MSc Program
Environmental Technology & International Affairs

The Future Development and Safety of Nuclear Energy in Danube River Basin: Assessing Nuclear Power Plant Safety With Regards To Managing Flood Hazards

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

supervised by
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Vienna, 30.03.2016

Affidavit

I, **Viktoria Racheva-Slavkova**, hereby declare

1. that I am the sole author of the present Master's Thesis, "The Future Development and Safety of Nuclear Energy in Danube River Basin: Assessing Nuclear Power Plant Safety With Regards To Managing Flood Hazards ", 70 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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Abstract

In the next 50 years, unless an alternative is found, energy demand and production will be increasing, and this will contribute to global warming through excessive release of more harmful greenhouse gas emissions into the atmosphere. If the energy is not created from Nuclear Power Plants (NPPs) or renewables limitations are not surpassed, new millions of tons of carbon emissions per year will be produced through combustion of coal and natural gas and the global temperature will increase by 2 degrees Celsius. On another hand, scientists project that climate change will increase the frequency of heavy rainstorms, putting many communities at risk of devastation from floods. Extreme rain, fast mountains ice melting, a dam rupture or embankment, or even a dam failure can flush with river water the floodplain. Some of the floods develop slowly and give a chance for reaction and even evacuation; others come so fast that there is no time for warning and preparation. These flash floods can also damage critical infrastructure like NPPs as the plants are usually built close to water bodies, for the sake of cooling. The site selection and the design of the plant take into account the worst case flooding scenarios as well as other possible natural disasters and, more recently, the possible effects of climate change. As a result, all the buildings with safety-related equipment are situated on high enough platforms so that they stand above underwater areas in case of inundating events. Although engineered countermeasures have been built, in the past, some buildings and back-up equipment have been sited too low, so that they are vulnerable to flood. In March 2011 at the Fukushima Daiichi NPP an earthquake shut down the three units and 14 meters high Tsunami coming ashore cut power supply and damaged seriously the back-up diesel generators. The reactor couldn't continue to cold shutdown status and the other units suffered flooding. The Japanese NPP catastrophe was a reminder for the European Union to carry out a complete up-to-date assessment of the current European nuclear reactors safety especially in respect of a combination of extreme external hazards.

In this paper I will focus on the future of the existing and forthcoming NPPs located at the second biggest European River- The Danube, observing the international and regional legal instruments and institutions for nuclear safety and flood protection cooperation. I will use Bulgarian Kozloduy NPP as an example for the study of the IAEA Safety Standards especially in the process of safety assessment and site evaluation, done during the European "stress test" in regards of floods. Finally, I will address recommendations and conclusions.

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List of Abbreviations

Action Programme for Sustainable Flood Protection	(APSFP)
Boiling Water Reactors	(BWRs)
Canada Deuterium Uranium	(CANDU)
Carbon capture and storage	(CCS)
Cernavoda NPP	(CNPP)
Danube-Black Sea Canal	(DBSC)
Danube River Protection Convention	(DRPC)
Design basis flood	(DBF)
Defence in depth	(DiD)
Directive 2009/28/EC on Renewable Energy	(RED)
Directorate General	(DG)
European Commission	(EC)
European Flood Alert System	(EFAS)
European Floods Directive	(EFD)
European Nuclear Safety Regulators Group	(ENSREG)
Environmental Technology and International Affairs	(ETIA)
European Strategy for the Danube Region	(EUSDR)
European Stress Tests	(EST)
European Union	(EU)
28 Member States of European Union	(EU-28)
Food and Agriculture Organization	(FAO)
General Safety Requirements	(GSR)
Geographic information system	(GIS)
Green-house-gasses	(GHG)
Hydro Power Plant	(HPP)
Instrument of Nuclear Safety Cooperation	(INSC)
International Atomic Energy Agency	(IAEA)
International Commission for the Protection of the Danube River	(ICPDR)
International Institute for Applied Systems Analysis	(IIASA)

International Labour Organization	(ILO)
International Maritime Organization	(IMO)
International Nuclear Safety Group	(INSAG)
International Seismic Safety Center	(ISSC)
Kozloduy NPP	(KNPP)
Light water reactors	(LWRs)
Meters Baltic See Level	(mBSL)
Not applicable	(n.a.)
Nuclear Energy Agency	(NEA)
Nuclear Power Plants	(NPPs)
Nuclear Regulatory Commission	(NRC)
Organization for Economic Cooperation and Development	(OECD)
Organization for Economic Cooperation and Development, Nuclear Energy Agency	(OECD NEA)
Paks NPP	(PNPP)
Pan American Health Organization	(PAHO)
Pressurized water reactor	(VVER)
Pressurized Water Reactors	(PWRs)
Probabilistic safety assessment	(PSA)
Reference Level	(RL)
Safety Reference Level	(SRL)
Specific Safety Guide -18	(SSG-18)
Special Safety Requirements	(SSR)
Structures, systems, and components	(SSCs)
Technical Documents Report	(TECDOC)
United Nations Environment Programme	(UNEP)
United Nation Framework Convention on Climate Change	(UNFCCC)
Water-Water Power Reactor	(VVERs)
Water Framework Directive	(WFD)
Western European Nuclear Regulators Association	(WENRA)
Working Group 1 on Nuclear Safety	(WGNS)
World Association of Nuclear Operators	(WANO)

World Health Organization	(WHO)
World Meteorological Organization	(WMO)
World Nuclear Association	(WNA)

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Introduction

The most common disaster in Europe is flooding and it is also the most expensive one considering the economic costs. (ICPDR 2011) Since 1998 not only the high-water levels of Danube River Basin broke the records three times, but also the frequency of the flooding is notably higher. In the last 15 years have happened the most significant floods ever. In the period 1998-2004 floods killed more than 700 people, displaced more than 500 000 people and caused economic damages for at least 25 billions in Europe. (EC,DG Environment 2014) Notably, in Danube River Basin Region there are 7 countries that operate 10 NPPs and the total number of operational nuclear reactors are 22. (IAEA 2015). This thesis identifies critical area among the Danube River Basin with NPPs flooding risk and analyse the potential causes of the flooding. The identification of the critical parts of the Danube River Basin is observed in the current situation as well as in the future scenarios.

Climate Change

The growing energy demand contributes to the climate change and consequent rise in the temperatures. The increasing temperatures brings change of rainfall patterns and European Environmental Agency is expecting that this weather extremes will bring natural hazards - more intensive floods and storms. Although more data and analyses of the last century series are needed, the European Environmental Agency connects the intensification of floods frequency with the climate change. Looking back in the 20th century it is most likely that the cause of climate change are due to observed rise of the man-made emitted greenhouse gases. As an effect of the climate change and respectively the rising temperatures the water cycle increases and cause higher evaporation and consequently greater volume of rainfalls. (European Environmental Agency 2013)

Floods in changing climates

In 2012 Slobodan Simonović offers in his book “Floods in a changing climate” a framework for identification and assessment of flooding risk resulting from climate change and measures for adaptations. (Simonovic 2012)

The European Directorate General (DG) for Regional Policy states in its report " The Climate Change Challenge For European Regions" that in the next 15-20 years the

Climate change will significantly affect the European counties. Extraordinary weather events such as winter floods will be more usual in Europe. Also, heavy rainstorms are expected in Western Europe.

But the most affected regions, mainly due to change in precipitation patterns are those located in south and east of Europe. Countries like Hungary, Romania and Bulgaria are expose to the risk of river floods. Report underline that countries with *"low GDP per capita and therefore lower capacity for adaptation to climate change"* are at a higher risk. (DIRECTORATE GENERAL FOR REGIONAL POLICY 2009)

But the topic of climate change and effect on floods in Europe is not new. On 5th of June 1999 an international conference in Laxenburg, Austria discussed the subject. During the conference was reported record frequency of natural disasters that threaten world-wide economic and social stability. In Europe, record amounts of precipitation in 1997 and 1998 have resulted in damaging, costly floods. The conference organized by the International Institute for Applied Systems Analysis (IIASA) and the European Commission (EC) addressed the issues related to the conference theme "Global Change and Catastrophe Risk Management: Flood Risks in Europe." The numbers distributed by an international re-insurance company informed the audience that major natural catastrophes (e.g., floods, hurricanes, and earthquakes) occurring in the '90s were three times larger, and cost the world's economies nine times more, as in the '60s. (International Institute for Applied Systems Analysis. 2004)

Renewables and Nuclear in EU

Nowadays, the leading position in the energy mix of European countries has fossil fuel, thus helping for the climate change and rise of the temperatures. The only way to stop the process is to limit the raise of temperature. Taking into consideration the UNFCCC goal of 2 °C limitation of global mean temperature increase, the EU countries decided to take measures and to reduce GHG emissions by elaborating three Energy Strategies for short-, mid- and long-term period (European Environmental Agency 2016):

In 2013 Meiswinkel, Meyer and Schnell stated that many countries are moving to or expanding their nuclear share in the energy mix, as they need reliable energy supply that still cannot be ensured from the renewable energy sources. (Meiswinkel, Meyer and Schnell, Design and construction of nuclear power plants 2013)

However, in 2014 “New nuclear in Europe: 2030 outlook” report of World Nuclear Association (WNA) discusses that the number of reactors in EU-28 in the future appears to decline, though many of the countries are presently preparing to build new NPPs. The WNA report observes the proposals for new nuclear reactors in the EU and evaluates the chance they to come to realization. (Tarlton 2014)

NPPs and floods in general

A technical requirement for every NPP is the installation to be sited close to a water body such as river, lake or sea as the NPPs need an abundant, consistent source of water for cooling not only the steam producing electricity but also the reactor core and used fuel rods even when the plant is closed for refuelling and so to avoid severe accident. (Union of Concerned Scientists 2014 a) Thus, the cooling function of the water appears to be of enormous importance for every NPP no matter of the reactor type. If water is not cooling the system, the reactor will overheat, the heat will damage the core and the harmful radiation from the core will be realized in the environment. Conversely, water can very easy turn it’s role- from cooling friend of the reactor to an enemy of the NPP in case of flooding.

Overflow of the water can destroy equipment or black out the electrical system of the station and in the region, stopping its cooling systems. (Union of Concerned Scientists 2014).

This thesis concentrate on the nine European NPPs located in seven countries among the second biggest river in the Europe- Danube, including its tributaries, in the light of natural hazards that can cause failure of the structures, systems, and components (SSCs) needed for the fundamental safety functions and shutdown state of the plants.

Floods in European Danube River

While tsunamis are not a significant risk in the second biggest European River Basin- Danube River Basin, as it was in Japan in 2011, the meteorological disasters as heavy rain, rapid spring snow melting and storms can cause floods threatening the NPPs sites among the river.

In this regards, European Environmental Agency (European Environmental Agency 2011) expect that European citizens and structures affected by flooding and the negative economic impact of the floods will rise significantly by 2100 as a result of climate change. Therefore, in 2007 European Union accepted Directive 2007/60/EC on the assessment and management of flood risks. The International Commission for the Protection of the Danube River (ICPDR) is the body that coordinates its application in the Danube River Basin.

Additionally, in the following years, European Union and the entire Danube River Basin will face major problem for water management caused by climate change. The 7th Framework Program' Project "ANVIL" predicts that the risk of more rain and higher floods will increase. (Butkovic and Samardzija 2013) The catastrophic floods of the last 15 years have caused many human victims and the economic cost reached record sums.

Earthquakes and Dam Failure

While the design features of NPPs take into account the earthquake risk and prevent the systems from accidents, the consequences of the dam failure caused from earthquake can be enormous. After Fukushima accident, United States Nuclear Regulatory Commission (NRC) announced in its 2011 report that 34 U.S. nuclear plants were identified as being at heightened risk of flood damage due to upstream dam failures. (Progressive Media Group Limited 2012). Some of the NPPs among the Danube River Basin are downstream from a dam. When the dam fails, the resulting flood is sudden and can be catastrophic. Unlike river overflows, dam failures are likely to occur with little or no advance warning, leaving plant operators scrambling to protect their facilities before the floodwaters arrive within hours. So far, dam failures have not affected any NPPs, but this was also the case of tsunamis before 11^{th} of March 2011. For this reason the dams among the Danube River Basin are also reviewed further in this paper and earthquake risk is taken into consideration in case the earthquake fail an upstream infrastructure and as a consequence NPPs are putted under flooding risk.

Safety Standards IAEA

In order to answer the research question for the future of the Danube River Basin NPPs with regards to natural hazards, the thesis will examine the consistency of the IAEA Safety Standards used as international reference for the implementation of high level of Nuclear Safety.

The IAEA offers a hierarchical system of Safety Standards Series including fundamental safety principles, safety requirements and safety guides to help the member States of IAEA in the safety protection process. (Picture 1). In order to cover all topics related to Nuclear Safety the IAEA documents covered general topics as governmental organization, quality assurance and emergency preparedness as well as four specific safety areas- nuclear, radiation, waste and transport. (International Atomic Energy Agency 2016) The IAEA safety standards are interrelated with the activities during the whole lifecycle of NPP – from construction, through operation and until decommissioning.

In the recent issued book of Katsuhiro Kamae "Earthquakes, tsunamis and nuclear risks: prediction and assessment beyond the Fukushima Accident" the seismic evaluation approach and important studies related to the safety of NPP are discussed. This book navigates the future direction of nuclear safety against natural disasters. The author stresses the attention on the fact that Fukushima accident proved the uncertainties in the risk assessment for natural hazards. (Kamae 2016)

Complete up-to-date assessment of EU NPPs- "stress tests"

Recently, after Fukushima Daiichi NPP accident in 2011, the European Union immediately carried out so called "stress-tests"- a complete up-to-date assessment of the current 132 European nuclear reactors safety especially in respect of a combination of extreme external hazards on the 58 sites. (European Commission 2012), (European Commission. Directorate-General for Research and Innovation 2014);

NPP Kozloduy example

During the European NPPs "stress test", the Bulgarian NPP Kozloduy reported that the Bulgarian national standards, norms and regulations for licensing are in compliance with the international requirements for the events within the scope of the stress tests taking the IAEA Safety Standards as a reference. (ENSREG 2012)

The "Peer review country report; Stress tests performed on European nuclear power plant" (ENSREG 2012) of European Nuclear Safety Regulators Group says that the Bulgarian safety regulations are in compliance with the international standards, however, the NPP has to prove details for their implementation. The report highlights the fact, that “the result from the probabilistic safety assessment (PSA) does not include external flooding or extreme weather.” (ENSREG 2012). It is noted that the plant design and safety requirements are in compliance with the WENRA RLs. However, at the time of peer review the RLs Issue-T- Natural Hazards were not elaborated and were not taken into consideration. Further, the thesis focuses on the stress tests, implemented in the EU-27 after Fukushima Daiichi accident, and precisely review the stress test and peer review process of NPP Kozlody as an example.

In July 2015, during an interview with Mr. Sujit Samaddar, Head of the International Seismic Safety Centre (ISSC) at the IAEA, was underlined the need for more sensitive studies on matters related to the safety of nuclear installations against external hazards, world wide.

According to the IAEA (IAEA International Seismic Safety Centre 2014) there are 2 methods for evaluation the safety risk in NPPs against natural hazards: One of the methods is deterministic (postulating or beyond design basis) – With this approach the events are completely determined by expected causes and cause-effect-chains is analysed. Using the design basic the method sets the limit values, beyond which limits the undesirable event will happen. All SSCs needed for fundamental safety functions and shutdown state are observed. The other method, more recommendable in the case of natural hazards, is probabilistic (prognostic) – the evaluation is more extensive and identifies possible weak points of the NPP and draws the safety frame of broad variety of issues, including the uncertainties of the data. Furthermore, IAEA’s International Seismic Safety Centre recommends rational probabilistic-based combinations of external-flooding phenomena cause by natural phenomena and by man-made events (principally failures of dams, levees, and dikes) to be considered, depending on the site. (IAEA International Seismic Safety Centre 2014)

(Samaddar 2015)

From one site, nuclear safety is a key aspect for the future of nuclear energy in Europe. From other site, the natural disasters related with the climate change increasing concerns and uncertainty in the nuclear energy, especially after 2011 accident in Japan. The Flood Risk Management Plan for the Danube River Basin District 2015-2021 has 3 type of floods scenarios- low, medium and high, however in this scenarios the high risk Industries at risk like NPPs in prone areas are not included.

Not only the ICPDR reports do not include the flood risk for NPPs safety in Danube River Basin, but also, there is no GIS spatial analysis to conduct the vulnerability of NPP flooding that could cause severe accident. (Miller et al.2015).

Relating this concerns with the fact that the floods are the most common natural phenomena that's frequency rose in the last century as a consequence of climate change (Pedroso 2014) and in particular, it is a major problem in EU among the Danube River Basin, in this thesis I study the safety and from this regard, the future of the existing and forthcoming NPPs located at the second biggest European River- The Danube. An important part in the thesis has the NPP cooperation and legal instruments for that and I review the topic from international, regional (European) and national level. I use Bulgarian Kozloduy NPP case as an example for the study of the European "stress test" addressing safety features and standards that should be followed especially in the process of choosing the site and in regards of floods. Additionally, I examine the safety, design, future technologies and public acceptance, awareness and preparedness in order to make the final recommendations and conclusions for the future of the nuclear energy development in Europe.

The thesis is developed in two fold. From one side it is reviewed the flooding risk and management of the floods in Danube River and from another the attention is stress on the technical features and emergency preparedness of the NPPs among the river in regards to external hazards.

In Chapter 1 the paper make an overview of Danube River Basin Region stressing the attention on each country among the Danube River that operates a NPP reactor, existing, under construction and planed and furthermore review the natural flood hazards in the region for their safety operation. In the examination it is summarized the date for every NPP including the year of construction, start of operation, type of the reactor and cooling system, capacity, years in operation, downstream dams and plant features. Furthermore, the section examines historically the major flood events that occurred in the past in these parts of the Danube River Basin and the consequences in social, environmental and economic aspects. As a result summarized data tables and special maps of the NPPs sites are elaborated.

Chapter 2 reviews the cooperation between the different institutions and related legal aspects relevant to management of Danube River Basin from international, European and Regional prospective. Furthermore, it focuses on the Safety Standards directly related to the natural hazards and in particular to flood risks taking into consideration the specific environment of the Danube River Basin. The author review the safety recommendation related to safety assessment, technical design, operation and site selection, against extreme natural hazards, Storage of spent fuel and emergency preparedness of the NPPs.

The Bulgarian NPP Kozloduy is observed in Chapter 3 as an example for the study of the so cold European "Stress Tests" addressing safety features and standards especially in the process of assessing the site and in regards of floods. In order to take into consideration the above mentioned, this thesis will study in details the Meteorological and hydrological hazards in site evaluation for nuclear installations: specific safety guide SSG-18 (International Atomic Energy Agency.; World Meteorological Organization. 2011) for the relevant NPPs in Danube River Basin.

Chapter 4 address recommendations for the future sustainable nuclear power program taking into consideration the high standards of safety, development of the new technologies and the needs of energy in the region. Availability of more accurate datasets and introduction of new analysis methodologies such as geographical information systems could facilitated rapid processing of large, spatially distributed datasets in the estimation of input for newer classes of hydrologic, hydraulic, and hydrodynamic models using GIS tools for determining the design-basis floods at nuclear power plant sites. Furthermore, for best results in safety and management it is necessary to be organized Central Command Centre for Danube Region that has to prepare NPPs Flooding Risk Simulations. The Centre should combine the expertise of all relevant stakeholders including IAEA, ICPDR, WMO and other relevant international organization.

