Appendix 2.1

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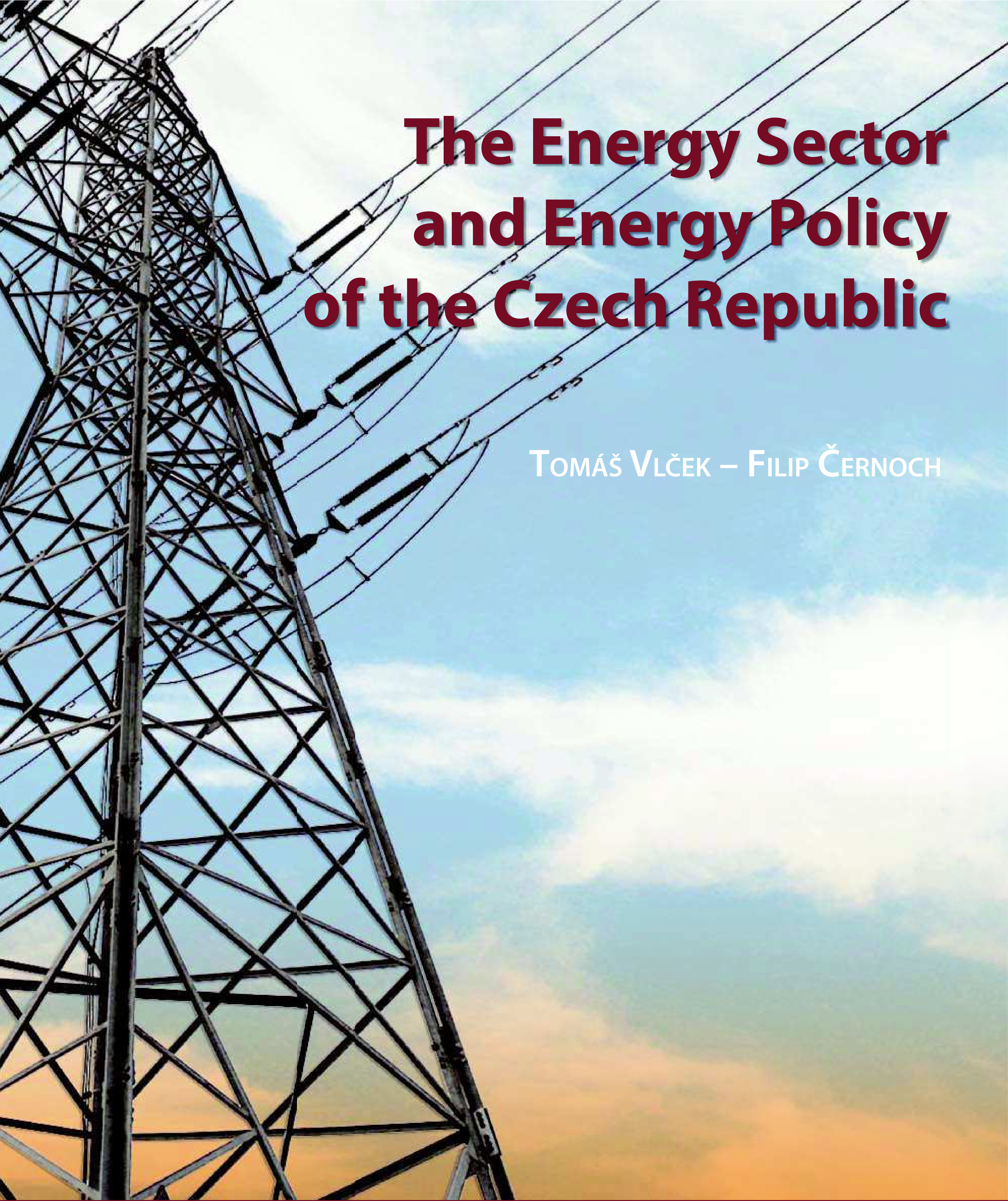

The Energy Sector and Energy Policy of the Czech Republic

Tomáš Vlček – Filip Černoch

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Chapter 6: The Nuclear Sector

Tomáš Vlček

6.1 Nuclear Power Plants in the Czech Republic

There are two nuclear power plants running in the Czech Republic using a total of six pressurized reactors cooled and moderated by light water. The Dukovany nuclear power plant is located in Southern Moravia with four VVER[119] V 213 pressurized reactors (after modernization, installed power capacity currently amounts to 4 x 510 MWe), which provided its first electricity in May 1985, while the Temelin nuclear power plant is located in Southern Bohemia, a set of two VVER 1000 V 320 pressurized reactors (installed capacity equal to 2 x 1,000 MWe, which was completed in December 2000. Both power plants are owned by CEZ. Thanks to the modernization of the technical part of the nuclear blocks, the power plants as of December 31, 2012, reached 4,404 MWe of installed electrical capacity and, therefore, made up a 19.7 % share in the electrical power mix of the Czech Republic (in terms of installed capacity).

Tab. 6.1: Review of CEZ Nuclear Power Plants as of December 31, 2012

Locality	Blocks marked as	Installed capacity (MWe)	Type of reactor	Total installed capacity (MWe)	Total installed capacity (MWt)	Start up	Distribution company	Voltage (kV)	Distribution point
Dukovany Nuclear Power Plant	1	510.0	VVER 440, V 213 type	2,040	5,500	1985 – 1988	CEPS	400	Slavetice
	2	510.0	VVER 440, V 213 type						
	3	510.0	VVER 440, V 213 type						
	4	510.0	VVER 440, V 213 type						
Temelin Nuclear Power Plant	1	1,000.0*	VVER 1000, V320 type	2,000	6,000	2002	CEPS	400	Kocin
	2	1,000.0*	VVER 1000, V320 type						

* In May, 2012, all the blocks of the Dukovany power plant were modernized, so its installed capacity increased from 4 x 440 MWe to 4 x 510 MWe. In 2007, the Temelin power plant underwent a modernization of turbines, so its capacity can range at the level of 2 x 1,020 to 1050 MWe, depending on circumstances (such as, for example, the temperature of the cooling water).
Source: Energetický regulační úřad, 2010b, p. 89*;* revised and modified by T. Vlček.

119 VVER means *water cooled, water moderated energy reactor* (or *water – water energy reactor*), in Russian *Vodo-Vodjanyj Energetičeskij Reaktor.* In Western Europe and elsewhere in the world also known as PWR (Pressurized Water Reactor).

6.2 Deposits, Mine Production, Companies and Traders

Uranium mining has a long history in the Czech Republic, which is currently the only European country still mining it. Of seven registered deposits, only the Rozna Deposit is still being mined. There is only one company engaged in uranium mining, namely DIAMO, state enterprise[120] (until May 1, 1992, known as the Czechoslovakian Uranium Industry, state enterprise).

DIAMO, state enterprise, was founded in 1946, and is under the full control of the Ministry of Industry and Trade of the Czech Republic, and headed by Jiri Jez since July 5, 2000. DIAMO provides, among others, mining activities and activities implemented by mining means, specifically, mining, the treatment and processing of radioactive minerals, remediation works, the removal of the consequences and the impact of mining and processing of uranium ores, base metals and coal, and the technical and biological recultivation of devastated properties after decommissioning works (see *DIAMO s.p.*). DIAMO, with its headquarters in Straz pod Ralskem, comprises of four divisions, while the GEAM division runs the uranium mining.

The Czech Republic used to be among the most important world producers of uranium. A historical total production of almost 111 thousand tonnes of uranium in the form of sorted ores and chemical concentrate in 1946 – 2009 made it the 10th biggest producer in the world. Unambiguously the dominant source of uranium is the Rozna deposit in Dolni Rozinka (216 tonnes of concentrate in 2011), while a small percentage of the overall mining comes from the remediation works in the Straz pod Ralskem deposit (25–30 tonnes per year, see MŽP / ČGS-G, 2010, p. 197) and management of mining waters at six locations in Pribramsko (12.58 tonnes of metal in 2009, see DIAMO s. p., 2010, p. 11). The Rozna mine was supposed to be shut down in the mid-1990s, when uranium experienced a sales crisis as the previously important customer, Slovakian Power Plants, refused to purchase Czech uranium and started obtaining enriched nuclear fuel directly. Government Decrees from 1994, 1997, 2000, 2002 and 2005 gradually prolonged the mining period in Dolni Rozinka, while the Government by passing Decree No. 565 from May 27, 2007, extended the mining and processing of uranium in the Rozna deposit for as long as mining remained economically effective[121], and the termination of mining is tied to the results of a profitability assessment[122], currently set for 2018. Given that one of potential deep geological repository localities is at the Dolni Rozinka site (Kravi hora), should it be selected, moving the employees from uranium mining to the construction of a deep geological repository is being considered.

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120 The term DIAMO is an abbreviation for ammonium diuranate, in Czech *Di*uranát *amo*nný.

121 According to its methodology, the International Agency for Atomic Energy considers economically efficient such mining as does not exceed a cost of 130 USD per to mine 1 kg of uranium.

122 DIAMO, state enterprise, carries out a mining profitability assessment every half year, and when it reaches negative figures, activity will be immediately terminated. Mining can be ended in several months on a regular basis, while remediation can, however, last for a decade.

Tab. 6.2: Deposits, reserves and mine production of uranium in the Czech Republic							
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Deposits – total number	7	7	7	7	7	7	7
- exploited	1	1	1	1	1	1	1
Total mineral reserves	135,990	135,812	135,729	135,553	135,425	135,361	135,276
- economic explored reserves	1,655	1,671	1,677	1,545	1,426	1,416	1,406
- economic prospected reserves	19,411	19,476	19,435	19,428	19,420	19,427	19,402
- potentially economic reserves	114,924	114,665	114,617	114,581	114,579	114,518	114,468
- exploitable (recoverable) res.	596	677	643	503	377	374	338
Mine production	420	383	322	290	286	259	252
Production of concentrate	409	358	291	261	243	237	216

Note: reserves, mining and the production of uranium concentrate expressed in tonnes, the production of uranium concentrate resulting from remediation works is not included in these values.
Source: Ministerstvo životního prostředí / Česká geologická služba – Geofond, 2010, p. 185; Ministerstvo životního prostředí / Česká geologická služba – Geofond, 2012, p. 102.

Since clean uranium in the Czech Republic at the present accounts for an average of 0.16 % of uranium ore[123], first it needs to be cleaned of waste rock. Cleaned up ore is then ground and, following chemical treatment with sulphuric acid, processed into uranium concentrate – triuranium octoxide U_3O_8 (or yellow cake[124]). DIAMO's intermediate product was purchased predominately by a single customer, namely CEZ.[125] In 2009, it bought a total of 270.4 tonnes of concentrate (see DIAMO s. p., 2010, p. 2). CEZ has been in the last 15 years almost the exclusive user of uranium concentrate (the production surplus was at the beginning of the 1990s sold on the world market). Domestic production, however, did not satisfy CEZ's demands as the use of uranium concentrate in the Dukovany and Temelin nuclear power plants ranges between 600 and 700 tonnes per year (MŽP / ČGS-G, 2010, p. 197). CEZ, therefore, either buys additional supplies on the world market or it directly purchases enriched fuel.

At the start of 2000, domestic mining covered approximately 93 % of domestic demand. Currently, however, it is only a third of consumption as a result of the inhibition program, while the remaining supplies are bought on the world market in the form of concentrate of already enriched fuel (see MŽP/ČGS-G, 2010, p. 200). Since the end of 2009, when the Russian company OAO TVEL began supplying fuel for both Dukovany and Temelin nuclear power plants, CEZ has been purchasing only the final product, enriched fuel, while DIAMO sells the domestic products on the market.

123 In the mid-19th century when the uranium mining was first initiated, uranium ores consisted of 65 % uranium (see Majer, 2004, p. 183).

124 Yellow cake does not always necessarily have a consistent chemical formula U_3O_8 and a yellow colour. It got the name based on the look of uranium concentrate from the early mining and production period. Yellow cake is nowadays rather brown or black. U_3O_8, for example, has an olive-green colour. Chemical formulae of yellow cake can take forms such as: U_3O_8, UO_2, UO_3, $(NH_4)_2U_2O_7 \cdot n\,H_2O$ or $Na_2U_2O_7 \cdot 6\,H_2O$. Yellow cake is transported in blue barrels.

125 Other customers were France, Germany, Canada and Russia.

Tab. 6.3: NYMEX Uranium Futures Price of Uranium Concentrate (U_3O_8)											
2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
21.16	22.71	34.17	46.30	82.67	165.35	171.96	110.23	93.70	158.73	114.64	97.01

Note: Values always as of January of the particular year. Data indicated in USD per kilogram.
Source: *UraniumMiner;* calculated by T. Vlček.

At the point when CEZ started to employ exclusively a purchased concentrate, following the shift to uranium hexafluoride UF_6, it had to search for sorting plants on the world market, i.e. for enrichment services. These can be obtained only in seven countries in the world[126], and CEZ went to buy in France. Enrichment plants are capable of enriching supplied uranium hexafluoride according to the client's requirements. Uranium has a constant ratio of isotopes: it consists of 99.284 % of ^{238}U, 0.711 % of ^{235}U and 0.005 % of ^{234}U. However, it is isotope ^{235}U that has been so far almost exclusively employed for fission reactions and use in the nuclear industry. Enrichment is a process during which uranium gets a greater concentration of the ^{235}U isotope, which is for Czech nuclear purposes 3.6 to 4.4 %.[127] From the point of mining through to enrichment, the volume of exploitable uranium in that manner rapidly declines. For initial processing, it is only 0.16 % of mined material that is employable, while during the enrichment process at the level of approximately 4 % ^{235}U, the volume of material lessens eight to eight and a half times (650-680 tonnes of concentrate for Czech nuclear power plants turn into approximately 80 tonnes of UO_2 fuel, see MŽP / ČGS-G, 2010, p. 200). In the case of uranium this is nevertheless an enormous energy density, where 1 kg of nuclear fuel generates 2,100 GJ of energy, compared to 0.033 GJ in the case of coal[128] (see *"Fyzikální aspekty,"* 2008, p. 24).

Enrichment is followed by the process of fabrication, where fuel gets processed into pellets (1 cm in diameter and height) which are then fitted into fuel rods[129], a specific number of which are then placed into fuel cassette (segments, assemblages). In the active zone of each reactor in the Dukovany nuclear power plant, there are 312 fuel cassettes, each weighing 215 kg and consisting of 137 kg UO_2 in 126 fuel rods, while the Temelin nuclear power plant has 163 fuel wrappers (cassettes[130]) in each reactor, each weighing 766 kg and consisting of 563 kg UO_2 in 312 fuel rods (each rod consists of approximately 370 pellets). In the active zone of the Dukovany nuclear power plant, there is, therefore, 42.7 tonnes of UO_2 fuel, and 91.8 tonnes in the Temelin nuclear power plant. The fuel made in this manner is then supplied to the client, to CEZ.

The long-term and permanent fuel supplier for the Dukovany nuclear power plant is the Russian company OAO TVEL. From 2002, when the plant was launched, to the end of 2009, fuel for the Temelin nuclear power plant was supplied by the American company Westinghouse Electric Company, LLC[131].

126 Sorted by capacity, the order is: Russia, the USA, France, Canada, the Great Kingdom, China and Brazil.

127 The Dukovany nuclear power plant has been during its entire operation period using fuel supplied by the Russian company OAO TVEL, which went through major development changes. Initial fuel with 3.6 % ^{235}U enrichment was employed in a three-year cycle, with an average calorific value of 30 MWd/kg U. A gradual improvement brought the plant to the zone of a low neutron spillage and 3.8 % ^{235}U enrichment. In the further phase, enrichment was lifted on 4.25 resp. 4.38 % ^{235}U, while a burning absorber started to be used in fuel cassettes (see ČEZ, a. s., 2010b, p. 31) lowering fuel reactivity.

128 Calculated by T. Vlček.

129 A length of a fuel rod for VVER 440 reactor is 242 cm.

130 Cassette is a Russian term for a fuel wrapper.

131 It is known that fuel rod buckling takes place in the active zone of reactor, because American nuclear reactors have four–squared fuel cassettes, while the Russian ones are six–squared. Six–squared cassettes for Temelin were initially provided by Westinghouse Electric Company, LLC and caused fuel rods torsion, which resulted in forced operational interruption, limited production and inability to produce electricity to its full capacity.

In 2010, a selection process for a new supplier took place, which was won by the Russian OAO TVEL by submitting a financially unbeatable offer. OAO TVEL will be until 2020, therefore, the exclusive fuel supplier for both Czech nuclear power plants.

Fuel used to be delivered to the Czech Republic by air from the USA or Russia[132], while it is presently also transported by air from the Russian Federation and then by wagons to the target power plants[133].

6.3 Spent Fuel and the Nuclear Waste Repository

Fission chain reactions exclusively consume the uranium isotope ^{235}U. Spent fuel contains approximately a quarter of the original value of that isotope, which means that it remains enriched at a level of 1 % ^{235}U. Spent fuel consists of more than 96 % of uranium dioxide (UO_2) and of newly emerged ingredients of plutonium(IV) oxide amounting to approximately 1 % and other compounds (3 %), whereas the majority of fission products are radioactive isotopes (see Laciok, Marková & Vokál, 2000, p. 190; Otčenášek, 2005, p. 536). Fuel assemblies with spent nuclear fuel that are removed from reactors look like fuel assemblies with fresh fuel. There are nuclear reactions taking place even after fuel is discharged from a reactor, as well as the release of alpha, beta and gamma radiation, neutrons and heat which must be exhausted.

The Dukovany nuclear power plant initiated its operation on the basis of a three-year fuel cycle. The increase of ^{235}U share in cassettes enabled it to reach a full five-year cycle (while even a six-year cycle is being considered). Nowadays this means that during the annual refuelling, only 1/5 of spent fuel is replaced out of the overall charge, i.e. 72 fuel assemblies (see ČEZ, a. s., 2010a, p. 31).

The active zone in the Temelin nuclear power plant includes 163 fuel assemblies, while the power plant's operation is set on a four-year fuel cycle, which means that 1/4 of spent fuel is replaced each year, i.e. 41–42 fuel cassettes (see ČEZ, a. s., n.d.a).

After removal from the reactor, three phases of fuel deposition follow. The first phase includes the collection of waste after its release from the primary circuit and subsequent processing until reaching treatable form preventing any further release of waste. The second phase includes safe transport to the location of final waste deposition. The third phase, deposition, is understood as the final operation, which is why the depository needs impenetrable protection shields (see Marek, 2007, p. 4).

In *the first phase*, fuel cassettes are actively cooled in a pool next to a reactor. After at least five years, they are moved into dry containers and then passively cooled in the interim storages. After removal from a reactor, the thermal capacity of spent nuclear fuel in the Dukovany power plant is 223.5 kW and then drops to 1 kW over the course of only one year (see Nachmilner, 2002, p. 12). The Dukovany power plant uses CASTOR 440/84[134] containers, supplied by the German Consortium GNS Gesellschaft für

132 In the 1990s, transport by sea via the Polish port Gdansk (from Russia) and then by railway to the final destination was also considered.

133 In Dukovany's case, for example, a cargo plane lands at Brno Turany International Airport, goes through the requisite customs and technical inspections and it is then reloaded onto the wagon and transported to the power plant under the police escort.

134 Or modernized Castor 440/84M.

Nuklear-Service mbH and RWE Nukem GmbH, which can be filled with 84 fuel cassettes.[135] A simple calculation based on the above-mentioned data can bring us to the conclusion that the Dukovany power plant produces less than a container of spent fuel per year. An empty container weights 93.7 tonnes and 116.1 tonnes when filled.

There are two interim storage facilities for spent fuel at the site of Dukovany nuclear power plant. The total capacity of the original Dukovany storage, opened in 1995, amounts to 600 tonnes of spent fuel stored in 60 CASTOR 440/84 containers. After filling this storage to its full capacity, in 2006, new storage was set up. Its capacity is 1,340 tonnes of spent fuel. In comparison to the first storage, the new one, therefore, incorporates approximately a two times larger area. The storage part of the facility can receive 133 CASTOR 440/84M containers, therefore, altogether allowing the Dukovany nuclear power plant to store spent fuel for 50 to 60 years, that is, for a period exceeding the lifespan of the power plant itself[136] (see ČEZ, a. s., n.d.d; Marková, 1996, p. 626-627).

The Temelin nuclear power plant uses CASTOR 1000/19 containers from the same German supplier[137]. They are 5.5 metres tall and when filled weigh approximately 116 tonnes. The Temelin power plant produces two full containers and 3–4 fuel assemblies of the third container of spent fuel per year. In 2010, a new interim storage facility was launched, with a capacity of 1,370 tonnes (152 CASTOR 1000/19 containers).[138] The capacity of a dark wet pool for spent fuel is 680 fuel assembly places and 25 places for hermetic cases. Spent fuel could be, therefore, stored in the pool for ten years, which is why wet interim storage did not prove necessary before 2010. After its removal from a reactor, the thermal capacity of spent nuclear fuel is 964 kW and then drops to 5 kW in the course of only one year (see Nachmilner, 2002, p. 12). The Skalka central dry storage of nuclear fuel in the vicinity of Bystrice nad Pernstejnem was built as backup storage with an overall capacity of approximately 2,900 tonnes of fuel.

The second phase, transportation, is currently by rail, while it is subject to a very strict monitoring by the State Office for Nuclear Safety. While it is likely that spent fuel will also be transported by rail for a few decades, if deposited in deep geological repositories. This, however, cannot be claimed with certainty because it will depend on available technologies as well as the locality and access to the future deep geological repository.

Fuel is stored in dry interim storage for a period of approximately 80 years. The final deep geological repository (*third phase*) is for that reason in the Czech Republic scheduled not before 2065. There are four surface repositories in the Czech Republic, namely the Radioactive Waste Repositories Richard near Litomerice, Brotherhood near Jachymov, Dukovany and Hostim near Beroun. These repositories store institutional radioactive waste, emerging during the processes of medical, industrial, agricultural and

135 Spent nuclear fuel from the Dukovany nuclear power plant used to be transported to the interim storage at the site of the Jaslovske Bohunice nuclear power plant in Slovakia. From this location, it was meant to be gradually used up on the basis of the interstate agreement with the Soviet Union. Following the demise of the Soviet Union, the Russian Federation, however, withdrew from these commitments. After 1993, nuclear fuel from Dukovany was brought back to the country and placed in interim storage in Dukovany power plant.

136 The present power plant is licensed only until 2025. An application was submitted to prolong this license until 2035, while the prolongation until 2045 is also considered, but, as previously indicated, its shut down is predicted for 2045 at latest.

137 CASTOR 440/84 and CASTOR 1000/19 containers are presently produced in the Czech Republic as well. Their licensed producer is Skoda JS, a. s.

138 In addition to the Dukovany and Temelin power plants, a high-activity radioactive waste repository is operated also by the Nuclear Research Institute Rez, plc, where there are two research nuclear reactors operating (LVR-15 and LR-0). The capacity of the high-activity radioactive waste repository in Rez is substantially lower, as the Nuclear Research Institute produces only about 15 spent fuel segments per year. In 2007, all waste was transported to the Russian Federation, so this repository is currently empty.

research activities, therefore, waste containing natural radionuclides and low-activity radioactive waste from nuclear power plants. One deep geological repository is planned as well.

In 1990–2005, the Radioactive Waste Repository Authority[139] originally selected 27 potential localities for building a deep geological repository of radioactive waste. It narrowed them down to 13, then to 11 and finally to the current 7: Brezovy potok near Pacejovo, Certovka near Lubence, Horka near Budisov, Hradek near Rohozna, Cihadlo near Lodherov, Magdalena near Bozejovice and Kravi hora near Moravske Pavlovice. In recent years, the Authority has been checking the possibility of using military areas, while it was the Boletice military area that was positively valued in terms of its site, therefore, qualifying as an eighth possible appropriate location.

Since 2010, these localities have been undergoing a basic land survey, consisting of three phases: the first research phase until 2015, the second exploratory phase in the period 2015–2025 and the third detailed exploratory phase in the period 2025–2050. The exploration of at least four localities is anticipated, as the company is expected not to receive an exploration permit for all localities. By 2018, two candidate localities should be chosen, one of which will be then chosen as the winner. After obtaining enough data proving the locality's safety, the submission of the application for construction permit of a deep geological repository will follow, which should take place in the period 2050–2065 (see *Správa úložišť radioaktivních odpadů*). After this period expires, it will also be decided whether to process spent fuel from nuclear power plants and to use it as energy material for production of new fuel or if it is to be finally stored in a deep geological repository.[140]

Processing is nowadays technically, energy and financially a very costly process, which only a few countries in the world[141] can afford, but the technology and initial costs can in the next 50 years however undergo such changes that it might become an entirely common practice. A deep geological repository is meant to be a final repository of spent nuclear fuel. It is questionable whether it should be technologically implemented so as make it impossible for already deposited waste to ever be picked up again or to enable deposited waste to be extracted and processed in the far future. Even though experts are rather inclined to the second alternative, because spent nuclear fuel represents a very valuable material which can be used as fresh fuel after being processed or even as fresh fuel without previous processing[142], economic reality suggests the first alternative. The most expensive feature of a repository is its operation, which makes it economically unreasonable to keep a repository open for decades. This means it is better to store spent fuel on a long-term basis in interim storages and only when so decided, to deposit high-activity radioactive waste rather at once, and to do it finally (opening and using it again would be impossible). A deep geological repository is constructed under the assumption it will work for the next hundred years.

The owner of spent nuclear fuel in the Czech Republic is CEZ. It is responsible for storage only, while the final deposition is the state's responsibility. This was the purpose for founding the Radioactive Waste Repository Authority, which is on the basis of The Atomic Act responsible for the treatment of spent or ra-

139 Due to the transience of private companies, the final radioactive waste repository is not under CEZ's but the state's responsibility, specifically through the means of the Radioactive Waste Repository Authority (Czech: SURAO – Správa úložišť radioaktivních odpadů).

140 Constructing a deep geological repository is a very complicated process which requires confident data regarding its locality. In terms of its radioactivity, spent fuel becomes safe at least 300 years after its removal from a reactor, which is accordingly the period for which a repository must function without difficulty. We can in that relation mention an interesting aspect of a nuclear sector, namely that spent fuel also alone protects itself against abuse, because its removal from the protection containers would, during this period, mean a deadly dose of radiation.

141 In 2011, it was only China, France, the Great Britain, India, Japan, Pakistan, Russia and the USA.

142 Some of the current fourth generation reactor projects plan to use previously spent fuel as a fuel.

dioactive fuel into a form adequate either for deposition or for further use. The point when to deliver spent nuclear fuel to the state is exclusively CEZ's decision. So far, it is not radioactive waste but potentially exploitable material that is involved (see Laciok et al., 2000, p. 190-191).

Tab. 6.4: Scheme of the End of the Nuclear Cycle in the Czech Republic			
Spent fuel dwell	App. 5-13 years	App. 80 years	Permanently or until potential re-processing
Location	Pools of spent fuel in the Dukovany and Temelin nuclear power plants	Storage in the Dukovany and Temelin nuclear power plants, backup repository Skalka	Deep geological repository
Responsible	CEZ, a. s.		SURAO
Supervised by	State Office for Nuclear Safety		
Financial means	Corresponding budget CEZ, a. s.		Nuclear account (CEZ, a. s. contributions)
Source: Otčenášek, 2005, p. 540; modified by T. Vlček.			

CEZ finances the deposition of spent fuel from its own budget, while the Radioactive Waste Repository Authority (SURAO) finances its activities from the nuclear account kept in the Czech National Bank, administered by the Ministry of Finance. The nuclear account is a financial account contributed to by all producers of radioactive waste in the amount laid down by Government Order No. 416/2002 Coll., which establishes the amount of the levy and the manner of its payment by the agents of radioactive waste to the nuclear account and the annual amount of the contribution for the municipalities and the rules for its granting. CEZ for example pays 50 CZK for each MWh produced in nuclear power plants, while other producers of radioactive waste pay 30,694 CZK for each barrel of 200l, which is the basic depositing unit in repositories. In 2013, there was approximately 19 billion CZK on the nuclear account. Besides payments to the nuclear account, each operator of a nuclear facility in the Czech Republic runs an individual financial reserve for dismantling and remediation of that facility, as prescribed by The Atomic Act.[143]

The warrant of temporary depositing of spent fuel is, therefore, provided by CEZ until its delivery to the Radioactive Waste Repository Authority. Then the state takes over responsibility.

6.4 The Regulatory and Safety Framework of the Nuclear Industry

Unambiguously the key document for the Czech nuclear sector is the Act of January 24, 1997, on peaceful use of nuclear energy and ionizing radiations (The Atomic Act) and on amendments and alternations to some acts (see "Zákon ze dne 24. ledna 1997"), which has been amended already ten times, then Act No. 19/1997 Coll., Act No. 281/2002 Coll. as well as Act No. 44/1988 Coll. on the protection and utilization of mineral resources (The Mining Act) (see "Zákon č. 44/1988 Sb.").

143 The annual reserve for the Dukovany nuclear power plant is set at 650 million CZK and 370.7 million CZK for the Temelin nuclear power plant (see Duda, 2002, p. 47).

The Atomic Act regulates basically all aspects of not only the nuclear industry, but of ionizing radiation in general, which is, among other things, the regulation of the method of utilizing nuclear energy and ionizing radiation, and conditions for the performance of practices related to nuclear energy utilization and radiation activities, conditions for safe management of radioactive waste, performance of state administration and supervision within nuclear energy utilization, within radiation activities and over nuclear items, etc. The Atomic Act is very severe, as the strict limits which it has laid down induced problems during the construction of interim spent fuel storage on nuclear power plants sites. In May 2011, already the eleventh revision of The Atomic Act was discussed, which among other things introduced the possibility to provide compensations from the nuclear account also to communities whose cadastral area is subject to exploratory work related to a deep geological repository or in which such repository already existed.

The Mining Act, on the other hand, treats uranium mining and, as in the case of coal, it is the Czech Mining Authority and District Mining Authorities who watch over mining activity, observance of working conditions, the management of mining waste and supervise adherence to Acts Nos. 44/1988 Coll., 61/1988 Coll. and 157/2009 Coll. and other regulations (see Státní báňská správa České republiky).

