy as one of the main pillows of its energy industry. Thus, the Federal Ministry for Nuclear Affaires was established and the "Eltviller Programme" was launched (Illing, 2012). The crisis in natural resources' export confirmed the necessity of the nuclear energy production, but large commercial companies did not seem to be interested in such large projects. Only in 1969, supported by the state subsidies, the first commercial reactor was connected to the grid.

In 1960s several environmental movements emerged. All of them strongly opposed nuclear energy. A permission to build a nuclear power plant near German city Wyhl became a milestone in German anti-nuclear movement: 30,000 people went to the streets protesting and achieved the withdrawal of the plan (Rudig, 1990; Meyer, 2014).

Figure 8. Anti-nuclear demonstration on Bonner Hofgarten on October 14, 1979 (Wiengartz, 1979)

Before 2011, nuclear energy policies in German depended on the government regardless public opinion. After the Chernobyl tragedy the German government (coalition of Christian Democratic Union and Free Democratic Party) was still committed to the nuclear energy, however, they decided to increase efforts towards higher safety measures. In 1998 Social Democratic and Green parties won the election and adopted "Atomkonsens" – an agreement on the nuclear phase-out. In 2009 the government changed again, and the plan for the phase-out were postponed (Feldhoff, 2014). However, after the 2011 the public pressure became too strong (according to the polls, 80% of citizens did not approve of the government's policies on the nuclear energy), so the Chancellor Angela Merkel's coalition announced that Germany's 17 nuclear power plants will be shut down by 2022 (Knight, 2011; Morris, 2016).

5.1.2 Current situation

There are 8 operational nuclear power reactors within 7 nuclear power plants. In 2015 they generated 86810.32 GWh, that is 14% of the total energy production. 28 reactors are permanently shutdown (IAEA, 2016).

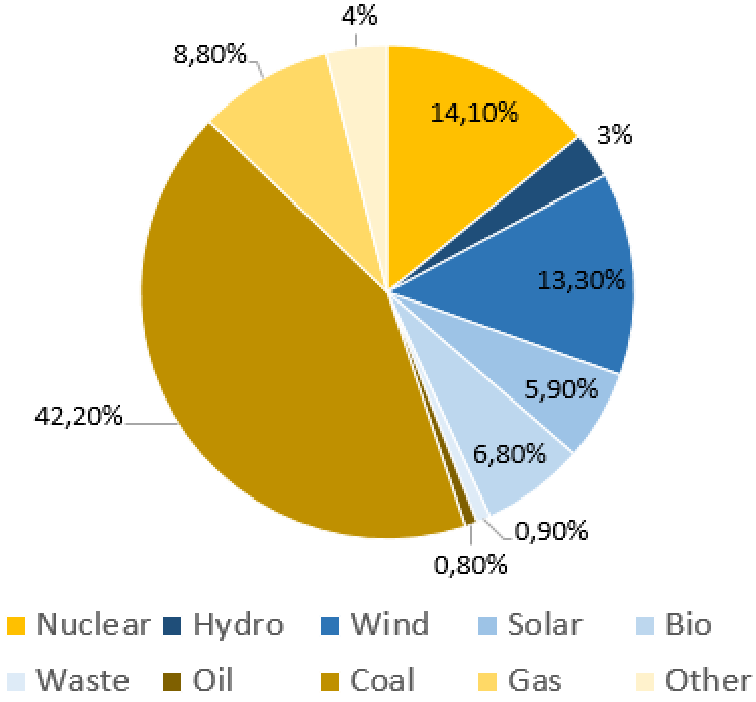


Figure 9. Energy production share in Germany, 2015 (Morris, 2016)

5.1.3 Plans for future

Germany has set an ambitious goal to be nuclear energy – free by 2022. It requires a permanent shutdown of 17 reactors (9 of them are already closed, but not defueled and decommissioned). The list of reactors to be stopped is shown in the table 1.

Table 2. Shutdown plans for 8 German reactors in operation

Reactors	Operational from	Shutdown plan (2001)	Shutdown plan (2010)	Shutdown plan (2011)
Gundremmingen B	1984	2016	2030	2017
Gundremmingen C	1985	2016	2030	2021
Grohnde	1985	2017	2031	2021
Phillipsburg 2	1985	2018	2032	2019
Brokdorf	1986	2019	2033	2021
Isar 2	1988	2020	2034	2022

Emsland	1988	2021	2035	2022
Neckarwestheim 2	1989	2022	2036	2022

Besides, the country plans to reduce by 40% its carbon dioxide emissions and to increase a share of renewables to 35%.

5.2 German nuclear policy description

There are two main legal bodies that manage nucler power in Germany: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the Federal Office for Radiation Protection (BfS).