1. Overview of Danube River Basin Region

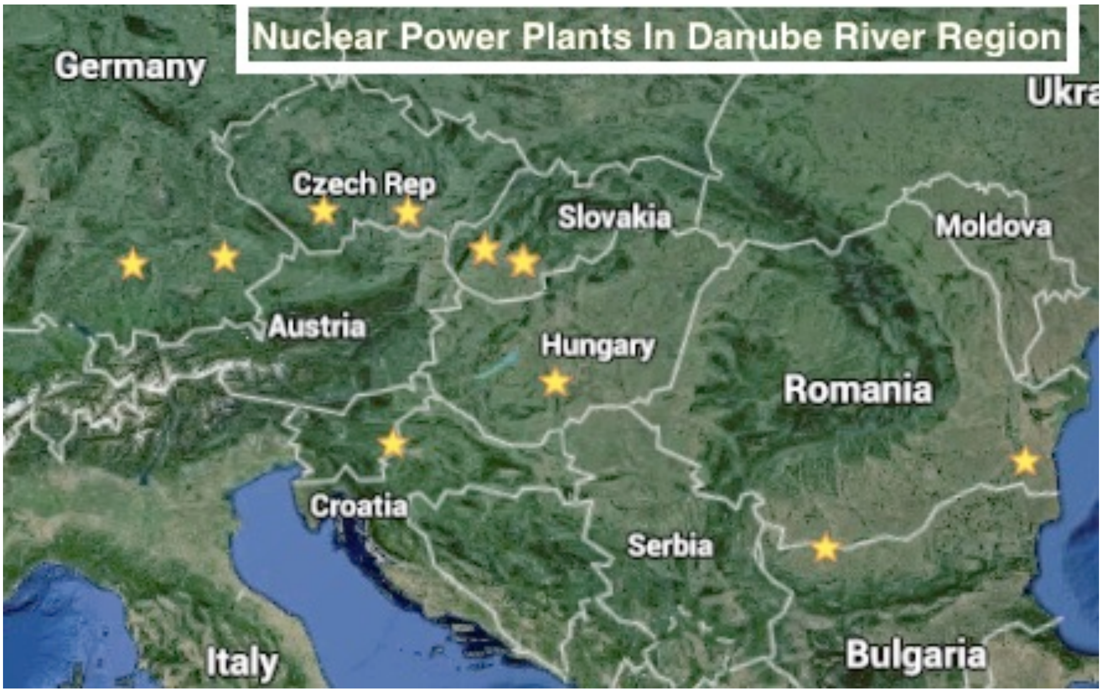
1.1. NPP in Danube River Basin Region

In Danube River Basin region there are 7 countries that operate 10 NPPs and the total number of nuclear reactors are 22. (IAEA 2015). In Table 1 are described all NPPs located in Danube River with all their units including operating, shutdown and planned. (Table 1: Existing and upcoming NPPs in Danube River Basin) (IAEA 2015)

The main type of nuclear reactors in EU are Generation II light water reactors (LWRs) which can be split in two major varieties: Boiling Water Reactors (BWRs) and Pressurized Water Reactors (PWRs) utilizing light water as a mediator and coolant. VVERs (Water-Water Power Reactor) are PWRs created in the previous Soviet Union, now Russia. To apply the Western safety standards to the Central and Eastern European NPPs, constructed by Soviet design, the EU disbursed around 1 billion Euros since 1991 to booster the safety of 50 NPPs. (Danube Watch 2005/4 2005). Nevertheless, one of the conditions to Bulgaria and Slovak Republic to be accepted as members of the European Union was the oldest units of their NPPs (4 reactors in Kozloduy NPP and 2 in Bohunice NPP) to be permanent shutdown.

There is additionally an alternate sort of Pressurized heavy-Water-Moderated and Cooled Reactor -Canadian reactor CANDU(CANada Deuterium Uranium) which operates only in Romania, using heavy tritiated water for its cooling system and moderation. However, the NPP required the river water for the cooling system. Generation II LWRs were developed in the middle of the1970s and the end of the 1990s, and initially was designed for 40 years life span. However, currently their life is extending from 10 to 60 years. (European Commission. Directorate-General for Research and Innovation, 2014).

Only 4 of the NPPs in Danube River Basin are located directly on the Danube River, while the other NPPs are located either on tributary of Danube River or are using cooling towers for their cooling needs. (Table 2: NPPs in Danube River Basin- location and institutions for cooperation in case of floods) (ICPDR 2011), (Liska, Höbart, et al. 2012), (Liska and Major , Floods in June 2013 in the Danube River Basin 2014) and Map 1.1.



Map 1. NPPs in Danube River Basin and Source: Google Maps (Data Maps Google 2016)

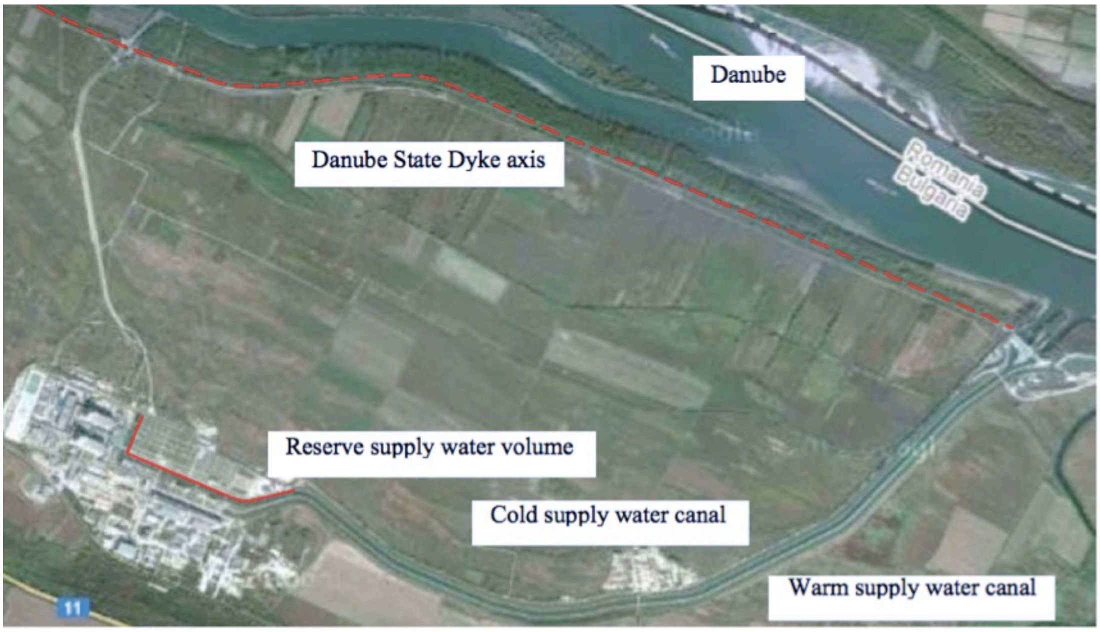
1.1.1. Bulgaria

1.1.1.1. Kozloduy NPP

As World Nuclear Association stated (World Nuclear Association 2016 b), one of the conditions to Bulgaria to be accepted as a members of the European Union was 4 of the reactors of Kozloduy NPP - Kozloduy1-2 to be shutdown within the end of 2002 and Kozloduy3-4 within the end of 2006. The compensation for that was a fund- Kozloduy International Decommissioning Support Fund (Ministry of Energy, Republic of Bulgaria 2012) amounting 880 million Euro and financing the decommissioning activities, mitigation of negative impact of earlier shutdown and future energy and environmental projects. The fund start operating in 2004 and is managed by the European Bank for Reconstruction and Development. (Ministry of Energy, Republic of Bulgaria 2012)

Although 4 of the Kozloduy NPP were shutdown, 2 others are still in operation and their net capacity assured 31,8 % nuclear share in 2014. (Table 3: NPPs in Danube River Basin net capacity in MW(e)) (IAEA 2015) . Additionally, in January 2016, Bulgaria signed a contract to extend the lifetime of the 6th reactor of Kozloduy NPP to 60 years. (World Nuclear News 2016)

The Kozloduy NPP is directly located on Danube River channel and use the river water for its cooling purposes.



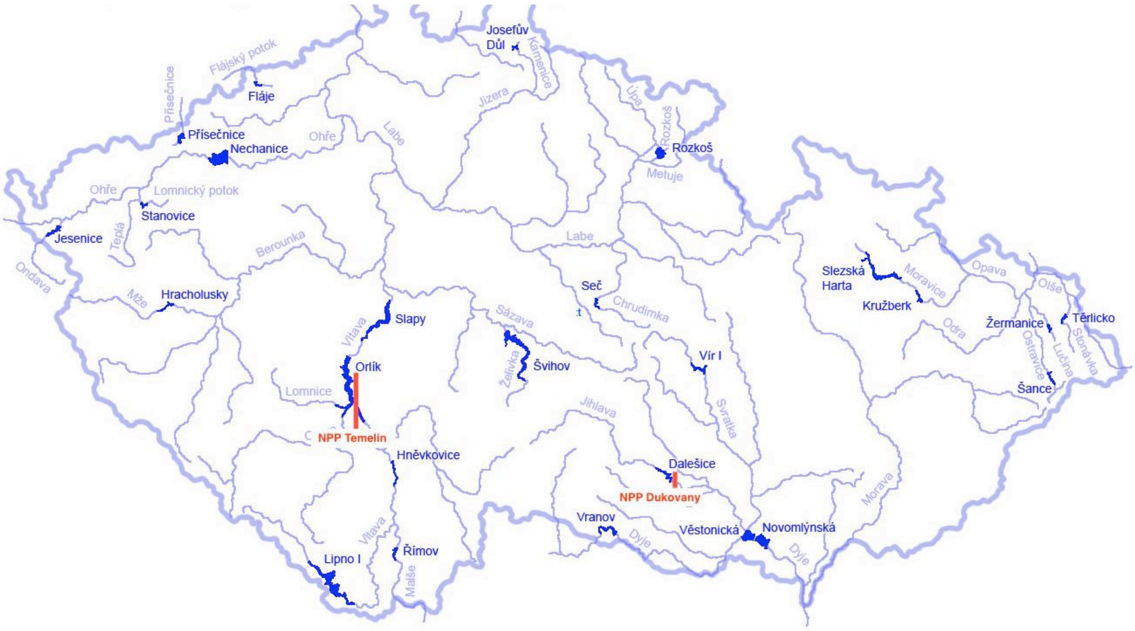
Map 1.1.1. Kozloduy NPP, Source: Google Maps (Map Data Google 2016)

1.1.2. Czech Republic

Czech Republic has 2 NPPs with total 6 operating units. Only Czech NPPs and the Slovakian NPPs from the observed NPPs in Danube River Basin are not located directly to the river, but have cooling towers for ultimate heat sink. (CEZ Group 2016)

The closest to the Dukovany NPP river is Jihlava River, a tributary of Danube River where is located Water Reservoir Mohelno part of Dalešice hydropower plant. (Table 2: NPPs in Danube River Basin- location and institutions for cooperation in case of floods) and Map 1.1.2.1.

The Temelin NPP is located 2 km away from the Danube River's tributary Vltava River and less than 5 km from Hněvkovice Dam, 10km from Kořensko Dam and 50 km from the largest hydroelectric dam in Czech Republic - Orlik Dam (Czech: Vodní nádrž Orlík). (Hrdlička 2015)



Map 1.1.2.1 biggest reservoirs of the Czech Republic and NPPs. Source: Wikipedia (Hrdlička 2015)

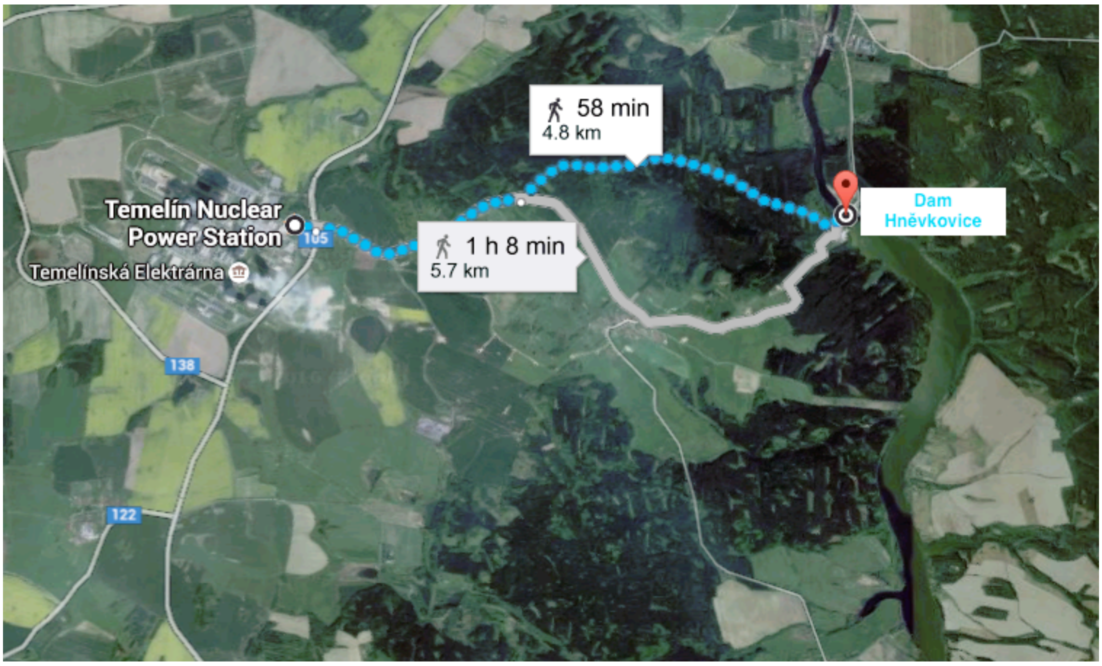
1.1.2.1. Dukovany NPP

The 4 reactors lifetime of Dukovany NPPs has been expand with 10 years and now they are licenced to 2025-2027. Additionally, the operator CEZ is preparing application to prolong the lifetime of Dukovany NPPs units to 60 years. However, the closest neighbour Austria opposed this proposal. (World Nuclear Association 2016)

Map 1.1.2.2. Dukovany NPP, Source: Google Maps (Map Data Google 2016c)

1.1.2.2. Temelin NPP

Temelin NPPs units were constructed in 2000 and 2003 and possess a licence, respectively, until 2020 and 2023.



Map 1.1.2.3. Temelin NPP and dam Hnekovice, Source: Google maps (Map Data Google 2016d)

1.1.3. Germany

In June 2001 the operators of German NPPs and the government signed an agreement that guarantee the operation of the plants for many years giving extension of the lifetime, although some compromised has been made with the shutdown deadlines. (World Nuclear Association 2016 c)

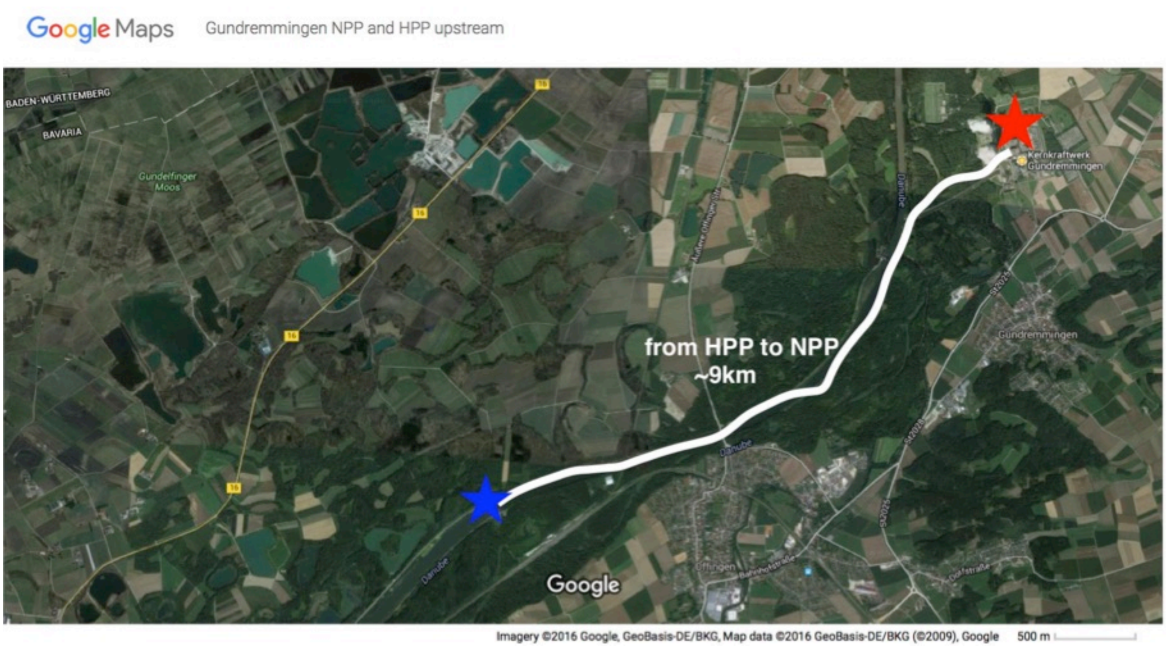
Furthermore, in November 2010 the life span of the NPPs reactors build before 1980 was prolonged with additional 8 years and 14 years more were given to the ones constructed later. The price for this extension was new taxes and subsidies for renewables. But, if the utilities upgrade their safety SSCs, they could save their green energy investments. (IAEA 2015)

Controversial to the agreements signed before, after Fukushima Accident in 2011, the German Chancellor Angela Merkel ordered 3 months moratorium to all NPPs and after that immediately shutdown of all NPPs constructed before 1980 and final shutdown of the rest of German NPPs within 2022, all this without any safety assessment. Although, the Reactor Safety Commission announced that all German reactors were in good safety condition, the decision was not changed. This was the case with the NPPs Gundremmingen and Isar located on Danube River and Isar River, a tributary of Danube River. The shutdown for Gundremmingen NPP has been changed as follow: Unit B from 2030 to 2017 and Unit C from 2030 to 2021,while in Isar NPP Unit 1 has been shutdown in August 2011 and Unit 2 is scheduled to be shutdown in 2022. (World Nuclear Association 2016 c)

Currently, the four NPPs operators are claiming compensation for the taxes agreed in the contract signed in 2010 in connection to the life extension of the units and which breach was done with the earlier closure of the reactors. (World Nuclear Association 2016 c)

1.1.3.1. Gundremmingen NPP

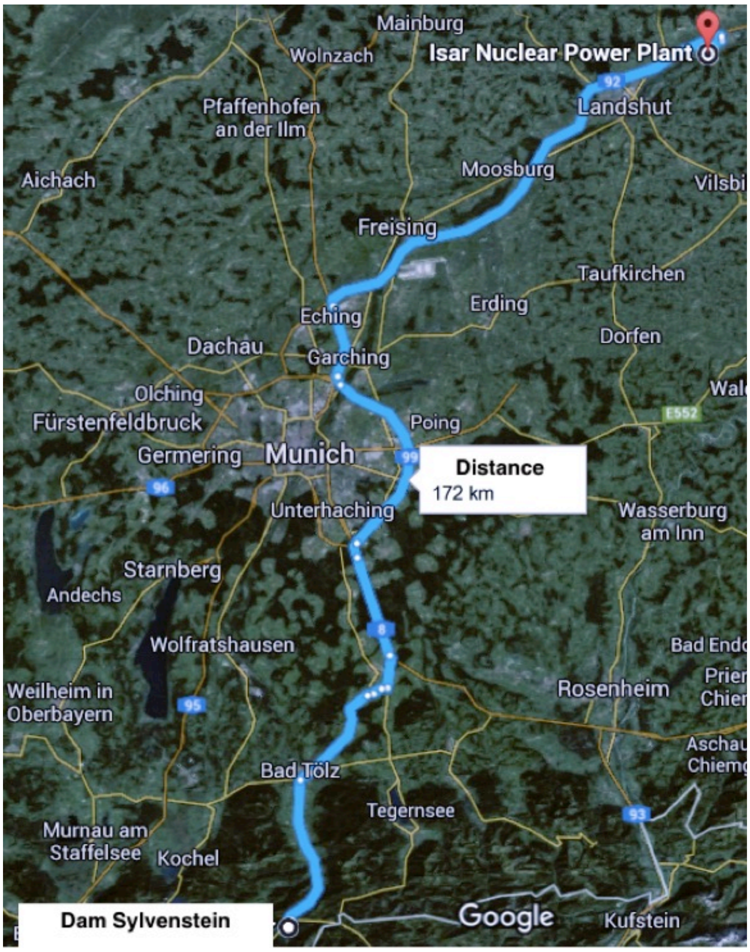
Gundremmingen NPP has 2 reactors and is located on a channel directly on Danube River. There is a small Hydropower Plant (HPP) on the Danube River 9 km upstream from the NPP. In 1978 1 km from the NPP was build a meteorological tower that monitor the climatic conditions.