Section 3 of The Atomic Act commissions the State Office for Nuclear Safety (SUJB) to perform the activities of public administration and supervision of nuclear energy and ionizing radiation use in the field of radioactive as well as in the field of nuclear, chemical and biological protection. The SUJB is the central organ of public administration subordinated to the Government, which makes the regulatory role in the field of nuclear industry held only by these two organs, the Government and the SUJB.

The SUJB implements the regulation process through decrees, addressing the fields of physical protection of nuclear materials and facilities; then the field of quality during activities related to nuclear energy use and activities leading to radiation, the field of criteria for facilities and the distribution of selected facilities across safety categories or criteria for placement of nuclear facilities or of sources of significant ionizing radiation. It, furthermore, treats the issue of radiation protection; emergency preparedness of nuclear facilities and workplaces exposed to sources of ionizing radiation. The SUJB is responsible for the functioning and organization of the National Radiation Monitoring Network. Organization of the National Radiation Monitoring Network as amended by Decree 27/2006 Coll. currently consists of 420 different monitoring points (early warning network, thermoluminescent dosimeter networks, air contamination monitoring points network), 12 laboratories and a range of mobile groups (see *Státní ústav radiační ochrany, v. v. i.*).

Tab. 6.5: Regulatory and Safety Organs for the Czech Nuclear Sector and Their Role	
Organ	**State Office for Nuclear Safety (SUJB)**
Headquarters	Prague, Senovazne namesti 9
Web	www.sujb.cz
Role	Its scope of authority, given by The Atomic Act No. 18/1997 Coll., Act No 19/1997 Coll. and by Act No. 281/2002 Coll., among others embraces the performance of state supervision of nuclear activities, nuclear items, physical protection of nuclear facilities, radioactive protection and emergency preparedness in the premises of a nuclear facility or of a workplace with sources of ionizing radiation; issuing authorizations for activities governed by Act No. 18/1997 Coll., for example, to placing and operating a nuclear facility or a workplace exposed to sources of high-level ionizing radiation, management of sources of ionizing radiation and radioactive waste, transport of nuclear materials and radionuclide emitters; approving documentation with reference to nuclear safety and radioactive protection set by The Atomic Act, to limits and terms of nuclear facilities' working process, means for assuring physical protection, emergency rules for transportation of nuclear materials and particular radionuclide emitters, internal emergency plans of nuclear facilities and workplaces exposed to sources of ionizing radiation; monitoring the level of radiation capturing residents and workers operating with sources of ionizing radiation; a competent cooperation with the International Atomic Energy Agency; coordination and security of activities while meeting the imperatives resulting from Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction within the meaning of Act No. 19/1997 Coll. and from the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction within the meaning of Act No. 281/2002 Coll., as well as the performance of the function of the national authority according to The Comprehensive Nuclear Test Ban Treaty, from Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction and Convention on the Prohibition of the Development, Production and. Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction.
Organ	**The National Institute for Nuclear, Chemical and Biological Protection (SUJCHBO)**
Headquarters	Milin, Kamenna 71
Web	www.sujchbo.cz
Role	The National Institute for Nuclear, Chemical and Biological Protection is the public research institution founded by the State Office for Nuclear Safety on the basis of Act No. 281/2002 Coll. aimed at providing research and development activities in the field of chemical, biological and radioactive substances and safety of technical support of supervision and inspection activities performed by the Office in the areas of radioactive protection and monitoring of the ban on the development, production, stockpiling and use of chemical and biological weapons. Research activity aims at identifying and quantifying radioactive, chemical and biological materials, assessing their impact on people and the environment, including the assessment and development of individual and collective means of human protection from these substances, decontamination and safety research as part of the fight against terrorism as well as against severe industrial accidents.
Organ	**National Radiation Protection Institute (SURO)**
Headquarters	Prague, Bartoskova 28
Web	www.suro.cz
Role	The main subject of the Institute's activity is research into protection from ionizing radiation, including the arrangement of the infrastructure of this research, specifically in the fields of safety research, research of the Radiation Monitoring Network and research into exposure to artificial sources of ionizing radiation (nuclear facilities, in the first place), research into medical exposure and research into exposure to natural sources of radiation. Other activities include support to state supervision and monitoring of prevention, support to the inspectors during their monitoring activities in the fields of radiation protection, emergency preparedness, including departures and interventions, ensuring the laboratory activities for founders, performing the function of an analytical and conceptual workplace for analysis of impacts following nuclear and radioactive accidents and preparing the drafting of measures, advisory and consulting services, education and public enlightenment, etc.
Organ	**Radioactive Waste Repository Authority (SÚRAO)**
Headquarters	Prague, Dlazdena 6
Web	www.surao.cz, www.rawra.cz

Role	The Authority's major tasks and activities are the preparation, construction, operation initiation, operation and shutdown of radioactive waste repositories and the monitoring of their environmental impact; ensuring the processing of spent or radioactive nuclear fuel to a form adequate for depositing or further use; keeping a record of received nuclear fuel and of its producers; managing levies of radioactive waste authors to the nuclear account; preparation of proposals with reference to the establishment of payers' levies to the nuclear account; management of radioactive waste which was brought to the Czech Republic from abroad and cannot be returned, etc. Since 2000, it has been regulating all radioactive waste repositories in the Czech Republic: Richard, Brotherhood, Dukovany and Hostim. It coordinates all work aiming at preparation and construction of a deep geological repository of high-activity radioactive waste and spent nuclear fuel, the launch of which is estimated in around 2065.
Sources: *Zákon 458/2000*; *Zákon ze dne 24. ledna 1997; Státní úřad pro jadernou bezpečnost.*; *Státní ústav radiační ochrany, v. v. i.*; *Správa úložišť radioaktivních odpadů*; composed by T. Vlček.	

The SUJB is the founder of two public research institutes, namely the National Institute of Nuclear, Chemical and Biological Safety (SUJCHBO) and the National Radiation Protection Institute (SURO). Their role is not a regulatory one, but they have great importance in terms of protection against ionizing radiation. The Radioactive Waste Repository Authority (SURAO) has a similar protective role.

The important agents at the level of the supranational legal framework are the European Atomic Energy Community (EURATOM) and the United Nations mediated by the International Atomic Energy Agency (IAEA).

EURATOM was founded on March 25, 1957, in Rome and it has its headquarters in Brussels. Given that nuclear safety, naturally, represents one of the priority fields of EURATOM, this organ issues a vast number of directives and recommendations aimed at unifying the practice of radiation protection in all member states, whereas the directives cover this radiation protection in a comprehensive manner; from the basic principles and medical use of radioactive materials through to transport of radioactive substances. These directives were implemented in the Czech legal framework on the *acquis communautaire* basis either through The Atomic Act amendments or SUJB decrees.

The most complex legislative changes imposed from the outside took place as a result of the accession negotiations of the Czech Republic to the European Union, on which occasion a White Paper of the European Commission on Preparing the Associated Countries of Central and Eastern Europe for Integration into the Internal Market of the Union was adopted in 1995 (see Commission of the European Communities, 1995). A White Paper brought several important directives with reference to the nuclear energy field, which are the Directive on shipments of radioactive waste No. 92/3/EURATOM, supplemented by Directive No. 93/552/EURATOM (both were then altered by Directive No. 2006/117/EURATOM), Directive on basic safety standards No. 96/29/EURATOM, referring to maximum permissible doses of radioactive contamination of food arising after a radioactive emergency (accident), the import of agricultural products following the accident in Chernobyl or shipments of radioactive materials. Beside the White Paper, the Czech Republic also adopted a string of directives addressing the radioactive protection of the public, workers, patients as well as the information standard of residents.

The IAEA emerged on June 29, 1957, in Vienna, which is also its current location. The former Czechoslovakia was a member from the Agency's founding, while the Czech Republic joined on January 1, 1993. The Mission of the Agency is to enforce the safe and peaceful use of nuclear technologies. Unequivocally the key carrier of this mission is The Treaty on the Non-Proliferation of Nuclear Weapons, NPT), which entered into effect on March 5, 1970, and it was in 1995 prolonged for an indefinite period. With respect to energy safety, one of the goals of the Treaty is monitoring and cooperation during peaceful nuclear activities (see Závěšický, 2005, p. 132). IAEA is the exclusive monitor in the field of peaceful use of nuclear energy, resting on a unique monitoring mechanism based on the political will of states to make their nuclear facilities available to this monitoring. By doing this, a state demonstrates that it has fulfilled its obligation resulting from the Non-Proliferation Treaty and its additional protocols.

By its mandate given by the Articles of Association/Statute, the IAEA is obliged to promote the peaceful use of nuclear energy and to control whether secret abuse for military purposes does not take place. A special type of inspector was established for this monitoring function, which on the basis of bilateral agreements of member states with EURATOM, Safeguard Agreements, execute regular inspections of all declared nuclear facilities in the countries not possessing nuclear weapons and non-military facilities in countries which *do* possess the weapons (see "*Stálá mise,"* 2010). Until 2009 the initial agreement between IAEA and Czechoslovakia from March 1972 was in charge, while the Czech Republic on October 1, 2009 approached a Trilateral Safeguard Agreement (INFCIRC/193 or also 78/164/EURATOM). The Czech Republic, therefore, accepted the commitment to approach trilateral agreements between EU member states not possessing nuclear weapons, EURATOM and IAEA as part of the IAEA safeguard system (see SÚJB, n.d.a). Based on the Trilateral Safeguard Agreement and within the meaning of Commission Decree No. 302/2005/EURATOM from February 8, 2005, on implementation of EURATOM safeguards, starting from 2005, inspections of nuclear facilities are performed by both IAEA and EURATOM inspectors.

When speaking of supranational regulation, the European Nuclear Safety Regulators Group, (ENSREG) should not be understated, as an independent body initiated in 2007 resulting from a Decision of the European Commission. The ENSREG consists both of EU members and officials from national nuclear safety offices, radioactive waste management offices and radioactive protection offices of all EU member states. The ENSREG's goal is reaching mutual understanding and development in the fields of nuclear safety and management of radioactive waste (see The European Nuclear Safety Regulators Group).

6.5 Demand Forecast

According to forecasts, power use will increase in the Czech Republic, while the country is accordingly limited by the current setting of the energy mix with a predominant share of the coal sector. Table 6.6 displays a comparison of goals declared in the State Energy Concept and its revisions with reference to consumption of energy sources by 2050. It is evident that the role of the nuclear sector in the Czech power industry will most likely improve to make up a third of all energy sources in the Czech Republic. In terms of installed capacity of nuclear power plants, scenarios also count on the increased capacity of existing blocks, whereas the actual installed capacity of nuclear power plants was 4,404 MWe as of December 31, 2012 (see table No. 6.1), and in the case of Temelin's completion, installed capacity will by 2030 be approximately 6,440 MWe (excluding the potential construction of the new block in the Dukovany power plant).

Tab. 6.6: The Shares of Solid, Liquid and Gas Fuels in Energy Resource Consumption According to the State Energy Policy of the Czech Republic from 2004 and Its Revisions from February 2010 and August 2012 (in %)

Type of Fuel	Level in 2000	Level in 2005	Level in 2008	Long-Term Goal (SEP 2004) by 2030	"Green" Scenario (SEP 2004) year 2030	Revised SEP (2/2010) Scenario by 2030	Revised SEP Scenario (2/2010) by 2050	Revised SEP (8/2012) Target Values by 2040
Solid	52.4	42.5	45.3	30-32	30.5	24	20	12-17
Gas	18.9	21.6	15.7	20-22	20.6	20	21	20-25
Liquid	18.6	15.7	20.9	11-12	11.9	20	19	14-17
Nuclear	**8.9**	**16.5**	**15.3**	**20-22**	**20.9**	**25**	**25**	**30-35**
Renewables	2.6	5.4	2.9	15-16	15.7	11	15	17-22

Source: *Státní energetická koncepce, 2004*, p. 11-12, 40-49; Ministerstvo průmyslu a obchodu, 2010a, p. 77-92; Český statistický úřad, 2008; Ministerstvo průmyslu a obchodu, 2012, p. 20-21.

According to the 2/2010 Revision, the mining of uranium should be "supported should it provide full compliance with the requirements of nature and landscape protection, applications for exploration areas should not be blocked, while mining should from now on be run by a state company. Continuation of uranium mining should be ensured by opening a new deposit already during the active operation of the Rozna Mine, in order not to lose the valuable know–how of the Czech uranium industry, whereas reversing the declining trend of the domestic production of uranium concentrate is also a requirement" (see MPO, 2010a, p. 31, 40). Revision even mentions the possibility to "support the potential construction of uranium concentrate processing plants in the Czech Republic with regard to enhancing energy security of the country (and for production for the Central European market) and screen the potential construction of the spent fuel processing plants" (see MPO, 2010a, p. 31).

The Government has several times declared its clear stance on the development of the nuclear sector (and completion of the Temelin nuclear power plant), while the Prime Minister, Petr Necas, declared at the 11th Energy Congress of the Czech Republic that the Czech Republic "intends to continue to run the Temelin and Dukovany nuclear power plants and to continue the process that will lead to the construction of additional nuclear units" (see Nečas, 2011, p. 199). The Dukovany nuclear power plant also has a much greater potential, as there is, according to its chairman, Tomas Zak, "producing potential at the site of Dukovany, given by the exterior conditions, around 3,000 to 3,500 MW by applying existing technologies, while there are more possibilities than that" (see Cieslar, 2010e).

Confidence in nuclear energy and interest in its development and completion is in a relatively stable manner demonstrated by the Chamber of Deputies. In May 2008, 190 deputies voted for completion of the Temelin nuclear power plant, in June 2010, it was 186 of them, and in April 2011, it was 181 out of a total of 200 deputies who supported this project (see Pravec, 2011, p. 44-45). As of the latter, the decision of the remaining four deputies was associated with events related to the Japanese Fukushima Daiichi nuclear power plant.

In 1980, Ludvik Kopacka wrote that "nuclear energy is truly becoming a developing energy source in the Czechoslovak context, which will gradually assume the role of covering increasing energy demand and gradually the increasing consumption of primary sources as well" (see Kopačka, 1980, p. 214-215). This idea basically remains applicable even in the second decade of the third millennium. The Paces Commission argues that "in the course of around 2020–2030, the lifespan of the existing nuclear power plants should be prolonged for at least 60 years, while the increase in energy consumption in the Czech Republic and the replacement of gradually closing coal-fired power plants in terms of their basic capacity should be covered by building new nuclear power plants, reaching the share in power production today already existing in France, for example (77 %)", and "in the course of around 2040–2050, to initiate the construction of fast reactors" (see ÚVČR&NEK, 2008, p. 108-109).

Based on this information, it is rather evident that the Czech Republic has a firm position regarding the development of nuclear industry, that this sector is not indifferent to it and that it has a very important potential for energy and supply safety of the Czech Republic and that the Czech Republic counts on the increasing use of this sort of energy both in the short and long term. We can say that state energy policies as well as the State Energy Concepts and their revisions support the development of the nuclear industry, while the intensity of this support grows with every new legislative or conceptual document. Table No. 6.9. clearly displays the increasing interest in nuclear energy, where every new document affords it a gradually broader share in primary sources consumption, specifically from 20 % in the 2004 State Energy Concept up to 35 % in the revised version of State Energy Policy (8/2012).

Unlike coal and natural gas, there is no legal obligation to keep reserves of uranium (OECD Nuclear Energy Agency / IEAE, 2008, p. 171), not even resulting from the membership in IAEA or EURATOM. One of many objectives declared in the so far applicable 2004 State Energy Concept is the generation of "nuclear fuel strategic reserves in a form adequate for filling up the reactor" (see *"SEK",* 2004, p. 27), which is, however, not binding. With regard to the high density of nuclear power plant fuel, the relative stability of its price and the vast number of active producers of uranium concentrate as well as the substantial number of processing institutions, it is possible to stock up for a decade in advance. The Revision of the State Energy Concept from February 2010, however, includes a reference to considering the possibility "to create strategic reserves of uranium concentrate relative to the increasing share of production in nuclear power plants and development of mining" (see MPO, 2010a, p. 29). Based on the following tables, it is evident that such thinking is definitely substantiated.

Tab. 6.7: Forecast of Uranium Concentrate Production in the Czech Republic (tonnes per year)

2005 (level)	**2007** (level)	**2009** (level)	**2010**	**2015**	**2020**	**2025**	**2030**
409	291	243	200	50	50	40	30

Source: OECD Nuclear Energy Agency, 2009, p. 42-43; Ministerstvo životního prostředí / Česká geologická služba – Geofond, 2010, p. 199; modified by T. Vlček.

Tab. 6.8: Forecast of Uranium Concentrate Demand in the Czech Republic (tonnes per year)

2007 (level)	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
772	860–870	670–680	675–880	830–1000	830–1000	830–1000

Source: OECD Nuclear Energy Agency, 2009, p. 44-45.

Revision of the State Energy Concept (2/2010) intended to ensure energy security of the country by setting a legal framework which would oblige nuclear power plant operators to keep reserves of nuclear fuels (fuel rods)[144]. The period of maximum use of a specific nuclear power plant, which obligatory reserves will be requested for, should be set so as to, in case of a supplier's delivery failure (failure to meet commitments resulting from agreement or impossibility of their enforcement) realistically ensure the provision of a supplementary supplier without jeopardizing the operating process, while considering the development of conversion and processing capacities, supplier's experiences and competition in the world market (see MPO, 2010a, p. 73). This idea also persisted in the Revised State Energy Policy 8/2012, where one of the strategies for increasing energy security and resilience of the Czech Republic was the "keeping of reserves of fuel rods by nuclear power plant operators, warranting facilities' full operating capacity for three years, potentially also by means of reserve contracts on reserving capacity for fuel supplies or by keeping corresponding reserves of enriched uranium and processing fuel on their own within the territory of the Czech Republic" (see MPO, 2012, p. 27).

6.6 Completion of the Temelin Nuclear Power Plant

On August 3, 2009, CEZ released the announcement about opening a call to tender for two new nuclear blocks for the Temelin nuclear power plant. To some extent it was based on the investment plan for the construction of the Temelin power plant with 4 x 1,000 MWe of installed capacity, adopted in February 1979, replicating the construction site itself and some already existing auxiliary systems. Some options which were exclusively in CEZ's interest were originally also a part of the tender, specifically to build three additional nuclear blocks in other potential localities in Europe. (see ČEZ, a. s., 2009a) Currently CEZ, however, does not count on these options and is preparing a separate tender for building the fifth block in Dukovany, which was one of these options. Although it is still not specified where, it will most likely involve the fifth block in Dukovany and two blocks in Slovak Jaslovicke Bohunice. Total capacity of the new nuclear plant has not been finally specified so far, while the propositions embraced the variants 2 x 1,200 MWe or 2 x 1,700 MWe (see Vnouček & Kasembe, 2000, p. II-III). Following the elimination of AREVA SA from the tender, only 2 x 1,200 MWe remained as an option. It is not just the project that is part of the tender, but the construction works itself, which makes the entire endeavour, therefore, a turnkey power plant.

After it is awarded, the overall administrative tender process will last for roughly 7 to 8 years (together with the construction, 15 years), which means that the connection of new blocks is estimated for around 2024. The tender's finale and the signing of the contract by its winner was set at the end of 2011, in October 2010 it was, however, decided that selecting the construction works' supplier must be postponed until 2013 due to the unpreparedness of suppliers, which will naturally lead to a delay in the entire process. According to recent updates, construction is meant to last for 12 years from the day of the tender's awarding. Should the tender truly be awarded in 2013, the power plant would emerge in 2025 (see Zelenka, 2011, p. 28). The deadlines are, however, impossible to meet without altering the applicable construction and permit legislation. The role of the Government's Commissioner for the CEZ, a. s. nuclear tender was given to Vaclav Bartuska, Special Envoy for Energy Security of the Czech Republic.

144 These reserves should be covered by an operator.

Three entities applied to the tender. It was a Consortium of the companies SKODA JS, a. s., from the Czech Republic, Atomstrojexport, a. s., from the Russian Federation (a daughter company of the Russian company ZAO Atomstrojexport[145]) and OKB Gidropress, a. s.[146] from the Russian Federation, offering the project MIR 1200 (Modernized International Reactor) with 1,198 MWe of capacity[147]. The French company Areva SA[148] offered the EPR™ (European Pressurized Reactor) with 1,700 MWe of capacity[149] and finally, the American Company Westinghouse Electric Company, LLC[150], offering the project AP1000 with 1,200 MWe of capacity. All cases refer to the reactors of the III, III+ generation.

Tab. 6.9: Technical Characteristics of the Projects Proposed by Single Nuclear Tender Applicants

Company	Westinghouse Electric Company, LLC	Areva SA	SKODA JS, a. s., Atomstrojexport, a. s., OKB Gidropress, a. s.
Project	AP1000	EPR™	MIR 1200 (AES 2006)
Thermal capacity(MWt)	3,415	4,590	3,200
Electrical capacity (MWe, net / gross)	1,117 / 1,200	1,590 / 1,700	1,113 / 1,198
Efficiency (%)	33	36	33.7
Capacity factor (%)	93	90.3	>98*
Number of cassettes in the active zone	157	241	163
Number of rods in cassettes	264	265	312
Number of steam generators	2	4	4

* Such a high value results from shorter maintenance and refuelling breaks and prolonged fuel campaigns.
Source: Bílý, 2011, p. 268; Company's official documents; selected and modified by T. Vlček.

145 ЗАО Атомстройэкспорт is the leading Russian organization building nuclear power plants abroad and accordingly engaged in their modernization. It is supervised by the Federal Agency for Nuclear Energy, Rosatom (Федеральное агентство по атомной энергии России, РосАтом). A larger part of the shares (50.2 %) of ZAO Atomstrojexport belongs to the companies VPO Zarubežatomenergostroj (44 %; Всероссийское производственное объединение "Зарубежатомэнергострой") and OAO TVEL (6.2 %; ОАО "ТВЭЛ"), which Rosatom controls on behalf of the state, and 49.8 % Gazprombance (ОАО "Газпромбанк").

146 A daughter company of the Russian company OAO OKB Gidropress (ОАО ОКБ "Гидропресс").

147 Based on talks with the Russian side, it is interesting that the tender should have included a seriously intended offer to build a manufacturing plant in the Czech Republic, i.e. a plant for assembling fuel cassettes out of single pallets. According to the Russian calculation, that sort of plant proves profitable for the state if there are at least eight reactors, which is the number the Temelin power plant will reach after completion. This is accordingly an opportunity for fuel fabrication for the Russian type of power plant in Slovakia and elsewhere. The paradox is that in this manner the most frequent comment on the Russian project, i.e. intensification of Czech energy dependence on Russia, to some extent ceases to be logical.

148 The ownership structure is as follows: 73.03 % Commissariat à l'énergie atomique (technological research institution financed by the French Government); 10.17 % French state; 4.82 % Korean car industry Kia Motors and the remaining 11.98 % other companies, employees and publicly traded stocks.

149 The great advantage of this reactor may be found in the high rate of capacity maneuverability.

150 Belonging to the Japanese companies Toshiba Corporation (67 %) and Ishikawajima-Harima Heavy Industries Co. Ltd. (3 %), American mechanical companies The Shaw Group (20 %) and Kazakh state company Kazatomprom NAC (Казатомпром НАК 10 %).

On October 5, 2012, CEZ announced the elimination of the French company Areva from the competition for building new blocks in the Temelin nuclear power plant, because it did not meet the basic commercial and legal terms of the competition (see "*ČEZ vyřadil AREVU"*). Areva submitted an appeal to the Czech Office for the Protection of Competition, which in February 2013, however, found the elimination substantiated. The company intends appeal to the Chairman of the Office, potentially also to forward the matter to the Czech courts.

In the first round of the tender, the subjects of evaluation were, for example, technology, price and safety. According to the results from March 2013, the American company Westinghouse Electric Company, LLC, was the first in this aspect, but the lowest price was, however, offered by the Russian-Czech consortium. CEZ is currently working on improving its negotiating position in relation to the tender applicants and also on deciding if the construction will take place in the first place. The AP1000 reactor is in many aspects *a revolutionary one,* with an advantage drawing from its modular construction, which, on the other hand, poses a problem in terms that it has not been tried before and that it could, therefore, potentially limit the inclusion of domestic companies in the project. MIR is *an evolutionary* reactor based on the long history of VVER reactors as well as on Russian experience with breakdowns. It is a tested and cheaper reactor, but, on the other hand, the technologically older one.

Although CEZ argues that the construction of new nuclear blocks arises from the applicable State Energy Concept, Policy of Spatial Development and the conclusion of the Paces energy commission (see ČEZ, a. s., 2009a), the company has been criticized for its poor communication with the majority stakeholder during the tender's preparation[151]. It is the greatest tender in the world and, according to Deputy Minister of Industry and Trade, Tomas Huner, the state will have its own part in it so to ensure full control over it: "The state has very strong options. It can change the Statute and it can directly express its opinion regarding the tender, bypassing the General Meeting of Stakeholders, where 70 % of shares are owned by CEZ. It also has the bluntest tool in its hands, that is the ability to even replace the management" (see Rafaelová, 2009).

In terms of the nuclear sector, the Government's policy statement is clear. It expresses the state's will to support both the construction of new blocks in the Temelin nuclear power plant and modernization of the Dukovany nuclear power plant, including the accompanying range of buildings so as to achieve a balanced energy mix. The state will, furthermore, proceed with its transparent approach while searching for sites for radioactive waste repositories, including support for other options leading to their decommissioning (see VČR, 2010a, p. 37). The Government, with respect to the development of the nuclear industry, is behaving in a very coherent and conceptual manner, arising from state energy policies as well as from State Energy Concept and its so far unapproved revision.

When the Expert Working Group for Energy Security in 2006 submitted its conclusions regarding Czech energy to the Committee for the Foreign Security Policy Coordination, it recommended prolonging the lifespan of the Dukovany and Temelin nuclear power plants, for the state to create the conditions for further quantitative and qualitative development of the nuclear sector and to seek to increase electricity production through the framework of the existing localities – in other words, to complete the Temelin nuclear power plant and, in the further perspective, also the facilities in the originally planned localities (Blahutovice[152]), whereas it is for diversification reasons recommended to have the new technologies supplied

151 The state, however, *was* informed, although probably indirectly. Already in July 2008, CEZ asked the Ministry of the Environment to assess the environmental impact of the intended completion of the Temelin nuclear power plant.

152 General Director of CEZ, Martin Roman, in May 2011 indicated the possibility of building a nuclear power plant in Blahutovice as "the very distant future", which would get its turn only after completion of the Temelin and Dukovany power plants, therefore not before 2040 (see "*Otázky Václava Moravce"*, 2009).

from EU countries (see Odborná pracovní skupina pro energetickou bezpečnost [OPSpEB], 2006, p. 14). The document also recommends "the restoration of uranium mining, because for the major construction of nuclear sources in the Russian Federation and, in parallel, unchanging capacity of nuclear fuel production, there could be a shortage of that fuel. A country capable of supplying its own uranium and asking only for its processing into fuel will be unambiguously at an advantage in comparison to those who asking for the complete purchasing of fuel" (see OPSpEB, 2006, p. 8-9). The discussed revision of The Atomic Act also advocates the development of uranium mining, which should enable the allocation of funds from the nuclear account also to municipalities subject to mining exploration related to a deep geological repository, which could be a good way to reach a consensus between the state's and municipalities' interests while searching for a proper locality for building this deep geological repository.

"Preparation of and proceeding with a schedule of a supplier selection process for the completion of Temelin nuclear power plant has been approved, and I hereby wish to confirm that this plan has stayed unchanged. The Government wishes and, through the means of its share in CEZ will achieve having a winner known by the end of 2013", are the words of Prime Minister, Petr Necas, at the 11th Energy Congress of the Czech Republic (see Nečas, 2011, p. 199-200). CEZ has been preparing very seriously for the Temelin project. Among these, on April 1, 2009, a new division, Construction of Nuclear Power Plants, emerged, coordinating the preparation of nuclear projects not only within the Czech Republic (Temelin and Dukovany), but also abroad (Jaslovske Bohunice – Slovakia) (see ČEZ, a. s., 2010b, p. 5). The inclination of the Czech residents to the nuclear sector is not just a relic of an open attitude towards heavy mechanical industry and a centralized power industry in past years, but also the success of CEZ's public relations policy.

Large coal power plants in the Czech Republic, Poland and Germany will be gradually shut down in forthcoming years due to age (after 2020, this is the scenario awaiting all Czech coal-fired power plants, aside from the new Ledvice and modernized Tusmice and Prunerov), the Czech Republic presently has difficulties with building any larger blocks (only the Pocerady combined cycle power plant and Ledvice power plant are in the building process), problems with integration of renewables are forcing the state to search for strong investments into regulatory energy and regulatory management, the political decision to depart from nuclear energy in Germany[153], all of these pose a serious threat of a power shortage from 2015 approximately to the period of expected completion of Temelin (while the situation on the market has already confirmed this threat following the disconnection of the German nuclear power plants after the incident in Fukushima). These circumstances, therefore, partially play into hands of the Temelin's completion with nuclear blocks with 2 x 1,700 MWe of installed capacity, regardless of substantially larger investments necessary for the transmission system than in the case of other two offers.[154]

Former Minister of Industry and Trade, Martin Kocourek, however, points to a particular deceleration of nuclear energy development tied to the accident in the Fukushima Daiichi nuclear power plant. "The security of these devices will be, without doubt, discussed in a comprehensive and rational manner, while the engineers will have to invent better ways of handling operation under emergency conditions" (see Kocourek, 2011, p. 11). This event together with the opposition of some organizations in the Czech Republic

153 After the accident in Fukushima Daiichi, Germany immediately suspended the operation of its eight older nuclear power plants, while the expert commission assessing their re-launch in May 2011 recommended leaving them closed. The Ethics Commission then decided to shut down all nuclear power plants by 2021, resp. 2022. The departure from the nuclear industry is not new for Germany, as it had six nuclear reactors closed within the territory of German Democratic Republic immediately after the unification of Germany in 1990, while the construction of five reactors already in the building process (Stendal nuclear power plant) was postponed and then entirely terminated a year after.