Although the talks about “Energiewende” (“Energy turn” or “Energy transition”) started in 1980s, only the coalition government of Social Democrats and Greens could have managed to make a complete nuclear phase-out one of their main objectives (Graupner, 2013).

The Atomic Energy Act (AtG) provides the legal framework for the use of nuclear energy and the safe operation of all nuclear installations in the country (ENSREG, 2016).

“No further licences will be issued for the construction and operation of installations for the fission of nuclear fuel for the commercial generation of electricity or of facilities for the reprocessing of irradiated nuclear fuel” – the AtG says.

“The authorisation to operate an installation for the fission of nuclear fuel for the commercial generation of electricity shall expire <...> not later than the end of:

1. 6 August 2011 for the nuclear power plants Biblis A, Neckarwestheim 1, Biblis B, Brunsbüttel, Isar 1, Unterweser, Philippsburg 1 and Krümmel,

2. 31 December 2015 for the nuclear power plant Grafenrheinfeld,

3. 31 December 2017 for the nuclear power plant Gundremmingen B,

4. 31 December 2019 for the nuclear power plant Philippsburg 2,

5. 31 December 2021 for the nuclear power plants Grohnde, Gundremmingen C and Brokdorf,

6. 31 December 2022 for the nuclear power plants Isar 2, Emsland and Neckarwestheim 2.”

“For the purposes of controlled disposal, proof must be furnished showing that the safe storage in interim storage facilities of both irradiated nuclear fuel and returned radioactive waste from the reprocessing of irradiated nuclear fuel is guaranteed until such time as it is surrendered to a facility for disposal” (The Federal Office for Radiation Protection, 2013).

5.3 Arguments for the German policy

5.3.1 No import of nuclear fuel

Germany does not have its own Uranium mines since 1990. All 3800 t/yr U are now imported mainly from Canada, Australia and Russia (World Nuclear Association, 2016).

5.3.2 No new radioactive wastes produced

Interim storage in repositories is the way Germany is dealing with nuclear wastes now (World Nuclear Association, 2016). All known RES do not produce radioactive wastes.

5.3.3 New jobs created in RES sector

The International Renewable Energy Agency (IRENA) reports that Germany is among countries with the highest number of renewable energy jobs - the industry employs 355,000 people there (IRENA, 2016).

5.3.4 Technology (RES) development and import

The German wind equipment manufacturing industry, which holds a 20% share of the global market, exported two-thirds of its production in 2015 (GWEC, 2016).

However, Germany's solar PV industry fared poorly in 2014, suffering a 38% decline in sales (O'Sullivan et al., 2015).

5.3.5 Long-term solution for sustainable energy production

The quantitative targets of the energy transition and status quo (2014) are the following:

	2014	2020	2030	2040	2050
Greenhouse gas emissions					
Greenhouse gas emissions (compared with 1990)	-27 %	at least -40 %	at least -55 %	at least -70 %	at least -80 bis -95 %
Renewable energy					
Share of gross final energy consumption	13.5 %	18 %	30 %	45 %	60 %
Share of gross electricity consumption	27.4 %	at least 35 %	at least 50 % Renewable Energy Sources Act 2025: 40–45 %	at least 65 % Renewable Energy Sources Act 2025: 55–60 %	at least 80 %
Share of heat consumption	12.0 %	14 %			
Share in transport sector	5.6 %				

Figure 10. Quantitative targets of the German energy transition (Federal Ministry for Economic Affaires and Energy, 2015)

5.3.6 Zero possibility of nuclear accidents

When all the nuclear reactors are shutdown, there will be no possibility of nuclear accident.

5.3.7 Public support

"Public perception of the Energiewende" report written in 2015 shows the following figures:

- "We need a resolute switch to renewable energies.": Fully agree/Agree somewhat - 60%. 43% of those agreed did so because of the nuclear power phase-out

- "Do you believe the decision to exit nuclear power and to move to renewable energies was the right decision from today's perspective?" "Yes"- 74%, "No" - 21% (Amelang et al., 2016).

5.3.8 The cheapest RES are chosen

Germany's Energiewende will be based upon two technologies - wind power and photovoltaics, as they are the cheapest ones in terms of costs for generated power – it has gone down 50% and 80-90% respectively since 1990s. The potential for expansion of other renewables is limited (Deutsche Bank, 2016; Agora, 2013).

However, this choice has its problems: the energy produced by wind and solar is not stable over time, and these sources cannot be regarded as a base load for an energy system, so there will be many hours when renewable energy will only be able to produce a small quantity of electricity. Balancing fluctuations in energy demand and production and energy storages creation are the main challenges for German Energiewende.

Besides, the fact that the cheapest RES options are chosen does not guarantee low energy prices. A renewable energy surcharge has already seen the average family's energy bill increase by 47% from 2011 to 2013. (Smedley, 2013). The green-power surcharge on electricity bills has already cost consumers €188 billion since it was first introduced in 2000 – or €4,700 for each of the country's 40 million households. The nuclear shutdown will cost another €149 billion by 2035, according to a Stuttgart University study (Kreijger et al., n.d.).