Map 1.1.3.1 Gundremmingen NPP, Source: Google Map (Map Data Google 2016e)

1.1.3.2. Isar NPP

Isar NPP is located direct o Isar River, a tributary of Danube River. On Isar River there are chains of dams and hydropower stations, the largest of which is Sylvenstein Dam located about 170km downstream of Isar NPP.



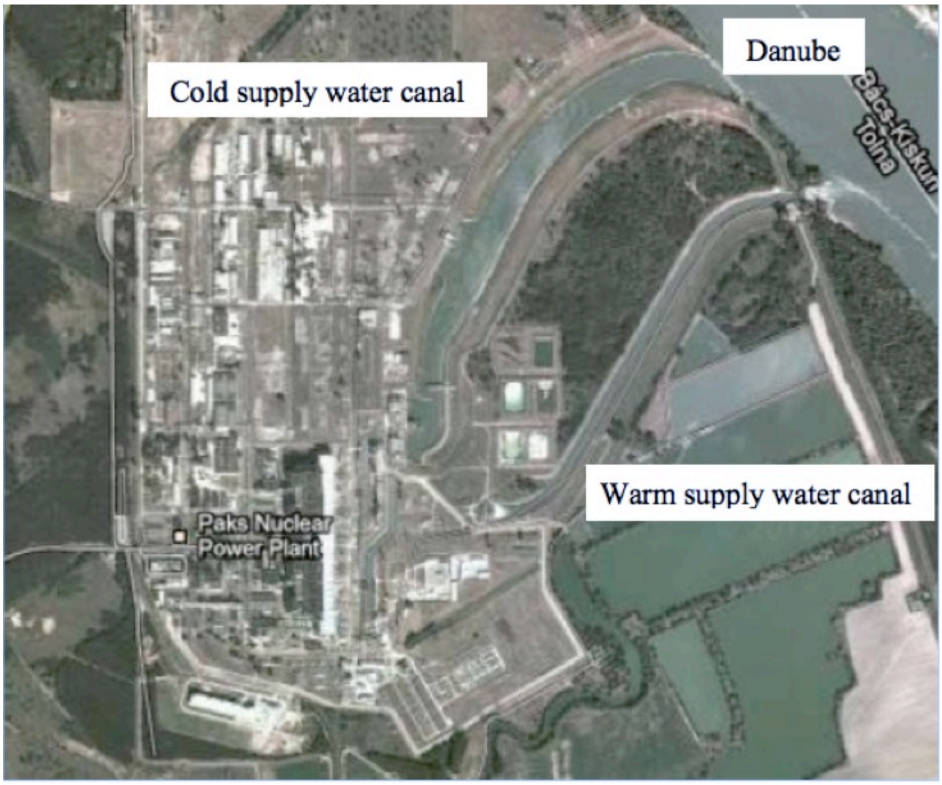
Map 1.1.3.2. Isar NPP, Source: Google Maps (Map Data Google 2016e)

1.1.4. Hungary

1.1.4.1. Paks

Hungary with its 4 reactors at Paks NPP, designed for 30 years lifetime, two of which has been extended to 50 years, is the leader among the Danube countries with 53.6% nuclear share of the national energy mix in 2014. (World Nuclear Association 2015 c).

The four units are located directly on Danube River.



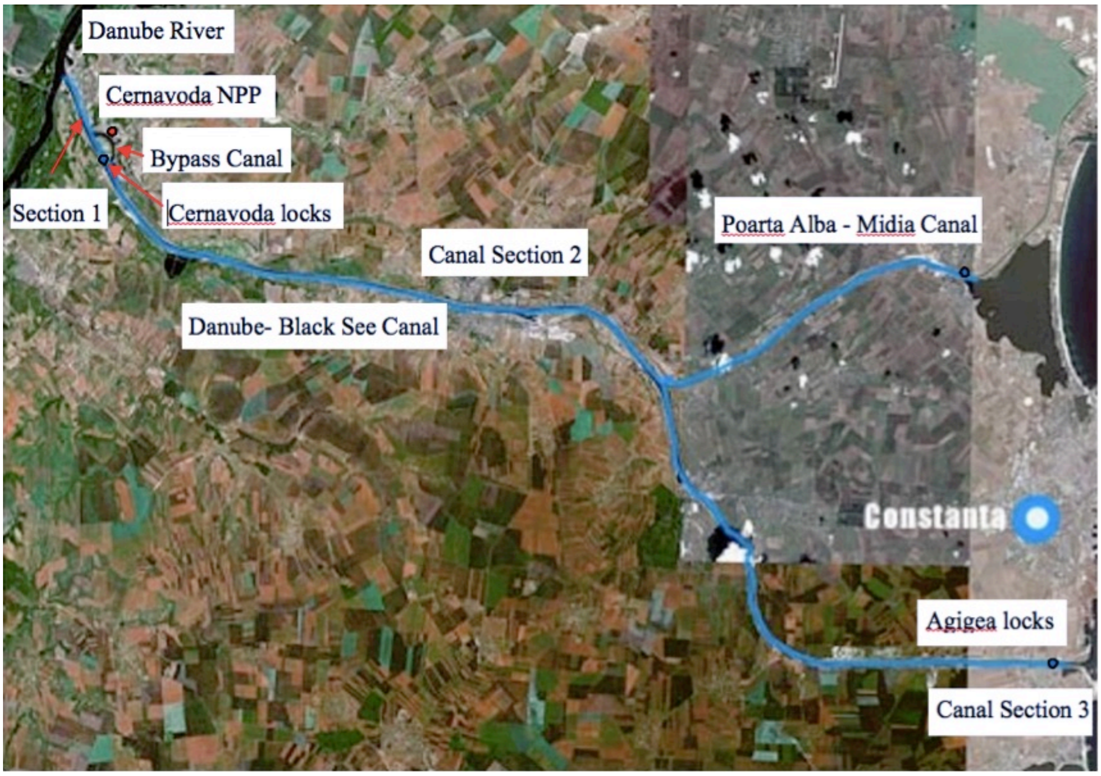
Map 1.1.4 Paks NPP, Source: Goolge Maps (Map Data Google 2016a)

1.1.5. Romania

1.1.5.1. Cernavoda NPP

Romania is the only country in the Danube River Basin that operates two Pressurized Heavy-Water-Moderated and Cooled Reactors -Canadian reactor CANDU, using heavy tritiated water for its cooling system and moderation. Cernavoda 1 and Cernavoda 2 were constructed and commissioned respectively in 1996 and 2007. (World Nuclear Association 2016a)

The NPP is located on the channel of Danube River.



Map 1.1.5 Cernavoda NPP, Source: Google Maps (Map Data Google 2016b)

1.1.6. Slovak Republic

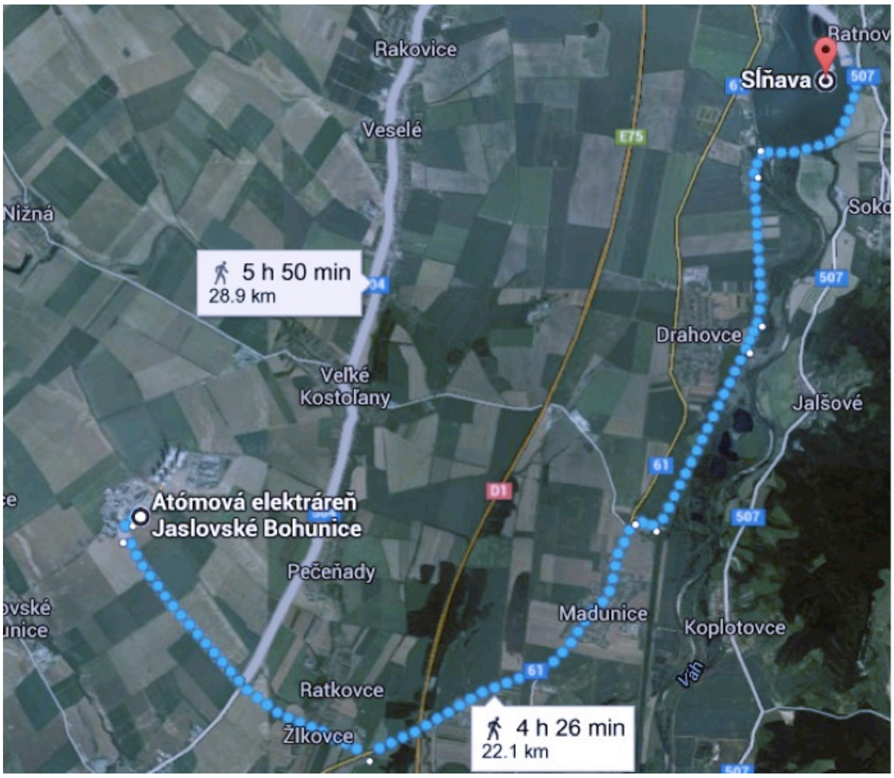
1.1.6.1. Bohunice NPP

Despite the invested money and efforts to upgrade the two Bohunice V1 nuclear reactors, Slovak Republic had to shutdown the units in respond to the European union conditions for membership accession.

For the other two units at Bohunice V2 the operator invested more than a half billion to improve the equipment, cooling systems and seismic resistance. The modernization program aimed to get an extension of the operational life of the reactors up to 40 years and the operator intend to apply for another 20 years. (World Nuclear Association 2015). If the extension of the licence up to 2045 is not approved the national energy strategy foresee a new *1200 MWe nuclear capacity at Kecerovce in the east of the country.* (World Nuclear Association 2015)

The Bochunice NPP is not located directly on a river and use cooling towers for the cooling needs. (Slovenské elektrárne JSC 2014)

The tributary of Danube River -Vah River flows 10 km from the Bohunice NPP and the reactors approximate Sĺňava dam, which is located 20km upstream.



Map 1.1.6.1 Bohunice NPP, Source: Google Maps (Data Maps Google 2016f)

1.1.6.2. Mochovche NPP

Mochovche NPP has two reactors in operation - Mochovche 1 and Mochovche 2 and two under construction. The commissioning of the two new reactors- Mochovche 3 and Mochovche 4 are foreseen for 2017 and 2018.

Mochovche NPP is located 10km from Hron River, which is tributary of Danube River.

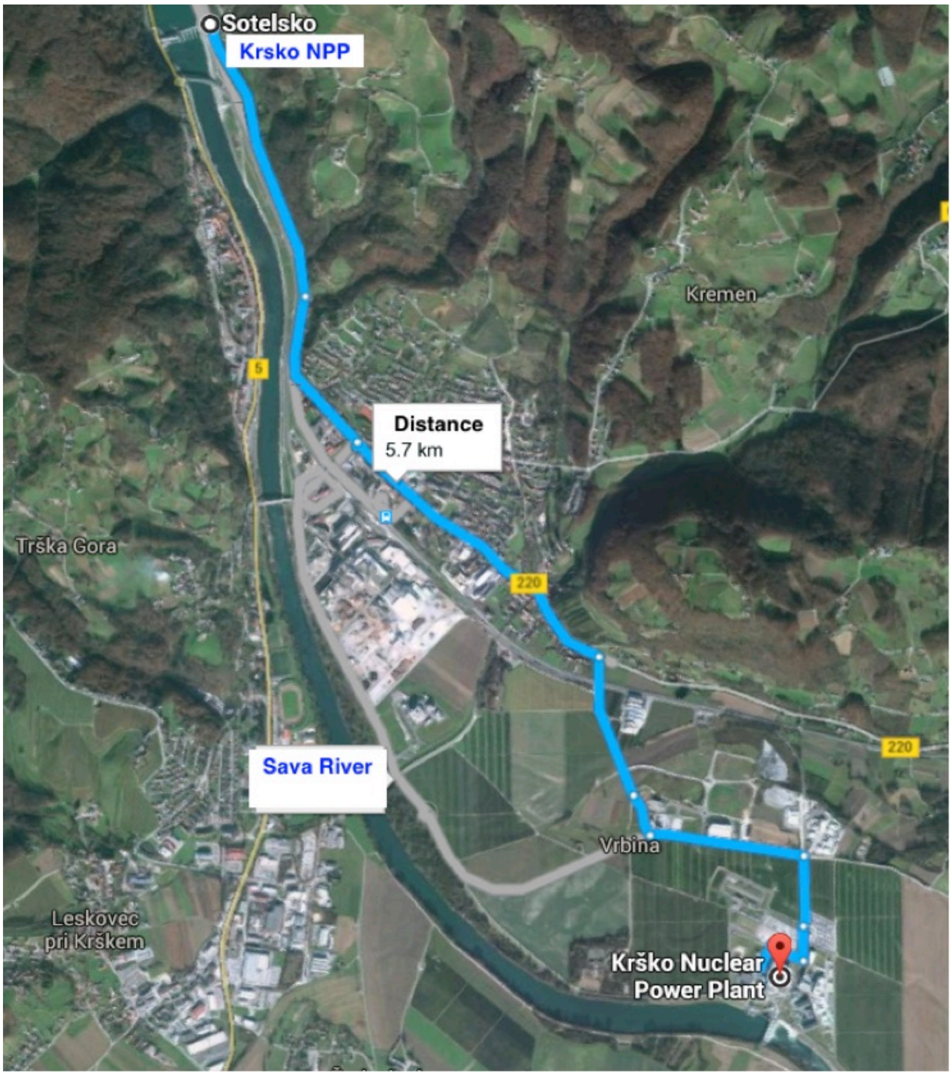
1.1.7. Slovenia

1.1.1.2. Krsko NPP

Slovenia has only one nuclear reactor- Krsko-1, which the country shares with Croatia since 1981. The preliminary shutdown was for 2021, but in 2015 the facility got 20 years extension of the life span. (World Nuclear Association 2015a)

The NPP is located at Sava River that flows in Danube River.

Traditionally, Slovenian flood protection of Sava is done by numbers of cross sections, water channels and dykes mainly build around Krsko. Hydropwer plant Krško is the fourth in the chain of six hydro power plants on lower Sava River and is used also for flood mitigation. However, coordination between all relevant institutions is needed. (ICPDR, 2009)



Map 1.1.7 Krsko NPP and Krsko Hydropower Plant (HPP), Source: Google Maps (Map Data Google 2016g)

1.2. NPPs in Danube River Basin Region under construction and planned

Only one of the 7 Danube River Basin Countries has on going project for construction of new nuclear power reactor and this is Slovak Republic. The project foresees the two new units of Mochovce NPP- 3 and 4 have to be ready for commissioning in 2017 and 2018. (Table 1: Existing and upcoming NPPs in Danube River Basin) (IAEA 2015)

However, in all other countries, except Germany, there are plans and national strategies for development of new units mainly at the existing NPPs.

In Bulgaria, despite the fact that in 2013 the government suspend the construction of new NPP at Belene located on Danube River (Novinite.com 2013), although the public supported further development of the project voting on referendum with 61,5% “Yes” and thus supporting future development of nuclear energy in Bulgaria (Central Voting Committee (Централна избирателна комисия) 2013), at the end of 2015 Deputy Prime Minister from the same 2013 government Mr. Tomislav Donchev introduced the intergovernmental Bulgarian-Chinese working group that was created to develop an economic model for a new reactor of Kozloduy NPP. (Bulgarian National Radio 2015)

Also, Prime Minister Oresharski stated during his Cabinet in 2013-2014 that there is a possible restart of Belene NPP project. (Novinite.com 2013a)

Hungary also started a project for two new reactors at Paks NPP, planned from 80s, but just in 2014 assured financing of the project. In January 2014 the government signed an agreement with Rosatom to build the reactors and Russia to finance with 80% low interest rate loan the project. The construction start was planned for 2018 and commissioning for 2023, nevertheless in November 2015 EC suspended the project and started a legal procedure against Hungary accusing the country of non-compliance with the EU public procurement low and procedures during the preparation of the Paks agreement. (World Nuclear Association 2015 c)

In 2015 Czech Republic approved its national energy policy up to 2060 including 50% share of nuclear energy. Also, in June 2015 the government accepted the plan of Ministry of Trade and Industry for 4 new reactors at the two existing NPP-Dukovany and Temelin. The plan is to start within 2025 with one new unit at Dukovany and the other 3 will follow depending of the financing options assured from the operator CEZ. (World Nuclear Association 2016)

In November 2013 the Romanian NPP operator Nuclearelectrica signed a letter of intent with China Nuclear Power Engineering Company for investment and development of two new nuclear reactors at Cernavoda NPP. The project was confirmed when the Chinese company signed a contract for construction of the units with Canadian Candu Energy Inc. The new reactors are foreseen to be with operating life of 30 years with the possibility of 25-year extension. (World Nuclear Association 2016a)

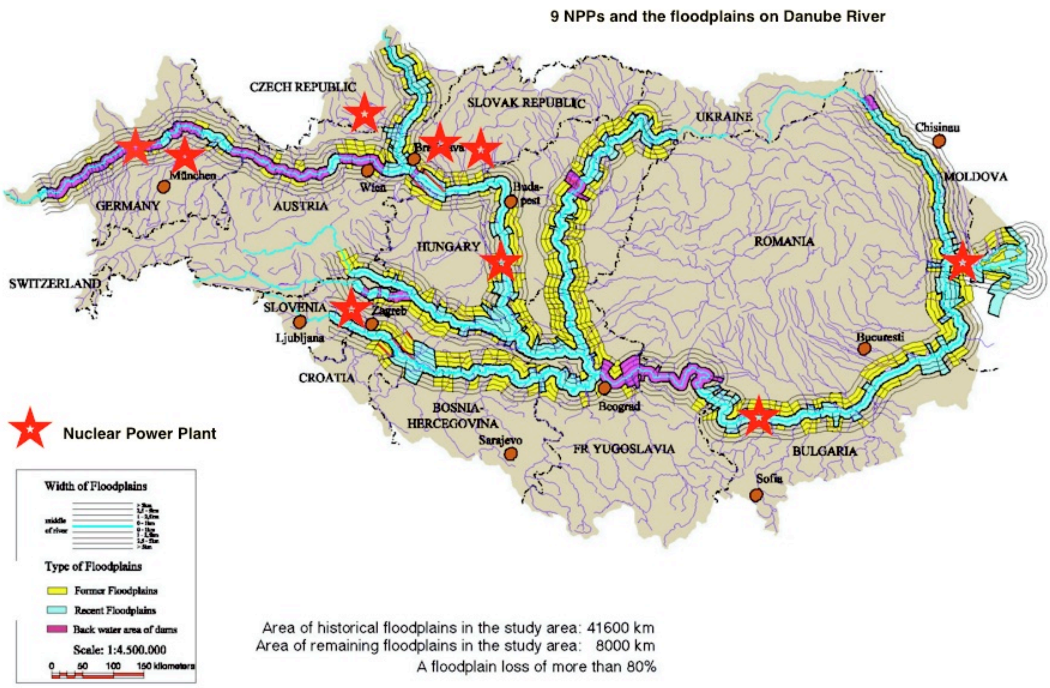
Finally, in Slovenia the parliament has to decide on the proposal of the Ministry of Economy for a second reactor at Krsko NPP that is foreseen to be owned solely by Slovenia. (World Nuclear Association 2015a)

From the above mentioned is seen that the nuclear power potential of the Danube River Basin will expand in the next 30 years and the safety in the region has to be assured.