154 For more details, see the Chapter about the electric power industry.

will represent the greatest limit of nuclear sector development from now on.[155]

The strongest protest against the completion of the Temelin nuclear power plant comes from the organizations DUHA Movement, South Bohemian Mothers, Greenpeace, Calla – Association for Preservation of the Environment, Citizens' Initiative for Environmental Protection, Green Circle and the above-mentioned Green Party. The idea common to all these organizations can be summed by the words of Martin Sedlak from the DUHA Movement: "The Czech Republic will make do without additional reactors. Green sources in combination with the enormous potential of increased efficiency can ensure enough energy for Czech households and industry. The new nuclear power plant looks like a mere footnote in comparison to these clean solutions. They, moreover, have an indisputable advantage as the costs of renewables decline and in the course of ten years they will be stepping on atom's toes" (see Jihočeské matky, 2011).

The DUHA movement also highlights the incapacity of some tender applicants to meet set deadlines, with a pretext of ongoing projects world-wide (see Polanecký & Sedlák, 2010). Their arguments should definitely be taken into consideration, as one of the pressing issues which organizations are warning about is the limited liability of the operator running the nuclear power plants across the Czech Republic for nuclear damage. "Should a serious accident occur in Temelin, all affected would together receive only six billion CZK. CEZ would in that case, paradoxically, receive 35 billion CZK from the insurance companies," says Martin Sedlak (see Sedlák, 2009, p. 31). According to environmental organizations, CEZ must take a full financial responsibility for nuclear damage, because the current limit of 8 billion CZK is insufficient and does not even correspond to the adopted international conventions (see Jihočeské matky, 2011).

Tab. 6.10: Comparison of Some Economic and Environmental Advantages and Disadvantages of Nuclear and Thermal Power Plants

Subject of Comparison	Nuclear Power Plant	Thermal Power Plant
Fly ash emissions	No	Only coal power plants
SO_2 and NO_x emissions	No	Yes
Operational spillage of radioactive materials	Yes (small amount)	Yes (small amount)
Ratio of produced energy per mass unit of fuel	2,100 GJ / kg	0.033 GJ / kg
Costs of fuel transport	Low	High
Exhaustibility of fuel sources	Yes (later than in the case of fossil fuels)	Yes
Amount of "ash" resp. of spent fuel	Small	Great
Costs of spent fuel liquidation	High (mainly resulting from the dangerousness and necessity of the long term deposition)	High (mainly resulting from greater volume)
Risk of a big accident	Small	Great
Consequences in case of big accident	Great	Small
Source: *Fyzikální aspekty zátěží životního prostředí,* 2008, p. 24; modified by T. Vlček.		

The safety of nuclear power plants is also subject to criticism, and especially in terms of spent nuclear fuel. Table 6.10 clearly illustrates that nuclear power plants are during regular operation much less risky than the thermal ones under conditions of notable energy density. In the event of a great accident, a nuclear

155 On the other hand, the accident in Fukushima Daiichi means work for Czech nuclear physicists as the escalation of monitoring and various tests of existing nuclear power plants will most probably become an interesting business, which the Institute of Nuclear Research in Rez is preparing for at the level of the Czech Republic (for more details see Korbel & Kostka, 2011, p. 30).

power plant is, nonetheless, unequivocally the most risky type of power plant and the criticism is here substantiated. The State Office for Nuclear Safety regularly and strictly monitors the existing nuclear power plants[156], while testing of both nuclear power plants was scheduled for 2011 even prior to the accident in the Japanese power plant.

As a result of the Fukushima Daiichi accident, in 2011 stress tests were carried out. These tests were done in three parts. The first was implemented on individual nuclear plant operators (i.e. CEZ), the other was executed by national regulators (SUJB) and the third involved the monitoring of inspectors from other countries (European Nuclear Safety Regulators Group[157], hence the European Commission) (see Macková, 2011; SÚJB, n.d.b). This plan was presented and confirmed in April 2011 in Vienna at the Convention on Nuclear Safety Fifth Review Meeting.

At the European Nuclear Energy Forum in May 2011 in Prague, Special Envoy for Energy Security the Czech Republic, Vaclav Varuska, said "European nuclear power plants should not undergo uniform stress tests, because there are different types of reactor in Europe and likewise unified tests cannot be implemented on, for example, motor bikes, cars and cargo vehicles" (see Egger & Schweiger, 2011). The Austrian association Atomstopp oberoesterreich immediately reacted with strong criticism of Czech nuclear plants' safety [158] (see Egger & Schweiger, 2011). The Czech Republic has in reality, however, executed the stress tests alone (like France, for example), while their form was delineated by the Ministry of Industry and Trade together with the SUJB. Preparatory work started already in April and the nuclear power plant operator had time to implement them by the end of September. In addition to the impact of natural disasters (for example, a tsunami or earthquake[159]), the possible effects of extremely high or low temperatures was tested as well (see ČTK, 2011). If the European Union orders the execution of further tests, they would be implemented additionally.

The final report following the process of mutual evaluation of nuclear plants' resistance by the members of the EU27 both for Temelin and Dukovany power plants was as follows: "No conditions were identified that would require an immediate solution. The power plant is able to safely manage even highly improbable extreme emergency conditions without posing any threat to its vicinity" (see ČEZ, a.s., 2011a; ČEZ, a.s., 2011b).

Although the completion of the Temelin nuclear power plant and further development of the nuclear sector in the Czech Republic is a priority and a conceptual matter for the Czech Government, these goals, however, remain so far uncertain. Aside from the abovementioned problems, the situation is not getting any better also due to the financial insufficiency of the main investor, CEZ, resulting from problematic investments it made in the Balkans in recent years. Martin Roman, former General Director of CEZ however justifies these investments by arguing that it was both a little above a fifth of overall CEZ investments and, accordingly, that foreign investments in the amount of 70 billion CZK have already in the last five years generated a cumulative profit of approximately 40 billion CZK. Investments are allegedly returning faster than expected (see "*Otázky Václava Moravce*", 2011).

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156 In relation to the character of the accident in Fukushima, it should be added that each Czech block has backup sources of power in the amount of three separate diesel aggregates, which are furthermore secured with batteries.

157 European Nuclear Safety Regulators Group, ENSREG.

158 With regard to the Austrian reaction, we should turn to Vaclav Baran who concludes that antinuclear movements are primarily an ideology in Austria, having little to do with rationality and which "safely know how to free the world from threats" (see Baran, 2002, p. 36). On this basis we can conclude that the Czech Republic will probably never satisfy Austrian criticism, regardless of a vast number of talks and agreements closed.

159 Seismic resistance of nuclear facilities in Czechoslovakia was set by the state standard at five on the Richter scale (see Blažek, 2009, p. 60).

CEZ is still at any rate looking for options of how to ensure good conditions for such a high investment. One of the variants is a permanent guarantee of purchase prices from new Temelin blocks provided by the state or a guarantee of the investment's return. According to the latest information, the Ministry of Industry and Trade headed by Martin Kuba disagrees with both options and proposes a short-term system which would provide CEZ with state support in case the market prices go lower than the prices agreed, and, in the opposite case, expect the company to allocate the surplus to the state (see "*Kuba je proti trvalé"*). We should, therefore, expect long and complicated discussions, where the position of the players involved will change many times.

According to Ladislav Blazek, Former Development Deputy of the Federal Ministry of Energy and one of the leading Czech experts in the field of mechanical mine installations, energy and gasworks, the prospects of this sector are entirely evident. "Without developing the nuclear industry, the Czech Republic can only barely make do, if it wishes to achieve energy independence, complete its commitments of emissions reduction and if it does not wish to waste the experience which was gained. No responsible politician can deny the need to construct additional sources of nuclear energy in the shortest period possible, if he or she does not wish to speculatively lower the hard won energy self-sufficiency of the Czech Republic" (see Blažek, 2009, p. 68).

Appendix 2.2

JIRUŠEK, Martin, Tomáš VLČEK, Hedvika KOĎOUSKOVÁ, Roger W. ROBINSON, Anna LESHCHENKO, Filip ČERNOCH, Lukáš LEHOTSKÝ and Veronika ZAPLETALOVÁ. *Energy Security in Central and Eastern Europe and the Operations of Russian State-Owned Energy Enterprises*. Brno: Masarykova univerzita, 2015. 696 p. ISBN 978-80-210-8048-5. doi:10.5817/CZ.MUNI.M210-8048-2015. pp. 73-287, 338-362

Chapter 4

Sector of Nuclear Energy in Central and Eastern Europe

4.1 Country Case Study: Belarus

Tomáš Vlček

4.1.1 Introduction

Belarus is a landlocked country bordering with Russian Federation, Ukraine, Poland, Lithuania and Latvia. Belarus declared independence at the end of the WWI just to be occupied by Soviet troops shortly after and eventually incorporated to USSR as Belarusian Soviet Socialist Republic from 1919. After the Russian-Polish war the country was divided between these two states. The USSR has taken back the Polish part in 1939 and Belarus was not an independent state until July 1990 when Republic of Belarus was created. In 1994, Alexander Lukashenko was elected president of Belarus; he was reelected again for the second term (2001-2006), the third term (2006-2011) and also the fourth term (2011-2016). The election process especially for the fourth term had been criticized as flawed by most EU and OSCE countries. As a result, Lukashenko and his associates are forbidden to travel to EU member countries. Belarus is also very well known for his authoritative leadership (sometimes called as Europe's last dictatorship), oppression and corruption.

Belarusian economy has been steadily growing since 1996 due to socially oriented economic policy of the state, favorable market conditions in the Russian Federation and EU countries for the export of Belarusian goods and an increase in labor productivity (Energy Charter Secretariat, 2013, p. 20).

Belarusian energy sector is heavily reliant on hydrocarbons, especially natural gas consisting 66% of Belarus' TPES and 97.1% of electricity generation share in 2010. Natural gas is imported explicitly from Russian Federation through Yamal-Europe gas pipeline. Belarus is also a crucial transit country for both natural gas and crude oil supplies to Europe. The Yamal-Europe gas pipeline and the Druzhba crude oil pipeline continue through CEE countries and end in Germany and the Czech Republic.

Tab. 4.1.1: Key Energy Statistics

Source	Consumption	Imports	TPES share	Electricity Generation share
Crude Oil	7.59 Mt	193%	25.7%	2.4%
Natural Gas	21.8 bcm	99%	66%	97.1%
Coal (all types)	0.15 Mt	87%	2%	0.1%
RES	-	-	5.5%	0.4%
Nuclear Energy	-	-	0%	0%
Note: 2010 data				

Source: *U.S. Energy Information Administration; International Energy Agency*; compiled and calculated by T. Vlcek

Belarus imports nearly twice as much crude oil as it consumes. The reason for this is the existence of Mozyr refinery owned by the company JSC "Mozyr Oil Refinery"[1]. The refinery has 4.75 Mt/y design capacity.

[1] The ownership structure consists of 42.76% Government of Republic Belarus; 42.58% OAO NGK Slavneft; 12.25% non-state individuals and entities; 2.41% other stakeholders. 99.8% of OAO NGK Slavneft is owned by Russian companies OAO NK RussNeft and OAO Gazprom Neft (JSC "Mozyr Oil Refinery").

The top electricity generation source is by far natural gas and there is practically no diversified electricity generation mix and diversified natural gas supply. This leads to regular Russia-Belarus disputes over gas prices that once (in 2004) escalated to a complete shutdown of gas supplies to Belarus. The full dependence on Russian Federation in natural gas and therefore also electricity production, and also in crude oil, together with the fact that Belarus' domestic electricity production does not cover the demand and Belarus imports electricity, are the main reasons for the construction of the Ostrovets NPP.

In 2010, 34.9 TWh of electricity was generated and around 32.7 TWh annually is produced on average in Belarus. The country imports another 4.4 TWh annually on average to cover its electricity demand (International Energy Agency). The country's electricity sector is managed by state-owned GPO BelEnergo divided into six areas with six subsidiary companies (Minskenergo, Gomelenergo, Brestenergo, Grodnoenergo, Vitebskenergo, Mogilevenergo). The installed capacity in GPO BelEnergo is 8,506.2 MWe in 2014 (ГПО "Белэнерго") and the total installed capacity in Belarus is 9,221.2 MWe in 2014 (Popov, 2014, p. 15).

Belarus is connected via electricity interconnectors with Russian Federation, Ukraine, Poland and Lithuania. There are three 330 kV lines to Russia and one 750 kV line to Russian Smolensk NPP with three RBMK-1000 reactors of 1,000 MWe each. There are two 330 kV interconnections to Ukraine (one from Chernobyl NPP) and five 330 kV interconnections with Lithuania (three from the Ignalina NPP). One 220 kV and two 110 kV interconnections heads to Poland (ГПО "Белэнерго").

Tab. 4.1.2: Gas Power Plants (100 MWe+) in Belarus

Power Plant	Installed Capacity	Fuel	Year of Construction
Novopolotskaya CHP	505 MWe	Gas, HFO	1962
Lukomlskaya TPP	2,462.6 MWe	Gas	1969
Mogilevskaya-2 CHP	345 MWe	Gas, HFO	-
Minskaya-3 CHP CCGT	542 MWe	Gas	-
Minskaya-4 CHP	1,035 MWe	Gas, HFO	1977
Minskaya-5 CHP CCGT	720 MWe	Gas	-
Bobruiskaya-2 CHP	182.6 MWe	Gas, HFO	1976
Svetlogorskaya CHP	155 MWe	Gas, HFO	-
Gomelskaya-2 CHP	544 MWe	Gas	1986
Mozyrskaya TPP	195 MWe	Gas, HFO	1974
Grodnenskaya-2 CHP	302.45 MWe	Gas	1970
Berezovskaya CHP	958.12 MWe	Gas, HFO	1961-1967
Note: CHP = Combined Heat Power Plant; TPP = Thermal Power Plant; HFO = Heavy Fuel Oil; CCGT - Combined Cycle Gas Turbine			

Source: *Global Energy Observatory*; ГПО "Белэнерго"

4.1.2 New Units and Financing of the Nuclear Power Plant

Belarus had some experience of building a nuclear power plant because construction of a 2,000 MWe plant comprising two Russian design VVER-1000 reactors began in 1983, at a site 35 km from Minsk. Work stopped in 1988, two years after the Chernobyl accident, and eventually a thermal power plant was constructed on this site (Kovynev, 2014).

The reasons described above led Belarus to adopt a decision to construct a nuclear power plant in 2006. The site selection process was difficult as there were many potentially optimal places. But after consultations with experts from the IAEA, Russia, Ukraine and other countries, two sites were identified and eventually the site near the town of Ostrovets, in the Grodno region, 150 km from Minsk, was chosen and approved by IAEA missions in 2008 (Kovynev, 2014).

After expressions of interest were invited by the Republic of Belarus, four proposals have been received in 2008 from Atomstroyexport, Westinghouse-Toshiba, Areva and China Guangdong Nuclear Power Corporation. For different reasons, the last three were scrapped; e.g. Areva's EPR was noted too big for the first power plant and US offer would have been too complicated and slow as intergovernmental agreement was needed (WNA, 2014). Russia's Atomstroyexport therefore emerged as the most suitable supplier with the offer of two VVER-1200/V-491 units of combined capacity 2,400 MWe.

Russia's Eximbank offered USD 2 billion credit in 2007 in line to enable purchase of equipment from Russia's Power Machines OJSC Company, the largest power plant engineering company in Russia, as a major part of the overall cost (WNA, 2014). This played definitely an important part in the decision as Belarus has not been able to finance the whole project on its own. Eventually, Russia (most likely the Eximbank and the Vnesheconombank) provided USD 6 billion loan for the construction and this loan was in 2009 and in 2011 renegotiated to final USD 10 billion loan including investment into a new infrastructure to accommodate the remoteness of Ostrovets in northern Belarus (Schneider & Froggat, 2014, p.

26). The term of the loan is 25 years and it is intended to finance 90% of the contract between AtomStroyExport and the Belarus Directorate for Nuclear Power Plant Construction. The whole process and also the particular aspects of the loan and construction contract are very similar to the Bulgarian one, i.e. a NPP delivery on a turnkey basis. Russian companies will receive no share in the company RUP Belarusian NPP, which will remain fully in hands of Belarusian state.

On October 11, 2011, the JSC AtomStroyExport affiliated with Rosatom, and the Belarusian Directorate for Nuclear Power Plant Construction signed the contractual agreement for the construction of power units 1 and 2 of the nuclear power plant in Belarus ("Belarusian Nuclear", 2014). The JSC AtomStroyExport is the general contractor with Russian and Belarus subcontractors, and the state enterprise "Directorate for Nuclear Power Plant Construction" is the customer of preparatory, design and survey works on the construction of the nuclear power plant. This directorate exists under the Nuclear Power Engineering Department of the Ministry of Energy. In December 2013, the directorate was converted to state unitary enterprise RUP Belarusian NPP. The licensing body, the Nuclear and Radiation Safety Department (Gosatomnadzor) of the Ministry for Emergency Situations of the Republic of Belarus was created in 2007 and issued the license for building the nuclear reactor in December 2013.

The construction of the Ostrovets NPP in Belarus started in November 2013 (Unit 1) and May 2014 (Unit 2) and should finish in 2018 (Unit 1) and 2020 (Unit 2). The second nuclear power plant, i.e. Units 3 and 4 at the Ostrovets NPP site is also planned. The construction should start in 2025.

4.1.3 The Front End of the Nuclear Fuel Cycle

As there are no Uranium deposits, and no production, processing and/or fabrication capabilities in Belarus, no Front End information can be presented.

There is an intergovernmental agreement between Belarus and Russia that guarantees the supply of nuclear fuel for the lifetime of the plant. Under this agreement the spent fuel of Russian production will be returned to Russia for reprocessing and temporary storage.

4.1.4 The Service Part of the Nuclear Fuel Cycle

Belarus conducts a small civilian nuclear research. There was a 5 MWt IRT-M nuclear research reactor operating from 1962 to 1988, decommissioned nowadays. It was managed by the Institute for Nuclear Power Engineering of the Academy of Sciences[2]. The institute was divided into three bodies in 1989 forming the Joint Institute for Power and Nuclear Research – Sosny of the National Academy of Sciences of Belarus. The institute now houses two critical assemblies (Yalina-T and Yalina-Booster) for civilian nuclear experiments. Both are not-operational due to lack of funding and the latter is being explored together with the US scientists for conversion to low-enriched fuel (Nuclear Threat Initiative).

However, as there are no nuclear power plants in Belarus, no Service Part information can be presented.

[2] Assisted by over 150 organizations and enterprises of the USSR, in 1985, the Institute created and started-up the world's first mobile nuclear power plant Pamir-630D, unfortunately the project was scrapped due to large amount of emergency shutdowns. There was also a project of pilot nuclear power station with a fast breeder reactor BRIG-300 (electric output of 300 MW) that was scrapped shortly before construction was about to begin (The Joint Institute for Power and Nuclear Research – Sosny; Nuclear Threat Initiative).

4.1.5 The Back End of the Nuclear Fuel Cycle

The irradiated material at Sosny and spent fuel was transported to the Russian Federation to be stored or reprocessed. Low-level waste is stored in the Spent Fuel Storage facility under the Institute of Atomic Energy in Minsk (State enterprise for nonreactor radioactive waste management) or in the underground storage facility near Sosny (Nuclear Threat Initiative).

The spent fuel from the Ostrovets NPP will be stored and actively cooled in storage pools next to the reactor for 5-10 years. Besides the small Sosny and Minsk storage facilities, there is currently no spent fuel repository in Belarus. An Intermediate storage for spent fuel in dry containers for 50 years is part of the Ostrovets NPP construction project.

As part of the contract, for the life of the plant, the used fuel will be repatriated to Russian Federation. It will be reprocessed there and the separated wastes returned to Belarus eventually. B. Popov suggests there might be an option to choose whether to dispose the separated wastes at home or abroad (WNA, 2014; Popov, 2014, p. 7). But it is more likely that high level waste final depository will eventually have to be constructed.

Tab. 4.1.3: Belarus Nuclear Sector Examination

Indicator	Description
Is there nuclear producing capacity present in the country?	No
Is there a project to expand the capacity? What is the status of the project?	Yes, the Ostrovets NPP (2x VVER-1200/V-491 units of combined capacity 2,400 MWe), the project is under construction, operation start expected in 2018 and 2020
How was the project procured?	Openly, with Russian bid, other bidders excluded on basis of too high installed capacity of the unit or the need of too complicated and slow intergovernmental agreement negotiation
Who is the contractor in charge of the project?	JSC AtomStroyExport (78.5362% Rosatom State Atomic Energy Corporation; 10.6989% OAO Gazprombank; 9.4346% AO VPO Zarubezhatomenergostroy; 1.3303 % OAO TVEL)
How is the financing secured?	Through USD 10 billion credit contract with Rosatom, the loan is for 25 years to finance 90% of the contract
Who is the operator of the facility?	State unitary enterprise RUP Belarusian NPP
Are there enough home-based experts to run the facility safely?	Yes, also training of the staff is part of the construction contract
Who is/will be in charge of decommissioning?	The contractor, the decommissioning will be funded from a special fund generated from the sales of electricity generated in Ostrovets NPP during its lifetime
Who provides nuclear fuel and under what conditions?	Russian OAO TVEL as part of the construction contract
What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	No operational experience so far as the Ostrovets NPP is the first NPP in Belarus
Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	No
How is used fuel treated and who is in charge of this?	As part of the contract, the used fuel will be repatriated to Russian Federation for the life of the plant, reprocessed there and the separated wastes returned to Belarus eventually

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4.2 Country Case Study: Bulgaria

Tomáš Vlček[1]

4.2.1 Introduction[2]

Bulgaria is a CEE country located in the south-eastern part of Europe and neighbouring with successor countries of former Yugoslavia, Greece, Romania and Turkey. This location gives the country an opportunity to play ever-greater role not only in energy sector in the future. Bulgaria was part of the so called Eastern Bloc and joined the European Union in 2007 along with Romania. As well as the other post-communist countries Bulgaria inherited specific structure of economy that has been influencing country's development not only in energy sector.

Bulgarian total primary energy supply (TPES) is by more than two thirds comprised of hydrocarbons. The greatest import dependency is in oil and gas sector. Almost whole oil consumption is imported while about 80% is of Russian origin and some limited amounts from Kazakh oil fields predominantly transported by CPC pipeline and by tankers from Novorossiysk. However, overall amount of imported oil is substantially bigger than the domestic consumption since Bulgaria is important manufacturer of refined oil products. All imported gas is delivered from Russian Federation through single pipeline running through Ukraine, Moldova and Romania (CSD, 2014, p.46-50, Nitzov et al., 2010). High dependency in oil and gas sectors and other unfavourable

[1] The chapter is based on a research that the author conducted in cooperation with Martin Jirušek.
[2] The chapter is based on the article previously published in the International Journal of Energy Economics and Policy journal in March 2015, where preliminary outcomes of the research were presented. (Vlček & Jirušek, 2015)

factors, like low gas storage capacity and limited reverse-flow capacity of gas pipelines on the borders with Romania and Greece, pose great threat for energy security of Bulgaria and makes it one of the most vulnerable country in the region. On the other hand, Bulgaria is important transit country with robust inland infrastructure serving to transit gas supplies to Turkey, Greece and Macedonia (Nitzov et al., 2010). The energy sector in Bulgaria further suffers from other chronical flaws that, despite serious threats, still remain rather unsolved. Apart from the insufficient gas reserve capacity, which has not been upgraded despite severe impact of the 2009 gas crisis, other structural threats are imminent.

Tab. 4.2.1: Key Energy Statistics

Power Plant	Installed Capacity	Fuel	Year of Construction
CHP Iru	207 MWe	Gas, solid waste	1976-1978, 2010-2013
CHP Balti*	765 MWe	Oil shale	1959-1965
CHP Eesti*	1,615 MWe	Oil shale	1963-1973
14 Wind Parks	143.8 MWe	Wind	-
* Together also known as Narva Power Plants			
Note: CHP = Combined Heat Power Plant			

Source: *IRENA, 2011; Energy Delta Institute, n.d.; European Commission; CSD, 2014*, pp. 46-66; ; compiled and calculated by M. Jirusek

The most pressing issue is energy sector underinvestment in general, which is one of the main reasons for poor energy efficiency represented by huge energy loses in processes of transformation, transmission and distribution. Over 50% of energy is lost before it reaches end customers making Bulgaria

the worst case of energy inefficiency in the region. Characteristic feature of practically all post-communist countries – high energy intensity (i.e. high ration of energy invested per unit of GDP) is also typical for Bulgaria adding up to the serious issues of the sector. Despite this severe inefficiency stemming out of gross underinvestment of infrastructure, the situation is still rather unaddressed. Rising costs of imported energy commodities and infrastructure maintenance are reflected in rising energy bills that pose a great financial burden for considerable share of Bulgarian population. The aforementioned factors have serious consequences – imminence of energy poverty. Over 1/3 of households are unable to keep adequate heating and are forced to switch-off heating due to high energy prices (CSD, 2014, pp. 33-34). Moreover, more than 1/2 of households use wood or coal for heating – a situation that is hardly to be seen anywhere else in the EU.

Electricity power generating capacity in Bulgaria is among the most diverse in EU and OECD countries. The high capacity also enables Bulgaria to be a substantial electricity exporter exporting about 20% of its power generation ("Bulgaria Exports", 2014). With the total power generation capacity of 42.9 TWh and about 2.5 TWh of electricity imported, the country is able to export around 10.5 TWh of electricity (Euracoal, n.d.). The majority of power generating capacity is generated by coal and its variants that comprise about 50% of total power generating capacity. Since the majority of coal-based power generating capacity finds itself struggling with EU environmental rules due to its outdated technology and low quality of used lignite and the nuclear power development is unclear (below), the future of Bulgarian power generation is endangered. There is also high concentration in terms of location and market concentration as majority of coal produced is supplied to three power plants located at the Maritsa site (Global Energy Observatory, 2014; Nitzov et al., 2010).

Tab. 4.2.2: Coal power plants in Bulgaria

Power plant	Installed capacity
Maritsa 3	120 Mwe
Bobov Dol	630MWe
Maritsa East 1	670 Mwe
Maritsa East 2	1450 Mwe
Maritsa East 3	840 Mwe
Varna Coal Power Plant	1260 Mwe

Source: *Global Energy Observatory*, 2014

The second most important source of electricity is nuclear power comprising over one third of the total power generating capacity. All nuclear-based power generation capacity of Bulgaria is concentrated at the Kozloduy NPP site, where total amount of six units is located (table 4.2.2). Units 1 and 2 were brought online in mid 1970s and employed VVER-440 units of Russian design, 405 MWe of power output each. Units 3 and 4 were brought online at the beginning of 1980s and although they employed upgraded version of the already used units, the power output was the same as in the case of units 1 and 2. Units 5 and 6 were built and started to operate at the break of 1980s and 1990s and unlike the first four units they employed more

powerful VVER-1000 units able to produce up to nearly 1000 MWe each. During the EU pre-accession period Kozloduy 1-4 were shut down in 2002 and 2006 respectively, although the government was trying to prolong the operating period for units 3 and 4 as they were substantially upgraded and were said to be complying with the required safety standards. The units 1-4 are thus currently undergoing decommission (World Nuclear Association, 2014b). Due to electricity shortages in Balkan region caused by series of draughts and declining power generating capacity that have become obvious in the region in the second half of previous decade, Bulgaria has the right to bring units 3 and 4 back online in case of energy crises.

4.2.2 New Units and Financing of the Nuclear Power Plant

There have been plans since the late 1970s and early 1980s to build two new units at the Kozloduy NPP site, but the economics of the project have consistently undermined the progress. Eventually, in 2010, it was assessed that new construction was possible at the Kozloduy site. Progress of the project was further slowed down by the decision to use finished parts of the Belene 1 unit (see below) for the Kozloduy 7 unit. A key feature of this project has been the fact that no state funding or guarantees will be provided for the construction phase, which made it necessary to find an investor to finance the plant. For the purpose of the project a new company – – Kozloduy NPP New Build – was established. For the technological part, the government was at that time still considering two options – using the Russian equipment already purchased and delivered for the Belene 1 unit or building a brand new unit using Westinghouse AP1000 design. Eventually, in mid 2013, the latter option was selected[3], although it was followed by the lawsuit with Rosatom (see below) and concerns regarding the transparency of the procedure (see above). Moreover, the financial part of the project still has not been satisfactorily settled. The whole enterprise was complicated in June 2014 by the withdrawal of Toshiba, the Westinghouse owner, which originally should have invested up to 30% of the project share. The 30% equity stake in the Kozloduy NPP New Build[4] was subsequently transferred to Westinghouse with the rest held by the Bulgarian Government. Although this deal was cemented in August 2014, it is rather a formal confirmation of the previous selection of Westinghouse unit rather than final settlement as the details of the financing as well as the inner structure of the project (i.e. involved subcontractors) are still to be secured, as the Westinghouse spokesman confirmed at the time the deal was signed. It is said that financing should be mainly secured by loans obtained by both sides of the contract (i.e. Westinghouse and Kozloduy NPP New Build – essentially Bulgarian government). However, the agreement is yet to be finally confirmed by the government after the October elections ("Bulgaria to sue Russia", 2011; „Bulgaria picks Westinghouse", 2012; "Commission wants EU capital", 2010; Russia offers Bulgaria", 2011; "Westinghouse moves forward", 2014; Bivol, 2010; World Nuclear Association, 2014b).

[3] Westinghouse is set to provide the needed equipment, project design, engineering and prospectively also fuel supplies for the unit (contract on fuel supplies is not yet agreed) (World Nuclear Association, 2014b)
[4] This means that Westinghouse will not remain the equity holder once the unit is built.