According to the "Public perception of the Energiewende" report, in 2015 88% of those polled agree to: "I am generally in favour of the principles behind the Energiewende, but the costs for private consumers are too high" (Amelang et al., 2016).

Arguments against the German nuclear energy policy

Additional costs. E.ON, RWE and EnBW (three main German energy companies) have lost €50 billion in combined market value. They have filed lawsuits against the government, claiming more than €24 billion related to German nuclear policy (Kreijger et al., n.d.). In November 2015, the Fraunhofer-Institut estimated that Energiewende may ultimately cost German taxpayers more than $1.2 trillion (Bryce, 2016).

Job losses. RWE has cut 7,000 jobs since 2011. At E.ON, the work force has shrunk by a third, a loss of over 25,000 jobs.

Loss of technology. The knowledge on nuclear and gas technologies is getting lost (Kreijger et al., n.d.).

Extra CO2 emissions. The German decision to phase out nuclear power needs a back-up from coal and gas to compensate electricity production losses. This will cost an extra 300 million tonnes of CO2 to 2020 due to higher fossil fuel use which makes ambitious goals almost unattainable (Mazur, 2011).

5.4 Evaluation of the arguments

The evaluation is held the same way as in 4.4, but the arguments assessed are shown in 5.3.

Table 3. Evaluation of the arguments for German nuclear policy

	Security of Supply		Economic competitiveness		Sustainability		
Arguments for German nuclear policy	Availability of resources	Independence from import	Low energy prices	Flexibility of energy production	No negative effect on GHG emissions	No other pollution caused	Positive impact on society
No import of nuclear fuel		+/-					
No new radioactive wastes produced						+	
New jobs created in RES sector							+
Technology (RES) development and import		+					+
Long-term solution for sustainable energy production	+	+			+/-	+	
Zero possibility of nuclear accidents						+	
Public support							+
The cheapest RES are chosen			-				

No import of nuclear fuel. With the nuclear power phase-out Germany does not have to import Uranium anymore. However, the load is switched to coal and gas which are also imported.

No new radioactive wastes produced. No more nuclear energy use means no more radioactive wastes from the energy industry.

New jobs created in RES sector. Many new jobs of different qualification levels are created in RES sector.

Technology (RES) development and import. Germany imports technologies and equipment for renewable energy production (mostly wind).

Long-term solution for sustainable energy production. RES technologies do not require nonrenewable resources, wind and solar power will always be available. In long-term perspective 80% of energy produced by RES will lead to Germany's independence from import. But first, to compensate losses from the nuclear power phase-out, more energy will be produced by coal and gas plants, that will lead to higher GHG emissions.

Zero possibility of nuclear accidents.

Public support. The governmental decisions on energy transition are widely supported by the public.

The cheapest RES are chosen. While the cheapest RES solutions are chosen, nuclear power alone and a mixed-source model are still much cheaper.

CHAPTER 6. COMPARISON OF FRENCH AND GERMAN NUCLEAR ENERGY POLICIES

Chapter 6 answers the 3rd sub-research question through comparison of the French and German arguments. It also shows specific features inherent to these paths that should be mentioned to formulate better recommendations.

6.1 Comparison

The comparison was held based on the marks in tables 4 and 5. It was decided to count the "+" from table as 1 point, "-" – as (-1) point. Of course, this approach does not give a full picture as it does not reflect each argument's weight. However, in this research it allows a reader to get an understanding of strong and weak points of each policy. The countries examined have the following scores on criteria for the European energy goals:

France

Security of Supply: 4

Economic Competitiveness: 4

Sustainability: 5

Total: 13 points

Germany

Security of Supply: 3

Economic Competitiveness: -1

Sustainability: 6

Total: 8 points

In the research it has been found that both “paths” – French and German - have many positive points related to different aspects of the European Union Energy Policy goals. The policies of France and Germany related to nuclear power production have almost the same global goals: security of supply and environmental and sustainability.

It can be easily seen from the figures that France and Germany have almost the same strength of argumentation for their paths on the security of supply. However, the two other goals set by European Union show the main difference in approaches.

The French model of nuclear energy policy is more down-to-earth, it is dealing with current issues – a need to reduce GHG emissions, keep low energy costs, provide secure energy supply, make additional profit.

On the contrary, German energy policy is less pragmatic, as it sets ambitious goals on environmental sustainability issues together with reaction to public negative perception of nuclear power. This duality already causes many problems – most of them are of financial kind.