1.3. Floods in Danube River Basin Region

The most common disaster in Europe is flooding and it is also the most expensive one considering the economic costs. (ICPDR 2011) Since 1998 not only the high-water levels of Danube River Basin broke the records three times, but also the frequency of the flooding is notably higher. In the last 15 years have happened the most significant floods ever. In the period 1998-2004 floods killed more than 700 people, displaced more than 500 000 people and caused economic damages for at least 25 billion in Europe. (EC,DG Environment 2014) In 2002 occurred the catastrophic floods along the Danube and Elbe rivers and further flood events in 2005 caused additional losses. (Danube Watch 2005/4 2005). In 2011 European Environmental Agency reported that flooding and storms are the most costly disasters. (European Environmental Agency 2011)

In 2004 ICPRD calculates that 6% of the total population of the Danube River Basin lives in cities, towns and villages below the flood levels and above 7% of the total area of the Danube River Basin is a floodplain. (ICPDR 2004)



Map 1.2.1: Floodplains in Danube River Basin, Sources: ICPDR, 1999 (ICPDR 1999)

1.3.1. Floodplains

On the Map 1.2.1 in yellow are seen the former floodplains and in purple the back water areas of dams in Danube region that because of human activates change the natural course of the river. Thus, the water finds new ways to flow and unexpected floods accrue. (ICPDR 2015)

Therefore, it is not surprising that the number of the affected from floods property and infrastructure is high. Extensive flood protection system is trying to defend this locations, as well as important industries, transport corridors, agrarian lands and telecommunications. Flood spread is stopped by “river training works” and “summer dikes” protecting the threaten valleys from frequent overflows (ICPDR 2004). Flood protection structures are design to resist at massive and intensive flood incidents. ICPDR estimated that more than 60,000 km2 are under the risk of flood events. This area would have been affected by regular or rare wave in case of lack of flood protections. The total length of these systems exceeds 13,000 km. (ICPDR 2004)

According to ICPDR report (ICPDR 2011) record flood levels of Danube River in 2005 took 31 lives in Romania, 55 roads were closed and 600 bridges have been washed away. In Bulgaria and Moldova 14,000 people have to been evacuated after the disaster.

In 2006 new record flood levels destroyed 782 buildings in Bulgaria and Romania, where 16,300 people have been evacuated 6,000 lives endangered. And150 villages flooded. Moreover, In Serbia several thousands have been evacuated due to a lack of clean water.

Another record rain and flood levels in 2009 affected 198,000 ha agricultural land in Hungary and other 110,000 ha in Romania.

In 2013 18 people have been killed, and tens of thousands have been evacuated in Germany, Austria, Switzerland, Hungary, Slovakia, Poland and the Czech Republic due to catastrophic flooding.

The recent and the worst floods in the Western Balkans for decades happened on 19th of May 2014 and was caused by record rainfalls. 40 lifes were lost and tens of thousands of people from Croatia, Serbia and Bosnia and Herzegovina were left homeless. Furthermore transport infrastructure was destroyed. (ICPDR 2015)

Table 4 “Table of Flood damages and related impact in Danube River Basin by NPP countries” (ICPDR 2002), (ICPDR 2008), (Liska, Höbart, et al. 2012), (Liska and

Major , Floods in June 2013 in the Danube River Basin 2014) compile the several flood events occurring in 2002, 2006, 2010 and 2013 in Danube River Basin Region where NPPs operate. The information in the table has been provided to the ICPDR by the responsible authorities from every country. However, the data in the table is not complete as the different reports provide different type of data and also the same report gives different information for every country. For further consideration and proper analysis of the information it is needed the data to be unified.

1.3.2. Return period

<u>LEGEND</u>

→ Recurrence period >100 years → Recurrence period = [51-100] years

→ Recurrence period = [21-50] years → Recurrence period < 20 years

Map 1.2.2. Return period of 2013 floods Source: ICPDR 2014 (Liska and Major , Floods in June 2013 in the Danube River Basin 2014)

Important for the good understanding of the thesis is to be clarified what is exactly a return period. It is also known as recurrence period and it estimates the likelihood of an event like flood to happen. It is measured mainly from historical data over a long period of time and it is used to assess the risk. This actually is the expected chance the event to occur. For example return period >100 years means that chance is 1/100 or less than 1%. (Mays 2011)

However, the precision of 1 % flood chance varies because it could be not enough quantitative or qualitative data available changes of the river area because of urban development, climate cycles or even flood control installations. (Holmes and Dinicola 2010).

The new historic records in the last 10 years change the statistical calculation of the design flood level and a detail revision for the complete Danube section is needed.

After 2013 floods The German Federal Water Act (Wasserhaushaltsgesetz) limits the land use and spatial planning in the flood areas with return period of 1000 years. (Liska and Major , Floods in June 2013 in the Danube River Basin 2014)

In Hungary long stretches of the Danube River area, previously assessed as "above the design flood level" areas, especially upstream Budapest, were inadequate to the flood in 2013. After this event a remarkable change in the "defence line" has to be done and a new flood hazard territory should be mapped out. (Liska and Major , Floods in June 2013 in the Danube River Basin 2014)

In Bulgaria was realised that there is a necessity of further analysis of the warning, response and management of a flash flood event.

Consequently, the new experience should be exchanged between responsible state water management agencies and the staff should be adequate trained.

1.3.3. Hydraulic Structures

It should also be mentioned that the hydraulic structure and flood protection structure may be very dangerous in a case of flash flood as the unexpected release and transfer of huge amount of water downstream may cause flood events in neighbouring countries. That is way the international solidarity and cooperation in Danube River Basin is of high importance. (Liska and Major , Floods in June 2013 in the Danube River Basin 2014) Additional negative impact of hydraulic structures is the reduced flood retention capacity and increased flood hazard and damages downstream of the dam.

Also, seismic risk should be taken into consideration. Unlike river overflows, dam failures are likely to occur with little or no advance warning, leaving plant operators scrambling to protect their facilities before the floodwaters arrive within hours. So far, dam failures have not affected any NPPs, but this was also the case of tsunamis before 11^{th} of March 2011. For this reason the dams among the Danube River

Basin are also reviewed in case an earthquake fail an upstream infrastructure, and as a consequence, downstream NPPs are putted under flooding risk.

Table 5 shows the biggest hydraulic structures among the Danube River and shows approximation from the NPPs downstream the river, while Table 6 summarizes all hydraulic structures in the Danube River Basin related to all NPPs.

Main findings

From the information gathered for the analysis of the NPP in the Danube Region the main findings are as follow:

- Nuclear share in the energy mix of the Danube countries is on an average of 35% and the trend is to grow;
- There are 21 reactors, 2 are under construction and 12 more are planned;
- 2 of the NPPs are not located directly on a river and use cooling towers for the ultimate heat sink. However, they are close to rivers and hydropower structure.;
- 4 of the NPPs are located directly on Danube River (in Germany, Hungary, Bulgaria, Romania);
- Only in Germany there is internal administrative link between all authorities related to the NPPs, River Basin and Flooding;
- The average density of the population in the exclusion zone of 30 km is around 60-90 thousands, however around Temelin NPP there are around 150 000, and only in Bulgaria and Slovakia density is less than 20 thousands;
- Almost every NPP has a upstream small Hydropower Plant or Dam, however there are only 3 big Hydraulic Structure that should be considered as danger: Gabčíkovo, Iron Gate I, Iron Gate II as well as the Black Sea as a water body close to Romanian NPP;
- Historical flood records were reported in the last 10 years in all regions where the NPPs are located;
- The Return Period of the floods often is >100 years and repeats in less then 5 years;
- The economic, social and environmental consequences are dramatic;

2. Legal Aspects & Cooperation Relevant To Safety And Management Of Danube River Basin

The safety of NPPs could be achieved only by global nuclear safety rules that have to be followed by every country possessing nuclear facility. But this is difficult aim because of the multitask issues that has to be coordinated and accepted. However, international networks between governments, operators, regulators, scientifically organizations and other stakeholders will help to the nuclear safety cooperation and future development of common framework. Thus, the exchange of experience, lessons learned and best practices will improve the effectiveness of the Nuclear Safety legal instruments. (International Atomic Energy Agency, 2006)

Picture 2 illustrates the complexity of the legal instruments and the different stakeholders and cooperation organizations aiming to strengthen the Global Nuclear Safety Regime.

2.1. International and european nuclear safety legal instrument

2.1.1. Relevant International Conventions

2.1.1.1. Convention on Nuclear Safety

The *Convention on Nuclear Safety* (IAEA, 1994) was adopted in 1994 and entered into force in 1996 with the main purpose legally to bind all NPPs to operate within certain international safety standards. 78 countries have signed the legal instrument and it was ratified/approved by all countries with NPPs in Danube River Basin. There are 10 other countries that have to ratify the convention. (International Atomic Energy Agency, 2016 a)

The convention covers the main fundamental topics related to the NPPs safety operation and is very close to the fundamental safety principle “SF-1” of IAEA (discussed further in p.2.2.4), however the IAEA Safety Standards are not included officially in the convention as most of the countries do not want to legally bind voluntary guides of IAEA. One of the arguments for this is that these guidelines have to be regularly updated and if they are fixed in the convention they will be no more flexible for the changing environment. (International Atomic Energy Agency, 2016 a)

Also, the legal document recognizes *“that responsibility for nuclear safety rests with the State having jurisdiction over a nuclear installation;”* (IAEA, 1994).

The Convention is the only legally binding document that discussed in *Paragraph (iv)* of the preamble (IAEA, 1994) promotion of an effective nuclear safety culture. Nevertheless, the definition of nuclear safety culture is difficult and is our day more often considered. During the 4 days *"International Conference on Human and Organizational Aspects of Assuring Nuclear Safety – Exploring 30 Years of Safety Culture"* (IAEA, 2016) held in February 2016 in Vienna, were discussed complex and dynamic sociotechnical systems related with the severe accidents in Chernobyl and Fukushima. The topics of *human and organizational factors, safety culture and leadership for safety* (IAEA, 2016) become more and more important part of the nuclear safety management.

2.1.1.2. Convention on Early Notification of a Nuclear Accident and Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency

The two conventions are the basis of the international emergency preparedness and response and have been opened for signature in 1986, after the Chernobyl accident, and in the same year entered into force. 87 countries and organizations (including FAO, WHO and WMO) signed and 70 ratified/approved the convention. All countries with NPPs in the Danube Basin region are legally bound by the convention.

Convention on Early Notification of a Nuclear Accident (IAEA, 1986a) was created in case of severe nuclear accident the country to provide prompt notification and information aiming to minimize of the trans-boundary consequences. IAEA should receive this information and from its side to disseminate it to other countries and relevant international organizations.

Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (IAEA, 1986) is the document that arranges the international cooperation mechanism between the States and IAEA for timely support in case of severe nuclear accident. IAEA is focal point for coordination and provides information and services for facilitation of the assistance. (International Atomic Energy Agency, 2016)

2.1.1.3. Vienna Convention on Civil Liability for Nuclear Damage

Convention on civil liability for nuclear damage has been created in 1988 also triggered from the Chernobyl accident. It is a joint protocol combining two conventions: Vienna Convention and the Paris Convention. The parties of the joint protocol can choose in case of accident, which one of the two conventions should apply to the exclusion of other. (International Atomic Energy Agency, 2016)

2.1.1.4. Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (IAEA, 2001) was agreed in1997 and entered into force in 2001. The instrument aim to promote relevant safety standards and to support international control system of the on-site spent fuel. (International Atomic Energy Agency, 2016)

2.1.1.5. IAEA Safety Standards- Fundamental Safety Principles, Safety Requirements, Safety Guides and Other IAEA publications

IAEA Safety Standards used as international reference for the implementation of high level of Nuclear Safety.

The IAEA offers a hierarchical system of Safety Standards Series including fundamental safety principles, safety requirements and safety guides to help the member States of IAEA in the safety protection process. (Picture 1). In order to cover all topics related to Nuclear Safety the IAEA documents covered general topics as governmental organization, quality assurance and emergency preparedness as well as four specific safety areas- nuclear, radiation, waste and transport. (International Atomic Energy Agency, 2016) The IAEA safety standards are interrelated with the activities during the whole lifecycle of NPP – from construction, through operation and until decommissioning.

On the top of the IAEA hierarchical pyramid of Safety Standards rule the **Fundamental Safety Principles**. They give the top-level policy statement of safety protection. The Fundamental Safety Principles are directly supported by the **Safety Requirements,** which have regulation equivalent and are elaborated to be followed, while protecting people and environment. Finally, the **Safety Guides** provide instruction how to apply the safety requirements giving the best examples from practice and advising the users for high levels of safety. (International Atomic Energy Agency, 2014)

During the meeting with Mrs. Cornelia Spitzer, Section Head of Safety Assessment, held on 29.04.2015 at the IAEA in Vienna, was clarified that 5 of the safety requirements were review and were under amendment procedure after the Fukushima Daiichi accident. (Spitzer, 2015) The secretariat of IAEA started the process in 2011 and after careful review of two of the Japanese governmental reports, IAEA fact finding expert mission report from 2011 and International Nuclear Safety Group

(INSAG) report, in October 2012 the Commission on Safety Standards approved the proposal for their revision and amendment. The safety requirements publication related to the "*regulatory structure, emergency preparedness and response, and nuclear safety and engineering aspects including site selection and evaluation, assessment of extreme natural hazards and their combined effects, management of severe accidents, station blackout, loss of heat sink, accumulation of explosive gases, the behaviour of nuclear fuel and the safety of spent fuel storage"* (International Atomic Energy Agency, 2016a) (International Atomic Energy Agency, 2016b) (International Atomic Energy Agency, 2016c) (International Atomic Energy Agency, 2016d). (International Atomic Energy Agency, 2016). As a result in February 2016 were published the following amended safety requirements publications:

- *Governmental, Legal and Regulatory Framework for Safety (IAEA Safety Standards Series No. GSR Part 1, 2010)*
- *Safety Assessment for Facilities and Activities (GSR Part 4, 2009)*
- *Safety of Nuclear Power Plants: Design (SSR-2/1, 2012)*
- *Safety of Nuclear Power Plants: Commissioning and Operation (SSR-2/2, 2011)*
- *Site Evaluation for Nuclear Installations (NS-R-3, 2003)*

The revisions to GSR Part 1 relate to the following main areas:

- *Independence of the regulatory body;*
- *Prime responsibility for safety;*
- *Emergency preparedness and response;*
- *International obligations and arrangements for international cooperation;*
- *Liaison between the regulatory body and authorized parties;*
- *Review and assessment of information relevant to safety;*
- *Communication and consultation with interested parties.* (International Atomic Energy Agency, 2016a)

The revisions to GSR Part 4 relate to the following main areas:

- *Margins for withstanding external events;*
- *Margins for avoiding cliff edge effects;*

- *Safety assessment for multiple facilities or activities at a single site;*
- *Safety assessment in cases where resources at a facility are shared;*
- *Human factors in accident conditions* (International Atomic Energy Agency, 2016b)

The revisions to SSR 2/1 relate to the following main areas:

- *Prevention of severe accident by strengthening the design basis for the plant;*
- *Prevention of unacceptable radiological consequences of a severe accident for the public and the environment;*
- *Mitigation of the consequences of severe accident to avoid or to minimize radioactive contamination off site;* (International Atomic Energy Agency, 2016)

The revisions to SSR 2/2 relate to the following main areas:

- *Periodic safety review and feedback from operating experience;*
- *Emergency preparedness;*
- *Accident management;*
- *Fire safety.* (International Atomic Energy Agency, 2016d)

The revisions to NS-R-3 relate to the following main areas:

- *The potential occurrence of events in combination;*
- *Establishing levels of hazard for the design basis for the installation and their associated uncertainties;*
- *Multiple facilities at a single site;*
- *Monitoring of hazards and periodic review of site specific hazards.* (International Atomic Energy Agency, 2016c)

2.1.1.5.1. Fundamental Safety Principles

The *Fundamental Safety Principles* related to the topic of this thesis are "*Principle 5 – Optimization of Protection, Principle 7- Protection of Present and Future Generation, Principle 8- Prevention of Accidents, Principle 9- Emergency Preparedness and Response"*. (EURATOM, FAO, IAEA, ILO, IMO, OECD NEA, PAHO, UNEP, WHO, 2006). These principles provide the basis for the safety requirements to relevant NPPs in the light of natural hazards. The general requirements for the NPPs safety are requirements for safety assessment for facilities and activities, evaluating safety vulnerabilities against site-specific extreme natural hazards, and requirements for preparedness and response for a nuclear emergency. Specific safety requirements related to natural hazards are requirements for site evaluation – including specific requirements for evaluating external events, earthquakes, metrological, hydrological and geotechnical hazards as well as requirements for safety of NPPs related with design, commissioning and operation of the facilities.

2.1.1.5.2. Safety Requirements

Safety assessment requirements evaluate compliance with safety fundamental principles and prepare safety analysis and evaluation of engineering factors. From one hand, the evaluation of the engineering factors is important for the NPPs safety and it makes use of the safety analysis. On another hand, the safety analysis use different types of assessment- probabilistic and deterministic and sometimes incudes statistical to calculate the uncertainty. Also, requirements for safety of NPP design against natural hazards stressing attention on the specific seismic design requirements and on the design of the specific safety systems- emergency power system, reactor coolant system, reactor containment systems and fuel handling and storage systems. Additionally, requirements for safety commissioning and operation evaluate seismic safety for existing NPP, and give guidelines for severe accident management programs. The safety requirements for *"Site Evaluation for Nuclear Installations NS-R-3"* (International Atomic Energy Agency, 2016c), *"Safety Assessment for Facilities and Activities evaluating safety vulnerabilities against site specific extreme natural hazards (GSR- Part 4 (Rev.1)", Safety of NPP Design against natural hazards (SSR-2/1 (rev.1), Safety Commissioning and Operation SSR-2/2 (Rev.1)* are the one directly related to natural hazards. After Fukushima Daiichi accident this requirements were revised and in February 2016 the more detailed criteria for safe site selection and evaluation were published to strengthen the implementation of the requirements. (International Atomic Energy Agency, 2016).