Plans have also been made to build other units at the Belene site, which was also selected back in the 1970s. The plan to build nuclear production units at this site was the subject of heated debate for many reasons and the project has been questioned, halted and resumed several times mostly because of its economic feasibility[5] and unclear financing[6], which, especially in the light of uneasy economic situation of the country after the collapse of the communist regime, made the project financially hazardous. The new units were later intended also to replace the Kozloduy 1-4 units that were shut down during the EU pre-accession period (see above). This project, which was originally set to utilize the Russian VVER-1000 design, has been offered a Russian loan several times to support the Atomstroyexport-led consortium. However, a succession of Bulgarian governments have refused this offer and a further Russian proposal to take an equity stake in the plant in return for financial and technical support, fearing a security of supply risk from being over-exposed to a Russian contractor even when the original strategic partner, RWE, withdrew from the project ("Commission wants EU capital", 2010; World Nuclear Association, 2014b; World Nuclear Association - Weekly Digest, 2012). Instead, the Bulgarian authorities decided to try and find a European partner, but without success ("Commission

[5] The study conducted by the Bulgarian electric system operator suggests that the new capacity is needed (and thus economically feasible) only if agreements on substantial future electricity exports are secured (CSD, 2014, pp. 93-97).
[6] The Belene NPP project is a fine example of how the upfront costs influence the price of the electricity generated by the plant. In this case the upfront cost of about EUR 10 billion have been one of the major arguments against the plant since the subsequent electricity price and further investments needed for the future exports (i.e. investments into infrastructure) would be hardly acceptable. Therefore the return-on-investment timeframe appears to be very unfavourable – 30-40 years – basically a great deal of typical nuclear plant's life cycle (CSD, 2014, p. 93-97).

wants EU capital", 2010; Bivol, 2010). Indeed, eventually financial concerns followed by a legal dispute between Atomstroyexport and Bulgaria's National Electric Company NEK prompted the Bulgarian government to start considering a brand new solution to the problem ("Russia offers Bulgaria", 2011). This involved installing the equipment originally designed for the Belene 1 unit at the site of Kozloduy 7 ("Bulgaria to sue Russia", 2011; World Nuclear Association, 2014b), as it was becoming clear that the Belene NPP project was about to be terminated[7]. However, the procurement procedure for a new unit at the Kozloduy site eventually led to selection of the Westinghouse AP – 1000 designs („Bulgaria picks Westinghouse"; World Nuclear Association, 2014b), and this again prompted a lawsuit brought by Atomstroyexport claiming around EUR 1 billion in damages for the aborted Belene project. Although the ultimate decision selecting Westinghouse as the technology supplier for the Kozloduy 7 unit was accepted as geopolitically more favourable than the Russian offer, concerns questioning transparency of the procedure remained pointing to alleged corruption practices. Overall, though, the problems that both Bulgarian projects have faced highlighted the importance of financing and to lesser extent a complicated perception of Russian involvement in nuclear projects in CEE countries. The fact that the technical

[7] This stems out of the development of the Kozloduy 7 project and the financial feasibility of building a completely new plant at Belene, and subsequent plans to build gas power plant on the site ("Bulgaria Quits", 2012). Also, the referendum on future development of nuclear energy in Bulgaria did not shed a light on the future of the project as it was non-binding due to low voter turnout and vague wording (CSD, 2014, pp. 93-97). On the other hand, governments have been sending mixed signals and have not been able to formulate a coherent energy strategy. This inability further harms the government's position in aforementioned lawsuits that still remain to be settled.

features of each design were treated as rather second-tier priority[8] indicates that it was the potential stake of Russian state-owned companies and the form of financing which has been of most concern.

4.2.3 The Front End of the Nuclear Fuel Cycle

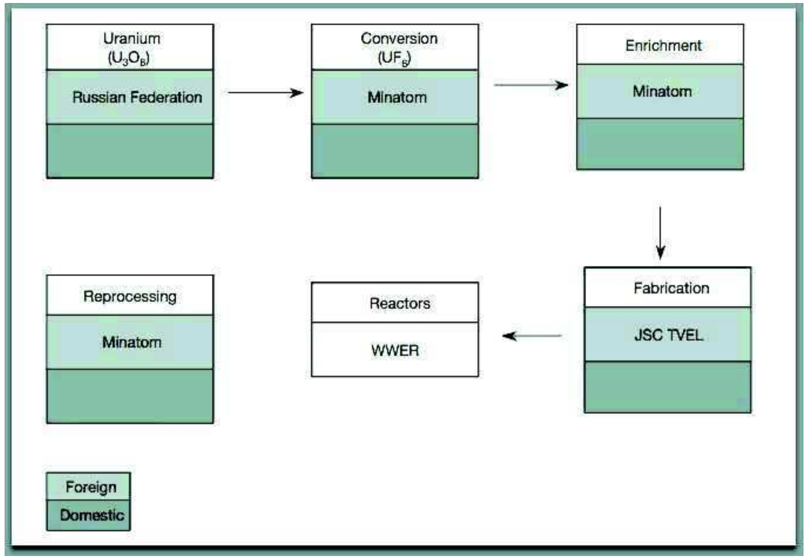
Uranium mining had been active since 1938. In 1992 and 1994, it was decided to shut down the mining and milling respectively, officially for ecologic and economic reasons. At its peak, the uranium mining industry produced approximately[9] up to 645 tonnes of uranium ore per year, employed up to 13,000 employees and was very autonomous in terms of management. Altogether up to 48 uranium mines were active in Bulgaria and the country also ran 2 uranium enrichment facilities. Current remaining reserves in Bulgaria are estimated to be around 20,000 tonnes out of which suitable and recoverable is the amount totalling about 6000 tonnes at annual rate of 300 tonnes (International Atomic Energy Agency, 2013).

The uranium industry was focused on mining, milling and uranium concentrate production (up to the stage of yellow cake) and in that stage of development the production was being sent to the Soviet Union, since the country did not possess plants for more sophisticated treatment. Until 1992, Bulgaria paid for reprocessing of their ore for use in the Kozloduy NPP and the remainder was being left for USSR as a provision (Lazarova, 2006). In mid 2000s, it was rumoured that Canadian Cameco

[8] The technology issue was addressed rather with connection to the already installed Russian equipment at the Belene site and its possible utilization at the Kozloduy site.
[9] Exact figures are unknown as they were confidential.

and Russian TVEL show interest in reviving uranium mining in Bulgaria. In 2006, Bulgarian – Russian intergovernmental commission expressed its opinion that Bulgaria should revive uranium mining. At that time, TVEL expressed the same opinion as the uranium production and cooperation with Russia in this regard would help reduce the price of Russian fuel shipped to the Bulgarian Kozloduy NPP (Wise Uranium Project, 2014). This interest was probably linked to plans of building new production units in which Russia expressed their interest ("Bulgaria considers", 2006).

Tab. 4.2.3: Bulgaria – nuclear fuel cycle profile



Source: IAEA, 2005

Nowadays, Bulgaria relies on fuel shipments from Russia and no part of the fuel producing cycle is present on Bulgarian soil. As Table 4.2.3 illustrates, all parts of the fuel cycle are secured by the Russian Federation and its state-owned companies (TVEL) or governmental bodies (Rosatom State Nuclear Energy Corporation). The current agreement on fuel supplies was prolonged by 3 years[10] in September this year ("АЭС Козлодуй опровергла", 2014). Although the country is 100% dependent on Russian fuel shipments, it does not mean that the country is vulnerable or exposed to unbearable economic, safety or political pressures from the Russian side. As stated in the first part of this study, the uranium market is highly competitive and it is thus no problem to obtain supplies from various sources. In this regard, Bulgaria is no way near vital and unbridgeable dependency on Russian fuel shipments. In case of supply cuts, the stored supplies of nuclear fuel can well bridge the period of curtailed or even none supplies. Although there have been accusations that Russian side was sending recycled fuel instead of fresh one, these were not proven and denied by both Russian side and the plant's officials ("Bulgaria Kozloduy asks", 2008).

4.2.4 The Service Part of the Nuclear Fuel Cycle

Nuclear industry is deeply rooted in Bulgaria since the development of nuclear facilities dates back to 1950s. The first research reactor started in 1961 and development of commercial use of nuclear energy started 5 years later, when the cooperation

[10] The three-year term is given by the fact that the current operating permission for Kozloduy 5 unit ends in 2017.

and future use of Russian nuclear technology was agreed. All nuclear units in Bulgaria are possessed by Bulgaria's National Electricity Company (NEK) a subsidiary of state-owned Bulgaria Energy Holdings. Two units in operation at the Kozloduy site NPP near the Danube River close to the northern border (Kozloduy 5&6) are currently the only nuclear units in operation. These reactors, Kozloduy 5 & 6, are the VVER-1000 type, each with an output of 953 MW and they are the last two out of six units built during two decades since the early 1970s on the site (see above). In 2012, the procedure to extend their life-cycle has begun. The life-time extension will be ultimately granted by the Bulgarian Nuclear Regulation Agency based on the modernization and survey procedure that is being undertaken by the consortium of Russian Rosenergoatom and French EDF ("Bulgaria's NPP Kozloduy Moves"). These units are licensed to 2017 and 2019 respectively and since there are no concerns regarding their safety, it is planned to extend the licenses beyond 2030.

Tab. 4.2.4: Nuclear Units in Bulgaria

Reactor	In Operation from	Type	Power output	Status	End of life-cycle
Kozloduy 1	1974	VVER-440	405 MWe	Shutdown	-
Kozloduy 2	1975	VVER-440	405 MWe	Shutdown	-
Kozloduy 3	1980	VVER-440	405 MWe	Shutdown	-
Kozloduy 4	1982	VVER-440	405 MWe	Shutdown	-
Kozloduy 5	1987	VVER-1000	953 MWe	Operating	2017[11]
Kozloduy 6	1991	VVER-1000	953 MWe	Operating	2019[12]

Source: *World Nuclear Association*, 2014b

4.2.5 The Back End of the Nuclear Fuel Cycle

The state-owned enterprise SE – RAW is responsible for dealing with nuclear waste. The way how the used fuel is treated in Bulgaria does not differ from how it is usually treated in other countries with nuclear production capacity. Initially, the used fuel is stored in cooling pools in reactors and in pool-type cooling facility in the area of the plant that was constructed in 2001 by German companies Nukem Technologies and GNS (World Nuclear Association, 2014b). A dry storage area for casks containing used fuel assemblies (i.e. fuel that already underwent initial cooling after being removed from the reactor) was opened near the Kozloduy site in 2011[13].

An intention to build a disposal facility for low-level and intermediate-level waste to extend the capacity of storage at the Kozloduy NPP was announced in 2005. An area near the Kozloduy was selected for this project, which is currently in the stage of planning and designing. This facility is planned to accept nuclear waste worth of 60 years of nuclear plants' life-cycle and to be able to store it for about 300 years. The overall costs of the project are estimated to be around EUR 120 million. Used nuclear fuel is also sent back to Russia for reprocessing under terms of the agreement from 2002. The price per one tonne is set at USD 620,000 (World Nuclear Association, 2014b.).

[11] It will be most probably prolonged by 10 or 20 years.
[12] This construction was financed from the same source as is the project on decommissioning the closed 4 reactors – European Bank for Reconstruction and Development. The decommissioning and nuclear waste treatment is also partially paid from the governmental funds financed from energy taxes. The Kozloduy NPP also participates on this fund (World Nuclear Association, 2014b.).
[13] This project will also be financed by the European Bank for Reconstruction and Development (World Nuclear Association, 2014b.).

Tab. 4.2.5: Bulgarian Nuclear Sector Examination

Indicator	Description
Is there nuclear producing capacity present in the country?	Yes, Kozloduy 5 & 6 operating at the Kozloduy NPP site (VVER-1000/V-320 design, 2 units of 953 MWe each).
Is there a project to expand the capacity? What is the status of the project?	Yes, cooperation agreement between Kozloduy NPP New Build and Westinghouse Electric Company LLC was signed in 2014. The financing is yet to be secured.
How was the project procured?	By lengthy and turbulent procurement procedure. Allegations of non-transparency and corruption emerged.
Who is the contractor in charge of the project?	Westinghouse Electric Company LLC
How is the financing secured?	Not clear yet. Should be secured by both parties (Westinghouse Electric Company LLC and Bulgarian Energy Holding state-owned company)
Who is the operator of the facility?	Bulgaria's National Electricity Company (NEK)
Are there enough home-based experts to run the facility safely?	Yes
Who is/will be in charge of decommissioning?	The State Enterprise Radioactive Wastes (SE-RAW)
Who provides nuclear fuel and under what conditions?	Russia's OAO TVEL through OAO Techsnabexport (Tenex)
What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	No operational issues; path dependency rationale found in nuclear fuel supply from Russian companies
Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	No part of the fuel producing cycle is present on Bulgarian soil.
How is used fuel treated and who is in charge of this?	Standard procedure of waste management. Used fuel stored initially in pool-type facility and in dry casks storage. Used fuel is being sent for reprocessing to Russia under the agreement from 2002 for USD 620,000 per tonne.

4.2.6 Summary

Bulgarian energy sector has several issues to deal with in foreseeable future. First, it is the high vulnerability of the sector caused by almost 100% one-sided dependency on Russia in terms of oil and gas imports. This issue proved to be especially pressing in 2009 gas crisis, but unfortunately, little has been done to change it since then. Despite the country's relative importance as important regional transit country, the country remains to be potentially endangered if any supply cuts or disruptions occur. The overarching issue of the whole Bulgarian energy sector is a gross underinvestment. This applies to practically all parts of the sector regardless energy source.

Solid fuels and nuclear energy play important role in both, total primary energy supply of and in electricity generation of Bulgaria. The two nuclear units in Kozloduy along with three major coal fired power plants account for almost two thirds of total electricity generation capacity. As the coal fired power plants are getting old and will probably have serious issues in complying with environmental norms, the nuclear power generating capacity will play ever-greater role even though its future is still unclear due to unresolved financing of planned units. The price of the project and overall economical feasibility contribute to overall uncertainty.

In nuclear sector, it is again rather the financing that poses the greatest threat than any inner or outer political pressure. Despite the fact that the whole nuclear sector relies on Russian technologies and fuel supplies, we can hardly state that this may lead to jeopardizing country's energy security. In fuel supply, the current contract with Russian side can be replaced by an agreement with different supplier, although this may come at higher price. Similarly, the nuclear waste treatment does not pose a threat since only a part of the nuclear waste is sent back to Russia, and additionally, Bulgaria has or plans to build capacities to store the used fuel. Since sober plans to extend nuclear producing capacity count with building only single unit at the Kozloduy NPP, the current repositories will be most probably able to handle this task for years to come even though the final deep geological repository has not been built yet.

Bulgaria may serve as a good example illustrating the risks in the nuclear plant life-cycle that were identified in the general part of this study. This case proves that the most sensitive part of the whole endeavor is financing and economic feasibility, as these were the principal reasons for several postponements in Kozloduy NPP extension and Belene NPP construction. Despite the fact that the contract for constructing new nuclear reactor was finally agreed, the financing is still unsolved. Apart from the financial part itself, corruption as a related issue undermines the development in the sector. Rumors related to the procurement procedure of both planned projects (Kozloduy NPP & Belene NPP) seriously harm the investment environment and aggravate the state of Bulgarian energy sector often seems to reach a dead end in terms of future development.

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4.3 Country Case Study: Czech Republic

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4.3.1 Introduction

The Czech Republic is a country that emerged in modern history as an independent state (Czechoslovakia) after the WWI after 400 years of existence under the Habsburg Monarchy. The so called First Republic was occupied by Germany during the WWII and was integrated to the USSR as the Czechoslovak Socialistic Republic between 1948 and 1989. The communist regime collapsed during the Velvet Revolution in 1989 and democratic parliamentary Czechoslovak republic was formed. On January 1, 1993, the country was eventually peacefully dissolved into Czech and Slovak Republic. The country entered the EU in 2004 and is also a member of the UN, NATO, the OECD, the OSCE, the IAEA and IEA, the Council of Europe and many other international institutions. The country's modern political history contains one specific feature – relatively unstable governments due to periodical affairs and scandals of public officials. Therefore, also the citizens' trust in politics and politicians is low.

The Czech Republic is almost fully dependent on imports of hydrocarbons. The country imports approximately 98 % of its crude oil consumption, and approximately 2/3 of the demand is imported from the Russian Federation via the Druzhba pipeline. The rest is imported from other production countries including Azerbaijan, Algeria, Kazakhstan, Norway, Nigeria, Libya and others, as the country has diversified routes of crude oil imports via the IKL and TAL oil pipelines. There are two processing companies in the Czech Republic - Česká rafinérská and Paramo. Each is divided into two more refining plants that make up the four refining plants in the Czech Republic (Litvinov, Kralupy nad Vltavou, Pardubice and Kolin; only the first two refine crude oil). The total primary distillation capacity is 9.7 Mt/y (OECD & IEA, 2014, p. 132). The majority owner of the refinery segment in the Czech Republic is the Polish company Polski Koncern Naftowy (PKN) Orlen SA. As the demand is higher than the refining capacity in the country, another approximately 15 % of the total petroleum consumption is imported directly in petroleum products.

Speaking about natural gas, the Czech Republic imports approximately 98 % of its consumption from two main sources based on long-term contracts with OOO Gazprom Export, the supplier of Russian gas, until 2035 and with a consortium of Norwegian producers[1] until 2017[2]. The proportional share between these sources is approximately 2:1. Table 4.3.1 shows 111% imports of gas in 2011; this is due to the fact that some gas is imported to be stored in the country's vast underground natural gas storages. The gas industry has recently finished projects to expand the gas storage; the capacity at three of the country's eight underground storage sites has been raised to a total of 3.5 bcm. When completely full, the storage is able to supply peak demand for approximately 50 days (see OECD & IEA, 2014, p. 370-371). Natural gas is also transported via the Transgas and Gazelle pipelines through the Czech Republic to Germany.

[1] ExxonMobil Production Norway Inc., Statoil Hydro ASA, Norske ConocoPhillips AS, TOTAL E&P NORGE AS, ENI Norge AS
[2] The contracts with companies that own the parts of the German gas network used for gas transport to the Czech Republic are also necessary. These companies include ONTRAS - VNG Gastransport GmbH and Wintershall AG.

Tab. 4.3.1: Key Energy Statistics

Source	Consumption	Imports	TPES share	Electricity Generation share
Crude Oil	9.81 Mt	98%	17.1%*	0.1%
Natural Gas	8.41 bcm	111%	15.8%	1.3%
Coal (all types)	52.3 Mt	6%	42.7%	57.1%
RES	-	-	7.5%**	9.2%
Nuclear Energy	-	-	17.2%	32.3%

* Oil products imports add another 3.1% of TPES share
** Biofuels and waste stand for 6.5% of TPES share and 3.2% of Electricity Generation share
Note: 2011 data

Source: ***U.S. Energy Information Administration***; International Energy Agency; OECD & IEA, 2013; compiled and calculated by T. Vlcek

The Czech Republic produced 87.56 TWh of electricity in 2011, of which 17 TWh exported. The Czech Republic is an important exporter of electricity in Central Europe; the average value of electricity export equals 14.9 TWh (Energeticky regulacni urad, 2012, p. 11-12; Energeticky regulacni urad, 2014, p. 13). The company ČEZ, a.s. operates 15,193 MWe of installed capacity in the country (72% of the total installed capacity) and produced 69.21 TWh of electricity in 2011 (79% of the total Czech production), which makes it sovereign on the market. The company is owned by the Ministry of Finance of the Czech Republic (69.78%), ČEZ, a.s. (0.72%), other legal entities (22.20%) and other private entities (7.3%) in 2013 (ČEZ, a.s.).

As seen in Table 4.3.2, coal fired power plants are the crucial part of the electricity generation in the Czech Republic as they provide 10,819 MWe of installed capacity, which makes up 51.3

% of the energy mix. Thermal power plants (powered by brown coal, bituminous coal and biomass) in the Czech Republic provided 44,737 GWh of electricity in 2013, which is 51.4 % of the total gross electricity produced (Energeticky regulacni urad, 2014, p. 4, 11).

Tab. 4.3.2: Installed Capacity in the Czech Electricity Grid on 31 December 2013

Type of Power Station	Installed Capacity (MWe)	Percentage (%)
Thermal Power Station	10,819	51.3
Gas Combined Cycle Power Station	518	2.5
Gas Fired Power Station	820	3.9
Hydroelectricity	1,083	5.1
Pumped-storage Hydroelectricity	1,147	5.4
Nuclear Power Station	4,290	20.4
Wind Power	270	1.3
Solar Power	2,132	10.1
Total	21,079	100

Source: *Energeticky regulacni urad*, 2014, p. 11.

The following Table 4.3.3 shows all the 150+ MWe power plants in the Czech Republic including life expectancy as one of the most crucial aspect of the Czech coal industry. As seen in the chart, the life expectancy of the power plants is rather short and the end of electricity production from coal will have two peaks. The first peak is likely to occur around the year 2025, and the second around the year 2040.

Tab. 4.3.3: 150+ MWe Coal Fired Power Plants in the Czech Republic

Power Plant	Owner	Installed Capacity	Connected to the Grid	Fired on	Life Expectancy*
Dětmarovice	ČEZ, a. s.	800 MWe	1975 - 1976	Bituminous coal	2020-2030
Chvaletice	Severní energetická a.s.	800 MWe	1977 - 1978	Brown coal	2020-2029
Kladno	Alpiq Generation (CZ), s. r. o.	299.1 Mwe	1976, 1999	Bituminous coal, brown coal	2045-2050
Komořany	United Energy pravni nastupce, a. s.	239 Mwe	1959, 1978, 1986, 1994, 1997, 1998	Brown coal**	2025
Ledvice II	ČEZ, a. s.	220 MWe	1966-1968	Brown coal	2015
Ledvice III	ČEZ, a. s.	110 MWe	1998	Brown coal	2040-2055
Ledvice IV	ČEZ, a. s.	660 MWe	2014 - 2015	Brown coal	2055
Mělník (II)	ČEZ, a. s.	220 MWe	1971	Brown coal	2015-2020
Mělník (III)	ČEZ, a. s.	500 MWe	1981	Brown coal	2015-2020
Mělník (I)	Energotrans, a. s.	352 MWe	1961, 1994 - 1995	Brown coal	?
Opatovice	Elektrárny Opatovice, a. s.	378 MWe	1979, 1987, 1995 - 1997	Brown coal	2020-2030
Počerady	ČEZ, a. s.	1,000 MWe	1970 - 1977	Brown coal	2029+
Poříčí	ČEZ, a. s.	165 MWe	1957	Brown coal, bituminous coal**	?
Prunéřov II	ČEZ, a. s.	1,050 MWe	1981 - 1982	Brown coal	2015-2023 (2040***)
Prunéřov I	ČEZ, a. s.	440 MWe	1967 - 1968	Brown coal	2015-2023 (2040***)
Tisová I	ČEZ, a. s.	183.8 MWe	1959 - 1961	Brown coal	2020+
Tisová II	ČEZ, a. s.	112 MWe	1959 - 1961	Brown coal **	2020+

Třebovice	Dalkia Česká Republika, a. s.	174 MWe	1961, 1998	Bituminous coal, light fuel oil	2015-2020
Tušimice II	ČEZ, a. s.	800 MWe	1974 - 1975	Brown coal	2035
* According to public open sources. ** The Komořany power plant is also partially ?red on natural gas. One 55 MW block of the Poříčí power plant and one 57 MW block of the Tisová power plant employ biomass combustion. *** After completion of the modernization process that is due in 2015. Source: Energeticky regulacni urad, 2010, p. 88, 92; Energeticky regulacni urad, 2012, p. 24. Livelong expectancy and overall adjustments by T. Vlcek.					

Source: ***Energeticky regulacni urad, 2010***, p. 88, 92; ***Energeticky regulacni urad***, 2012, p. 24. Livelong expectancy and overall adjustments by T. Vlcek.

Going further in detail, we need to distinguish between brown coal and bituminous coal, as these are two separate markets in the Czech Republic. At this moment, the bituminous coal sector is very negatively affected by the world market. The low prices of (especially quality bituminous) coal mean low profit from the mining. The bituminous coal mining is much more costly compared to brown coal mining. The bituminous coal in the Czech Republic is mined in deep underground shafts in Silesian region unlike the brown coal that is mined in large open pits in northern Bohemia. The fluctuations in price is thus more effective on bituminous coal production that on brown coal production.

The negative effects are rather limited also thanks to the character of use of the bituminous coal. Only approximately, a half of the mined coal is used for energy production. This coal is used in the only bituminous coal power plant (800 MWe Dětmarovice) and only a few bituminous coal cogeneration units (28 MWe Kladno I-B3 and 174 MWe Třebovice). The current domestic bituminous coal production covers the

demand of these facilities taking their life expectancy into account. The rest of the mined coal is high quality coal intended and used for metallurgical coke production. The mine with highest life expectancy is the ČSM mine that produces coal for energy production. Currently, it is relatively easier to find client for this product than for metallurgical coke. The economic slowdown of recent years led to lower demand for metallurgical coke by the steel industry.

Speaking about the brown coal sub-sector, the life expectancy of exploitable reserves covers the two above mentioned power plant life expectancy peaks, i.e. the current electricity production from coal until the end of the production. The market subjects of the brown coal industry in the Czech Republic behave rather in comparative mood. On a background of the end of the coal industry itself (according to the territorial ecological limits[3]) they make efforts to maximize their profits by coupling the coal production with the coal use. Mining companies buy coal fired electricity or heat power plants and the operators of such power plants are trying to buy their own mines or to secure long-term contracts. Both sides act to maximize their profits in the last years or decades of life of the coal sector.

The nuclear energy sector is analyzed further in the text and is the second most important source of electricity. There are two

[3] Territorial Ecological Limits on Brown Coal Mining guided by the Government's Resolution No. 444/1991 on territorial ecological limits on brown coal mining in the North Bohemian Basin of October 30, 1991. This resolution specified the final lines of mining and landfill in the mines Merkur, Březno, Libouš, Šverma, Vršany, ČSA, Ležáky, Bílina and Chabařovice and in Růžodolská and Radovesická landfills as well as the limit values of air pollution in basins in the regions Chomutov, Most, Teplice, Ústí nad Labem and Louny. (Vlada Ceske republiky, 1991) The idea behind these limits was to provide the regions with some sort of government's guarantee that the city environment would not go worse and provide the inhabitants a stable ground for local investments, reconstructions, etc. The topic of territorial ecological limits on brown coal mining has been making its appearance on the political scene for years now.

nuclear power plants in the country, the Dukovany NPP with four Russian design 510 MWe VVER-440/V-213 units and the Temelín NPP with two Russian design VVER-1000/V-320 units (1x 1,078 MWe and 1x 1,056 MWe). Thanks to the modernization of the technical part of nuclear blocks, the power plants as of December 31, 2012, reached 4,404 MWe of installed electrical capacity and, therefore, made a 19.7% electricity generation share. The development of nuclear energy as the least bad of bad alternatives takes place on the background of the end of the coal industry itself (according to the territorial ecological limits), which is the key electricity producer in the Czech Republic. To cover the loss of the electricity generation capacities in coal, the country aims at developing the nuclear energy as a capable, stable and cumulative source of electricity.

4.3.2 New Units and Financing of the Nuclear Power Plant

The plan to expand the nuclear capacity exists since the 2004 State Energy Policy was presented. On August 3, 2009, ČEZ, a.s. released the announcement about opening a call to tender for two new nuclear blocks for the Temeĺin nuclear power plant. To some extent it was based on the investment plan for the construction of the Temeĺin power plant with 4 x 1,000 MWe of installed capacity, adopted in February 1979, replicating the construction site itself and some already existing auxiliary systems.

In the procurement procedure for the Temelín NPP project and construction (i.e. turnkey power plant) it took 3 years to prepare the documentation specifying the conditions of the

project and was created by group of several tens of experts. Ultimately this documentation comprised of more than 6,000 pages employing over 11,000 criteria to be met by the bidders in order to succeed in the procedure. In return each bidder provided the Czech side with documentation exceeding 10,000 pages each (Horacek & Topic, 2012; interview with a responsible Czech MFA official).

Three entities applied to the tender in July 2012. It was a Consortium of the companies ŠKODA JS, a. s., from the Czech Republic, Atomstrojexport, a. s., from the Russian Federation (a daughter company of the Russian company ZAO Atomstroyexport[4]) and OKB Gidropress, a. s.[5] from the Russian Federation, offering the project MIR 1200 (Modernized International Reactor) with 1,198 MWe of capacity[6]. The French company Areva SA[7] offered the EPR™ (European Pressurized Reactor) with 1,700 MWe of capacity and finally, the American Westinghouse Electric Company, LLC[8], offering the project AP1000 with 1,200 MWe of

[4] ЗАО Атомстройэкспорт is the leading Russian organization building nuclear power plants abroad and accordingly engaged in their modernization. It is supervised by the Federal Agency for Nuclear Energy, Rosatom (Федеральное агентство по атомной энергии России, РосАтом) through Open Joint-Stock Company Nizhny Novgorod Engineering Company "Atomenergoproekt" (JSC NIAEP), and the ownership structure is 78.5362% Rosatom State Atomic Energy Corporation; 10.6989% OAO Gazprombank; 9.4346% AO VPO Zarubezhatomenergostroy; and 1.3303 % OAO TVEL.

[5] A daughter company of the Russian company OAO OKB Gidropress (ОАО ОКБ "Гидропресс").

[6] Based on talks with the Russian side, it is interesting that the tender should have included a seriously intended offer to build a manufacturing plant in the Czech Republic, i.e. a plant for assembling fuel cassettes out of single pallets. According to the Russian calculation, that sort of plant proves profitable for the state if there are at least eight reactors, which is the number the Temelín power plant will reach after completion. This is accordingly an opportunity for fuel fabrication for the Russian type of power plant in Slovakia and elsewhere. The paradox is that in this manner the most frequent comment on the Russian project, i.e. intensification of Czech energy dependence on Russia, to some extent ceases to be logical.

[7] The ownership structure is as follows: 73.03 % Commissariat à l'énergie atomique (technological research institution financed by the French Government); 10.17 % French state; 4.82 % Korean car industry Kia Motors and the remaining 11.98 % other companies, employees and publicly traded stocks.

[8] Belonging to the Japanese companies Toshiba Corporation (67 %) and Ishikawajima-Harima Heavy Industries Co. Ltd. (3 %), American mechanical companies The Shaw Group (20 %) and Kazakh state company Kazatomprom NAC (Казатомпром НАК 10 %).

capacity. All cases refer to the reactors of the III, III+ generation (Vlček & Černoch, 2013b, p. 144-146).