6.2 Advantages and disadvantages

The main advantages of each "path" are described in detail in Chapters 4 and 5. Here are several main points worth noticing:

France

- French policy-makers pay more attention to the economic competitiveness of their energy industry. That is why nuclear power is the main source of energy, and electricity bills in France are among the lowest in Europe.
- France makes a lot of efforts to make nuclear industry as understandable and transparent to all stakeholders as possible.
- The government provides strict framework for safe nuclear power plant operation process.
- Dedication to the nuclear power allows France to be one of the least GHG-producing countries in Europe.
- o The main disadvantage of nuclear power production in France (like everywhere is the world) is nuclear wastes management. Large amounts of radioactive wastes are being store for years, and even being safe, it can cause problems in future.

Germany

- German nuclear path's main advantage is a zero production of radioactive wastes.
- The nuclear power waiver gives stimulus to the RES-technologies development.
- This policy is supported by most of the country's population.
- In a long-term perspective a transition to the renewable energy sources will lead to independence of Germany from import and natural nonrenewable resources.
- o The main disadvantage is an extremely high cost of energy transition.
- o Germany will have to replace missing nuclear power with fossil fuels for decades before it achieves its goals on almost totally renewable energy production, that will have a negative impact on the environment.

CHAPTER 7. CONCLUSIONS AND RECOMMENDATIONS

The modern world is facing many dangers. Energy crisis and environmental problems are among them. European Union is aimed at bringing all member-states together to fight global challenges and to ensure sustainable development of the region. New policy documents are being written every year for this reason. However, even having the same goals, its member-states choose different strategies to attain it.

Nuclear energy production might be a topic that illustrates this the best. This paper is aimed at looking at two opposite attitudes of two European countries, France and Germany, to nuclear energy issue to develop recommendations for future policy-makers.

To assess the policies performed by France and Germany, it was decided to follow European energy policy goals – security of supply, economic competitiveness and sustainability. These three goal were transformed into assessment criteria. Then, the arguments for each strategy were derived from policy documents and analyzed based on scientific literature, expert opinions and statistics from reliable sources (official documents, expert reports) and compared to find advantages of each path and to give recommendations.

Recommendations

The example of France examined in this paper has shown that the nuclear power production continuation and development strategy is more profitable when regarded from the European Union Energy Policy goals' perspective. It scores much higher on the **economic competitiveness**. However, there are several requirements needed to successfully implement such a model:

First of them is a well-developed nuclear energy industry that comprises technological base, knowledge, specialists or large finances available for this development. Secondly, high social acceptance of nuclear power in general. It is important to underline that the latter in France is a result of three conditions: longtime lobbying from the government, high level of transparency and specific mentality of the nation.

German example lets us think that the country is dedicated to the idea of nuclear phase-out no matter what more than to the idea of environmental goals attainment. Such a radical change in energy production structure brings up many socio-economic problems. However, in a long-term perspective in may work well. That is why this approach scores higher on **sustainability** criteria. This model can also be applied only under several conditions.

First, there should be a public support of such a policy (nuclear energy phase-out). Secondly, an average household income and standard of living must be high, as a sharp turn to the renewables will increase dramatically electricity and heating bills. Thirdly, high education level of citizens is required to explain them the necessity of such an expensive energy in favor of environmental sustainability. And the last, the government should be ready to invest a lot to subsidies for RES and compensations (in case there are nuclear power plants operating in the country).

As it was already discussed, these are two extremely opposite attitudes and policies related to nuclear energy production. Both of them have serious and important conditions for successful implementation that are inherent to these two specific countries – France and Germany. That is why a mixed approach seems more favorable. This kind of approaches might be based on the risks of each source of energy evaluation based on the EU Energy Policy recommendations. As it was described above, nuclear energy is regarded by most scientists as a source "between" fossil fuels and renewables. With existing amounts of Uranium, the resource is almost never-ceasing, and the only negative impact on the environment it has are radioactive wastes. Thus, it might be reasonable to develop a policy with gradual waiver of non-renewable sources of energy: first from fossils (coal, gas) to nuclear and renewables, and then from nuclear to renewables closing existing nuclear power plants at the due date (~50 years of operation) and not building the new ones. This could allow to avoid a "conflict" between two now almost opposing goals – economic **competitiveness** and **sustainability**.

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Appendix 1. Time Schedule

Activities	**Time**																	
	W3	**W4**	**W1**	**W2**	**W3**	**W4**	**W1**	**W2**	**W3**	**W4**	**W1**	**W2**	**W3**	**W4**	**W1**	**W2**	**W3**	**W4**
Preparation																		
Research idea development																		
Literature review																		
Research proposal development																		
Draft research proposal submitted																		
Final research proposal submitted																		
Research																		
Material collection																		
Data Analysis																		
Writing Activities																		
Chapters 1,2,3																		
Chapter 4																		
Chapter 5																		
Chapter 6																		
Chapter 7																		
First Draft of Master Thesis																		
Ongoing feedback and revision																		