The nuclear safety requirements directly connected to the thesis are discussed in more details in Chapter 3.

2.1.1.5.3. Safety Guides

Hereafter are the Safety Guides related to the above-mentioned requirements:

In connection to requirements for *"Safety Assessment for Facilities and Activities evaluating safety vulnerabilities against site specific extreme natural hazards (GSR- Part 4 (Rev.1)"* the following Specific Safety Guides are issue to facilitate the implementation of the requirements:

- *Probabilistic assessment Level 1 (SSG-3) and Level 2 (SSG-4)*
- *Deterministic assessment (SSG-2)*
- *Safety assessment for decommissioning of facilities (WS-G-5.2)*

For the requirements related to the *Safety of NPP Design against natural hazards (SSR-2/1 (rev.1)* IAEA issued the following Specific Safety Guides:

- *External Events Excluding Earthquakes (NS-G-1.5)*
- *Seismic Design for NPPs (NS-G-1.6)*
- *Design of Emergency Power System (NS-G-1.8)*
- *Design of Reactor Coolant System (NS-G-1.9)*
- *Design of Reactor Containment Systems (NS-G-1.10)*
- *Design of Fuel Handling and Storage Systems (NS-G-1.4)*

The Requirements for *Safety Commissioning and Operation SSR-2/2 (Rev.1)* have Specific Safety Guides as follow:

- *Evaluation of seismic safety for existing NPP (NS-G-2.3)*
- *Severe Accident Management Programs (NS-G-2.15)*
- *Periodic Safety Review for Nuclear Power Plants (SSG-25)*

Finally, the most relevant to the topic of the thesis requirements for *Site Evaluation (NS-R-3 (Rev.1)* have the following Specific Safety Guides:

- *Metrological and hydrological hazards in site evaluation (SSG-18/ NS-G3.5/NS-G-1.5)*
- *Geotechnical Aspects of Site Evaluation (NS-G-3.6)*
- *Site Survey and site selection (SSG-35)*
- *Storage of Spent Nuclear Fuel (SSG-15)*

For the purpose of nuclear safety assurance a regular review according to the above mentioned Safety Standards has to be implemented.

2.1.1.5.4. Other IAEA relevant publications

Additional to the IAEA Safety Standards Series, Safety reports on protection in nuclear activates are regularly issued. Also, other IAEA safety related publications are released from International Nuclear Safety Group (INSAG). Last, but not least Technical Reports on Safety in TECDOCs series play an essential role in ensuring safety. The TECDOC *"Modelling of Water Cooled Fuel Including Design Basis and Severe Accidents"* (International Atomic Energy Agency, Nuclear Fuel Cycle and Materials Section, 2015) presents the outcome of technical meetings for exchange of experience and lessons learned on modelling of water cooled fuel including design basis and severe accidents. The Fukushima accident proved the need of R&D in prediction of severe accidents system behaviour and the TECDOC discuss the possible solutions.

In Chapter 3 the thesis will use as an example the Safety Standards directly related with the natural flood hazards, and in particular requirements for *Site Evaluation (NS-R-3 (Rev.1)* with the Specific Safety Guides for "*Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations" Specific Safety Guide- SSG-18* (International Atomic Energy Agency, World Meteorological Organization, 2011), taking into consideration the specific environment of Danube River Basin at Kozloduy NPP.

In addition to the *IAEA Safety Guide NS-G-3.5* and *IAEA Safety Guide NS-G-3.4*, considering the lessons learned from the recent nuclear accident in Japan and the new tendency in climate change findings, IAEA together with the World Meteorological Organization issued *Safety Guide SSG-18 (2011) Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations*. In addition, the document guides how to frame the natural hazards design bases and proposes protection measures against these hazards. (International Atomic Energy Agency and World Meteorological Organization, 2011)

2.1.2. EU Legislation and strategies

2.1.2.1. Euratom Treaty

EURATOM Treaty was signed in 1957 together with the creation of the EU at that time European Economic Community.

EURATOM treaty draws the framework for nuclear safety in the European Union and creates the basis for the safety standards related to the whole nuclear cycle. (ENSREG, 2016a)

2.1.2.2. Council Euratom Directives

The following Directives were issued by the European Council:

Council Directive 2014/87/Euratom

Council Directive 2013/59/Euratom

Council Directive 2009/71/ Euratom

Council Directive 2003/122/Euratom

Council Directive 97/43/Euratom

Council Directive 96/29/Euratom

Council Directive 90/641/Euratom

Council Directive 89/618/Euratom

The European Council has improved, added and revised several times the directives related to Euratom, in order to improve protection of the people and the environment, to imply high nuclear safety standards and to assure emergency preparedness and response. (COUNCIL OF THE EUROPEAN UNION, 2014)

With Directive 2013/59/Euratom the European Council update and combines the requirements of four of the above mentioned directives. The most important directive for the Basic Safety Standards is the one from 1996 (96/29/Euratom). According to Directive 2013/59/Euratom it will take effect from 6 February 2018. (COUNCIL OF THE EUROPEAN UNION, 2014)

2.1.2.3. Directive 2009/28/EC on Renewable Energy (RED)

On 23 April 2009 the European Parliament and the Council revoked the Directives 2001/77/EC and 2003/30/EC, replaced them with Directive 2009/28/EC and established the new framework for promotion of the use of energy from renewable sources.

According to the RED each member state has a specific target that is in line with the Community goal "20-20-20". Moreover, the directive requires development of national renewable energy action plan, specific cooperation between the Member States, infrastructure and guarantee of electricity origin for heating and cooling products. (European Comission, 2009)

The requirements of the RED are important and valuable toward meeting the need of diminishing the greenhouse gases and raising energy security (European Union Official Journal, 2009). There are different guiding principles on energy production development renewables, but there is nothing related to the nuclear power industry.

2.1.2.4. Directive 2000/60/EC Water Framework Directive

Since 22 December 2000 EU Member States have the obligation to fulfill the EC Water Framework Directive (European Union Official Journal, 2000). The directive aims to coordinate the joint forecast in international river basin districts, to identify and assess the water bodies at risk, to manage artificial and modified water bodies, to develop monitoring programs, to reduce water pollution, to address climate change and finally to integrate EU water policy in the single framework and to coordinate it with other EU strategies.

Taking into consideration the need of wide implementation of WFD in 2000 the ICPDR President questioned the ICPDR Ministers about their readiness to implement the directive. All of them declare their definite will to implement the WFD in their countries. Consequently, in the resolution of the ICPDR 3rd Plenary Session, held on 27-28 of November 2000 in Sofia, was decided "The implementation of the EC Water Framework Directive is considered as being the highest priority for the ICPDR". (ICPDR, 2005).

On 13 December 2004 the Ministers of the ICPDR met in Vienna and underline their goals and objectives related to the WFD in the Danube Declaration:

"(6) agree that in the coming years we aspire to achieve the following goals and objectives, taking into account the sometimes more ambitious commitments already made by other countries at the national or EU level:

i) to implement the EU Water Framework Directive, including the development of a co-ordinated River Basin Management Plan for the Danube Basin by 2009 (see annex for more detailed actions);

ii) to reduce further the risks from floods within the Danube basin through the implementation of the Action Programme for Sustainable Flood Protection (see annex for more detailed actions) and taking full account of the principles set out in the communication from the European Commission on flood-risk management, flood prevention, protection and mitigation;" (ICPDR Ministerial Meeting, 2004)

Furthermore, in 2006 the ICPDR adopted its Rules of Procedure, including in Art.8 the decision-making procedures in urgent cases. (ICPDR, 2006)

2.1.2.5. Directive 2007/60/EC on the assessment and management of flood risks (European Floods Directive, EFD)

The European Flood Directive states *"floods are natural phenomena which cannot be prevented. However, some human activities (such as increasing human* *settlements and economic assets in floodplains and the reduction of the natural water retention by land use) and climate change contribute to an increase in the likelihood and adverse impacts of flood events"* (European Parliament and the Council, 2007)

On 26 November 2007 Directive 2007/60/EC on the assessment and management of flood risks (European Floods Directive, EFD) entered into force. All Member States are required to make full assessment of all waters, to calculate the flood risk and related hazards, to map floods range and to coordinate measures for trans-boundary cooperation including Non-EU Members. (European Union Offcial Journal, 2007)

The EFD shall be coordinated with the WFD, particularly by flood risk management plans and river basin management plans. Additionally, all information related to the assessments, maps and plans of the basins shall be public. (ICPDR, 2011)

In 2008 ICPDR and Joint Research Centre of EC launched the first European Flood Alert System (EFAS) for forecasting incidents. This was the first international system that is able to forecast with up to 10 days floods preliminary informing the authorities.

Development of the project "Danube-EFAS" has been approved from Austria, Bulgaria, Czech Republic, Germany, Hungary, Moldova, Serbia, Slovakia, Slovenia, and Romania. EFAS added value but doesn't replaced existing national flood forecasting system. (Flood Protection Expert Group, ICPDR, 2009)

2.2. International and Regional (European Union) NPP cooperation

2.2.1. International NPP organizations

2.2.1.1. IAEA

The International Atomic Energy Agency has been set up in 1957 for international cooperation in the sphere of use of atomic energy for peaceful purposes and is a part of the United Nation organizations. (IAEA, 2016) Currently the agency has 168 members that meets officially once per year at the General Conference, which is one of the two policy making bodies of the organizations. The other one is the Board of the Governors and both are supported by the Secretariat. Director General, who managed the 6 departments of the agency, heads the Secretariat. The department working in the area of nuclear energy and safety are two:

Nuclear Energy Department responsible for safe lifetime operation of present reactor systems and safe use of the NPP and Nuclear Safety and Security Department including:

- Incident and Emergency Centre
- Nuclear Safety Action Team (created after Fukushima Daiichi accident for implementation of the IAEA Action Plan on Nuclear Safety and coordination)
- Division of Nuclear Installation Safety (responsible for preparation of Safety Standards for the whole life cycle of NPPs and promotion of international nuclear safety instruments)

The Division of Nuclear Installation Safety has 5 Sections. Two of them- International Seismic Safety Centre and Safety Assessment Section, are relevant to the topic of the thesis and during the preparation of the paper the Heads of the Sections - Mr. Samaddar and Mrs. Spitzer gave their professional opinion.

2.2.1.2. OECD- Nuclear Energy Agency (NEA)

The Nuclear Energy Agency is intergovernmental organization under the framework of the Organization for Economic Cooperation and Development (OECD) that facilitate the cooperation between its member states with nuclear facilities through forum for sharing experience and policy. *The Strategic Plan of the Nuclear Energy Agency: 2011-2016* (OECD-NEA, 2010) *assists the members of NEA giving them legal bases for safe, sustainable and economical use of nuclear energy.* The organization provides also assessment and clear definitions on key issues needed to the governments and policy makers. 31 countries are members of the organization, however two of the Danube Basin Region countries operating NPPs are not- Romania and Bulgaria. (OECD, 2016)

The work areas of NEA related to this thesis are:

Nuclear safety and regulation including assistance in preparation and implementing of high nuclear safety standards regulation (OECD, 2014)

Nuclear development – NEA provides decision makers with information on technologies, strategies and economics (OECD, 2015)

2.2.1.3. World Nuclear Association

The World Nuclear Association is the organization of the major players from the nuclear industries: all reactor producers, key nuclear engineering and construction companies, most of the world's nuclear operators. The mission of the association is to present a common industry position, to take part in related debates and to promote nuclear energy. (World Nuclear Association, 2016)

2.2.1.4. World Association of Nuclear Operators (WANO)

The World Association of Nuclear Operators is an organization of all commercial NPPs operators in the world and was created after the accident in Chernobyl NPP. The mission of the association is to assist the operators to accomplish the highest possible standards of nuclear safety. The organization does not advice about the design of the NPP, but has the only goal the operators to achieve nuclear safety and reliability providing them with a forum for exchange of good practices, lessons learned from accidents and cooperation. (WANO, 2015)

2.2.2. Regional/EU institutions for cooperation

2.2.2.1. Directorate-General for Energy

Directorate-General for Energy is responsible for developing and implementing a European energy policy under the political guidance of the European Commission Vice-President for Energy Union and Climate Action and Energy Commissioner. (European Commision, 2016)

Under the management of Deputy Director-General is DIRECTORATE D – the directorate responsible for Nuclear energy and safety, as well as coordination with EURATOM and international relations. (European Commission, 2016)

2.2.2.2. ENSREG

European Council has created European Nuclear Safety Regulators Group in 2007. Its object is to promote and improving nuclear safety, radioactive waste and spent fuel management by assisting the Member State and developing safety standards. The members of the ENSREG are mainly experts from the regulatory bodies of the national states. The group advises the EC, European Parliament and the European Council in regards to nuclear safety. The main aim of the group is to assure compliance with the national, European and international nuclear safety standards. (ENSREG, 2016)

ENSREG has different working groups two of which are direct related to nuclear safety and international cooperation.

Working Group 1 on Nuclear Safety (WGNS) was created to increase nuclear safety by improving national nuclear safety regulations in the Member States.

Workshops, Technical meetings and different forums are arranged for exchange of good practices, lessons learned and facilitation of the application of the European legislation. Guidelines for nuclear safety are disseminated among the Member State aiming good understanding of the European targets. Group 1 use the Convention on Nuclear Safety for improving the EU nuclear safety. (ENSREG, 2016)

Working Group 4 (WGIC) was created to facilitate the Nuclear Safety International Cooperation using the Instrument of Nuclear Safety Cooperation. The Instrument has a budget for the period 2014-2020 of € 225 million and partners with 20 non-EU countries. (ENSREG, 2016b). WGIC gives to the EU strategic advice related to the nuclear safety in international activities.

2.2.2.3. Foratom

Foratom is a non-governmental organization that represents the nuclear power industry. It unites 16 European non-governmental nuclear organizations representing the voice of the European nuclear industry. However, there is no Czech organization among the members. Foratom discusses the European energy policy with the EU and the other relevant stakeholders and mediate between the policy makers and industry. (Foratom, 2016)

2.2.2.4. WENRA

In 1999 was created the Western European Nuclear Regulators Association (WENRA) for two reasons:

- The nuclear safety became on of the criteria for enlargement of the EU
- National Nuclear Safety frameworks were developed on the basis of IAEA

Safety standards and the Convention on Nuclear Safety had to be promoted, but separately.

Therefore, WENRA had to develop a common approach for a nuclear safety and to become a body for expertise and inspection of the candidate countries.
(Westrn Union Nuclera Regulators Association, 2016)

2.3. Direct Local/ Danube River Basin cooperation

The institutional framework for hydrological and environmental cooperation in Danube River has a long-term history and was established for the first time in 80s under the Bucharest Declaration. But, the issue about nuclear safety was not included in the cooperation.

Also, the multilateral cooperation for water quality and protection policy has been limited for long period due to political barriers. After the political transformations in 1989 it was achievable to improve the international protection and to develop a common strategy in the Danube River Basin. On the basis of the UN/ECE Convention on the Protection and the Use of Trans-boundary Waters (Helsinki Convention) and outstanding need to ensure sustainable use and management of the waters of the Danube River Basin convinced all 14 countries with more than 2000 km2 of the Danube River Basin, and the European Union, to become a contracting parties of the *"Cooperation for the Protection and Sustainable Use of the River Danube"* (Danube River Protection Convention- DRPC). Additionally, Danube River Basin counties have bilateral cooperation agreements for flood protection related activities in the Danube River Basin.

After the catastrophic flooding in 2002 and 2005 ICPRD member countries learned their lesson -*"Greater international efforts are needed for the long-term,"* (Weller, 2006) as says Philip Weller, the ICPDR's Executive Secretary.

2.3.1. "Convention on the Cooperation for the Protection and Sustainable Use of the Danube River" (Danube River Protection Convention – DRPC) in 1994 in Sofia and International

The DRPC was signed from 9 countries and the European Community on 29 June 1994 in Sofia, Bulgaria and came into force in October 1998 after the ratification of the ninth instrument. The DRPC formulates the general legal act for cooperation and aims to ensure sustainable and equitable trans-boundary water management. As a result the parties to the convention have contracted to collaborate on crucial water management issues by taking "all appropriate legal, administrative and technical measures to at least maintain and where possible improve the current water quality and environmental conditions of the Danube river and of the waters in its catchment area, and to prevent and reduce as far as possible adverse impacts and changes occurring or likely to be caused." (Danube River Protection Convention, 1994)

Due to the increasing concern of the trans-boundary hydropower facilities environmental impact and the growing need of flooding precautionary prevention, involving rational use of waters and preventive measures to control hazards, the DRPC planned activities and ongoing measures describes in its scope in Article 3 (2) of the convention:

"…(b) planned activities and measures in the field of water construction works, in particular regulation as well as run-off and storage level control of water courses, flood control and ice-hazards abatement, as well as the effect of facilities situated in or aside the watercourse on its hydraulic regime;

(c) other planned activities and measures for the purposes of water use, such as water power utilization, water transfer and withdrawal;

(d) the operation of the existing hydro-technical constructions e. g. reservoirs, water power plants: measures to prevent environmental impact including: deterioration in the hydrological conditions, erosion, abrasion, inundation and sediment flow; measures to protect the ecosystems;

(e) the handling of substances hazardous to water and the precautionary prevention of accidents…." (Danube River Protection Convention, 1994)

2.3.2. International Commission for the Protection of the Danube River (ICPDR)

The DRPC established an International Commission for the Protection of the Danube River (ICPDR) that undertakes the implementation of the objectives and provisions of the Convention. It consists of 15 contracting parties- Austria, Bosnia and Herzegovina, Bulgaria, Croatia, the Czech Republic, Germany, Hungary, Moldova, Montenegro, Romania, Serbia, Slovakia, Slovenia, Ukraine and the European Union. The International Commission is the cooperation framework of the contracting parties and it elaborates proposals and recommendations for the fulfilling of the obligations of the contracting parties. The ICPRD facilitate the coordination and cooperation on important water management issues and facilitate the implementation of the EU Directives related to Danube River Basin. Although not all contracting parties are members of the European Union they agreed to meet the goals of the Water Framework Directive of the EU by 2015. (ICPDR, 2011)

In the frame of the DRPC the contracting parties commit to implement some specific actions and to observe certain rules. However, in case of dispute ICPDR contribute to the peaceful settlement of the dispute by providing venue for discussion. Moreover, the President of ICPDR or the secretariat can encourage dialogue on specific questions and support fruitful agreement. DRPC specifies a dispute settlement mechanism, but actually it has never been used, as the countries disagreements have been solved during the induced talks.

The ICPDR involves mainly contracting countries delegates and they meet twice a year. Moreover Expert Groups, team of specialist from ICPDR national delegations, and 21 official observers support the work of ICPDR. Eventually ICPDR evaluates the results from Expert Groups, follow up activities and approves of annual work program and budget.