On October 5, 2012, ČEZ, a.s. announced the elimination of the French company Areva SA from the competition, because it did not meet the basic commercial and legal terms of the competition ("ČEZ vyřadil AREVU", 2012). Areva submitted an appeal to the Czech Office for the Protection of Competition, which in February 2013, however, found the elimination substantiated.

Originally it was planned the overall administrative tender process will last for roughly 7 to 8 years (15 years together with the construction), which means that the connection of new blocks was estimated for around 2024. The procurement process deferred for about 18 months, to mid-2015, following completion of a new energy strategy by the new government. In parallel with the tender discussion about new State Energy Policy as well as governmental guarantees and stabilization mechanisms for construction of the NPP took place. These eventually led to the governmental expression in April 2014 it will not provide any price guarantees. CEO of ČEZ, a.s. shortly after announced the procurement procedure was cancelled in accordance with Public Procurement Act and explained: "while originally the project was fully economically feasible given the market price of electricity and other factors, today all investments into power plants, which revenues depend on sales of electricity in the free market, are threatened" (ČEZ, a.s.). The project is being reconsidered now and new tender and new bids are expected in 2015. Besides the three original bidders, Korea Electric Power Corporation (KEPCO) and China's deputy prime minister expressed interest in the project (WNA, 2014).

Also a tender the construction of fifth unit in Dukovany is being considered.

Speaking about the financing, ČEZ, a.s. has said it would seek a strategic partner with which to share the risk of the project, following the choice of reactor technology. (WNA, 2014) And even though vendor financing offers were later offered by the bidders (up to 100% of the project costs from JSC Rusatom Overseas; 50% of the project costs as a loan from the Export-Import Bank of the United States), no agreements were closed and ČEZ, a.s. strictly followed its strategy.

In January 2015 the draft version of "National Action Plan for the development of nuclear energy in the Czech Republic" was presented envisaging construction of two new units by 2037 at the latest (one at Temelín NPP site, the other at Dukovany NPP site with respect to regional employment issues). The material was prepared by the Ministry of Industry and Trade; Ministry of Finance, ČEZ, a.s.; and State Office for Nuclear Safety. Speaking about financing two options were presented: either will be the new blocks financed fully by the company ČEZ, a.s.; or through a new parastatal project company where strategic financial partner will be invited. The partner could be either the technology supplier, or big energy consumer in the Czech Republic. The latter option is the most probable.

4.3.3 The Front End of the Nuclear Fuel Cycle

Uranium mining has a long history in the Czech Republic, and the Czech Rožná mine together with the Romanian Crucea-Botușana mines make the Czech Republic and Romania the only European countries still mining it. The Czech Republic used to be among the most important world producers of uranium. A total historical production of almost 111 thousand tons of uranium in the form of sorted ores and chemical concentrate in 1946-2009 made it the 10th biggest producer in the world. The uranium has been mined in the country since 1843, and it was in Jáchymov where P. Currie and M. Curie-Skłodowska discovered first radioactive elements.

The production of uranium did not stop even during the Nazi occupation as the mining continued for German war purposes. After the WWII, an agreement between Czechoslovakia and the USSR was concluded and under this agreement the USSR invested in uranium exploration and production in Czechoslovakia and 96,660.6 tons of uranium metal and chemical concentrate was exported to the USSR in 1945-1991 (Tomek, 2000, p. 18; Poková, 1995, p. 504).

The extraction took place in many deposits near the cities of Jáchymov, Příbram, Horní Slavkov, Dolní Rožínka, Stráž pod Ralskem, Vítkov, Okrouhlá Radouň, Hamr na Jezeře, Chotěboř, Nové Město na Moravě and many others. All mines except one were closed in the second half of the 20th century. Currently the last mine Rožná in the city of Dolní Rožínka is still operating by the branch plant GEAM of the state enterprise DIAMO s.p. (under full control of the Ministry of Industry and Trade of the Czech Republic)[9]. The Rožná mine was supposed to be shut down in the mid-1990s, when uranium experienced a sales crisis as the previously important customer, Slovakian Slovenské elektrárne, a. s., refused to purchase Czech uranium and started purchasing enriched nuclear fuel directly.

[9] The term DIAMO is an abbreviation for ammonium diuranate, in Czech "Diuranát amonný".

Government Decrees from 1994, 1997, 2000, 2002 and 2005 gradually prolonged the mining period in Dolní Rožínka, while the government extended the mining and processing of uranium in the Rožná deposit for as long as mining remained economically effective by passing the Decree No. 565 from May 27, 2007, and the termination of mining is tied to the results of a profitability assessment, currently set for 2018 (Vlček & Černoch, 2013b, p. 132). The CEO of the DIAMO s.p. recently stated that the market situation is unfavourable and it is likely that the uranium mining will be shut down sooner than expected, by the year 2016 (Lukáč, 2014). This is also due to the fact that the resources are almost depleted and the extraction drops annually, from 420 and 383 tons of uranium in 2005 and 2006 to 191 and 170 tonnes in 2013 and 2014 (Ministerstvo životního prostředí / Česká geologická služba – Geofond, 2010, p. 185; Lukáč, 2014). Connected to the mining, there is a processing facility of the DIAMO s.p. state enterprise near the Rožná mine, where yellow cake is produced from the mined uranium ore.

Uranium prospecting activities take place in the Czech Republic and the total identified uranium resources estimation amount to 5,656 tons in the Brzkov, Horní Věžice and Polná deposits (Lazárek, 2012), all of the in the vicinity of the operating Rožná deposit. The Brzkov deposit, as the most promising one, was destroyed and buried in 1990s during the reduction program. The reintroduction of this site to mining would thus require a CZK 1 billion investment. Even though, the prime minister is interested in opening the mine not for the uranium it contains itself, but rather for social reasons. Around 900 employers work in GEAM in the Rožná mine and the shutdown will cause a rise of unemployment in the region. The preparatory work in Brzkov would last 6-7 years and the subsequent mining period is estimated at 16 years. Therefore the employers could be transferred to the Brzkov mine in the vicinity of their current workplace, which allows for flexible management of employment and retirement of the miners.

At the beginning of 2000s, domestic mining covered approximately 93% of domestic demand. But later on, the domestic uranium production has not been able to cover the demand (e.g. the 230 mined tons in 2011 covers 27% of the uranium demand; Lazárek, 2012) and DIAMO, s.p. sold the domestic mined uranium on the market, and ČEZ, a.s., the operator of the NPPs, has been purchasing the final product since the end of 2009.

The long-term and permanent fuel supplier for the Dukovany nuclear power plant is the Russian company OAO TVEL. From 2002, when the plant was launched, until the end of 2009, fuel for the Temelín nuclear power plant was supplied by the American company Westinghouse Electric Company, LLC. Well known is the affair of the fuel rods deflections in the active zone of reactor at that time, because Western nuclear reactors have square-shaped fuel assemblies, while the Russian ones are hexagonal. Hexagonal assemblies for Temelín NPP were initially provided by Westinghouse Electric Company, LLC and caused fuel rods torsion, which resulted in forced operational interruption, limited production, and inability to produce electricity to its full capacity. Westinghouse's experience with VVER design fuel assemblies was short, as they started providing this product in 1997. That is why technological issues occurred. In 2010, a selection process for a

new supplier took place, which was won by the Russian TVEL by submitting a financially unbeatable offer. Until 2020, TVEL will therefore be the exclusive fuel supplier for both Czech nuclear power plants (Vlcek & Cernoch, 2013, p. 134-135). In 2014, the contract was renewed for the Dukovany NPP and prolonged to 2028 (OAO TVEL, 2014, p .12).

In June 2014, the company UJP Invest, s. r. o. (a subsidiary of UJP Praha a.s.), which profiles in nuclear fuel fabrication, design and manufacture of packaging for the transport and storage of radioactivity, research into materials for the nuclear power sector and other industries, heavy metal processing etc., announced that it is interested in building a nuclear fuel fabrication facility in Bystřice nad Pernštejnem approximately 50 km from Brno. The municipal council has called a referendum in October 2014 where 80% of respondents were against this investment. The company thus searches for different industrial area in the Czech Republic and Slovakia ("V Bystřici by mohl", 2014; Bytřičtí v referendu", 2014).

4.3.4 The Service Part of the Nuclear Fuel Cycle

The agreement between Czechoslovakia and the USSR on the uranium exploration and production allowed for further cooperation, and in 1955, the Institute for Nuclear Research in the small town of Řež near Prague was established (Ústav jaderného výzkumu Řež a.s., current name ÚJV Řež, a. s.). The USSR supplied the Institute with research equipment including a cyclotron and a VVR-S research reactor. Nowadays it is a recognized institute specializing in applied research and engineering activities, safety analyses, documents for technical changes in nuclear power plant projects, designing in the sectors of conventional and nuclear energy etc.[10] (ÚJV Řež a.s.).

Currently there are 3 research reactors in the Czech Republic; the LR-0 (5 kWt, in 1983 reconstructed TR-0 reactor) and LVR-15 (10 MWt, in 1989 reconstructed VVR-S reactor) based at the Institute for Nuclear Research in Řež and the educational VR-1 Vrabec (1-5 kWt) based since 1990 at the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague.

There are two nuclear power plants operating in the Czech Republic with a total of six pressurized water reactors cooled and moderated by light water. The Dukovany NPP is located in the Southern Moravia with four VVER-440/V-213 pressurized reactors (after the modernization, installed power capacity currently amounts to 4x 510 MWe), which had provided its first electricity in May 1985. The design was Soviet and the project base documents were prepared by the Soviet OOO LOTEP company, but the project was executed by Energoprojekt Praha a.s. and the general contractor was Průmyslové stavby Brno a.s. together with the technology contractor Škoda Praha a.s. (ČEZ, a.s.).

The Temelín NPP is located in the Southern Bohemia, a set of two VVER-1000/V-320 pressurized reactors (installed capacity equals to 2,134 MWe after turbine modernization), which was completed in December 2000. The initial power plant design was developed from the Soviet design by Energoprojekt Praha a.s. and construction of operating units was launched in 1987. After November 1989, under new

[10] The ownership structure includes ČEZ, a.s. (52.46%), Slovenské elektrárne, a.s. (27.77%), ŠKODA JS a.s. (17.39%) and town Husinec (2.38%) (ÚJV Řež a.s.).

political and economic conditions, it was decided to reduce the number of production units to only two (ČEZ, a.s.). Both power plants are owned by ČEZ, a. s. Thanks to the modernization of the technical part of nuclear blocks, the power plants reached 4,404 MWe of installed electrical capacity on December 31, 2012, and therefore made a 19.7% electricity generation share.

Tab. 4.3.4: Nuclear Units in the Czech Republic

Reactor	Type	Power Output	Status	End of life-cycle
Dukovany 1	VVER-440/V-213	510 MWe	Operating	2015
Dukovany 2	VVER-440/V-213	510 MWe	Operating	2016
Dukovany 3	VVER-440/V-213	510 MWe	Operating	2016
Dukovany 4	VVER-440/V-213	510 MWe	Operating	2017
Temelín 1	VVER-1000/V-320	1,078 MWe	Operating	2020
Temelín 2	VVER-1000/V-320	1,056 MWe*	Operating	2022
ÚJV Řež LR-0	LR-0 (TR-0)	5 kWt	Operating	-
ÚJV Řež LVR-15	LVR-15 (VVR-S)	10 MWt	Operating	-
FJFI ČVUT Praha	VR-1 Vrabec	1-5 kWt	Operating	-
* Will be modernized to 1,078 MWe in 2015				

Source: Energetický regulační úřad, 2010b, p. 89; open sources; updated and modified by T. Vlcek.

Both of the power plants were constructed with Soviet assistance end employs Soviet design VVER reactors. The Dukovany NPP was put into service in 1985-1987 and the Temelín NPP in 2000 (Unit 1) and 2002 (Unit 2). According to the Czech Atomic law, the licensing process for life-extension can be started in the last year of the unit's life-cycle; therefore the Dukovany NPP will go through this process in the following years. It is expected a 10-year life extension without any issues; the following life extension might be problematic as Dukovany NPP does not have the typical passive containment structure, but active pressure suppression containment, which is an outdated technology in reactor safety today. Temelín NPP operation is designed for 30 years but the operator's management expects longer operation depending on the condition of the reactor pressure vessel; the only part of technology that cannot be replaced.

4.3.5 The Back End of the Nuclear Fuel Cycle

The owner of spent nuclear fuel in the Czech Republic is ČEZ, a.s., the operator of the NPPs, and is responsible only for storage. The spent fuel is stored in interim dry storages in the areas of the Dukovany and Temelín NPPs. Due to the transience of private companies, the final radioactive waste repository is not under ČEZ, a.s., but the state's responsibility, specifically through the Radioactive Waste Repository Authority (RAWRA; in Czech SÚRAO, Správa úložišť radioaktivních odpadů). Once the spent fuel is declared waste, the ownership and also responsibility of spent fuel management will pass to RAWRA. RAWRA is subordinated to the Ministry of Trade and Industry of the Czech Republic and has been financed since 1997 from the so-called Nuclear Account, which was established at the Czech National Bank by the Ministry of Finance. All activities related to radioactive waste are financed from the Nuclear Account, which consists of payments by radioactive waste producers, revenues from investment in the financial market, RAWRA's own revenues, account interest,

grants, donations and other revenue (Správa úložišť radioaktivních odpadů).

RAWRA currently manages four surface radioactive waste repositories in the Czech Republic, namely the Richard near Litoměřice, Bratrství near Jáchymov, Dukovany and Hostim near Beroun. These repositories store institutional radioactive waste, emerging during the processes of medical, industrial, agricultural and research activities, therefore, waste containing natural radionuclides and low-activity radioactive waste from nuclear power plants (Vlček & Černoch, 2013b, p. 136-137).

RAWRA is responsible for the activities connected with the construction of the final underground geological repository. In 1990–2005, RAWRA originally selected 27 potential localities for building a deep geological repository of radioactive waste. It narrowed them down to 13, then to 11 and finally to the current 7: Březový potok near Pačejovo, Čertovka near Lubenec, Horka near Budišov, Hrádek near Rohožná, Čihadlo near Lodhéřov, Magdaléna near Božejovice and Kraví hora near Moravské Pavlovice. In recent years, the Authority has been checking the possibility of using military areas, while it was the Boletice military area that was positively valued in terms of its site, therefore, qualifying as an eighth possible appropriate location (Vlček & Černoch, 2013b, p. 137). Since 2010, these localities have been undergoing a basic land survey, consisting of three phases: the first research phase until 2015, the second exploratory phase in the period 2015–2025 and the third detailed exploratory phase in the period 2025–2050. The exploration of at least four localities is anticipated, as the company is expected not to receive an exploration permit for all localities. By 2018, two candidate localities should be chosen, one of which will be then chosen as the winner. After obtaining enough data proving the localityôs safety, the submission of the application for construction permit of a deep geological repository will follow, which should take place in the period 2050–2065 (Správa úložišť radioaktivních odpadů).

Since 1995, there has also been the high-level waste store (HLWS) at the Institute for Nuclear Reaearch in Řež used for the storage of solid or solidified medium and high-level waste and for the storage of spent fuel from research reactors.

Tab. 4.3.5: Czech Nuclear Sector Examination

Indicator	**Description**
Is there nuclear producing capacity present in the country?	Yes, the Dukovany NPP with four 510 MWe VVER-440/V-213 units and the Temelín NPP with two VVER-1000/V-320 units (1x 1,078 MWe and 1x 1,056 MWe)
Is there a project to expand the capacity? What is the status of the project?	Yes, the public procurement process took place in 2009-2014 and was cancelled in April 2014 for no governmental price guarantees were secured; the project is being reconsidered now and a new tender and new bids are expected in 2015
How was the project procured?	Openly and professionally, the process was cancelled in April 2014 for no governmental price guarantees were secured
Who is the contractor in charge of the project?	ČEZ, a.s. (69.78 % Ministry of Finance of the Czech Republic; 0.72% ČEZ, a.s.; 22.2% other legal entities; 7.3% other private entities)
How is the financing secured?	From the ČEZ, a.s. capital, probably with strategic investor
Who is the operator of the facility?	ČEZ, a.s.
Are there enough home-based experts to run the facility safely?	Yes
Who is/will be in charge of decommissioning?	ČEZ, a.s. overseen by the State Office for Nuclear Safety

Who provides nuclear fuel and under what conditions?	OAO TVEL under the contract from 2010 (based on a selection process for a new supplier); it will supply nuclear fuel for both Czech nuclear power plants until 2020, the contract for Dukovany NPP was prolonged in 2014 until 2028
What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	No issues, any potentially defective fuel assemblies are swiftly exchanged for new ones; there is a bad experience with fuel supplied by Westinghouse Electric Company, LLC in 2000s and this is likely to influence the future supplier selection
Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	Uranium mining, yellow cake production and radioactive waste management; it does however not contribute to the country's nuclear fuel cycle as domestic yellow cake production is low and therefore sold at the market, while the final product (nuclear fuel) is purchased directly on a long-term contract basis
How is used fuel treated and who is in charge of this?	Spent fuel is owned by ČEZ, a.s. and stored in interim dry storages in the areas of the Dukovany and Temelín NPPs; once declared waste, the Radioactive Waste Repository Authority will take over the responsibility of spent fuel management; the RAWRA is subordinated to the Ministry of Trade and Industry of the Czech Republic and is responsible for management of four surface radioactive waste repositories and the development and operation of the final underground geological repository

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4.4 Country Case Study: Estonia

Tomáš Vlček

4.4.1 Introduction

Estonia is the northernmost Baltic republic that borders with Russian Federation and Latvia, and Sweden and Finland over the Baltic Sea. Estonia declared independence in 1918 to be immediately occupied by Germany and eventually fought for it against Red Army in 1918-1920. And even though Estonia declared neutrality before the WWII, the Molotov-Ribbentrop Pact assigned Estonia to USSR. Estonia was then occupied both by the USSR and the Nazi Germany and after the end of the war, Estonia was Sovietized and became the Estonian Soviet Socialist Republic until 1991 when independence was declared. Estonia joined the EU in May 2004 together with the Baltic and 7 other countries. Due to the history, the political and social mood is strongly anti-Russian, likewise in Latvia.

Speaking about the energy sector, Estonia is in much better position in terms of the energy security then the other two Baltic countries. The consumption of 100% Russian imported natural gas is very low (0.62 bcm in 2011) and also, together with Finland, Estonia agreed to build two LNG terminals connected via pipeline in Gulf of Finland to reduce dependency on Russia. The countries aim to have the gas pipeline in operation in 2019 (Molin, 2014). Coal use and imports are negligible and coal is used for some local minor heat generation.

Speaking about oil, Estonia's Eesti Energia AS has mined shale oil since 1928 and produces synthetic crude oil from shale oil deposits. By doing this, Estonia produces over 1 million

barrels (140,000 tonnes) of shale oil annually. This positively affects the dependency on imports of crude oil products as the reserves are about 1-2 billion tonnes of oil shale, i.e. 125-250 million tonnes of oil (Eesti energia AS). Estonia does not have a refinery; therefore some oil is exported to Lithuanian Mažeikiai oil refinery. Still, Estonia is a net importer of petroleum products (around 70 % of consumption). Likewise Latvia, Estonia imports directly oil products, not crude oil. Most importantly, oil shale is used as fuel in Narva Power Plants (2,380 MWe combined) for electricity and heat generation.

Tab. 4.4.1: Key Energy Statistics

Source	Consumption	ImportsTPES share	Electricity	Generation share
Crude Oil	1.32 Mt	0%	14.6%	0.3%
Natural Gas	0.62 bcm	100%	8%	1.9%
Coal (all types)	0.07 Mt	94.9%	64.2%	88.6%
RES	-	-	13.2%*	9.2%
Nuclear Energy	-	-	0%	0%
Note: 2011 data				
* Biofuels and waste stands for 12.7 % of TPES share				

Source: ***U.S. Energy Information Administration; International Energy Agency***; compiled and calculated by T. Vlcek

In 2013, Estonian private chemical company Viru Keemia Grupp (VKG) chose a consortium made up of the Italian company KT - Kinetics Technology and the Spanish company OHL Industrial as the winner of a tender to build a diesel refinery in Estonia. But only a month later, the plan was dropped as financing of the investment proved too expensive. A few months later, the idea was revitalized by STK Group, Estonian company owned by Russian investors and it has a plan to build refinery with 2 Mt/y capacity ("Estonia's VKG", 2013; Karnau, 2013; "Russian investors", 2013).

Estonia produces its electricity mainly from oil shale, wind and gas. The CHP Balti and CHP Eesti are big oil shale fired power plants with combined capacity of 2,380 MWe. They are fully supplied by domestic oil shale production. Estonia is also intensively developing wind power plants; currently there are 11 wind parks with the overall capacity of 186.6 MWe (the biggest being Paldiski, Aseri, Viru-Nigula and Pakri). Estonia also plans to build a huge offshore wind park Hiiumaa with the capacity of 700 MWe.

Tab. 4.4.2: Key Power Plants in Estonia

Power Plant	Installed Capacity	Fuel	Year of Construction
CHP Iru	207 MWe	Gas, solid waste	1976-1978, 2010-2013
CHP Balti*	765 MWe	Oil shale	1959-1965
CHP Eesti*	1,615 MWe	Oil shale	1963-1973
14 Wind Parks	143.8 MWe	Wind	-
* Together also known as Narva Power Plants			
Note: CHP = Combined Heat Power Plant			

Source: *Eesti Energia AS*

In 2011, 12,893 GWh of electricity was generated, but around 11,500 GWh annually is produced on average. The consumption in 2011 counted for 9,331 GWh and therefore Estonia also exports electricity to neighbouring countries. The average net export value is 2,000 GWh annually (International Energy Agency).

4.4.2 New Units and Financing of the Nuclear Power Plant

Estonia is very interested in the planned Lithuanian Visaginas NPP and is the 22% share holder in the future Visagino atominė elektrinė (VAE) Project Company through Eesti Energia AS. No domestic NPP project is planned or being developed. See Lithuania Case Study for detailed information.

4.4.3 The Front End of the Nuclear Fuel Cycle

In 1927-1928 Swedish-Norwegian Eestimaa Õlikonsortsium founded oil shale extraction plant in Sillamäe, Estonia. As part of the Soviet nuclear weapons program during Soviet era, it was decided to covertly mine uranium from the so called Dictyonema Shale in the Sillamäe mine and in 1946 the factory was renamed to Kombinat No 7. As this production soon proved to be uncompetitive (only 22.5 tonnes of elemental uranium produced between 1948 and 1952), the factory was then used only for enrichment of uranium mined elsewhere. A total of 4 million tonnes of uranium ore at grades of up to 1% from various East European countries were processed: 2.2 million tonnes from Czechoslovakia, 1.2 million tonnes from Hungary, as well as smaller amounts from Poland, Rumania, Bulgaria, and the German Democratic Republic. Altogether, the uranium production from imported ores and concentrates amounted to 96,681 tons in 1950-1989 (Ehdwall 1993, cited according to Diehl, 1995; Maremäe, 2003, p. 34; *Nuclear Heritage Network*). The uranium processing was stopped in 1990 and the factory was renamed to Silmet. This company was eventually renamed again to Molycorp Silmet AS when U.S. mining group *Molycorp, Inc*. bought the company. Molycorp Silmet AS is today one of only two centers in Europe for the processing of rare earths (*Molycorp, Inc*.; *Nuclear Heritage Network*).

As there are currently no uranium deposits and no production, processing and/or fabrication capabilities in Latvia anymore, no Front End information can be presented.

4.4.4 The Service Part of the Nuclear Fuel Cycle

As there are no nuclear power plants in Estonia, no Service Part information can be presented.

4.4.5 The Back End of the Nuclear Fuel Cycle

There are three disposal sites for radioactive material in Estonia and both are connected with Estonian history. The Sillamäe Radioactive Tailings Depository owned by Molycorp Silmet AS had been receiving radioactive waste from 1948 to 1989 from the processing and enrichment factory at Sillamäe. In 2008, liquidation of the tailing ponds at Sillamäe was finished.

The Paldiski long-term storage facility was originally USSR's Nuclear Submarine Training Centre established in the early 1960s for training the USSR navy personnel for the

operation on nuclear submarines. Two PWR reactors used on the Echo and Delta classes submarines were constructed here in 1968 (70 MWt) and 1983 (90 MWt) for training purposes. Both reactors were shut down in 1989 and after difficult negotiations with Russia, the training centre itself was closed in 1994. All the facilities were decommissioned and dismantled by the end of 2007, sarcophagi were constructed at Paldiski and radioactive material was disposed in the Paldiski long-term storage facility (Lust & Muru, 2009, p. 2; Putnik, 2003, p. 39-46).

It is the state company Ltd A.L.A.R.A. that implements the activities in radioactive management, and decontamination and decommissioning, and that is in charge of the Paldiski and Tammiku storage facilities. The Tammiku radioactive waste storage facility for institutional radioactive waste was built in 1960 and it is the third disposal site in Estonia. The facility operation was finished in 1996 due to an incident with radioactive sources and the waste storage had to be decommissioned. The radioactive waste was transported to Paldiski until 2011, the facility had been cleaned in 2012-2013 and demolished in 2013 (Lust & Muru, 2009, p. 2; Tatrik, 2011; The Ministry of the Environment of Estonia, 2008, p. 13).

Tab. 4.4.3: Estonian Nuclear Sector Examination

Indicator	Description
Is there nuclear producing capacity present in the country?	No
Is there a project to expand the capacity? What is the status of the project?	No, Estonia is a partner of the Lithuanian Visaginas NPP project
How was the project procured?	-
Who is the contractor in charge of the project?	-
How is the financing secured?	-
Who is the operator of the facility?	-
Are there enough home-based experts to run the facility safely?	-
Who is/will be in charge of decommissioning?	-
Who provides nuclear fuel and under what conditions?	-
What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	-
Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	Not anymore, Estonia used to produce uranium from Dictyonema shale until 1952 and enrich uranium mined elsewhere until 1989; the radioactive waste disposal sites serve for decommissioning and dismantlement of Sillamäe and Paldiski facilities
How is used fuel treated and who is in charge of this?	Radioactive material from the Sillamäe and Paldiski facilities is stored in the Sillamäe Radioactive Tailings Depository owned by Molycorp Silmet AS and in the Paldiski long-term storage facility owned by state company Ltd A.L.A.R.A.

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4.5 Country Case Study: Hungary

Tomáš Vlček

4.5.1 Introduction[1]

Hungary is a relative newcomer to the EU, joined in May 2004, and as a result, its energy economy still bears many of the hallmarks of a centrally planned economy in the Eastern Bloc. This is among the reasons why many of the CEE countries deal with similar issues in their respective energy sectors. Hungarian revolution in 1989 changed the track of the country towards democracy and market economy. Obviously, this was and is a huge change that has been addressed ever since.

As seen in table 4.5.1, over 60 % of Hungarian TPES share consist of hydrocarbons and this share is historically rather stable. The import dependency in oil sector is basically entirely on Russian Federation and amounts approximately to 5.7-6.5 Mt annually. Analogical is the situation in natural gas sector, where over 60% of supply is imported from Russian Federation and up to 17% from other former Soviet Union countries.

When speaking about electricity generation, the key source is nuclear energy covering 42% of the country's production. Hungary accommodates four Soviet designed PWR reactor VVER 440/V 213 models at the Paks Nuclear Power Plant in central Hungary, which will be described in detail later in the text. The Paks NPP is in the portfolio of the MVM Paks

[1] The chapter is based on the article previously published in the International Journal of Energy Economics and Policy journal in March 2015, where preliminary outcomes of the research were presented. (Vlček & Jirušek, 2015)

Nuclear Power Plant Ltd. That is owned by MVM Group[2], which is a fully state owned company. It is the largest power company in Hungary responsible for production, distribution as well as sale of electricity. MVM Group consists of 61 companies[3] operating not only in the electricity sector (all types of power and heat plants, distribution, accounting, etc.), but also in gas sector.

Tab. 4.5.1: Key Energy Statistics

Source	Consumption	Imports	TPES share	Electricity Generation share
Crude Oil	6.52 Mt	89%	25%	1.2%
Natural Gas	12.27 bcm	79%	38%	31%
Coal (all types)	11.1 Mt	19%	11%	17%
RES	-	-	7.9%	8.7%
Nuclear Energy	-	-	16%	42%
Note: 2010 data				

Source: ***OECD & IEA***, 2011; compiled and calculated by T. Vlcek

Quite uncommon is a high share of natural gas used on electricity generation. The 38% share on TPES and 31% share on electricity generation was produced in 6 gas-fired power plants totaling at 2,748 MWe of installed capacity.

[2] Magyar Villamos Muvek Zartkoruen mukodo Reszvenytarsasag, Hungarian Electricity Private Limited Company.
[3] On December 31, 2013, the MVM Group consisted of a total of 61 companies, including, with regard to ownership rights, one parent company, 41 subsidiaries, one joint management company, eight associated companies and ten other interests. (MVM Group, 2014, p. 5)

Tab. 4.5.2: Key Gas-fired Power Plants in Hungaria

Power Plant	Installed Capacity
Dunamenti	1,938 MWe
Csepel	389 Mwe
Kelenfold	196 Mwe
Debrecen	95 Mwe
Kispest	114 Mwe
Kobanya	15.6 MWe

Source: compiled by T. Vlcek from open sources.

Given the high reliance on Russian imports, it is not surprising that Hungarian energy policy is focused on diversifying the country's energy mix and reducing its dependence on gas and oil. One clear strategy to achieve this goal is via increased use of nuclear power because, as the IEA has pointed out in its Review of Hungarian Energy Policies ", any plans to significantly increase nuclear power capacity have a direct impact on the profitability outlook for gas fired power plants" (OECD & IEA, 2011, p. 66). This basically means that once a new nuclear power plant is constructed, cheap (in terms of production) electricity would be available, and this may cause a drop in demand of electricity from gas-fired power plants. Based on the merit order principle, the nuclear power plant would be able to cover the demand for electricity and also push the electricity produced in gas-fired power plants to the edge of competitiveness in Hungarian energy sector. This is also due to the fact that fuel costs are very high with gas-fired power plants and very low with nuclear power plants.