Permanent Secretariat (PS) supports the ICPDR sessions, Expert Groups and Programme Management Task Force. Additionally PS coordinate work program, project development and implementation and maintenance of Information system. Organization of the ICPDR, the competences and the procedures are detailed specified in Annex IV of the DRPC, acting as statutes of the commission.

2.3.3. ICPDR Action Programme for Sustainable Flood Protection (APSFP)

In response to the destructive flooding that happened frequently after 1995 in Danube Basin, ICPDR proposed a long-term Action Programme for Sustainable Flood Protection (APSFP) that has been adopted on Ministerial Meeting in 2004. (ICPDR, 2006)

The aim of the APSFP is to protect citizen, infrastructure and property through sustainable management of the flooding by prevention measures and in the same time to preserve water related ecosystems.

APSFP main target is to improve flood forecasting and early flood warning systems by connection between national and regional Systems; Additionally, it gives opportunities for expert know how exchange and helps with guidelines for a joint approach in evaluation of flood-prone regions and assessment of flood hazard. Finally, the programme supports the development and harmonization of the flood action plans on sub-basin level. For regional level APSFP recommends capacity building, raise the level of readiness of the responsible organizations, preparation of flood risk maps and international harmonization of the procedures in case of a flood event. (ICPDR, 2006)

APSFP is a general framework that is detailed in sub-basins plans. In 2009 were published 17 sub-basin flood action plans that were based on 45 national planning documents (ICPDR, 2012) The APSFP is in consistent with the EU Water Framework Directive that helps to merge the parallel planning process. Moreover, the Action Programme includes the necessary information for the financial and structural mechanisms for its realization. (ICPDR, 2004)

2.3.4. ICPDR Danube River Basin Management Plan (DRBMP) and its Joint Program of Measures

On one hand EU Water Framework Directive 2000/60/EC (WFD) aims to protect and enhance all water bodies to the level of good status (ecological, chemical and quantitative by 2015. Focusing on entire river basins, it requires the coordination of all aspects of water management via a River Basin Management Plan (reviewed every six years) with a Programme of Measures, consisting of policies, strategies and actions to allow all water bodies to achieve and maintain good status. (European Union Official Journal, 2000)

On another hand the Danube River Basin Management Plan covered period 2009-2015 has been elaborated to guide achievement of “good status” (requirement of the WFD) for all Danube Basin waters according to the Danube Declaration from 2004 (ICPDR Ministerial Meeting, 2004). The DRBMP has been updated in December 2015.

Accordingly, all Danube Basin countries (involving non-EU states) prepared their national management plans. The members of the ICPDR had to work in close international cooperation, as the plans had to cover every river basin.

In this regard ICPDR has been used as platform for debates and agreement on the trans-boundary management of the Danube River waters and coordinator between EU and non-EU countries in regards of follow up measures. Together, the parties of the ICPDR have established the Danube River Basin Management Plan including actions up to 2021.

2.3.5. Single international Flood Risk Management Plan/Set of flood risk management plans

In 2010 Danube Ministers reconfirmed in the adopted Danube Declaration that “flood prevention and protection are not short term tasks but permanent tasks of highest priority”. (Ministerial Meeting, ICPDR, 2010). The Member countries affirm their readiness to apply the EU Floods Directive throughout the whole Danube River Basin (including non-EU member states). They agree up to 2015 to be prepared one Single International Flood Risk Management Plan /Set of Flood Risk Management Plans, taking into consideration the ICPDR Action Programme for Sustainable Flood Protection and the sub-basin plans, coordinated at the level of the international river basin district by 2015 making full use of the existing synergies with the Danube River Basin Management Plan. The data was collected until November 2015 and in December 2015 the Flood Protection Management Plan was issued by the ICPDR.

2.3.6. EU strategy for the Danube region

There is a reasonable link between the European Strategy for the Danube Region (EUSDR) and the ICPDR tasks identified in Danube Region. (ICPDR 2013)

The EUSDR includes an Action Plan reflecting the Danube Region Strategy and focuses on 11 priority areas. The following areas are related to energy and quality of waters:

Priority Area 2 "To Encourage More Sustainable Energy"

For this priority the action plan order high level of nuclear safety and underline the importance specially while using the river water for ultimate heat sink. (EUROPEAN COMMISSION 2010)

Priority Area 4 "to restore and maintain the quality of waters"

Under this priority is mainly observed the pollution of water from industry-operational or accidental hazardous pollution. Also, it is considered the alternation of the river basin that changes the river hydro-morphology. (EUROPEAN COMMISSION 2010)

Priority Area 5 "to manage environmental risks"

This priority action refers to the ICPDR and the Danube River basin Management Plans as well as to the Danube Declaration 2010. (Ministerial Meeting, ICPDR 2010) The ICPDR Secretariat is in close cooperation with the Coordinators of the activities under the EUSDR. (EUROPEAN COMMISSION 2010)

<u>Main Findings:</u>

- IAEA Safety Standards are not included officially in the Nuclear Safety Convention as most of the countries do not want to legally bind voluntary guides of IAEA.
- Responsibility for nuclear safety rests with the State having jurisdiction over a nuclear installation.
- The Nuclear safety Convention is the only legally binding document that discussed promotion of an effective nuclear safety culture including human and organizational factors, safety culture and leadership for safety, however this part

of the nuclear safety become more and more important part of the nuclear safety management.

- The history of the legal instruments (Table 7.1) shows that after severe nuclear accidents new conventions, standards, and agreements were adopted or were revised.
  Notably, after the severe nuclear accident in Chernobil NPP accident:
  - Convention on Early Notification of a Nuclear Accident and Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency have been opened for signature in 1986 and in the same year entered into force.
  - Vienna Convention on Civil Liability for Nuclear Damage- in 1988
  - World Association of Nuclear Operators was created

  And after Fukushima:
  - IAEA Safety Standards used as international reference for the implementation of high level of Nuclear Safety. Five of the safety requirements were review and were under amendment procedure after the Fukushima Daiichi accident. The revisions were related to regulatory structure, emergency preparedness and response, site selection and evaluation, assessment of extreme natural hazards and their combined effects, management of severe accidents, station blackout and loss of heat sink. All revision were essential but the most relevant to the thesis are:
    - ✓ Margins for withstanding external events;
    - ✓ Margins for avoiding cliff edge effects;
    - ✓ Safety assessment for multiple facilities or activities at a single site;
    - ✓ Safety assessment in cases where resources at a facility are shared;
    - ✓ Human factors in accident conditions
    - ✓ Prevention of severe accident by strengthening the design basis for the plant;
    - ✓ Emergency preparedness;
    - ✓ The potential occurrence of events in combination;
    - ✓ Establishing levels of hazard for the design basis for the installation and their associated uncertainties;

- ✓ Multiple facilities at a single site;

  - The European Council also has improved, added and revised several times the directives related to Euratom, in order to improve protection of the people and the environment, to imply high nuclear safety standards and to assure emergency preparedness and response.
  - The Fukushima accident proved the need of R&D in prediction of severe accidents system behaviour and the IAEA TECDOC discuss the possible solutions.
- Moreover, after severe flood events and increase of flood frequency in the last 15 years new conventions, EU directives and action plans were issued.
  - Convention on the Cooperation for the Protection and Sustainable Use of the Danube River" (Danube River Protection Convention – DRPC) entered into force in 1998
  - Water Framework Directive issued in 2000
  - ICPDR Action Programme for Sustainable Flood Protection issued in 2004 and updated in 2009
  - European Floods Directive issued in 2007
  - Renewable Energy Directive issued in 2009
  - EU strategy for the Danube region in 2013
  - ICPDR Danube River Basin Management Plan and its Joint Program of Measures 2009-2015 (also updated in 2015)
  - 1st Flood Risk Management Plan issued in 2015
- Another fact from the newly issued documents related to sustainable energy production, notably in RED, is that there are different guiding principles on sustainable energy production, but there is no word for nuclear power industry, although is could be taken as a renewable energy as well.

Reviewing the different cooperation organizations (table 7.2) shows that not all NPPs countries participate in all organizations:

In NEA two of the Danube Basin Region countries operating NPPs are not members- Romania and Bulgaria. Also in Foratom there is no Czech organization among the members.

Furthermore, the institutional framework for hydrological and environmental cooperation in Danube River has a long-term history and was established for the first time in 80s under the Bucharest Declaration, but the issue about nuclear safety was not included in the cooperation.

There are many separate legal instruments for NPP safety and flood protection that adequately answer the needs for the nuclear safety and flood management, all of them ratified/approved from the NPPs countries, nevertheless only few are combined and specific to the contemporary needs of protection against natural flood hazards for the nuclear facilities in the region of the second largest river in Europe and are not legally binding.

3. The safety of NPP in Danube River Basin Region against natural flood hazards- Example study

The consequences of flooding a NPP site may danger the safety systems. Flooding in many zones of the NPP may trigger a "*common cause failure (CCF)*" for safety of the plant, such as the "*emergency power supply systems or the electric switchyard, with the associated possibility of losing the external connection to the electrical power grid, the decay heat removal system and other vital systems.*" (IAEA International Seismic Safety Centre, 2014). For this reason the thesis stop attention of the NPPs site selection and evaluation and will use the Bulgarian Kozloduy NPP as an example

Although engineered countermeasures have been built, in the past, some buildings and back-up equipment have been sited too low, so that they are vulnerable to flood.

Such examples exist in the world history of NPPs:

- In mid-July 1993, near Brownville, Nebraska the Cooper NPP, built on a 100-year flood plain, was flooded from the waters of the Missouri River and was forced to shutdown the reactor. (Gunter 2004)
- In 1994 the Kakrapar NPP near the west coast of India was flooded due to heavy rains together with failure of dam control for an adjoining water pond, swamping basement equipment. The back-up diesel generators on site enabled core cooling since the offsite power supply failed. (World Nucear Assosiation 2015 b)
- In June 2011, unusually high water on the Missouri River, caused by a combination of heavy spring rains and Rocky Mountain snowmelt, inundated the Fort Calhoun plant in Nebraska. (Wikipedia Foundation 2015)

In December 2011 The NRC issued a report *"Design-basis flood estimation for site characterization at nuclear power plants in the United States of America"* (Prasad , et al. 2011) with a safety analysis of SSCs significant for the NPP safety in case of NPP's site flooding. The report highlights the benefits of the *"Probabilistic Flood Assessment Method"* (Prasad , et al. 2011) showing the benefit of going beyond the selected design basis. Hence, this methodology helps for the further decision-making process giving advantage through a risk-informed approach. However, the document recommends that, although, there are some segments of Probabilistic Flood Hazard Assessment established in the last years, there is a necessity of complete methodology for this natural hazard. The report uses flood-simulation models according to the conditions of the specific site. It also debates the climate change and the prognostications of the design-basis flood hazards of the NPP that could be expose at risk. Recognizing the need of profound research of the studies of Intergovernmental Panel on Climate Change fourth assessment report of 2007 and the lack of any complete findings, this report concludes that the design-basis flood hazard must be observed in additional "*sensitivity studies*". (Prasad , et al. 2011).

3.1. Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations - IAEA Safety Standards Series No. SSG-18 review

Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations - IAEA Safety Standards Series No. SSG-18 (SSG-18) (International Atomic Energy Agency, World Meteorological Organization 2011) gives guidance for a site-specific review of the potential risk of flooding of a site due to diverse initiating events and scenarios and relevant potential combinations. The flooding hazards relevant for the NPP sites situated along the Danube River comprise of two main categories:

- Floods due to meteorological and hydrological causes;
- Floods due to the sudden release of impounded water by human made structures;

Considerations were made on all of the listed in SSG-18 hazards of flooding and the irrelevant were excluded:

On the matter of including Storm Surges in this study, it is considered that the water surface of the Danube River is not large enough to feed a storm surge representing a credible hazard for the plants. (National Commission for Nuclear Activities Control 2011)

It is considered very unlikely that Tsunamis generated in the Black See could induce flooding at the Cernavoda NPP site (National Commission for Nuclear Activities Control 2011), (ENSREG 2012) and the rest of the NPP sites are situated further up the Danube River.

Seiche is a phenomenon, which has never been observed at any of the sites of the NPPs, it is mostly connected with enclosed or partially enclosed bodies of water, which is not the case of the Danube River.

All the locations of the NPP sites along the Danube River are situated far enough up the stream in order to exclude tidal bores as a hazard-generating event. At present none of the NPP sites is situated alongside headrace or a reservoir of any hydroelectric power plant downstream of the NPP. This fact eliminates the possibility of formation of a mechanically induced bore from sudden stop of the inflow into the powerhouse.

3.1.1. Floods due to meteorological and hydrological causes

As stated in SSG-18 flood hazards due to natural causes relevant for a land locked NPP site situated on a river are the following:

- Wind generation of waves;
- Extreme precipitation events;
- High groundwater levels;
- Formation of ice coverage and damming effect of the ice;
- Blocking of water intakes due to ice and debris;
- Meandering of the river bed;
- Landslides into water bodies

(International Atomic Energy Agency, World Meteorological Organization 2011)

For the determination of design basis flood (DBF) each from the listed above events and a combination of them are considered during the example study of Kozloduy NPP.

3.1.2. Floods due to the sudden release of impounded water by human made structures

The sudden release of impounded water may cause flood that exceeds the natural flood due to hydrological causes. In the middle and lower course of the Danube River there are several dams with large reservoirs. In the same part of the river course are situated all of the observed NPP sites.

According to SSG-18 among others the following aspects should be considered for the hazard assessment of floods due to the sudden release of impounded water:

- Conservative assumption of failure or faulty operation of existing or planned upstream dams on the river or its tributaries;
- Investigation of the possibility of failure of more than one dam caused by the same event;
- Failure of protective dykes evaluated with a conservative water level behind the structure and the duration of this level;
- The water volume stored in the reservoir at the time of failure should be considered to be the maximum possible;

For the determination of the DBF the sudden release of impounded water as well as combination with appropriate events due to meteorological causes are taken into account while studying the Kozloduy NPP.

3.1.3. Recommended methods for flood hazard assessment

The recommended in SSG-18 methods for hazard assessment are:

- Deterministic methods
- Probabilistic methods

Where possible a combination of both methods for hazard assessment is used.

3.2. Kozloduy NPP example

The author visit the KNPP on 12.04.2015 for the aim of good understanding of the technical questions related to the site selection and evaluation, as well as emergency preparedness of the NPP in case of flooding in the region and hazards for the SSC.

The site for the Kozloduy NPP is chosen on a non-floodable terrace in the Danube Plane and has average height of +35.00 m. (Nuclear Regulatory Agency 2011) The seismicity of the region is one of the lowest in the Bulgarian territory and the water of the Danube River was chosen for ultimate heat sink. The project studies began in 1965 and the construction started in 1970, commercial operation started in 1974. The site is located 176 km downstream of the Iron Gate II reservoir, which is the reason for the flood hazard due to the sudden release of impounded water to be the most severe flooding scenario for the site.

3.2.1. Meteorological and hydrological causes

The KNPP site is located 4 km south of the Danube River midstream; the water body that reaches the site is the reserve supply water volume. It does not have sufficient area for generating wind waves, which could endanger the structures and the site stability of the NPP.

Wind generated waves that could reach the NPP site are considered in the estimation of the DBF, they could occur in case of break of the Danube state dyke and flooding of the valley between the dyke and the NPP site. It is calculated that the wind-generated waves in this case would be with height of 0,60 m. (Nuclear Regulatory Agency, Bulgaria 2011)

Extreme precipitation in the Danube River catchment area, upstream the KNPP site is taken into account in the determination of the DBF for the site. Due to the large wave that can be formed by the sudden release of impounded water, the flood solely due to extreme precipitation does not increase the DBF level.

Extreme precipitation in the plane of the KNPP site could lead to increase in the groundwater level, but there is no danger of flooding the site.

Nevertheless, ICPDR Report *"Floods in June 2013 in the Danube River Basin"* (Liska and Major , Floods in June 2013 in the Danube River Basin 2014) reports that extreme floods that happen in June 2013 among the upper and lower Danube affected almost all countries among the Danube River. Notably, in Bulgaria the situation was so risky that, after *"analysis of the meteorological situation and hydrological information including prognosis about the water quantity and water-level of Danube, internal rivers and dams ... Due to the complicated situation in June 2013, alert messages about an increased flood danger have been sent by MoEW (the responsible authority- Ministry of Environment and Water) to the Fire Safety and Civil Protection, Irrigation systems, Kozloduy nuclear power plant and River Basin Directorates."*. (Liska and Major , Floods in June 2013 in the Danube River Basin 2014) Luckily, the situation didn't escalate, but the danger for the NPP infrastructure was announced.

Due to the existence of high groundwater levels in the plane north of the Kozloduy NPP, between the site and the Danube State Dyke drainage system has been developed. The water level in the canals of that system is constantly kept at +23,00 mBSL and thus helps keeping low the groundwater levels in the site and in the dams of the cold and warm supply water canals. For the constant monitoring of the ground water levels on the site and around the hydro-technical structures, series of piezometer wells were constructed and are inspected with varying frequency.

Rains and storms could cause erosion of the air slopes of the dykes of the cold and warm supply water canals. Such erosion could occur also in the case of break in the Danube State Dyke and flooding of the plane between the river and the site.

Ice drifts in the Bulgarian part of the Danube River have been rarely observed only until 1963 occurring at flow rate up to 11 910 m3/s. The construction Iron Gate I in 1974 has significantly decreased the possibility of freezing of the river. (Nuclear Regulatory Agency, Bulgaria 2011) If there would be a formation of ice dams at such flow rate, the resulting increase in the water level would be within the normal fluctuation of the river level and would not lead to flood hazard for the KNPP site.

The water intake for the KNPP from the Danube River is through the bank pumping station. The formation and floating of ice and the possibility of blocking the intakes is very low, due to the possibility of discharging water from the warm supply water canal in front of the intakes. For prevention of blocking the intakes from floating debris a special construction exists in the mouth of the suction bay.

The water intakes for the units of the NPP are located at the Reserve supply water volume. Discharging of warm water prevents the formation of ice coverage in it. The water in that volume and the cold supply water canal has passed through the bank pump station and thus carries no debris.

There is no possibility of natural meandering and change in the river channel used by the bank pumping station for the KNPP, due to the Danube State Dyke and the cultivated forest on the Kozloduy river island.

The hazard of landslide into water body is credible hazard for the reservoirs of Iron Gate I and II and would lead to the formation of a flood wave. This scenario is covered in the conservative assumption for the sudden release of impounded water due to failure of the dams.

3.2.2. Sudden release of impounded water

For the KNPP site the hazard of sudden release of impounded water exists due to the possible failure of the reservoirs Iron Gate I and II containing respectively 1 380 and 700 million cubic meters of water.

For the purpose of flood hazard assessment a conservative assumption is made for sudden release of the water impounded in both reservoirs, including failure of both dams due to beyond the design basis earthquake and overlaying of the formed waves with a river discharge of 10 000 m^3/s. Following the stated scenario and observing the current state of the hydro technical structures on the Danube River, the maximum water level at the KNPP site is expected to reach +32,93 mBSL for period of 2 hours. (Nuclear Regulatory Agency, Bulgaria 2011) This level reflects all influencing factors and coinciding of low probability events and is increased by 0,30 m to account for the effect of wind-generated waves.

The Danube State Dyke protects the plane between the KNPP site and the Danube River with crown elevation between +31,80 and +33,00 mBSL. The scenario used for the determination of the DBF for the site is based on the conservative assumption that the dyke will be overtopped or will have a failure leading to flooding of the plane. There is no possibility of any damage to the site, due to the site elevation of +35,00 mBSL. The reservoir of Shishmanov Val Dam is situated higher than the site of the KNPP and has volume of 8,1 million cubic meters. A conservative scenario including flood induced by the sudden release of impounded water due to a total failure of the dam has been studied. The maximal water elevation in proximity to the site, derived from that scenario is +29,00 mBSL which is 6 m lower that the elevation of the KNPP site.

The combination of catastrophic wave due to the sudden release of impounded in the Iron Gate I and II water and formation of ice dam in the river is highly unlikely, mainly because of the water quantity of the catastrophic wave - over 20 000 m^3/s and the duration of that water level. Ice coverage usually forms at low and medium water levels.

Extreme precipitation with probability of p=0.01% and catastrophic wave due to the sudden release of impounded water are independent events and the simultaneous occurrence of both would be with negligible probability. Therefor for the determination of the DBF in combination with the catastrophic wave induced due to the destruction of Iron Gate I and II, precipitation with probability of p=1% is taken into account, leading to increase of the DBF with 0,1 m. (Nuclear Regulatory Agency, Bulgaria 2011)

3.2.3. Methods for flood hazard assessment

For the determination of the peak water level and the peak flow in the Danube River at the Kozloduy NPP site probabilistic method based on time series recorded since the 1940-s was used. For accounting the effect of the sudden release of the water impounded in the reservoirs Iron Gate I and II and for the assumption of break of the Danube State Dyke, deterministic method was utilized.

The statistical data for the conduction of the stress test including the flow rate and the water level of the Danube River at the site of the Kozloduy NPP has been collected for over 70 years. (Nuclear Regulatory Agency, Bulgaria 2011)

However, this is not enough taking into consideration the flood records reported in the last 10 years referring often to return period >100 years. Also, after the stress test done in 2011, additional 2 mobile DG was purchased and other improvements in the emergency center were done. Although, the stress test was important after the dynamic changes in the climate in the last years and respectively in the natural disaster hazards, the difference between earlier scenario and last scenario has to be analyzed in the further.

3.3. EU Stress Test and peer review process in 2011-2012

In March 2011 ENSREG requested Western European Nuclear Regulators Association (WENRA) to provide know-how for the scope and methodology of a comprehensive and transparent risk and safety assessment ("stress tests") of all EU-27 NPPs. (European Council 2011)

In May 2011 the WENRA submitted the final version of common methodology to ENSREG, included two tracks: Safety and Security.

The Safety track review how the facilities withstand different events and were split in tree phases: self-assessment, national review of the self-assessment and peer review of the national report.

During the European NPPs “stress test”, the Bulgarian NPP Kozloduy reported that the Bulgarian national standards, norms and regulations for licensing are in

compliance with the international requirements for the events within the scope of the stress tests taking the IAEA Safety Standards as a reference. (ENSREG, 2012)
The "Peer review country report; Stress tests performed on European nuclear power plant" (ENSREG, 2012) of European Nuclear Safety Regulators Group says that the Bulgarian safety regulations are in compliance with the international standards, however, the NPP has to prove details for their implementation. The report highlights the fact, that "the result from the probabilistic safety assessment (PSA) does not include external flooding or extreme weather." (ENSREG, 2012). It is noted that the plant design and safety requirements are in compliance with the WENRA RLs. However, at the time of peer review the RLs Issue-T- Natural Hazards were not elaborated and were not taken into consideration. Further, the thesis focuses on the stress tests, implemented in the EU-27 after Fukushima Daiichi accident, and precisely review the stress test and peer review process of NPP Kozloduy as an example.

In 2013 the EC issued a technical summary after the review of the European "stress tests". The report is divided in tree main parts:

- *"extreme natural events (earthquake, flooding, extreme weather conditions)*
- *response of the plants to prolonged loss of electric power and/or loss of the ultimate heat sink (irrespective of the initiating cause)*
- *severe accident management.* (European Commission 2013)

The following recommendations were made for Bulgarian KNPP:

"− *Adequacy of paleoseismological studies should be further analyzed throughout the periodic updates of the seismic PSA and in the PSR, on the basis of the information available and verified, to evaluate the need of re-assessment of the seismic hazard on site.*

− *Implementation of the complementary improvement measures for beyond design basis conditions identified in the Action Plan (such as improvement of the leak tightness of certain rooms below ground level) should be monitored.*

− *A combination of extreme weather conditions still needs to be considered.*

− *Although the batteries have 10 hours discharge time, a possibility of their recharging from a mobile DG should be considered.*

− *Concerning SAM, there is still an open issue under which conditions is the implementation of different SAM measures feasible, e.g. due to possible lacking* *some hardware provisions for mitigation of severe accidents. It is recommended that additional improvements for SAM covered by the "Program for Implementation of Recommendations Following the Stress Tests Carried out on Nuclear Facilities at Kozloduy NPP plc." is pursued. "* (European Commission 2013)

Under good practices it is reported, that during the peer review it was mentioned that regulate checks are performed. Also important notice in the report is the improvement of the safety equipment and mainly the 2 new mobile Diesel generators were expected to be delivered as well as the existing one will be maintain.

During the visit of the KNPP the author saw the new Emergency Management Centre, outside the Kozloduy site as well as on-site the two new mobile Diesel generators that also was mentioned in the 2013 Stress Tests Summary report (European Commission 2013)

However, the limitation of the stress test is broadly discussed. During the examination was not taken into consideration the ageing of the facilities and the safety culture of the staff. According to the Green Peace Report *"the design basis of the plants concerning natural events are not consistent, therefore engineering judgment can only assess the safety margins. For extreme weather events the design basis and the robustness evaluation were done only superficial."* (Wenisch and Becker 2012)
The new IEA Safety Guide for Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations - IAEA Safety Standards Series No. SSG-18 should be taken into consideration during the safety assessments. There was no simulation of severe nuclear accident, except in Slovenia, and thus it is not recognizable if the facility would withstand, or if the safety culture of the staff is on the level to manage the situation.

Main Findings:

The example application of IAEA Safety Standards Series No. SSG-18 for KNPP concludes that:

- Due to the large wave that can be formed by the sudden release of impounded water, the flood solely due to extreme precipitation does not increase the DBF level.
- Extreme precipitation in the plane of the KNPP site could lead to increase in the groundwater level, but there is no danger of flooding the site.

- A formation of ice dams will not lead to flood hazard for the KNPP site.

Stress test and pear review of KNPP report and recommend:

- Bulgarian safety regulations are in compliance with the international standards, however, the NPP has to prove details for their implementation.
- The result from the probabilistic safety assessment (PSA) of the stress tests of KNPP does not include external flooding or extreme weather.
- The data for the stress tests was collected for over 70 years. However, this is not enough taking into consideration the flood records reported in the last 10 years referring often to return period >100 years.
- The recommendations for supply of new safety equipment and preparedness activities after the stress test of KNPP were taken into account and100% implemented.
- The difference between earlier scenario and last scenario has to be analyzed in the future.

4. Recommendations and Conclusions

4.1. Recommendations

Having in mind the historic records in the last 10 years that change the methodology for assessment and the design flood level, combined with the inexperience in the prolong of the lifetime of the old nuclear power plants, it is necessary more detail analysis of the risk from natural flood hazards to be conducted.

More detailed, precise and unified information for the flood event should be provided from the responsible national authorities to the international bodies such as ICPDR and IAEA in order to assess the last years flood events and to prepare comprehensive methodology for analysis of the safety of NPPs in the Danube Region.

The resent results for climate change has to be included in the prognostications of the design-basis flood hazards of the NPP that could be expose at risk.

Regular review and if necessary amendment of the Safety Standards – so safety standards improvement will assure free of accidents future of the NPPs, but only if the implementation of the safety standards from the responsible authority must be strictly followed. Also, for the purpose of nuclear safety assurance a regular review of the NPPs according to the IAEA Safety Standards has to be implemented.

Synchronized action at the level of the whole Danube basin would bring a considerable added value and improve the overall level of flood protection.

An Official agreements or at least working, technical or even preliminary documents for cooperation between ICPDR, IAEA and ENSREG has to be elaborated.

In this regard, the ICPDR Action Programme for Sustainable Flood Protection was prepared and is fully in consistent with the EU Water Framework Directive but it must include safety measures for flood protection of NPPs taking into consideration the international nuclear safety standards.

The cooperation between EU, IAEA, ICPDR, WMO and other relevant international organizations and stakeholders are crucial for the nuclear safety in the Danube region. There are common guiding principles on sustainable hydropower development in the

Danube Basin, which balance between all legislative documents, but there is no corresponding for nuclear energy development. Such must be elaborated.

On national level, additionally to the sustainable nuclear documents, further joint cross-border actions and coordination activities are needed for early flood prevention and exchange of information between river basin, hydropower and nuclear sectors and relevant management authorities- Basin Directorates, Nuclear operators, Metrological organizations, Civil and Rescue Services.

A simulation of severe nuclear accident must be organized in every NPP's country in the Danube River Region.

Finally, a new flood-simulation models using GIS spatial analysis for the mentioned regions of NPPs have to be prepared to conduct the vulnerability of the facilities that could cause severe accident.

4.2. Conclusions

From the overview of the Danube River Basin Region it is seen that the future development of the nuclear power in the region is promising. The growing needs for energy and energy security booster the plans for new reactors and sooner or later they will be implemented. Also, the operational life of many of the old units build in early 80's and 90's has been or is planed to be expanded up to 40-60 years. Even Germany, with its absolute anti-nuclear policy, could reconsider the NPP plans, triggered from the energy demand and insufficient renewable energy production.

The main areas of amendment of the Safety Standards used as a international reference for nuclear safety framework are related with the weak points of the Fukushima Daiichi accident, thus supports the theory of the thesis that not only safety standards improvement will assure free of accidents future of the NPPs, but an implementation of the safety standards from the responsible authority must be strictly followed. However, the IAEA Safety Standards are not obligatory which raise the question about the fulfillment of the safety engagement of the government, regulatory body and operator.

Flood management is the most difficult issue for management as the floods are natural phenomena that could not been absolutely foreseen. Many EU Member States are already taking flood protection measures but intensive and synchronized action at the level of the whole Danube basin would bring a considerable added value and improve the overall level of flood protection. Although, ICPDR is the legal body to implement the cooperation and coordination of the actions, it is not an implementing body, but only a coordinating body. The small number of the staff of the Permanent Secretariat of the ICPDR cannot respond in case of disaster or emergencies. Instead, the ICPDR harmonized the management plans among the ICPDR contracting parties and in the ICPDR expert groups, but eventually the national authorities remain responsible for adequate reactions in case of crises.

There are no official agreements, nor any working, technical or even preliminary documents for cooperation between ICPDR, IAEA and ENSREG. The only official agreement is between ICPDR and the European Union for the implementation of the EU Water Framework Directive2000/60/EC (WFD) in the entire Danube basin and joint paper for cooperation between ICPDR and EUSDR for complimentary and joint activities of ICPDR and PA4/PA5.

Additionally, Sustainable hydropower construction was taken into consideration after ICPDR prepared an Assessment Report on Hydropower Generation in the Danube Basin in the context of the Water Framework Directive and the Renewable Energy Directive. The report was aiming to review key information on hydropower generation in the context of sustainable water management and flood protection. The results of the Report formulate the common guiding principles on sustainable hydropower development in the Danube Basin, which balance between all legislative documents, however does not include NPPs safety.

In conclusion, ICPDR proved that cooperation in the Danube region is possible and important part of the environment security policy of the Danube Basin Region. On national level, additionally to the sustainable hydropower documents, further joint cross-border actions and coordination activities are needed for early flood prevention and exchange of information between water, hydropower and nuclear sectors and relevant management authorities- Basin Directorates, Nuclear and Hydropower operators, Metrological organizations, Civil and Rescue Services.

The issue of the flood hazards is well understood from the European stakeholders and necessary measures are taken (stress tests, pear review, standards). The work for improvement the safety of NPP in Danube River Region and cooperation continues. Legal instruments exist and tools for assessment and safety management as IAEA safety standards are improved, taking into consideration the trends of climate change and growing energy needs. There are many separate legal instruments for NPP safety and flood protection that adequately answer the needs for the nuclear safety and flood management, nevertheless only few are combined and specific to the contemporary needs of protection against natural flood hazards for the nuclear facilities in the region of the second largest river in Europe and this are not legally binding.

The example study of Kozloduy NPP shows that the facility will withstand an external flood event, but more detailed analysis of the engineering judgment for extreme weather events, and particularly combination of external events, and the design basis must be further developed.

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Picture 1: Hierarchy of IAEA Safety Standards, Source: IAEA

Picture 2: Strengthening the Global Nuclear Safety Regime (INSAG 21), 2006.

Source: IAEA

Table 1: Existing and upcoming NPPs in Danube River Basin

Country	NPP name	Reactor in operation/ commissioning date	Scheduled shutdown Provisionaly	Scheduled shutdown actual	Shut down/ in decommissioning process	commissioning /shut down year	Reactors under construction/first power	Planed new NPP reactor/construction start date	Reactor type
Bulgaria	Kozloduy NPP								
					KOZLODUY-1	1974/2002			PWR
					KOZLODUY-2	1975/2002			PWR
					KOZLODUY-3	1981/2006			PWR
					KOZLODUY-4	1982/2006			PWR
			2017	2017					
		KOZLODUY-5/1987							PWR
		KOZLODUY-6/1991	2021						PWR
								KOZLODUY- 7/2021?	
								BELENE-1- frozen	
								BELENE-2- frozen	
Czech Republic	Dukovany NPP								
		DUKOVANY-1/1985	2015	2025/2045?					PWR
		DUKOVANY-2/1986	2016	2026/2046?					PWR
		DUKOVANY-3/1986	2016	2026/2046?					PWR
		DUKOVANY-4/1987	2017	2027/2047?					PWR
	Temelin NPP* DH								
		TEMELIN-1/2000	2020						PWR
		TEMELIN-2/2002	2022						PWR
								TEMELIN-3	
								TEMELIN-4	
								DUKOVANY-5/2020	
								DUKOVANY-6	
Germany	Isar NPP								
	Gundremmingen NPP								
					Gundremmingen A	1967/1977			BWR
		Gundremmingen B/1984	2016/2030	2017					BWR
		Gundremmingen C/1985	2016/2031	2021					BWR
			2019	shutdown	ISAR-1	1979/2011			BWR
		ISAR-2/1988	2020/2034**	2022***					PWR
Hungary	Paks NPP								
		PAKS-1/1982	2012	2032					PWR
		PAKS-2/1984	2014	2034					PWR
		PAKS-3/1986	2016						PWR
		PAKS-4/1987	2017						PWR
								PAKS-5****	
								PAKS-6****	
Romania	Cherna Voda NPP								
		CERNAVODA-1/1996							PHWR
		CERNAVODA-2/2007							PHWR
								CERNAVODA-3/2019	
								CERNAVODA-4/2020	
Slovak Republic	Bohunice NPP								
					BOHUNICE-A1	1972/1977			HWGCR
					BOHUNICE-1	1978/2006			PWR
					BOHUNICE-2	1980/2008			PWR
		BOHUNICE-V2-1/1984	2024	2044?					PWR
		BOHUNICE-V2-2/1985	2025	2045?					PWR
	Mochovche NPP								
		MOCHOVCHE- 1/1998							PWR
		MOCHOVCHE- 2/1999							PWR
							MOCHOVCHE- 3/2017		PWR
							MOCHOVCHE- 4/2018		PWR
Slovenia	Krsko NPP								
			2021	2043					
		KRSKO/1981							
								KRSKO-2	PWR

legend:

PWR- Pressurized Light-Water-Moderated and Cooled Reactor
BWR- Boiling Light-Water-Cooled and Moderated Reactor
PHWR- Pressurized heavy-Water-Moderated and Cooled Reactor
HWGCR- Heavy-Water-moderated, Gas-Cooled Reactor
*DH- District heating
** Provisionally scheduled shutdown in 2001/in 2010 agreed shutdown
*** finally March 2011 shutdown & May 2011 closure plan
**** suspended by the EU

Sources: IAEA Country Reports 2015, World Nuclear Association 2016

Table 2: NPPs in Danube River Basin- location and institutions for cooperation in case of floods

Country	NPP name	cooling method	River used for cooling system	Approximation from Danube River/others	Town/city in the NPP area (2km radius)	town/population of exclusion zone up to 30km	hydropower stations /dams upstream	Operator of NPP	Safety Regulator	Responsible institution for the River	Flood maintanance services	Flood warrning service	Forecasting weather service
Bulgaria	Kozloduy NPP	"once-through" cooling	Channel of Danube River	500m	Kozloduy, Glojne, Harlets, Butan, Mizia	Kozloduy/13700, Orjahovo(BG)/5400 ; Bechet(Ro)/3300	Iron Gate I, Iron Gate II	"Kozlodu yNPP v PLC owned by Bulgarian Energy Holding EAD	Nuclear Regulatory Authority	Ministry of Environment and Water and Danube Region Basin Direcotrate;	Fire Safety and Protection of the Population Directorate at the Ministry of Interior; Irrigation systems	Ministry of Environment and Water and Danube Region Basin Direcotrate;	National Institute for Meteorology and Hydrology at Bulgarian Science Academy
Czech Republic	Dukovany NPP	cooling towers	n.a.	1 km from Jihlava River, >50km from Danube River	Dukovany, Slavětice, Rouchovany	Třebíč/36800; MoravskeBudejovice/8000; Oslavany/4600	Vodní elektrárna Dalešice Hydropower Station, Water Reservoir Mohelno	CEZ, a.s. (plc.)	State Office for Nuclear Safety	River Basin Authorities	Czech Republic Fire Rescue Corps, Regional Flood Control Authorities, Crisis Management;	Czech Hydrometeorological Institute	Czech Hydrometeorological Institute
	Temelin NPP	cooling towers	n.a.	2km from Vltava River, >50km from Danube	Temelín	Týn nad Vltavou/8200 Ceske Budejovice/93300, Pisek/36700,	Dam Hněvkovice, Dam Kořensko,						
Germany	Isar NPP	"once-through" cooling	Isar River	>50km from Danube	Niederaichbach	Dingolfing/18000 Essenbach/11000	Sylvenstein Dam, chains of dams and hydropower stations	E.ON Kernkraft GmbH owned by 1. (75%) E.ON Kernkraft GmbH 2. (25%) Stadtwerke München	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety - oversees the licensing and supervisory activities of Bavarian State Ministry of the Environment and Consumer Protection in agreement with Bavarian State Ministry of Economic Affairs and Media, Energy and Technology	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Water Management Agencies, Bavarian Environment Agency	Bavarian state	Bavarian Flood Warning Service, Flood Prediction Centres Danube and Isar, Flood Warning Service in Baden-Wuerttemberg,	German Weather Service (DWD), the U.S. Weather Service and the European Centre for Medium-Range Weather Forecasts
	Gundremmingen NPP	"once-through" cooling	Danube River	Channel on Danube River	Gundremmingen, Gundelfingen an der Donau	Dillingen/18000, Offingen/4000, Höchstädt an der Donau/6500	chains of dams and hydropower stations	RWE owned by 1. (75%)RWE GmbH 2. (25%) Stadtwerke München					