The third most important fuel for electricity production (17%) is coal. Hungary has domestic sources of sub-bituminous coal in the Markushegy underground mine and Visonta and Bukkabrany opencast mines (one of the largest coal reserves in Europe). The Markushegy mine is the last deep-cast coal mine in Hungary; it will be shut down in 2015 as part of the EU initiative to replace coal with cleaner energy (Hungary was approved to receive HUF 42.247 billion (€140 million) European Commission grant in January 2013 to shut down the uncompetitive coal mine operated by Vertes Power Plant by the end of 2014; "State aid: Commission", 2014). The coal extracted in the opencast mines is not a subject to cross-border trade; it is used for power generation in coal-fired power plants (260 MWe Oroszlany; and 950 MWe Matra) in the vicinity of the mines (Euracoal, 2013). The Matra power plant consumes roughly 8.5 million tons of lignite annually and produces more than 15% of Hungary's electricity demand by itself. Its life was extended for 10 years in 2005 thanks to the refurbishment of boilers and other equipment, and further plans to expand its capacity by 440MW were also announced by the owner RWE, but this scheme was abandoned in 2010 on economic and environmental grounds, and it now appears that the plant will close at the end of its life-cycle in 2015. This will significantly reduce generating capacity in Hungary, raising the question of the need for new sources of power, as the country is already an electricity importer. There are currently no hard coal power stations in Hungary, as the last hard coal mine was closed in 2003. The Pecs hard coal-fired power station was reconstructed to combust biomass and natural gas recently; it had been supplied from abroad in the time between the loss of domestic black coal and the reconstruction.

National electricity generation in 2012 amounted to 31.9 TWh, with an installed capacity totaling to around 10 GWe, of which 8.3 GWe are constantly available. A net 8 TWh of electricity was imported (Euracoal, 2013).

4.5.2 New Units and Financing of the Nuclear Power Plant

Besides the one NPP Hungary already operates, plans for construction of new units have been present in Hungary since 1980s. The original idea was the construction of another VVER-440/V-213 type reactor unit, but those efforts were cancelled because the manufacture and standardizing of the VVER-1000 units were decided in the Soviet Union. Preparation of the VVER-1000 project (landscaping, ground replenishment and building of the on-site transportation infrastructure) was cancelled by the government during the social changes (officially in 1990). The sole exception was the only high school in the country founded by the Paks Nuclear Power Plant specifically for the training of the future specialists – the school works effectively even today (Paks Nuclear Power Plant Ltd.). Together with experience from the operation of the NPP, and the KFKI Atomic Energy Research Institute with Csilleberc, research reactor thus adds very much to Hungary developing domestic expertise.

The current construction plans are thus based on 1980s plans and project preparations for VVER design reactors. This also might be among the reasons the contract was granted to the Russian Rosatom company without any procurement, even though these preparations are not at all obliging from the

technical and also political point of view. The planned NPP should consist of two Russian design VVER-1200 models (also known as Modernized International Reactor 1200, MIR-1200) with 3,200 MWt/1,198 MWe of installed capacity each, an evolutionary model based on the previous VVER-1000 and VVER-440 models. In 2012, the company MVM Paks II Nuclear Power Plant Development Ltd owned by MVM Group was established to conduct preparatory work for the construction of new units. This company signed three implementation agreements with JSC NIAEP on December 12, 2014, a company forming part of the State Corporation Rosatom. The first document is the EPC contract (engineering, equipment supply, construction) for the two new power units, which stipulates the tasks for the next 12 years. The second one is the operation and maintenance contract for the future power units, and the third document is the fuel supply contract. The power units will remain under Hungary's ownership, while the total investment cost will be within a cost frame of 12.5 billion euros in all circumstances ("Contracts for constructing", 2014).

The example of Hungary's Paks NPP can thus serve as a negative example, as the decision to grant the project to the Russians was made by the prime minister and his closest collaborators without any consultations with other interested parties, industry experts, or the public at large (Field, 2014). In this situation, the state (i.e. the contracting party) leaves itself extremely vulnerable due to a lack of expertise on its side in a complex negotiation, with the lack of transparency only adding to the sense of an improper deal being concluded. In contrast, in the procurement procedure for the Czech Temelin NPP, just the documentation specifying the conditions of the project took three years to prepare and was created by group of several tens of experts. Ultimately, this documentation comprised more than 6,000 pages establishing over 11,000 criteria that needed to be met by any successful bidders. In return, each bidder provided the Czech side with the documentation exceeding 10,000 pages each (Horacek & Topic, 2012; interview with a Czech official responsible for the process), while the procurement period itself took several years.

On the contrary, in Hungary the decision appears to have been made on rather less thorough basis. The project involving two Russian design VVER-1000 units has been planned since the 1980s, but the project was cancelled after the fall of the communist regime, due to both economic issues and a decrease in energy demand. A later initiative to build the new units in the mid-1990s also stalled, but the project has been revived due to the need to replace obsolete power generating plants and supplement them with 6000 MWe of new capacity by 2030 (WNA, 2014). Although the parliament agreed that it was necessary to expand the nuclear generating capacity, it has also been clear from the very beginning that the project could not be carried out without the financial support of an external project partner. As a result, when an EUR 10 billion loan to co-finance the project was offered by the Russian Federation,[4] it soon became evident that the Russian VVER-1200 units were the preferred option and a deal was eventually cemented in January 2014[5], when Hungary entered into an international agreement with the government of the Russian Federation on the

[4] The Russian side was allegedly the only one prepared to offer financing to support the project. The loan equals 80% of the total costs of the project ("A Brief Summary, n.d.").
[5] France's Areva and US electric company Westinghouse along with Japanese and South Korean power suppliers had previously expressed interest in bidding for a contract of the Hungarian plant's expansion.

cooperation in peaceful use of nuclear energy (Balogh, 2014). Under the terms of the deal, the Russian Federation will grant Hungary an interest-only loan at an annual rate of 3.9%, starting in 2014. Once the construction is completed in 2026 (the expected start date), the principal balance will be amortized for 21 years, with an interest rate of 4.5% for the first seven years, 4.8% for the next seven, and 4.95% for the final seven ("A Brief Summary", 2014; "Kiderultek a reszletek", 2014).

However, it is the conditions of the deal and the way they were negotiated that have raised concern about Hungarian dependency on Russia. Not only was Hungary granted a loan of EUR 10 billion to co-finance the project by the Russian Federation,[6] but the deal was negotiated by the Hungarian prime minister and was granted to Rosatom without any official procurement procedure, causing a great outrage among the opposition parties in the parliament (Nolan, 2014). The specific terms of the loan have been called into question amid fears that Hungary could face significant losses in future.[7] Many also fear that the deal will tie Hungary to the Russian Federation for many years to come, as part of an apparent foreign policy turn to the East conducted under the Prime Minister Viktor Orban's administration in recent years (Buckley & Eddy, 2014; "Atment a parlamenten", 2014).

Additionally, Hungary may also be accused of breaching EU rules by omitting to carry out a proper procurement process

[6] The Russian side was allegedly the only one prepared to offer financing to support the project. The loan equals 80% of the total costs of the project ("A Brief Summary, n.d.").
[7] Some sources claim that one of the catches within the agreement is the price of particular construction work that is to be defined by the contractor. Also, the payment conditions are allegedly very strict and may lead to severe financial losses for the Hungary, since the interest rates are quite high (around 4% at the beginning and rising progressively during the contract duration) and the penalties for overdue payments are also harsh ("A Brief Summary, n.d.").

("Russia, Hungary sign", 2014), and the EU could also object to the state subsidies being granted to MVM Group, both of which could obviously lead to a long term political and legal dispute. Indeed, unofficial sources suggest that the European Commission has already started an initial investigation against the Paks NPP. Overall, though, the crux of the issue remains the financing of the deal, with the loan offered by Russia being a crucial element in the choice of reactor. Other issues have also undermined the credibility of the project, but essentially, the need to raise funds to pay for the construction has been at the heart of the decision-making process.

After the European Commission has checked the Russia-Hungary deals, the objection was basically against fuel supply part of the contract only. The EPC contract and the operation and maintenance contract was approved and signed by the European Commission, only the fuel supply contract was objected by Euratom Supply Agency (ESA). ESA objected to long-term supply contract from Russia as "rules in the European Union require all power plants to have more than one fuel supplier in the long term" ("Euratom approves Paks II", 2015). After amending this particular contract, i.e. removing exclusivity of Russian fuel supplies (which of course does not mean Russian Federation will not supply fuel, only exclusive fuel contract was replaced by public procurement obligation for Hungary), the deal was accepted. Hungary is however still in talks with the European Commission concerning competition law and missing public procurement procedure. These talks have not been resolved so far.

4.5.3 The Front End of the Nuclear Fuel Cycle

Hungary does not currently have any capacity in the Front End of the Nuclear Fuel Cycle, although it is possible that uranium mining could be restarted at some point. Historically, Hungary had mined uranium from 1956 to 1997 in the Mecsek underground mine near the city of Pecs. The concentration of uranium in uranium ore was 0.1-0.15%; and 18,103 tons of uranium had been mined and sold during 1958-1997 (Csovari, 2008). Hungary consequently developed processing capabilities for ore milling and yellow cake production in the vicinity of the mine. The production and the processing were closed down in 1997 for economic reasons, i.e. due to the low price levels in the world market at that time. The remediation of the mine ended in 2008 with expenditures of EUR 83 million. Still, 19 million tons of uranium ore (of uranium concentration ≈0.12%) were left behind in the mine (Csovari, 2008).

In 2006, an Australian company WildHorse Energy joined with state-owned firm Mecsekerc to assess the feasibility of restarting uranium mining in four locations of the seven exploration licenses of WildHorse Energy (namely Mecsek, Bataszek, Dinnyeberki and Mariakemend). In 2012, the exploration drilling was completed, but the last three locations were completed without noteworthy success. However, a joint venture of WildHorse Energy, Mecsekerc, Mecsek-Oko and Hungarian Electricity Ltd. emerged around the Mecsek location as the inferred resources are of about 17,946 tons of uranium (tU). The high price of uranium is one of the reasons of driving the proposed re-start of operations (Malovics, 2014; OECD NEA & IAEA, 2014, p. 49, 244). Anyway, the exploration activities appear to be very limited and the possible production is highly uncertain. Also, it is questionable whether the old processing facilities might be used. Moreover, restarting of mining operations would require investment into new processing facility, or an investment into reconstruction of the old one.

In present, given that Hungary does not currently produce uranium, there is a long term contract with Russian TVEL for nuclear fuel supply. The Paks power plant signed this contract in 1999 and the contract is valid as long as its reactors are operating, including the new service life extensions. The contract is worth EUR 83 million in 2013 ("Hungarian Nuclear Power", 2014; "Paks moving to", 2014). Starting in 2015, the power plant will be supplied with new generation fuel with higher enrichment (from 4.2% to 4.7% of 235U) prolonging the fuel campaign of one assembly from 12 to 15 months (e.g. from three-year-cycle to five-year-cycle).

4.5.4 The Service Part of the Nuclear Fuel Cycle

Hungary has a long-term experience with nuclear energy; the first nuclear power plant was built at Csilleberc in Budapest in 1959. It is a research reactor reconstructed and upgraded in 1986-1993, based at KFKI Atomic Energy Research Institute in Budapest-Csilleberc. Similarly to many other CEE and world countries, the development of nuclear energy was connected to the world oil crisis in 1970s.

There is currently one nuclear power plant in Hungary, the Paks NPP in central Hungary, 5 kilometers from the city of Paks. The Paks NPP is operated by the state company MVM, and much of the country's experience and expertise in the sector is located in Paks. As a result, Hungary is certainly competent

to run its own nuclear plants without an external assistance, including the provision of parts and maintenance. All repair and maintenance as well as the design and construction of different machinery and technology sets can be and usually is delivered by a range of companies around the world, especially from countries that operate nuclear power plants - many of them coming from the CEE region with a lot of experience with Russian technology.

Tab. 4.5.3: Nuclear Units in Hungary

Reactor	Type	Power Output	Status	End of life-cycle
Csilleberc*	VVR-S	10 MWt	Operating	-
Paks 1	VVER-440/V-213	500 MWe	Operating	2032
Paks 2	VVER-440/V-213	500 MWe	Operating	2014 (2034)**
Paks 3	VVER-440/V-213	500 MWe	Operating	2016 (2036)**
Paks 4	VVER-440/V-213	500 MWe	Operating	2017 (2037)**
Paks II 5	VVER-1200	1,198 MWe	Planned	-
Paks II 6	VVER-1200	1,198 MWe	Planned	-

* It is a research reactor built in 1959, reconstructed and upgraded in 1986-1993, based at KFKI Atomic Energy Research Institute in Budapest-Csilleberc.
** It is very likely that the lifetime of all units will be extended for 20 years, like with the Unit 1; see below.

Source: compiled by T. Vlcek from open sources.

The Paks NPP consists of 4 units of Soviet designed VVER 440, model V 213. It is an evolutional model from the original V-230 model. Unlike the V-230 model that has no containment at all, the V-213 does have a specific type of containment, the so called pressure suppression containment. This equipment suppress pressure in the event of an accident in sealed areas of nuclear power plant (i.e. primary circuit) to minimize the risk of leakage of radioactivity outside these areas.

The nuclear power plant was constructed between 1974 and 1987 and the original installed capacity was 4x 440 MWe[8]. The power plant underwent two series of modernizations and an upgrade in the 1990s and between 2002 and 2009[9], and the installed capacity was thus raised to 4x 500 MWe. The power plant was connected to the grid during 1982-1987[10] with 30 years lifetime expectancy. A feasibility study for the lifetime extension of the nuclear power plant units was carried out in 2000 stating that no technical or safety obstacles to extend the operational lifetime of the plant exist ("Report on the preparation", n.d.). Since 2001, the company has successfully worked on all the required documentation for the lifetime extension program, including the most important Environmental Impact Assessment.

The Hungarian Atomic Energy Authority (HAEA) has approved the lifetime extension program (submitted in November 2008) for all four reactors, and in December 2012, it approved a 20-year license extension for unit 1 only (WNA, 2014), as the license for extended operation must be applied for each unit, one year before the original lifetime ends. It is very likely that all units will be extended and the life expectancy of the power plant will thus be 50 years, i.e. 2032-2037. The current government considers energy production as a way of

[8] It is interesting to add that one of the four reactors was bought from Poland after the Polish Zarnowiec NPP project was abandoned in 1990 after strong public opposition, the Chernobyl disaster, and the public referendum in late 1980s.
[9] The second modernization increasing the capacity by 8% was carried out by Russian Atomstroyexport. The EUR 19 million uprate program included modifications to reactor core control and primary circuit pressure control principles ("More Power for Paks", 2007).
[10] Unit 1 in 1982, unit 2 in 1984, unit 3 in 1986, and unit 4 in 1987.

emerging from the economic crisis, and one pillar of the strategy is to maintain the current share of nuclear generating capacity in the long term (OECD NEA & IAEA, 2014, p. 83). The lifetime extension of Paks NPP as well as the development of the Paks II NPP is in compliance with this strategy.

In 2003, Level 3 accident on the International Nuclear Event Scale (INES) took place. Paks NPP unit 2 had experienced problems with Russian fuel elements due to the presence of corrosion deposits. These deposits resulted in coolant flow problems which had resulted in an unscheduled refueling outage. Thus a cleaning system placed on the bottom of the spent fuel pool, next to the reactor, was hired from Framatome ANP (a joint company of French Areva and German Siemens). On April 10, the partially spent fuel rods undergoing cleaning in a tank of heavy water ruptured and spilled fuel pellets. It is suspected that inadequate cooling of the rods during the cleaning process combined with a sudden influx of cold water thermally shocked fuel rods causing them to split. Release of radioactive gases followed for several days and the unit was shut down until the end of 2006. In 2014, the 30 damaged fuel assemblies were sent to FSUE Mayak PA in Russia for reprocessing (World Nuclear Association, 2014c; "Serious incident", 2003; IAEA, 2009).

4.5.5 The Back End of the Nuclear Fuel Cycle

The used fuel in Paks NPP is cooled in the basins next to the reactor and then stored in interim storages. The pool storage capacity at Paks NPP was expanded almost twofold during 1984-1987, after the first units were commissioned. There are no plans for the reprocessing of the spent fuel. The first interim storage is located approximately 5 km from the power plant, in the city of Paks in the Interim Storage of Irradiated Fuel (ISIF[11]). This storage facility is used for about 3-5 years and the assemblies are transported to long term storage facility after 3-5 years.

The spent fuel is subsequently transferred to long-term storage facility near the village Puspokszilagy, which was constructed in 1960s and came into operation in 1976. It is operated by state owned Public Limited Company for Radioactive Waste Management (PURAM[12]). The problem with the site is that it was not primarily meant as a repository for radioactive waste from nuclear power plants, and therefore its capacity is insufficient. First capacity problems have already emerged in 2005, as 115 spent fuel assemblies are generated per unit annually.

As a result, it was deemed necessary to build a separate long-term storage facility, and in 1997, the location Bataapati located south of the nuclear power plant in Paks, was found to have suitable geological conditions. The spent fuel was stored in surface long-term storages in the complex and recently, on December 5, 2012, the first underground chamber of the final repository for low and intermediate-level radioactive waste was inaugurated, an important developmental step for the nuclear industry. The Bataapati municipality agreed to build the complex quite enthusiastically (with 90% of referendum respondents) and part of the residents also contribute to its functioning, i.e. is employed at the facility (Paks Nuclear Power

[11] Or KKAT, Kiegett Kazettak Atmeneti Taroloja in Hungarian.
[12] Or RHK, Radioaktiv Hulladekokat Kezelo Kozhasznu Nonprofit Kft in Hungarian. PURAM is also the responsible organization for decommissioning of nuclear installations in Hungary.

Plant Ltd.; Radioaktiv Hulladekokat Kezelo Kozhasznu Nonprofit Kft; Andras, 2012; Kovacs, 2010; OECD NEA & IAEA, 2014, p. 247).

It is calculated that the 2007 capacity was 7,200 fuel assemblies and the total number of spent fuel assemblies including the extended service of the power plant will be 17,900 (Hegyhati & Ormai, 2010). The company thus works on the expansion of the facility and the construction design allows for the extension of the storage facility. The work is financed from the Central Nuclear Financial Fund that was established as of the 1st of January 1998 by the Act on Atomic Energy and the executive orders thereof, with the purpose of financing the disposal of radioactive wastes, the interim storage, and final disposal of spent nuclear fuels and the decommissioning and dismantling of nuclear facilities.

Hungary does not have a final high-level wastes deep underground depository, but a claystone formation near the city of Buda in the southwest Mecsek Mountains is being investigated, and a preliminary safety analysis has been made for a deep geological repository there. It is expected to begin operation after 2060 (World Nuclear Association, 2014c).

Tab. 4.5.4: Hungarian Nuclear Sector Examination

Indicator	Description
Is there nuclear producing capacity present in the country?	Yes, Paks NPP (VVER-440/V-213 deign, 4 Units of 500 MWe each)
Is there a project to expand the capacity? What is the status of the project?	Yes, planned, securing of finances in process
How was the project procured?	Without procurement process, bilateral agreement with Russia
Who is the contractor in charge of the project?	Rosatom State Nuclear Energy Corporation
How is the financing secured?	Hungary was granted a loan of EUR 10 billion to co-finance the project by the Russian Federation
Who is the operator of the facility?	MVM Paks Nuclear Power Plant Ltd. (owned by MVM Group, a fully state owned company) for Paks 1-4; MVM Paks II Nuclear Power Plant Development Ltd (owned by MVM Group) for Paks II 5 and 6
Are there enough home-based experts to run the facility safely?	Yes
Who is/will be in charge of decommissioning?	State owned Public Limited Company for Radioactive Waste Management (PURAM)
Who provides nuclear fuel and under what conditions?	Long term contract with Russian TVEL signed in 1999 and valid as long as its reactors are operating, including the new service life extensions
What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	No operational issues; path dependency rationale found in nuclear fuel supply from Russian companies
Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	Uranium mining could be restarted at some point; currently, Hungary has capacities only in the Back End of the Nuclear Fuel Cycle
How is used fuel treated and who is in charge of this?	The used fuel is stored in domestic interim and in long-term storage facilities of the state owned Public Limited Company for Radioactive Waste Management (PURAM)

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4.6 Country Case Study: Latvia

Tomáš Vlček

4.6.1 Introduction

Latvia is a Baltic republic that borders with Estonia, Russian Federation, Belarus and Lithuania and also with Sweden and Finland over the Baltic Sea. Latvia gained sovereignty which was recognized by Russia in 1920 but lost it again in 1940 when it was unwillingly incorporated into the Soviet Union and shortly occupied by Nazi Germany in 1941-1944. Since that time, Latvia had been part of the USSR as the Latvian Soviet Socialist Republic until 1991. Latvia joined the EU in May 2004 together with Estonia and Lithuania and seven other countries. Due to the history, the political and social mood is strongly anti-Russian. Latvia was always a country with rather well-off economy and today the Latvian economy is basically unconnected with the Russian economy.

Speaking about the energy sector, Latvia is fully dependent on energy imports. It imports all of its natural gas, oil products and coal consumption almost exquisitely from Russia. Latvia does not import crude oil, but imports all of its oil needs in oil products directly. Biofuel production and electricity generation in hydro power plants and wind power are basically the only domestic sources of energy. As such, they are being well maintained and further developed.

Even though coal is not an issue in terms of energy security due to its negligible consumption, Latvia plays an important role in coal transportation; its JSC Baltic Coal Terminal in Ventspils with 6 Mt/y capacity is actively used for Russian coal

export in the EU. The port's capacity is currently being enhanced by another 4.5 Mt/y (JSC Baltic Coal Terminal).

Tab. 4.6.1: Key Energy Statistics

Source	Consumption	Imports	TPES share	Electricity Generation share
Crude Oil	1.58 Mt	0%	30.2%	0.03%
Natural Gas	1.53 bcm	100%	31.5%	45.1%
Coal (all types)	0.17 Mt	100%	2.3%	0.03%
RES	-	-	34.4%*	54.84%**
Nuclear Energy	-	-	0%	0%
Note: 2010 data				
* Biofuels and waste stands for 27.8 % of TPES share ** Hydro stands for 53.1% of Electricity Generation share				

Source: ***U.S. Energy Information Administration***; International Energy Agency; compiled and calculated by T. Vlcek

Latvia produces its electricity mainly from gas and water. The river Daugava, flowing through Russia, Belarus, and Latvia to the Baltic Sea, is therefore very important, as a cascade of hydroelectric power plants is constructed on its course. The biggest HPPs are Rīgas (402 MWe), Ķeguma 1 (72 MWe), Ķeguma 2 (192 MWe), and Pļaviņu (883.5 MWe). Natural gas is used as fuel in the combined heat power plants Riga 1 (144 MWe) and Riga 2 (832 MWe) and in some other very small CHPs in the country.

Tab. 4.6.2: Key Power Plants in Latvia

Power Plant	Installed Capacity	Fuel	Year of Construction
HPP Rīgas	402 MWe	Water	1966-1974
HPP Ķeguma 1	72 MWe	Water	1936-1940, renovated 1998-2001
HPP Ķeguma 2	192 MWe	Water	1976-1979
HPP Pļaviņu	883.5 MWe	Water	1961-1966
CHP Riga 1	144 MWe	Gas	1954-1958 renovated 2003-2005
CHP Riga 2	832 MWe	Gas	1975-1979 renovated 2006-2013
Note: CHP = Combined Heat Power Plant, HPP = Hydroelectric Power Plant			

Source: *Latvenergo AS*

More than 90% of electric energy generated in Latvia is generated by the Latvenergo AS. In 2010, 5,851 GWh was generated but around 5,100 GWh annually is produced on average (Latvenergo AS, 2014, p. 4). The consumption in 2010 reached 7,500 GWh and as the domestic production does not cover the demand, another approximately 1,600 GWh on average annually has to be imported from neighbouring states (International Energy Agency).

4.6.2 New Units and Financing of the Nuclear Power Plant

Latvia is very interested in the planned Lithuanian Visaginas NPP and is the 20% share holder in the future Visagino atominė elektrinė (VAE) Project Company through Latvenergo AS. No domestic NPP project is planned or being developed. See Lithuania Case Study for detailed information.

4.6.3 The Front End of the Nuclear Fuel Cycle

As there are no Uranium deposits, and no production, processing and/or fabrication capabilities in Latvia, no Front End information can be presented.

4.6.4 The Service Part of the Nuclear Fuel Cycle

There are no nuclear power plants in Latvia, but in the past there was a plan to construct a nuclear power plant. The project called Pāvilostas NPP originated in 1960s but was postponed after Lithuania agreed to build Ignalina NPP on its territory. The project was repeatedly suggested by the USSR Ministry of Energy and Electrification and VVER design reactors were planned first with 3,000 MWe, later with 4,000 MWe, and in the end, even with 6,000 MWe installed capacity. The project was definitely abandoned after the Chernobyl accident as well as due to the restructuring of the Soviet political and economic system in 1980s (*Nuclear Heritage Network*).

However, Latvia does have experience with nuclear energy as Latvian researchers participate in developing the ITER fusion reactor in Cadarache France, and also as one of the first research reactors in the USSR, the Salaspils 5 MWt research reactor, was constructed in 1959 at the Latvian Institute of Nuclear Physics. The reactor was shut down in 1998 and the option of dismantling of the reactor to “green-field” was chosen (Abramenkovs, 2011, p. 78). However, the plan was partly changed in 2006, when National multifunctional cyclotron center with Latvian Government's support has started to develop in Salaspils.

4.6.5 The Back End of the Nuclear Fuel Cycle

At the end of the 1950s and at the beginning of the 1960s, a radioactive waste repository was built in Latvia. This near-surface repository for both burial and storage of low and intermediate level radioactive waste is called Radons and is located in Baldone municipality in the vicinity of Riga. Local radioactive waste, especially from the Salaspils Research Reactor as well as waste from other Baltic states, is stored here and there are plans for considerable extension (approximately doubling the capacity) of the facility connected with the dismantling of Salaspils Research Reactor (*Nuclear Heritage Network*). The repository is operated by State Ltd "Latvian Environment, Geology and Meteorology Centre" under the Ministry of Environment of Latvia.

Tab. 4.6.3: Latvian Nuclear Sector Examination

Indicator	**Description**
Is there nuclear producing capacity present in the country?	No
Is there a project to expand the capacity? What is the status of the project?	No, Latvia is a partner of the Lithuanian Visaginas NPP project
How was the project procured?	-
Who is the contractor in charge of the project?	-
How is the financing secured?	-
Who is the operator of the facility?	-
Are there enough home-based experts to run the facility safely?	-
Who is/will be in charge of decommissioning?	-
Who provides nuclear fuel and under what conditions?	-
What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	-
Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	No, except for the Radons low and intermediate level radioactive waste; this is however not intended for NPP's spent fuel and it would not contribute to country's nuclear fuel cycle
How is used fuel treated and who is in charge of this?	Radioactive material from the Salaspils Research Reactor decommissioning and dismantling is stored in the repository for low and intermediate level radioactive waste called Radons operated by State Ltd "Latvian Environment, Geology and Meteorology Centre" under the Ministry of Environment of Latvia

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4.7 Country Case Study: Lithuania

Tomáš Vlček

4.7.1 Introduction

Lithuania is a Baltic state that borders with Latvia, Belarus, Poland and Russia (Russian exclave of Kaliningrad). The history of Lithuania is grim, the country had been occupied, annexed or Sovietized during the 20th century, basically since its emergence in 1918 until the dissolution of the Soviet Union in 1991. The Lithuanian Soviet Socialistic Republic declared independence in March 1990 as the first Soviet republic and had to fight for it until 1993 when last Soviet troops left the country, which became the Republic of Lithuania. Lithuania joined the EU in May 2004 together with 9 other countries.

As a country with very limited domestic energy resources, Lithuania currently imports basically all natural resources including around 50% of its electricity needs (*International Energy Agency*). The Lithuanian energy system is linked with Latvia, Belarus and Russia via cross-border connections and new interconnectors to Sweden and Poland will begin operation in January 2016.

The top three electricity generation sources are gas, hydro and oil. On the country's total electricity production of 5.75 TWh in 2010, these accounted for 55.4%; 22.5% and 11.3% (see Table 4.7.1). The total installed capacity in Lithuania in 2011 was 4,021 MWe of which 3,681 was available (National Control Commission for Prices and Energy, 2012, p. 43).

Tab. 4.7.1: Key Energy Statistics

Source	Consumption	Imports	TPES share	Electricity Generation share
Crude Oil	2.84 Mt	333%	36.4%	11.3%
Natural Gas	3.11 bcm	100%	35.3%	55.4%
Coal (all types)	0.32 Mt	100%	2.9%	0%
RES	-	-	15.1%	33.3%*
Nuclear Energy	-	-	0%	0%
Note: 2010 data * Hydro stands for 22.5% of electricity production				

Source: *U.S. Energy Information Administration; International Energy Agency*; compiled and calculated by T. Vlcek

Lithuania imports nearly all of its oil consumption from Russia. As Russia has blocked imports to Lithuania via the Druzhba pipeline, all imports go through the Būtingė maritime oil terminal (European Commission, 2013, p. 168). Lithuania imports more than three times more oil than it consumes. The reason for this is the fact that Lithuania houses large Mažeikiai oil refinery and oil-processing plant with the capacity of 15 Mt/y of which 8 Mt/y is efficiently used given the existing technologies and current marketing conditions (*Orlen Lietuva*). Lithuania thus exports large volumes of crude oil products mainly through the Būtingė oil terminal.

Speaking about natural gas, the situation is not that different; Lithuania has no domestic production and is fully dependent on Russia and the country has active interconnections only with Latvia, Russia and Belarus (European Commission, 2013, p. 169). An interesting project to avoid the dependency on Russian gas supplies is the LNG Floating Storage

Regasification Unit (FSRU), a ship named Independence lent for 10 years from Norwegian company Höegh LNG with the option of purchase (“Independence LNG”, n.d.). Together with the LNG port Klaipėda, of which the operation start is scheduled for December 2014, this FSRU ship represents 100% diversification of Lithuanian imports as the capacity of the FSRU is nearly 4 bcm/y.

Tab. 4.7.2: Key Power Plants in Lithuania

Power Plant	Installed Capacity	Fuel	Year of Construction
TPP Lithuanian (Elektrėnai)	1,955 MWe	Gas, HFO	1960-1972
CHP Vilnius	388.8 MWe	Bio, Gas, HFO	1976-1983
CHP Kaunas	170 MWe	Gas, HFO	1971-1975
Mažeikiai	160 MWe	HFO	1979-1982
Panevėžys	35 MWe	Gas	2006-2008
HPP Kaunas	100.8 MWe	Water	1955-1960
PSHPP Kruonis	900 MWe	Water	1984-1998
Note: CHP = Combined Heat Power Plant, HPP = Hydroelectric Power Plant; TPP = Thermal Power Plant; HFO = Heavy Fuel Oil; PSHPP = Pumped Storage Hydroelectric Power Plant			

Source: *Lietuvos Energijos Gamyba AB; “Installed generation”*, 2014

Beyond the smaller gas- and oil-fired Combined Heat Power Plants in Vilnius, Kaunas, Mažeikiai and Panevėžys, Lithuania houses a big condensing thermal power plant 2 km from the city of Elektrėnai. This Lithuanian Power Plant's (LPP) installed capacity is 1,955 MWe of which 6 Units (1,355 MWe) combust natural gas and 2 Units (600 MWe) combust heavy fuel oil (HFO) (Lietuvos Energijos Gamyba AB).

There was 127 MWe installed capacity in Hydro in 2011 of which 116 was available. The biggest hydroelectric power plant in Lithuania is the 100.8 MWe Kaunas Algirdas Brazauskas' Hydroelectric Power Plant (KPP). There is also the 900 MWe Kruonis Pumped Storage Hydroelectric Plant (KPHP), an important part of the Lithuanian electricity system that helps balancing electricity supply and demand.

Until 2009, Lithuania generated electricity also from nuclear energy. The Ignalina NPP (Ignalinos atominė elektrinė) was shut down as part of Lithuania's accession agreement to the EU. Unit 1 was closed in 2004, and upon the shutdown of the Unit II in 2009 Lithuania lost the generation capacity meeting approximately 80% of total national electricity demand and 77% of domestic electricity production at the end of 2009, and the previous net exporter of electricity suddenly became net importer, importing electricity from the Russian Federation (National Control Commission for Prices and Energy, 2012, p. 9; Grigas, 2013, p. 71-72). Also, electricity prices increased dramatically after 2009.

4.7.2 New Units and Financing of the Nuclear Power Plant

Following the shutdown of Ignalina NPP and the sudden switch of Lithuania from being a net exporter to being a net importer of electricity, Lithuania has been developing a project to construct a new nuclear power plant at the same site as Ignalina NPP stands, but named Visaginas after a nearby city. The idea emerged in 2006 and since the beginning it was warmly welcomed by neighbouring countries, Latvia, Estonia

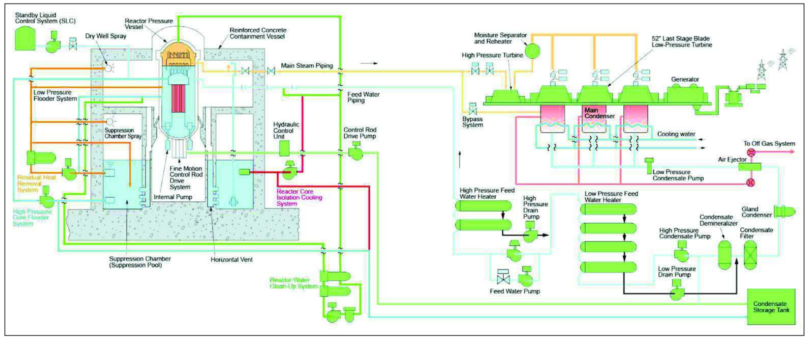
and Poland. In fact, these four countries initiated and prospected the construction of a new NPP with 3,200 MWe installed capacity in two units in Lithuania together since the beginning. The preparatory works were conducted by Lietuvos Energija UAB until 2008, when Visagino atominė elektrinė (VAE) Company was created and took over the preparatory works. The VAE is still owned by Lietuvos Energija UAB.

In 2009, the approved Environmental Impact Assessment imposed a limit of 3,200 MWt to be discharged into Lake Drūkšiai without the need to construct cooling towers (WNA, 2014a). This eventually led to reduction in the planned capacity to single unit of 1,350 MWe. In 2009, the business model and the financing plan for the new Visaginas NPP was prepared and presented. Considering the economic situation and the particularities of the development of NPP projects, a decision was made to attract a Strategic Investor with the experience in nuclear energy and the development of NPP construction projects as well as funds to invest in the Visaginas NPP (*Visagino atominė elektrinė*). The investor was supposed to get majority in the future VAE Project Company and the remaining stake should have been divided among Poland, Lithuania, Latvia, and Estonia. Unfortunately, with Lithuania wanting 34% of the project and Poland then wanting 30% of it, Latvia and Estonia were unhappy with the prospect of minor stakes and the discussion was not clearly resolved (WNA, 2014a).

In 2010, a tender for the selection of a Strategic Investor into Visaginas NPP was organized and also, the IAEA mission evaluated that the assessment of the new NPP's sites was conducted in accordance with its recommendations. There were only two responses received, but unfortunately one undisclosed did not meet the official tender requirements and the other by Korea Electric Power Corporation (KEPCO) withdrew two weeks later (*Visagino atominė elektrinė*). Therefore later that year it was decided to continue with the selection of a Strategic Investor using direct negotiations.

In May 2011, two proposals from potential strategic investors were received, namely from Westinghouse Electric Company LLC and Hitachi-GE Nuclear Energy Ltd. Westinghouse offered AP1000 reactor technology with the capacity of 1,154 MWe and Hitachi-GE's offer was 1,350 MWe Advanced Boiling Water Reactor. Hitachi-GE was eventually selected to be the strategic investor. Moreover, as it is an EPC contract, the company will also engineer, procure and construct the Visaginas NPP. Through Hitachi-GE, the VAE was later joined by the project company Exelon Corporation, which has the most experience with BWR reactors in the USA.

Tab. 4.7.3: The Hitachi-GE ABW Reactor Scheme



Source: *Hitachi-GE Nuclear Energy, Ltd.*

Shortly after, Poland withdrew from the project because the VAE's conditions were reported "unacceptable" to PGE SA (state-owned company Polish Energy Group). Thus, the future VAE's Project Company equity shares were redistributed as follows: Hitachi-GE Nuclear Energy, Ltd. 20%, Latvia 20%, Estonia 22%, and Lithuania 38% (WNA, 2014a) through state companies Latvenergo AS, Eesti Energia AS, and Lietuvos Energija, UAB. The shares are described in detail in Table 4.7.4.

Tab. 4.7.4: Equity Shares of Shareholders in the Future Visagino atomine elektrine (VAE) Project Company

Shareholder	Ownership	Equity Share (%)	Visaginas NPP Installed Capacity Share (Mwe)
Hitachi-GE Nuclear Energy, Ltd.	Hitachi Ltd. 80.01%; General Electric Company 19.99%	20	-
Latvenergo AS	Latvian Government	20	330*
Eesti Energia AS	Estonian Government	22	363*
Lietuvos Energija, UAB	Lithuanian Government	38	657
* estimated			

Source: compiled by T. Vlcek from open sources and *WNA*, 2014a; *Ministry of Energy of the Republic of Lithuania*, 2013

A consultative referendum about the construction of the Visaginas NPP was held in Lithuania in October 2012 and 62.7% of voters were against the construction (Ministry of Energy of the Republic of Lithuania, 2013). These unfavourable outcomes led Prime Minister Algirdas Butkevičius to form a special work group to analyze the Visaginas NPP project. The work group eventually stated that the development of the project is possible only if following additional conditions are fulfilled:

- sharing of project implementation expenses, responsibilities, and risks, by entering into legal agreements with regional partners on joint participation in Visaginas NPP project has to be ensured;
- together with Strategic Investor and Regional Partners to ensure maximum project financing at the lowest costs from international financial institutions and export credit agencies, thus securing economic competitiveness of electricity generated by Visaginas NPP;
- to ensure sustained and comprehensive public awareness of the project, considering the fact that the project can be implemented only if national agreement on rational, competitive, sustainable and perspective electricity supply is in place. The project must be developed by the use of the most modern and practically tested nuclear technology (Ministry of Energy of the Republic of Lithuania, 2013, p. 7).

The working group also proposed a balanced and diversified energy self-provision scenario, based on safe nuclear energy development together with renewables to be the best scenario option. Generally, the project was stalled since April 2013 as Lithuania started negotiating the economic conditions of the project with Hitachi-GE, Latvia and Estonia showed some reluctance, and prosecutions against VAE for non-tender purchases of services took place.

It was the Ukrainian Crisis in 2014 that added new energy into the process. A document setting out the nation's strategic goals and the commitment to the construction of the Visaginas NPP as soon as possible was signed by the representatives of all the parliament parties in the presence of Lithuanian president Dalia Grybauskaitė (WNN, 2014). In July, the Ministry of Energy of Lithuania and Hitachi-GE signed the Memorandum of Understanding, in which the establishment of an interim project company to enhance to project was agreed ("Memorandum of Understanding", 2014). However, several unresolved issues are still to be clarified, including Lithuania's grid synchronization with the EU, project issues with other shareholders, and interconnectors' development.

As the Lithuanian government explicitly excluded the choice of a Russian design, there has been no direct Russian presence in the procurement of VAE. However, Russia is present in two other competing projects in the region, namely in Belarusian Ostrovets NPP (two VVER-1200/491 units of combined capacity of 2,400 MWe) and Russian Kaliningrad's Neman NPP[1] (two VVER-1200/491 units of combined capacity of 2,400 MWe) announced in 2008.

Lithuania and Ukraine has complained about the construction of the Ostrovets NPP in Belarus that should finish in 2018 (Unit 1) and 2020 (Unit 2) for numerous violations of the Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention). But the parties of the Convention at a meeting in Geneva in June 2014 eventually decided that the Belarus NPP under construction at Ostrovets

[1] Also referred to as Baltic Nuclear Power Plant or Kaliningrad Nuclear Power Plant.

is in non-compliance with the provisions of the Espoo Convention (Mitev, 2014). Even though the Lithuanian complaints seemed to be forced rather by political targets than environmental concerns, Belarus has been asked by the parties of the Espoo Convention to take these into consideration and also recommended to approach the International Atomic Energy Agency for an independent assessment of the nuclear power plant site. The Ostrovets NPP is discussed in detail in the Belarus Case Study.

Tab. 4.7.5: Nuclear Power Plant Projects in the Baltic Region

Source: *„Baltic or Visaginas"*, 2014

The greatest rival to the Visaginas NPP is the Russian project of construction of Neman NPP in the Russian exclave Kaliningrad. The idea came up several times in 1990s with lack of interest from Kaliningrad's authorities. After a new pro-Putin governor of Kaliningrad entered his office in 2005, the political environment and interest in Neman NPP changed. In 2008, JSC Inter RAO UES, where the Rosatom State Atomic Energy Corporation indirectly owns 13.42% stake[2], eventually presented a proposal to construct a NPP in Kaliningrad. Two units of VVER-1000 were originally intended to be constructed at Neman, but later enhanced to two VVER-1200/V-491 units. The design is the common project of OKB "Gidropress" and JSC "Atomenergoproekt" with the scientific supervision of Kurchatov Institute from Moscow (Jesien & Tolak, 2013, p. 5). It is important to stress that the Neman NPP has been promoted not as a source of electricity for Kaliningrad area, but since the beginning as a source of electricity to be exported to foreign countries, namely Germany, Poland and the Baltic countries. Even though the construction started in February 2010, a search for Strategic Investor was not finished and took place at the same time. The logic was to sell 49% of the Neman NPP to foreign investor, while the control share of 51% would remain in the hands of Russian Federation[3]. The original plan was to start commercial operations in 2017 (Unit 1) and 2018 (Unit 2). JSC InterRAO UES was responsible for soliciting investment and also for electricity sales but as there are two more NPP projects in the region and basically all of the regional

[2] See Moldova Case Study for information on equity shareholders.
[3] Using money directly from Rosatom as well as from funding from the state budget and loans from Russian banks (see Menkiszak, 2013).

countries had some common history with Russia or Kaliningrad, no investors and no electricity sales were secured in the end, even though Germany and Poland supposedly participated in negotiations with JSC InterRAO UES. Eventually, in May 2013, Rosatom decided to revise its plans to build the Neman NPP and will consider building small- (40 MWe) and medium-sized (640 MWe) reactors instead (Menkiszak, 2013). There are probably several reasons reasons for this decision: no cooperation or support from regional countries, the inability to attract foreign investors, the inability to close contracts for electricity sales, the imminent overcapacity in the region, and also the electricity systems issue. If these problems will not be resolved, Russia will not resume the construction of Neman NPP.

Speaking about the electricity systems issue, the electricity systems of Baltic States operate on the grid of Belarus, Russia, Estonia, Latvia and Lithuania (BRELL), which is a part of IPS/UPS system controlled by Moscow (Grigas, 2013, p. 79-80; Usanov & Kharin, 2014, p. 10). It would be therefore easy to supply electricity in the region after the construction of Neman NPP and this is the main reason why no Baltic country is interested in the Neman NPP project. It would also block the plans for development of electricity interconnectors and synchronizing the grid with the European ENTSO-E. The avoidance of physical dependence on BRELL electricity is among the key targets of Baltic countries nowadays. Besides the new EstLink[4] and EstLink 2[5] interconnectors, two new

[4] From Harku, EST to Espoo, FIN; 330/400 kV; 350 MWe capacity, in operation from 12/2006.
[5] From Püssi, EST over Nikuviken, FIN to Anttila, FIN; 330/400 kV; 650 MWe capacity, in operation from 3/2014.

electricity interconnectors are being constructed (see Table 4.7.6) to further develop the grid and the connections to ENTSO-E grid. The three Baltic States have already agreed to break up the BRELL and de-synchronize from the IPS/UPS system by 2020 (Menkiszak, 2013).

Tab. 4.7.6: Planned Electricity Interconnectors in the Baltic Region

Interconnector	Voltage	Capacity	In operation date
LitPol (Alytus, LT – Ełk, PL)	330/400 kV	1,000 MWe	12/2015
NordBalt (Klaipėda, LT – Nybro, SWE)	330/400 kV	700 MWe	12/2015
Source: compiled by T. Vlcek from open sources			

Source: compiled by T. Vlcek from open sources

Unfortunately, the de-synchronization would leave Kaliningrad without a connection to the rest of Russia and make it an energy island dependent on its own production of electricity. Moreover, the options of securing electricity supplies are being seriously considered by Russian government, including mentioned small- to medium-sized reactors, electricity link between Kaliningrad and Poland, or integration of Kaliningrad into the ENTSO-E together with the Baltic States. When we add the current very bad relations between the EU and Russia, Kaliningrad's future as an energy island looks like a predetermined outcome (Usanov & Kharin, 2014, p. 10-11; Jesien & Tolak, 2013, p. 4-5; Menkiszak, 2013).

4.7.3 The Front End of the Nuclear Fuel Cycle

As there are no Uranium deposits, and no production, processing and/or fabrication capabilities in Lithuania, no Front End information can be presented.

4.7.4 The Service Part of the Nuclear Fuel Cycle

As stated above, Lithuania operated two units of a RBMK reactor at Ignalina NPP until their shutdown in 2004 and 2009. The idea of construction of the Ignalina NPP emerged during the era of nuclear industry boom in 1970s. The power plant was built as a part of the Soviet Union's North-West Unified Power System rather than to meet Lithuania's needs (Cesna, 2004, p. 159). The first unit was commissioned in 1983, the second in 1987.

Tab. 4.7.7: Nuclear Units in Lithuania

Reactor	Type	Power Output	Status	End of life-cycle
Ignalina 1	RBMK-1500	1,300 MWe*	Decommissioning	2004
Ignalina 2	RBMK-1500	1,300 MWe*	Decommissioning	2009
Visaginas 1	ABWR	1,350 MWe	Planned	-

* Originally 1,500 MWe, but the reactors were de-rated to 1,300 MWe after the 1986 Chernobyl accident as they were of the same type. Construction of Ignalina 3 commenced in 1985 but was suspended after the accident, and the unit was later demolished.

Source: compiled by T. Vlcek from open sources.

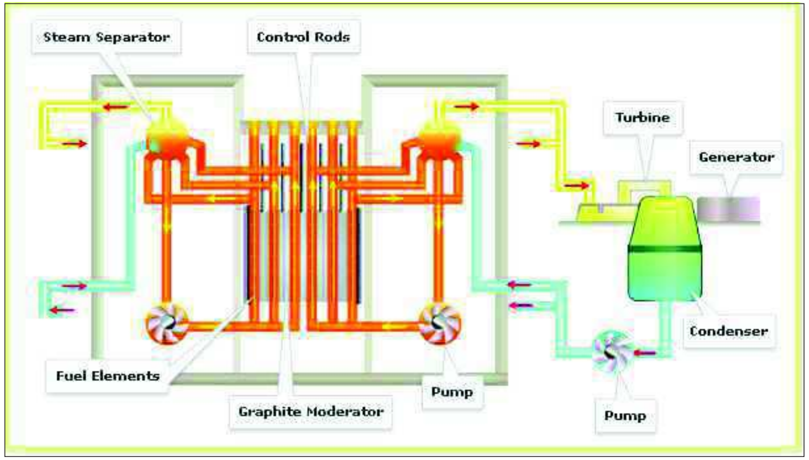
After Lithuania declared independence in 1990, the Ignalina NPP was still guarded by Soviet troops and KGB operatives, and remained under the jurisdiction of the Soviet Union until the August of 1991 (Cesna, 2004, p. 159). Today, the Ignalina NPP is regulated and supervised by Lithuanian State nuclear

power safety inspectorate (VATESI). Even though the plant's operators are ethnic Russians, most have agreed to stay on and become Lithuanian citizens (Pacific Northwest National Laboratory, n.d.). This does not mean that Lithuania does not have enough home-based experts to run the power plant. On the contrary, Lithuania established a complex system of education of nuclear energy engineers at Kaunas University of Technology and is able to secure its own operating personnel (Ziedelis, Gylys, Gediminskas & Brandisauskas, 2014).

The power plant was inherited from the former Soviet Union with a rather low level of safety culture and even though a lot has been done to enhance safety and security standards, this was the reason why Lithuania had to close the power plant's Unit 1 upon joining the EU in 2004 and the second Unit until 2009 as a safety precaution.

Lithuania was dependent solely on Russia in terms of the fuel supplies for Ignalina NPP. As the RBMK reactor design has been invented and developed in Russia and no other country in the world operates these reactors today, Russian company TVEL is the only supplier of nuclear fuel to RBMK nuclear reactors. According to A. Ozharovsky, M. Kaminskaya and C. Digges, the only player on this fuel market - Rosatom - also holds the prerogative to set its pricing policy. Additionally, for all kinds of planned repairs, upgrades, and procedures requiring the replacement of the facility's equipment and materials, Lithuania, again, have had to depend on Rosatom's enterprises. In return for the fuel supplies and services, Lithuania was expected to pay, partly, in power supplies, including the supplies to Russia's Kaliningrad Region (Ozharovsky, Kaminskaya & Digges, 2010).

Tab. 4.7.8: The RBMK Reactor Scheme



Source: *Hong Kong Nuclear Investment Co. Ltd.*

The RBMK is a light-water, graphite-moderated reactor designed by the Soviet Union and currently, all the 11 remaining RBMK operating reactors in the world are in Russia. The shutdown of the last one is planned for 2026.

It is a pressurized water-cooled reactor with individual fuel channels using only slightly-enriched uranium oxide as fuel and graphite as its moderator. The RBMK design allows fuel replenishment while the reactor is in operation. The reactor is very different from most of the other power reactor designs as it is derived from a design intended principally for plutonium production and was used in Russia for both plutonium and power production (WNA, 2010). The RBMK design contains no protective shell, i.e. containment structure which is one of the very basic passive safety measures of nuclear reactors.

Lithuania, forced to shut down the reactors, received assistance for this commitment from EU funds. Out of the total decommissioning costs of €2.8 billion, the EU has committed €1.37 billion up to the end of 2013 ("EU freezes Lithuanian", 2012). The end stage of the decommissioning process is expected by 2038. The decommissioning process is coordinated by the Ministry of Energy of the Republic of Lithuania.

4.7.5 The Back End of the Nuclear Fuel Cycle

Originally spent nuclear fuel from Ignalina was to be managed by USSR. However, with the disintegration of the Soviet Union, Lithuania was obliged to find other solutions. Therefore, Lithuania now runs facilities for disposal of low, intermediate and high radioactive waste. The Ministry of Economy of Lithuania established state enterprise Radioactive Waste Management Agency (Radioaktyviųjų atliekų tvarkymo agentūra, RATA) in July 2001 to assume the responsibility for the safe management and final disposal of all radioactive waste.

The used fuel was cooled and stored in special storage pools constructed near the reactor premises. But as it is a temporary method, it was decided to construct dry storage at Drūkšiniai at the Ignalina NPP site, approximately 1 km from the reactors. The storage facility was commenced in 1999 and up to 80 casks will be stored here for 50 years. However, the existing dry storage facility has been totally filled and the left spent fuel is still stored in the Unit 2 reactor and storage pools of both units until the new interim storage facility (ISFSF) will be constructed. The new ISFSF will be commissioned at Drūkšiniai in early 2017. The total storage capacity will be about 17,000 fuel assemblies (190 casks). The construction was financed from the Ignalina International Decommissioning Support Fund (IIDSF) administered by the European Bank for Reconstruction and Development (EBRD) and the constructor was German Consortium NUKEM Technologies GmbH and GNS Gesellschaft für Nuklear-Service mbH (Ignalinos atominė elektrinė). NUKEM Technologies GmbH has been owned by the Russian AtomStroyExport since 2009, and GNS is a joint venture of E.ON, RWE, EnBW and Vattenfall. The construction works are performed by the Lithuanian subcontractor Vetrūna UAB.

There is also the closed Maišiagala Radioactive Waste Storage Facility in Lithuania for radioactive waste generated in industry, medicine, scientific research etc. and Lithuania also plans its final underground repository. Location in the crystalline rocks in southern Lithuania is being developed with the assistance of Swedish experts. The project is in its very beginning.

Tab. 4.7.9: Lithuanian Nuclear Sector Examination

Indicator	Description
Is there nuclear producing capacity present in the country?	Not anymore, the Ignalina NPP (RBMK design, 2 Units of 1,300 MWe each) was shut down in 2009
Is there a project to expand the capacity? What is the status of the project?	Yes, the project is in pre-construction period (licensing, project company establishment, plant designing etc.), construction start is expected in 2015, financing is basically resolved
How was the project procured?	Openly, without Russian bid; Rosatom has been competing through Neman NPP in Kaliningrad and Ostrovets NPP in Belarus
Who is the contractor in charge of the project?	VAE Project Company (20% Hitachi-GE Nuclear Energy, Ltd.; 20% Latvia; 22% Estonia; and 38% Lithuania)
How is the financing secured?	The shareholders will finance the construction according to their shares together with Strategic Investor Hitachi-GE Nuclear Energy, Ltd. (80.01% Hitachi Ltd.; 19.99% General Electric Company)
Who is the operator of the facility?	VAE Project Company (20% Hitachi-GE Nuclear Energy, Ltd.; 20% Latvia; 22% Estonia; and 38% Lithuania)
Are there enough home-based experts to run the facility safely?	Yes
Who is/will be in charge of decommissioning?	Russian TVEL was supplying fuel to the Ignalina NPP as the only supplier in the world for the RBMK reactors; BWR fuel fabrication takes place in much the same way as PWR fuel, therefore many subjects can supply fuel for the Visaginas NPP
What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	The Ignalina NPP is shutdown and the potential Visaginas NPP is of different type with different technical aspects of fuel demand, the path-dependency is thus impossible
Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	Lithuania has limited capacities only in the Back End of the Nuclear Fuel Cycle that has to be developed
How is used fuel treated and who is in charge of this?	The spent fuel is partly stored in storage pools next to the reactors, and partly in dry storage at the Ignalina NPP site; as the capacity is not enough, new interim storage facility is to be commissioned nearby the Ignalina NPP in early 2017; Radioactive Waste Management Agency established by The Ministry of Economy of Lithuania is in charge of this

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4.8 Country Case Study: Moldova

Tomáš Vlček

4.8.1 Introduction

Moldova (officially the Republic of Moldova) declared its independence in 1991 and it is currently the poorest country in Europe, even though Moldovan economy was able to transform from centrally planned economy quite satisfyingly. The economy is based on service sector and the GDP has slowly but steadily growed since 1999. Approximately 70-75% of the energy sector equipment is worn out. For example, over 2001-2008, gas pipeline losses were estimated at an average of 7% (Moldova Government, 2013, p. 8). As seen in Table 4.8.1, Moldova is nearly 100% dependent on energy sources imports (Moldova does not import crude oil, but imports nearly all consumed oil products; 0.8 Mt in 2010). The renewable energy potential is installed in hydro and this source is inevitably very affected by weather.

Tab. 4.8.1: Key Energy Statistics

Source	Consumption	Imports	TPES share	Electricity Generation share
Crude Oil	0.85 Mt	0%	22.5%	0.5%
Natural Gas	2.18 bcm	100%	67.9%	92.9%
Coal (all types)	0.19 Mt	97.4%	2.8%	0%
RES	-	-	3.1%	6.6%
Nuclear Energy	-	-	0%	0%
Note: 2010 data				

Source: ***U.S. Energy Information Administration; International Energy Agency***; compiled and calculated by T. Vlcek

Moldova is a small landlocked country and the energy sector is rather small too. The total installed capacity in the electricity system is only 3,016 MWe and the electricity sector is dominated by natural gas (see Table 4.8.2). Out of this nominal capacity, only about 346 MWe in cogeneration in Chisinau and Balti and in the hydro can be used, and only about a half of the capacity of the GRES is used (due to the difficult trading conditions) (Moldova Government, 2013, p. 6-7).

Tab. 4.8.2: Power Plants in Moldova

Power Plant	Installed Capacity	Fuel	Year of Construction
CHP-1 Chisinau	66 MWe	Gas, HFO	1951-1961
CHP-2 Chisinau	240 MWe	Gas, HFO	1976-1980
CHP-North Balti	28.5 MWe	Gas, HFO	1956-1970
4 CHP in Falesti and Drochia Sugar Factories*	97.5 MWe	Biogas from sugar beet pulp	1956-1981**
HPP Costesti	16 MWe	Water	1978**
HPP Dubasari	48 MWe	Water	1954-1966**
TPP Dnestrovsc (GRES)	2,520 MWe	Gas, coal, HFO	1964-1982
Note: CHP = Combined Heat Power Plant, HPP = Hydroelectric Power Plant; TPP = Thermal Power Plant; HFO = Heavy Fuel Oil * Factories owned by Südzucker Moldova SA ** Modernized during 2010-2013			

Source: *UNECE, 2009*, p. 3; T. Vlcek

The TPP Cuciurgan in Dnestrovsc is the biggest power plant in Moldova with the installed capacity of 2,520 MWe. The power plant is located on the left bank of the river Dniester in the Transnistrian Region, which after the war in 1992

declared itself the Pridnestrovian Moldavian Republic. The territory is unrecognized by any UN member state and by Moldova it is recognized as the Transnistria autonomous territorial unit with a special legal status. Therefore, electricity produced here and used in Moldova is deemed imported. Anyway, the fact that only about a half of the capacity of the GRES is used is caused by no connection with the EU's internal electricity market, which significantly affects the regional prices of electricity. The high prices of electricity generation at GRES and the volatile import tariffs for electricity from Ukraine are among the reasons for regular supplier switches between Transnistria and Ukraine. The Moldovan possible connection to ENTSO-E is very difficult due to historical connection and synchronization with Ukrainian system.

Moldova does not have any other option than to import electricity from Ukraine, Transnistria or potentially from Romania. There are seven double-330 kV international transmission lines between Moldova and Ukraine capable of transporting 1,400-1,500 MWe. As about 1,000 MWe are used by transits to Odessa, the net import capacity of Moldova is about 400-500 MWe (Zachmann & Oprunenco, 2010, p. 6). There is one 400 kV transmission line to Romania from Vulkănești in the south. This line is used for exports of electricity produced at GRES to Romania as electricity prices in Romania are much higher than in Ukraine or GRES. But it is exported only to a small border part of Romania due technical and historical reasons as the two countries are not synchronized. The local consumption in this area equals to only about 3-5% of Romanian consumption.

Due to the difference in frequency standards the systems do not work in parallel, i.e. import or export of power can take place based on island principal only (The Carbon Finance Unit of the Republic of Moldova, 2011, p. 11). There is a planned project of a converter station at the line to Romania to link the two asynchronous systems.

The Moldovan domestic production of electricity in 2010 reached 888.1 GWh while the consumption was 3,915.6 GWh (Moldova Government, 2013, p. 67). Moldova is therefore a net importer of electricity with the need of approximately 3,000 GWh annually. Since 2009, nearly 100% of electricity imports have come from Transnistria's Cuciurgan power plant (known as GRES in Moldova). Due to high prices of electricity produced in GRES and other reasons, in 2006-2008, Moldova imported electricity from Ukraine, and as explained above, Moldova imports electricity only either from Ukraine or Transnistria.

The situation with Transnistria's Cuciurgan power plant is very complicated. The power plant is supplied with natural gas through the company Tiraspoltransgas-Pridnestrovie (OOO Тираспольтрансгаз-Приднестровье) based in Transnistria. This is a daughter company of Moldavian JSC MoldovaGaz (AO Молдовагаз). Since 1993, Tiraspoltransgas does not pay for natural gas and this debt passes to MoldovaGaz as it is the mother company. The debt is currently calculated for USD 3 billion. A long discussion with Gazprom and Moldovan aiming to pass the debt back to Tiraspoltransgas has not ended with understanding, as Gazprom uses the Moldovan debt for Cuciurgan power plant's consumption as a political leverage. Gazprom is also a shareholder in both Tiraspoltransgas and

MoldovaGaz (51% in both companies supposedly). Moldovan foreign policy is thus strongly influenced by Gazprom.