Hungary	Paks NPP	"once-through" cooling	Danube River	500m	Dunaszentbenedek, Uszód, Foktő, Dunaszentgyörgy	Szekszárd/33700, Kalocsa/17400, Tolna/11400	vodné dielo Gabčíkovo (Reservoir)	PAKS NUCLEAR POWER PLANT LTD owned by HUNGARIAN POWER COMPANIES LTD.	Hungarian Atomic Energy Authority	Ministry of Rural Development, General Directorate of Water Management	National Directorate General for Disaster Management, Ministry of the Interior	National Directorate General for Disaster Management, Ministry of the Interior	Hungarian forecasting group, Hungarian Hydrological Forecasting Service
Romania	Chernavoda NPP		Channel of Danube River	500m	Cernavodă, Ştefan cel Mare	Medgidia/36000, Cernavodă/20000, Feteşti/34000	none	SOCIETATEA NATIONALA NUCLEARELECTRICA S.A owned by Ministry of Economy,Trade and Bussines Enviroment	National Commission for Nuclear Activities Control		Romanian Water, County and Local Committees for Emergency Situations; General Inspectorate for Emergency Situations)	National Hydrological Forecasts Centre (NHFC) at National Institute of Hydrology and Water Management	National Meteorological Administration (NMA)
Slovak Republic	Bohunice NPP	cooling towers	n.a.	10 km from Vah River, >50km from Danube River	Jaslovské Bohunice, Radošovce, Pečeňady, Ratkovce, Žlkovce, Veľké Kostoľany, Nižná	Trnava/65500	Sĺňava Hydropower plant	Slovenské elektrárne, a.s.	Nuclear Regulatory Authority of the Slovak Republic	Ministry of the Environment	Fire brigades of the Department of Interior, Safeguard brigades, flood protection authorities, crisis staff, water management authorities, firemen and rescue brigades, police;	Slovak Water Management Enterprise	Hydrological forecasting and warning service at the Slovak Hydrometeorological Institute
	Mochovche NPP	cooling towers	n.a.	Hron River, >50km from Danube	Čifáre, Nový Tekov, Kalná nad Hronom, Malé	Levice/36000, Vráble/9000, Tlmače/4172	none	Slovenské elektrárne, a.s.					
Slovenia	Krsko NPP	"once-through" cooling	Sava River	>100km from Danube River	Krsko	Krško/6900, Brežice/6800,	Hydropower Plant KRŠKO	Nuklerana elektrarna Krško owned by GEN energija, d.o.o (joint Slovene-Croat company)	Slovenian Nuclear Safety Administration	Ministry of the Environment and Spatial Planning, Slovenian Environmental Agency	Civil Protection Staf under Civil Protection Commander of the Republic of Slovenia;protection, rescue and relief forces	Administration of the Republic of Slovenia for Civil Protection and Disaster Relief	National Meteorological Service of Slovenia at Slovenian Environmental Agency, Ministry of the Environment and Spatial Planning;

Table 3: NPPs in Danube River Basin net capacity in MW(e)						
	Reactor in operation		Reactors under construction		% nuclear share of the energy mix in 2014	Total years of operating experience
Country	**No.**	**Net capacity MW(e)**	**No.**	**Net capacity MW(e)**		
Bulgaria	2	1926			31.8	157
Czech Republic	6	3904			35.8	140
Germany	3	4163			7	808
Hungary	4	1889			53.6	118
Romania	2	1300			18.5	25
Slovak Republic	4	1814	2	880	56.8	152
Slovenia	1	688			37.3	33
avarage					34.4	204.7

Table 4: Flood damages and related impacts in the Danube River Basin by NPP countries

2002 flood damages and related impacts in the Danube River Basin by NPP countries

Country	**Tributaries of Danube River concerned**	**cause of the flood**	**return period**	**location**	**Conceauences economic losses**	**social losses**	**environmental**	**comments**
Czech Republic	Morava River Basin	no data	no data		€11.7 million	20 communities		urban settlements, infrastructure and agriculture
Germany	Inn, Traun, Salzach and Regen Rivers	no data	no data	Bavaria-Regensburg to Passau	230 million Euro			
Hungary	Danube River	no data	no data	Visegrad	€43.2 million	2000 people evacuated, 4370 homes damaged		flood prevention structures helped
Romania	Suceava River	no data	no data	Suceava	1624 houses flooded, 1000 km of roads and 567 bridges destroyed	11 casualties		
Slovak Republic	Danube River	no data	no data	Bratislava	€38.4 million	144 settlement	8,678 hectares of land	

Table 4: Flood damages and related impacts in the Danube River Basin by NPP countries

2006 flood damages and related impacts in the Danube River Basin by NPP countries

Country	**Tributaries of Danube River concerned**	**cause of the flood**	**return period in years**	**location**	**Concequences from flooding economic losses**	**social losses**	**environmental**	**comments**
Bulgaria	Danybe River	snowmelt	>100	Vidin, Nikopol, Rouse, Silistra		2000 people evacuated		
Czech Republic	Morava and Dyje rivers	temperature rise,snowmelt and heavy rain	100-200		€ 70 million	3 casualities	16,000 hectares of agricultural land were under water	Nové Mlýny hydraulic structure on the Dyje River was already full
Germany	Danube River and		5	Ulm and Passau-				Emergency dikes and
Hungary	Danube, Tisza, Maros/Mures and the Körösök/Crisul Rivers	spring flood	Danube River-100; Tiza River - 50	Nagymaros and Budapest	€88.6 million	267 communities, 70180 buildings, 200890 inhabitants		flood crests exceeded the highest ever-recorded highest high water values
Romania	Danube River	long period of precipitation	>100	Caras-Severin, Mehedinti, Dolj, Calarasi, Constanza, Tulcea, Braila and Gori	€200 million	681 buildings and 487 bridges destroied, 2,598hauses affected		historical flows and water levels registered; seven of nine floodplain basins were flooded due to dike failure
Slovak Republic	Danube, Morava, Nitra and Vah Rivers	highest precipitation, 109-211% above the long-term average	Morava River > 100; Danube River > 50; Nitra River >10; Vah River >10	Morava Basin, Váh, Hron, Komárno, Štúrovo	€65.4 million	1 casuality		backwater from the Danube and Váh almost overtopped the protection dike and inundated the village of Trstice

Table 4: Flood damages and related impacts in the Danube River Basin by NPP countries

2010 flood damages and related impacts in the Danube River Basin by NPP countries

Country	**Tributaries of Danube River concerned**	**cause of the flood**	**return period in years**	**location**	**Conceq… economic losses**	**social losses**	**environmental**	**comments**
Bulgaria	Timok River	Precipitation combined with a heavy snowmelt	>100	Bregovo	no data	2000 people evacuated		
Czech Republic	Morava tributaries	long period of precipitation	>100		€96 million	3 casualities, 199 bridges, 550 km roads damaged,187 affected municipalities, 1287 houses destroyed		second most significant summer flood event in the Morava basin during the last 100 years
Hungary	Danube River, Tiza River	torrential rains	50	southern and central Transdanubian parts of Hungary.	€147 million	989 homes destroyed motorway M1, roads and railway lines were cut in the Sajó, Bódva Hernád andIpoly valleys. 510 communities damaged	10000 ha of arable land	flood crests exceeded the highest ever-recorded highest high water values
Romania	Siret, Prut and Jijia rivers	long period of precipitation, extreme rainfall	>100	Harghita, Covasna, Prahova and Suceava county	€870 million	33936 houses affected,707 bridges, 31 km of water supply,87 schools,3 hospitals and 33 churches, 5200 km roads	110000 ha agricultural field	In the Constanta county (Dobrogea region) 116 mm were recorded on 9 July at Cernavoda
Slovak Republic	Slana,Rimava, Nitra,Ipel Rivers		10-100	whole territory of the Slovak Republic	€337 million	2 casualities, 27521 residential, 6700 non-residential buildings damaged 6,680 ha urban area,87,370 ha agricultural land, 3240 ha forest land, 733 bridges, over600 km of roads destroyed	87370 ha agricultural land, 3240 ha forest land	
Slovenia	Sava River		>100	south-western Slovenia	€207 million	4 casualities, 8241 buildings, 868 land slides, 91 bridges colapsed	30000 ha agricultural land	

Table 4: Flood damages and related impacts in the Danube River Basin by NPP countries

2013 flood damages and related impacts in the Danube River Basin by NPP countries

Country	**Tributaries of Danube River concerned**	**cause of the flood**	**return period in years**	**location**	**Conceguences economic losses**	**social losses**	**environmental**	**comments**
Bulgaria	Danybe River	raising of the Danube-level in the upstream countries;increased level of the ground water; precipitation; heavy rains (flash floods),	50	Silistra, Dobrich and Russe, Sofia Region, Lovech	€1 million	108 hauses		“yellow code” of flood-danger (increased attention) announced;
Germany	Danube River and its northern and southern Danube tributaries		>100	all over Bavaria	€1.4 billion			
Hungary	Danube River		>100	Danube valley (8 counties) and the connected riverbed network	€58 million	2,2 million inhabitants and 52 directly affected, 199 endangered settlements		highest ever recorded flood level all along the Hungarian Danube section. Values were exceeded with 13-44 cm overtop;
Romania	Danube River		>100	Arges, Bacau, Dambovita, Harghita, Hunedoara, Iasi, Mures, Neamt, Sibiu, Suceava, Tulcea, Vaslui and Vrance	€46.1 million	4 casualities, 13 affected counties, 336 houses, 544 households, 822 bridges, 2225 km roads,52 hydraulic structures	16190 ha of agricultural field	highest level was in Bechet (1-9 cm over inundation level) on 18-20 June. Attention level exceeded in Gruia-Zimnicea, Harsova and Isaccea-Tulcea sectors, (yellow and orange code were announced)
Slovak Republic	Danube, Morava, Vah, Hron and Ipel Rivers		>100		€12.1 million	742 persons endangered, 245 roofless, 150 persons evacuation, 1 person injured, 2.478 buildings damaged		Water level records were exceeded at all stations on the Slovak section of the Danube. Heavy flooding on the Danube stopped inflowing water from tributaries and has caused backwater and very high water levels in lower parts of Morava, Vah, Nitra and Hron Rivers;

Table 5: Hydraulic Structure among the Danube

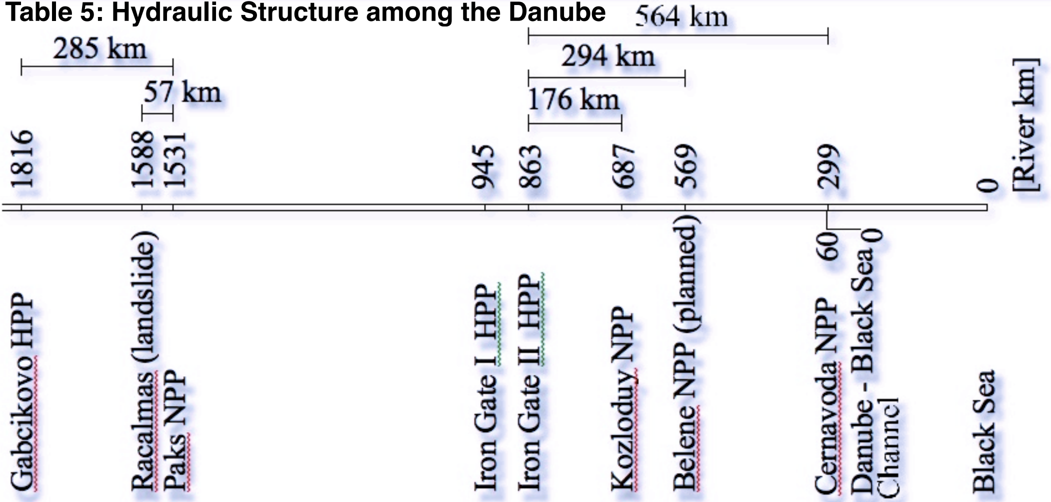

Table 6:Major Hydrolic Structures among the Danube River Basin

River/ Country	**Total lenght of the river *rkm-rkm*** ***(from source to mouth)***	**Total Free-flowing sections** ***rkm-rkm***	**Total regulated sections *rkm-rkm***	**Total impounded sections *rkm-rkm***	**Number of dams/ reservoirs**	**Number of dams/ reservoirs** **> 15 m**	**Number of Hydropower dams**
Danube D	2,780 – 2,200	183	139	332	49		**27**
Danube A	2,200 – 1,873				9		
Danube SK	1,880 – 1,700				2	1	2
Danube H	1,850 - 1,433	417	383	8	1		
Danube YU	1,433 - 845	1,433-1,215	414		2	1	2
Danube BG	845 – 375			0	0	0	0
Danube RO	1,075 – 0		863	212	2/2	2/2	2
Isar (D)	263.3	59	86 (+55 diverted)	63	10	1	10

Source: UNDP/GEF 1999

Table 7.1 Legal Instruments for nuclear anf flood safety

Legal Instrument	short describtion	ratification/apporval by all Danube NPPs countries (Yes/No)	relevance to NPP	Flood hazards
International				
Convention on Nuclear Safety	Covers the main fundamental topics related to the NPPs safety, unofficially corresponds to SF-1	Yes	Yes	Yes*
Convention on Early Notification of a Nuclear Accident and Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency	Accident notification and emergency assistance between coutries and IAEA	Yes	Yes	Yes*
Vienna Convention on Civil Liability for Nuclear Damage	bearer of the corresponding civil responsibility	Yes	Yes	Yes*
Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management	Safety aspects of spent fuel and waste management on-site	Yes	Yes	Yes*
IAEA Safety Standards	Safety requirements relevant NPPs in light of natural hazards: Fundamental:“Principle 5 – Optimization of Protection, Principle 7- Protection of Present and Future Generation, Principle 8- Prevention of Accidents, Principle 9- Emergency Preparedness and Response” Requirements: for Site Evaluation for Nuclear Installations NS-R-3 and for Safety Assessment for Facilities and Activities evaluating safety vulnerabilities against site specific extreme natural hazards (GSR- Part 4 (Rev.1), Safety of NPP Design against natural hazards (SSR-2/1 (rev.1), Safety Commissioning and Operation SSR-2/2 (Rev.1) Relevant Guides: • Metrological and hydrological hazards in site evaluation (SSG-18/ NS-G3.5/NS-G-1.5) • Geotechnical Aspects of Site Evaluation (NS-G-3.6) • Site Survey and site selection (SSG-35) • Storage of Spent Nuclear Fuel (SSG-15)	not obligatory	Yes	Yes
Regional/EU				
TREATY ESTABLISHING THE EUROPEAN ATOMIC ENERGY COMMUNITY (2010/C 84/01) (Euratom Treaty)	Speedy establishment and growth of nuclear industries	Yes	Yes	Yes*
Directive 2009/71/Euratom Directive 2014/87/Euratom (amendment of 2009/71)	Community framework in order to maintain and promote the continuous improvement of nuclear safety and its regulation	Yes Yes	Yes Yes	Yes* Yes
Directive 2009/28/EC on Renewable Energy (RED)	Promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC	Yes	No	No
Directive 2000/60/EC Water Framework Directive (WFD)	Establish a framework for the Directive aims protection of inland surface waters, transitional waters, coastal waters and groundwater	Yes	No	Yes
Directive 2007/60/EC on the assessment and management of flood risks (European Floods Directive, EFD)	The purpose of this Directive is to establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community	Yes	No	Yes
Local/Danube Region				
“Convention on the Cooperation for the Protection and Sustainable Use of the Danube River” (Danube River Protection Convention – DRPC	Co-operation on transboundary water management in the Danube River Basin. It aims to ensure that surface waters and groundwater within the Danube River Basin are managed and used sustainably and equitably.	Yes	No	Yes
EU strategy for the Danube region	Priority Area 2 “To Encourage More Sustainable Energy” - high level of nuclear safety and underline the importance specialy while using the river water for ultimate heat sink. Priority Area 4 “to restore and maintain the quality of waters” pollution of water from industry- operational or accidental hazardous pollution, alternation of the river basin that changes the river hydromorphology. Priority Area 5 “to manage environmental risks”	Yes	Yes	Yes
ICPDR Danube River Basin Management Plan (DRBMP) and its Joint Program of Measures (updated in 2015)	Defining the water management priorities for the Danube Basin until 2021	Yes	No	Yes
ICPDR Action Programme for Sustainable Flood Protection	After the Action program in 2015 was adopted the flood	Yes	No	Yes
1st Danube Flood Risk Management Plan/Set of national flood risk management plans	First-ever basin-wide plan to manage flood risks for the entire Danube River Basin	Yes	No	Yes

Legend:
yes*= hazards in general

Table 7.2 Cooperation Bodies for nuclear safety and flood protection				
Cooperarion body	short describtion	all Danube NPPs countries Members	relevant to	
			NPP	Floods
International				
International Atomic Energy Agency (IAEA)	Set up for cooperation in the nuclear field, the Agency works with its Member States and multiple partners worldwide to promote the safe, secure and peaceful use of nuclear technologies.	Yes	Yes	Yes*
International Nuclear Safety Group (INSAG)	Group of experts under IAEA with high professional competence in the field of safety working in regulatory organizations, research and academic institutions and the nuclear industry	Yes		
Nuclear Energy Agency (NEA)		No*	Yes	No
World Nuclear Association		n.a./companies	Yes	No
World Association of Nuclear Operators (WANO)	The organisation exists purely to help its members accomplish the highest levels of operational safety and reliability. This is achieved through a series of highly-regarded programmes, such as peer reviews, and access to technical support and a global library of operating experience.	Yes	Yes	No
Regional/EU				
EURATOM	EURATOM is legally distinct from the European Union (EU), but has the same membership, and is governed by the EU's institutions;One of the purpse of the EURATOM is to establish uniform safety standards to protect the health of workers and of the general public and ensure that they are applied	Yes	Yes	Yes*
Directorate-General for Energy	DIRECTORATE D – the directorate responsible for Nuclear energy and safety, as well as coordination with EURATOM and international relations	Yes	Yes	No
European Nuclear Safety Regulators Group (ENSREG)	ENSREG is a high-level group at EU level aimed at furthering a common approach for the safety of nuclear installations. The working groups direct related to nuclear safety and international cooperation within ENSREG are: Working Group 1 on Nuclear Safety- use the Convention on Nuclear Safety for improving the EU nuclear safety and Working Group 4 (WGIC) was created to facilitate the Nuclear Safety International Cooperation	Yes+ IAEA observer	Yes	Yes*
Foratom	16 European non-governmental nuclear organizations	No**	Yes	No
Western European Nuclear Regulators Association (WENRA)	Develops a common approach to nuclear safety and provides an independent capabilityand expertise to examine nuclear safety	Yes	Yes	Yes**
Local/Danube Region				
International Commission for the Protection of the Danube River (ICPDR)	The final goals are to co-operate on fundamental water management issues and to take all appropriate legal, administrative and technical measures to maintain and improve the quality of the Danube River and its environment	Yes+EU	No	Yes

Legend:

No*- Bulgaria and Romania are not
No*- no Czech organization
Yes*- through Safety Standards related to external natural hazards
Yes**- after Fukushima Daiichi WENRA accident prepared stress tests for the EU NPPs in relation to natural hazards