Moldova purchases electricity in Transnistrian Cuciurgan TPP and also owes for this TPP´s consumption of natural gas, which is, of course, strongly uneconomical for Moldova. Chisinau solves the situation by switching from Cuciurgan's electricity to electricity imported from Ukraine, where the power plants has been already paid off and the electricity price was lower due to overcapacity in the country. However, this situation has changed recently for two reasons. First, the Ukrainian crisis led to problems in domestic electricity production, and since 2014, Ukraine is no longer willing and able to export electricity to Moldova. And second, Ukrainian export policy changed in terms of pricing in 2011. Ukraine raised electricity price and also added new condition – the price of electricity shall be raised every month by 2.1 USD cents per 1 MWh. This eventually led Moldova to return to electricity imports from undesirable Transnistrian Cuciurgan TPP for economic reasons.

Until 1997, the state company Moldenergo had been in charge of the Moldovan electricity sector, then after liberalization and unbundling, Moldenergo transformed into 16 new entities. There are 3 electricity generation companies, 5 distribution companies and state-owned transmission and central dispatch “Moldtranselectro”. In 2000, the Spanish company “Union Fenosa” acquired 100% of the share capital in three out of five distribution companies (Zadnipru, 2011, p. 4). The ZAO Moldavskaya GRES Company operating the biggest power plant GRES is owned by the company JSC Inter RAO UES. The ownership structure is seen in Table 4.8.3.

Tab. 4.8.3: The Ownership Structure of JSC Inter RAO UES

Equity holder	Share
Rosneftegaz Group	27.63 %
FGC UES Group	18.57 %
Minorities	16.65 %
INTER RAO Capital	13.93 %
Norilsk Nickel Group	13.21 %
VEB	5.11 %
RusHydro Group	4.92 %
Note: through minorities Atomstroyexport JSC, Rosenergoatom Concern OJSC, Rosatom Securities Limited the Rosatom State Atomic Energy Corporation owns 13.42% stake in JSC Inter RAO UES as of 2012.	

Source: *JSC Inter RAO UES; „JSC Inter RAO UES"*, 2012

4.8.2 New Units and Financing of the Nuclear Plant

As Moldavian Soviet Socialist Republic Moldova had been one of the fifteen republics of the USSR until the dissolution of the Soviet Union, the planned Soviet design NPP at Piatra Neamț in Romania have had supposedly been a source of electricity not only for Romania but for Moldova as well. But the plan for the construction of VVER-440 or VVER-1000 design in Romania was cancelled in 1980s (see Romania case study for detailed information). Another plan to construct Soviet-design NPP in Rîbnița emerged in 1985 and building foundations were prepared. But this plan was dismissed after the Chernobyl accident and no plan for NPP in Moldova was considered ever after.

In 2003, there were information that Moldova is investigating possibilities of building a NPP and the president of Moldova V. Voronin and French ambassador to Moldova

E. Pamboukjian spoke out for prompt beginning of consultations on the issue ("Moldova builds", 2003). The topic stayed only within the mentioned consultations and was not further developed. The whole topic seems to be just political expressions during mutual visits of the presidents of Moldova and France. The plan was eventually changed for 400 MWe natural gas power plant in Burlăceni, but this was also rejected due to lack of finances.

In December 2014, Romanian Minister for Energy Răzvan-Eugen Nicolescu said that Romania would welcome Moldova as a partner in the Cernavoda NPP expansion project ("Romania wants", 2014), e.g. to become a shareholder in the EnergoNuclear SA. Moldova's partnership in the project would be a third competitive option for electricity imports besides Ukraine and Transnistria and the proposal seems beneficial even though additional investments to synchronize the two countries' electricity sectors would be necessary. However, it is impossible for Moldova to take part in the project financially, so Moldova's partnership is deemed rather symbolical.

4.8.3 The Front End of the Nuclear Fuel Cycle

As there are no Uranium deposits and no production, processing and/or fabrication capabilities in Moldova, no Front End information can be presented.

4.8.4 The Service Part of the Nuclear Fuel Cycle

As there are no nuclear power plants in Moldova, no Service Part information can be presented.

4.8.5 The Back End of the Nuclear Fuel Cycle

As there are no nuclear power plants and nuclear industry in Moldova, no Beck End information can be presented.

Tab. 4.8.4: Moldovan Nuclear Sector Examination

Indicator	Description
Is there nuclear producing capacity present in the country?	No
Is there a project to expand the capacity? What is the status of the project?	No
How was the project procured?	-
Who is the contractor in charge of the project?	-
How is the financing secured?	-
Who is the operator of the facility?	-
Are there enough home-based experts to run the facility safely?	No
Who is/will be in charge of decommissioning?	-
Who provides nuclear fuel and under what conditions?	-
What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	-
Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	No
How is used fuel treated and who is in charge of this?	-

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4.9 Country Case Study: Poland

Tomáš Vlček

4.9.1 Introduction

Poland played an important role in European history, as powerful kingdoms were spread on today's Polish soil since the time of Bolesław I Chrobry, the first Polish king, until the end of the Polish–Lithuanian union and Polish–Lithuanian Commonwealth. The historical importance and strategic position of Poland in Central Europe and the Baltic could also be deduced from the so called Partitions of Poland, when Europe's powers divided Polish territory among themselves in 1772, 1793, 1795, and 1939.

The Polish Republic emerged according to the Treaty of Versailles after the WWI. Unfortunately, Poland had to fight several border wars and the war with Soviet Union for its independence. Poland was occupied by Germany and the USSR during the WWII and eventually left under Soviet control after the war. Poland is very famous for the anti-communist socio-political opposition called Solidarity - an independent trade union created in 1980 that significantly contributed to the collapse of communism in Poland. The modern Republic of Poland was created on September 13, 1989, and since that time managed to enter the NATO, the EU, implement market economy principles in the country, and significantly restore its diplomatic power.

Although Poland is practically self-sufficient in terms of electricity production, it is dependent on imports of hydrocarbons. Poland imports nearly all of its oil demand from a single source being the Russian Federation through the Druzhba pipeline (96% in 2012). There are six refineries in Poland, with a total primary distillation capacity of around 25.3 Mt/y (OECD & IEA, 2014, p. 363). These are the Refineries Lotos S.A. (in Gdańsk), Orlen S.A. (in Płock), Trzebinia S.A. (at Czyżówka near Trzebinia), Czechowice S.A. (in Czechowice-Dziedzice), Jaslo, S.A. (in Jaslo) and Jedlicze S.A. (in Jedlicze). Polski Koncern Naftowy (PKN) Orlen SA and Grupa Lotos S.A. are owners of these refineries and account for almost the entire Polish refining industry.

Speaking about natural gas, Poland imports approximately 2/3 of domestic demand and the rest is produced in the country (6.2 bcm in 2012). The share of Russian gas in Poland's total gas imports stood at 80% in 2012, while gas imports from Germany accounted for 15% in the same year (OECD & IEA, 2014, p. 370-371).

Both crude oil and natural gas are also transported via the Druzhba and Yamal pipelines through Poland to Germany.

Tab. 4.9.1: Key Energy Statistics

Source	Consumption	Imports	TPES share	Electricity Generation share
Crude Oil	27.74 Mt	85%	24.9%	1.5%
Natural Gas	17.19 bcm	69%	12.7%	3.6%
Coal (all types)	139.1 Mt	11%	54%	86.6%
RES	-	-	8.5%*	8.3%
Nuclear Energy	-	-	0%	0%
* Biofuels and waste stand for 8% of TPES and 4.7 % of electricity generation shares Note: 2011 data				

Source: U.S. Energy Information Administration; International Energy Agency; compiled and calculated by T. Vlcek

Poland is strongly dependent on coal in electricity production; in fact, it is the world´s most coal-dependent country. There are some small capacities in other power plant types, such as natural gas in Gorzów CCGT (65.5 MWe) and Zielona Góra CCGT (198 MWe), water in Pumped Storage Hydroelectric Power Plant in Żarnowiec (680 MWe) and Żydowo (150 MWe), in some RES projects, especially wind farms, and as it is relatively easy to transform a coal-fired power plant to waste-fired one, 4.7% of electricity in 2011 was generated from waste.

But 86.6 % of electricity in 2011 was produced in coal-fired power plants, including hard coal as well as low-quality lignite. There are 65 hard coal and 5 lignite power plants in Poland (Kudelko, Suwala & Kaminski, n.d., p. 7). Table 4.9.2 presents the biggest coal-fired power plants in Poland. Bełchatów TPP (5,354 MWe) is the world´s third largest coal-fired power plant after Taiwanese Taichung TPP (5,834 MWe) and Chinese Tuoketuo TPP (5,400 MWe, to be expanded by another 1,320 MWe).

This obviously causes trouble for the environment in Poland and for Polish CO2 emissions reduction targets. There is already an impending penalty of over EUR 133 thousand for Poland failing to transpose its Renewable Energy Directive, which aimed at ensuring a 20% share of renewable energy in the EU by 2020 (Yeo, 2013), and as Poland is failing to achieve its part in the EU goal to reduce emissions by 20% by 2020, it is opposing the EU and the European Commission's plans to set more ambitious goals of 40% cut in CO2 emissions by 2030 versus 1990 levels (Wasilewski, 2013). Due to Poland´s coal-dependence, the country is a long-term stable critic of EU environmental goals.

Tab. 4.9.2: 1,000 MWe+ Power Plants in Poland

Power Plant	Installed Capacity	Fuel	Operator	Construction Year
Bełchatów TPP	5,354 MWe	Lignite	PGE GiEK S.A.	1981
Kozienice TPP	2,913 MWe	Hard Coal	ENEA S.A.	1972
Połaniec TPP	1,800 MWe	Hard Coal	Electrabel Połaniec SA (GDF Suez)	1973-1979
Rybnik TPP	1,775 MWe	Hard Coal	EDF Polska Oddział w Rybniku	1972
Turów CHP	1,694.8 MWe	Lignite	PGE GiEK S.A.	1962-1971
Pątnów I, II CHP	1,669 MWe	Lignite	Zespół Elektrowni Pątnów-Adamów-Konin SA*	1958-1974
Opole TPP	1,532 MWe**	Hard Coal	PGE GiEK S.A.	-
Jaworzno II, III CHP	1,485 MWe	Hard Coal	Tauron Polska Energia S.A.	1972-1979
Dolna Odra CHP	1,362 MWe	Hard Coal	PGE GiEK S.A.	1974
Łaziska CHP	1,155 MWe	Hard Coal	Tauron Polska Energia S.A.	1967-1972

* Ownership structure: 52.67% Zygmunt Solorz-Żak; 10.76% ING Open-end Pension Fund; 36.57% Others
** A 1800 MW expansion of the station began construction in 2014
Note: CHP = Combined Heat Power Plant, TPP = Thermal Power Plant

Source: *Polska Grupa Energetyczna SA and other open sources*

Poland produced 163.5 TWh of electricity in 2011, of which 57 TWh was produced within the company PGE SA (Polska Grupa Energetyczna) (*International Energy Agency*; *Polska Grupa Energetyczna SA*). The company production portfolio thus constitutes 34.9 % of the country's electricity production with 12.86 GWe of installed capacity. The company is owned by State Treasury (58.39%) and other investors (41.61%) in 2014. Other important electricity generating companies include Tauron Polska Energia S.A., ENEA S.A., EDF Polska, GDF SUEZ Energia Polska S.A., ZE PAK SA, and others.

4.9.2 New Units and Financing of the Nuclear Power Plant

Poland's problematic dependence on domestic coal in electricity production is the key reason for nuclear energy development plans, and much has been done since 2005, when it was decided to introduce nuclear energy to Poland again. On November 10, 2009, the Council of Ministers adopted a resolution on the Polish Energy Policy until 2030. This resolution expects 10% of electricity generation share to be from nuclear energy (Ministerstwo Gospodarki, 2009a, p. 28) and in the appendix 2 it is planned to operate nuclear capacities of 1,600 MWe in 2020, 3,200 MWe in 2025, and eventually 4,800 MWe in 2030 (Ministerstwo Gospodarki, 2009b, p. 16). The Council of Ministers also issued a resolution on the actions taken for the development of nuclear power industry in 2009, where it was stated that it is necessary to prepare and implement a program for Polish nuclear power industry. Therefore the Government Plenipotentiary for Polish Nuclear Power was appointed and in January 2014 the Council of Ministers adopted the Polish Nuclear Power Program (PNPP; the first draft of the PNPP was presented in 2010), which envisions the construction of country's first nuclear power plant by 2024 (Unit 1) and 2029 (Unit 2). The capacity targets were reconsidered to be of minimum value 1,000 MWe for 2024; 3,000 MWe minimum value for 2030, and 6,000 MWe as a 2035 target (Ministerstwo Gospodarki, 2014, p. 19).

Since 2009 the Government has been searching for the optimal NPP site. The first appraisal of the site criteria by Energoprojekt Warszawa SA proposed 28 locations, of which eventually three were chosen by the investor: Żarnowiec (in the city of Kartoszyno), Choczewo (5 km from Żarnowiec) and Gąski (between the towns of Kołobrzeg and Koszalin on the coast of the Baltic Sea). Preparations for location and environmental research were started in February 2013 for the sites of Choczewo and Żarnowiec. The outcome will enable to finally indicate the site for the first Polish NPP (Ministerstwo Gospodarki, 2014, p. 100-103). It is likely that the second power plant would stand on the second location coming out from this research.

The company PGE SA (Polska Grupa Energetyczna) – Poland's largest power group by generating capacity – is the investor in the nuclear project. In January 2010, a limited liability company PGE Energia Jądrowa 1 Sp. z o.o. in the portfolio of the PGE SA company was established as the project company responsible for preparing the investment process and the construction (the construction itself will be overseen by the National Atomic Energy Agency), as well as to be the future operator and licensee. Originally, the PGE SA aimed at 51% share in a consortium with foreign strategic partners, but after several changes throughout the years, the PGE SA holds 70% in the project company, while ENEA S.A., KGHM Polska Miedź and Tauron Polska Energia S.A. own 10% stake each. This was confirmed in a Shareholders' Agreement in September 2014 (*PGE Energia Jądrowa 1 Sp. z o.o.*). The project total expenditures are estimated to USD 10.3-11.3 billion (WNA, 2014) that these companies will split according to their shares in the project company.

Tab. 4.9.3: Shareholders of the PGE Energia Jądrowa 1 Sp. z o.o. project company

Shareholder	Share	Ownership Structure
PGE SA	70%	58.39% Ministry of State Treasury; 41.61% Other Investors (Free float)
ENEA S.A.	10%	51.50% Ministry of State Treasury; 48,50% Other Investors (Free float)
Tauron Polska Energia S.A.	10%	30.06% Ministry of State Treasury; 10.31% KGHM Polska Miedź S.A.; 5.06% ING Otwarty Fundusz Emerytalny; 54.49% Other Investors (Free float)
KGHM Polska Miedź S.A.	10%	31.79% Ministry of State Treasury; 68.21% Other Investors (Free float)

Source: compiled by T. Vlcek from open sources

The actual tender for the contractor has not been opened yet, but it is very likely that there will be no Russian contractor or subcontractor in the project due to Polish very strong traditional anti-Russian feeling. In February 2014, four bidders submitted tender offers to PGE EJ 1 Sp. z o.o. to provide technical assistance as owner's engineer for the program. These were AMEC Nuclear UK Limited, Exelon Generation Company, LLC, a Mott MacDonald Limited – Aktiebolaget Ångpanneföreningen AB consortium, and a URS Polska Sp. z o.o. – Tractebel Engineering GDF-Suez consortium. In July, the company announced its selection of AMEC Nuclear UK Limited. The owner's engineer will help select EPC (Engineering, procurement and construction) contractor, oversee project management, and supply chain contract management as well as regulatory aspects (WNA, 2014).

Several non-exclusive agreements were signed between PGE SA and Électricité de France S.A., GE Hitachi Nuclear Energy and Westinghouse Electric Company LLC to investigate using their respective technologies in Poland. Korea Electric Power Corporation KEPCO is interested in Polish nuclear project as well, and estimates so far pointed towards the selection of Korean APR1400 or AREVA´s EPR (Kulczynski, 2014).

PGE SA expects to make a final investment decision on the two plants by 2018. Final design and permits for the first are expected to be ready in 2018, allowing construction start in 2020. The first unit is now expected to be operational in 2024, the second one in 2029 (WNA, 2014). The financing model is not completed, but to avoid breaking the EU state-aid rules, the Ministry of State Treasury is not expected to involve directly.

4.9.3 The Front End of the Nuclear Fuel Cycle

Poland has historical experience with uranium mining and processing. First uranium ores were found in 1853, but until 1942, uranium was treated as waste with no commercial value as radium was the desired mineral (Chajduk & Polkowska-Motrenko, 2012, p. 4). Uranium was mined in Sudetenland for German WWII nuclear projects and eventually for Soviet projects. During 1948-1963, the Polish-Soviet enterprise "Kowarski Mines" named after Kowary site was responsible for the production of c.a. 704 tons of uranium that has all been sent to the USSR. The uranium mining facilities were secret and were codenamed R1. The extraction took place in many underground mines in Poland, such as Wolność, Podgórze, Miedzianka, Radoniów, Rubezal, Mniszków, Wiktoria, Wołowa Góra, Radoniów, Wojcieszyce and others (Chajduk & Polkowska-Motrenko, 2012, p. 5-9; Rewerski, Mielnicki, Bartosiewicz, Polkowska-Motrenko & Sklodowska, 2013, p. 5-6).

All mines were closed in 1960s and 1970s and there are no operating mines nowadays. Although uranium had no commercial value in the past, there are large number of abandoned piles of waste rock that contain uranium. And even though the concentration is generally very low (under 0.01%), there are some interesting locations such as Kopaniec pile where the concentration reaches up to 0.24%. Therefore the possibility of uranium extraction from post-mining wastes is also analyzed (Rewerski, Mielnicki, Bartosiewicz, Polkowska-Motrenko & Sklodowska, 2013, p. 7) together with the possibility of mining domestic uranium resources after the plan to construct an NPP has been introduced.

Polish historic geological documentation (see Table 4.9.4) suggests that there are uranium deposits in Poland, but no modern prospects were executed, except for the Radoniów area that is being prospected since 2012 (OECD & IAEA, 2014, p. 348).

Tab. 4.9.4: Potential Conventional Uranium Resources in Poland

Region	**Resources in place (t)**	**Uranium content (%)**
"Rajsk" deposit	5,320.0	0.025
Okrzeszyn	937.6	0.05-0.11
Grzmiaca	792.0	0.05
Wambierzyce	217.5	0.0236

Source: ***OECD & IAEA***, 2014, p. 348

The estimation of the total identified uranium resources amount to 7,267.1 tons, which is the reason why Poland is interested in the extraction. The potential uranium reserves could positively affect the dependency on imported nuclear fuel. On the other hand, it is more likely that they would stay as potential uranium reserves, as it is very likely that the price of extraction and its use in the fuel would be more expensive than the purchase of commercial fuel. Also, there is strong local opposition in the potentially uranium-rich sites (*Powiedz Nie dla Kopalni Uranu w Sudetach*). For example, the prospecting process at Kopaniec (undertaken by Australian company European Resources Pty Ltd) was strongly opposed both by the Municipality of Stara Kamienica and the local inhabitants.

It is important to mention that Poland has also some short experience with uranium processing. It was the ore, not the metal that was transported to the USSR under the Polish-Soviet enterprise "Kowarski Mines". And when the Polish mines became depleted and closed, the chemical processing of low-grade ore waste in Kowary began operation in 1969 and lasted until 1972, extracting some uranium even from the waste. One of the biggest environmental radioactive isotope contaminations in Poland, the Kowary tailing pond, was remediated with financial support of the European Commission in 2001.

In the end, as no Uranium is produced nowadays, and there are no processing and/or fabrication capabilities in Poland, no Front End information can be presented.

4.9.4 The Service Part of the Nuclear Fuel Cycle

In 1982, Poland started construction of a nuclear power plant called Żarnowiec (named after the Jezioro Żarnowieckie lake) in the city of Kartoszyno, not far from the Gdynia and Gdańsk ports. It was an NPP with four VVER-440 units and it was planned as only a first step in Poland's nuclear power program, as the construction of the Warta NPP in the village of Klempicz was envisaged. The Żarnowiec project was carefully planned and a superb infrastructure developed in the area. The reactor vessels were manufactured in Škoda factory in Czechoslovakia, while the turbines and generators were made in Poland. Polish boiler factory Rafako built the Steam Generators (Kulczynski, 2010). After the Chernobyl accident, protests against the Żarnowiec NPP were strong in Poland and after the construction break, the government eventually decided to abandon the project. A referendum in 1990 in the Gdańsk Voivodeship with very clear outcome played also its part in the decision.

The components in the under-construction plant were sold and the country became very anti-nuclear, putting a temporary freeze on nuclear projects overall until at least 2000 (Raguzina & Kamiskaya, 2010). And truly, the nuclear project has been reconsidered in 2005, when it was decided by the Polish cabinet to introduce nuclear energy to Poland again.

There is a quite extensive nuclear research in Poland taking place at the National Center for Nuclear Research (Narodowe Centrum Badań Jądrowych, NCBJ) in Otwock-Świerk. The NCBJ emerged in 2011 by joining the former Institute of Atomic Energy POLATOM (Instytut Energii Atomowej POLATOM) with the former Andrzej Sołtan Institute for Nuclear Studies (Instytut Badań Jądrowych im. Andrzeja Sołtana). The NCBJ houses a Polish-design MARIA research reactor of 20-30 MWt operating since 1974. The NCBJ is currently the largest research Institute in Poland that is expanding quickly.

Between 1958 and 1995, the Andrzej Sołtan Institute for Nuclear Studies operated also the Russian design VVR-S research reactor named EWA (Eksperymentalny Wodny Atomowy Reaktor) with 2 MWt (later increased to 10 MWt) installed capacity. Also other nuclear research devices (MARYLA 0.1 MWt research reactor, AGATA and ANNA critical assemblies) have been already dismantled in the past.

And as there are no nuclear power plants in Poland, no Service Part information can be presented.

4.9.5 The Back End of the Nuclear Fuel Cycle

There are currently four spent fuel storages in Poland. Three of them (the interim spent fuel storage facilities 19 and 19A and technological pool of MARIA research reactor) are situated at Świerk. The fourth facility is the near-surface National Radioactive Waste Repository in Różan (Krajowe Składowisko Odpadów Promieniotwórczych, KSOP Różan) operating since 1961.

The National Radioactive Waste Repository is subject to the state enterprise Radioactive Waste Management Plant (przedsiębiorstwo państwowe Zakład Unieszkodliwiania Odpadów Promieniotwórczych, ZUOP) that also operates the 19 and 19A pool-type facilities in Świerk (the technological pool of MARIA reactor is of course operated by the NCBJ). The Plant (a state-owned company) is subordinated to the Polish Ministry of State Treasury, while National Atomic Energy Agency (Państwowa Agencja Atomistyki, PAA) under the Ministry of Environment is responsible for activities connected with the licensing and oversight of nuclear safety and radiological protection[1].

As the Różan repository will be closed in 2020-2022, a new repository should be constructed and the Ministry of State Treasury is currently working on the National Plan of Radioactive Waste and Spent Nuclear Fuel Management (European Commission, 2012, p. 4). Therefore the new Low and Intermediate Radioactivity Waste Disposal is one of the most important goals of Polish Nuclear Power Program. The site selection process has not yet been closed but the construction should be completed before 2020.

A deep underground geological repository is also considered as the final repository of spent fuel from the future nuclear units. However, the necessity to construct such a repository will arise in about 30-40 years after commissioning the first nuclear power plant, i.e. in about 2050 at the earliest. By this time, spent nuclear fuel will be stored on-site the NPP (Ministerstwo Gospodarki, 2011, p. 32).

[1] There is also a Government Commissioner for Nuclear Energy under the Ministry of Economy for activities related to peaceful use of nuclear energy to satisfy social and economic Leeds of Poland (Ministry of Economy of Poland, 2011, p. 15).

Tab. 4.9.5: Polish Nuclear Sector Examination

Indicator	Description
Is there nuclear producing capacity present in the country?	No
Is there a project to expand the capacity? What is the status of the project?	Yes, 2 units of 3,000 MWe combined until 2029, another 3,000 MWe until 2035; site selection process is finishing and public procurement for the contractor is expected to be open soon
How was the project procured?	So far openly and professionally, the public procurement for the contractor did not yet take place; Russian technology is not considered at all, bids from following four subjects can be expected: Électricité de France S.A. together with AREVA S.A.; GE Hitachi Nuclear Energy; Westinghouse Electric Company LLC; Korea Electric Power Corporation KEPCO
Who is the contractor in charge of the project?	Unknown yet
How is the financing secured?	There are four investors in the project company to finance the construction, contractor's financial participation is possible and expected
Who is the operator of the facility?	PGE Energia Jądrowa 1 Sp. z o.o. (70% PGE SA; 10% ENEA S.A.; 10% Tauron Polska Energia S.A.; 10% KGHM Polska Miedź S.A.)
Are there enough home-based experts to run the facility safely?	Yes
Who is/will be in charge of decommissioning?	The responsibility for radioactive waste management issues rests with the Ministry of Economy and the Minister State Treasury (superviser of the state-owned "Radioactive Waste Management Plant") overseen by the Polish National Atomic Energy Agency
Who provides nuclear fuel and under what conditions?	The issue of nuclear fuel supply will likely be addressed in the tender or after the NPP construction
What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	As there is no NPP, there is no fuel experience
Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	No
How is used fuel treated and who is in charge of this?	Standard cooling in ponds followed by interim storage; Radioactive Waste Management Plant (state enterprise managed by the Polish Ministry of State Treasury) is in charge of storage

4.9.6 Sources

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4.10 Country Case Study: Romania

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4.10.1 Introduction

Romania, together with Bulgaria, is one of the very latest countries to join the European Union. They have been member states since January 1, 2007, and only Croatia's joining in 2013 followed ever since. As one of the countries of the former Eastern Bloc, the Romanian economy is still burdened with residues of the centrally planned economy, even though all the former Eastern Bloc countries underwent the process of transition towards market economy in 1990s. The energy efficiency of transport has been dropping since 2000, and the trend is considered irreversible at present. On the other hand, in the period 2000-2010, the whole country's energy efficiency was twice as good as the EU's according to energy efficiency indicator (ODEX) (ICEMENERG & ANRE, 2012, p. 66). This has a lot to do with the fact that the Romanian energy sector is not as heavily reliant on hydrocarbon imports and on the use as other post-Soviet countries.

The top three electricity generation sources are hydro, coal and nuclear. On the country's total electricity production of 57.8 TWh in 2010, these accounted for 35.7%, 33.8%, and 19.4% (see Table 4.10.1). The total installed capacity in SEN (National Energy System) in 2011 was 21,717 MWe (Hidroelectrica, 2012, p. 14). With the installed capacity of 6,382 MWe in 2011 (Renewable Facts, 2011), hydropower is among the most important sources of electricity in Romania. This is due to a very favourable situation in Romanian hydrogeology. All the 587 hydro production units are united under the company S.C. HIDROELECTRICA S.A., out of which 7 have more than 200 MWe of installed capacity and 5 are pumping stations (S.C. Hidroelectrica S.A.). The largest one is The Iron Gate I (Porțile de Fier I) on the Danube River with 2,246 MWe installed capacity built as a joint venture with the former Yugoslavia. Nowadays, half of the power plant belongs to Serbians and half to Romanians.

Tab. 4.10.1: Key Energy Statistics

Source	Consumption	Imports	TPES share	Electricity Generation share
Crude Oil	10.81 Mt	56%	25%	0.9%
Natural Gas	13.76 bcm	23%	30%	10.2%
Coal (all types)	39 Mt	4.6%	22%	33.8%
RES	-	-	15%	35.7%*
Nuclear Energy	-	-	8%	19.4%

Note: 2011 data, Oil Consumption and Electricity Generation share data from 2010
* Almost the whole figure stands for hydropower. Wind power as the second most developed RES in Romania has risen from 7 MWe in 2007, over 440 MWe in 2010, to 2,599 MWe in 2013. Other RES are negligible.

Source: ***International Renewable Energy Agency, 2012; European Commission, 2012; U.S. Energy Information Administration; Lificiu***, 2012; compiled and calculated by T. Vlcek

Altogether 5,918 MWe of installed capacity in the Romanian electricity sector in 2011 accounts to coal-fired power plants. Hard coal reserves and resources are estimated at 2,446 Mt, of which 252.5 Mt are commercially exploitable within the currently leased perimeters, although as little as 11 Mt might be economically recoverable. Proven reserves of lignite total to 280 Mt, with further 9,640 Mt of resources. 95%

of lignite deposits are situated in the Oltenia mining basin and more than 80% of these can be mined in opencast mines. The main consumers of hard coal are the thermal power plants at Paroşeni (3 x 50 MWe) and Mintia (6 x 210 MWe). The main consumers of lignite are Turceni (2,640 MWe), Rovinari (1,720 MWe) and Mintia - Deva (1,260 MWe) and 300 MWe Craiova power plant (Euracoal, 2013). Coal sector is quite supported also by the inhabitants, as the monoeconomical mining areas are strongly connected with employment.

Romania has one nuclear power plant at Cernovoda with 1,413 MWe, which has two Canadian designed CANDU pressurized heavy water reactors that began operating in 1996 and 2007. Construction started in the 1980s, with the initial intention of five units. The first two units were partly funded by the Canadian Export Development Corporation with the second unit co-funded by Euratom (Schneider & Froggat et al., 2014, p. 134). Construction of the first unit started in 1980, and construction of units 2-5 in 1982. In 1991, work on the last four was suspended in order to focus on the unit 1, responsibility for which was handed to an AECL-Ansaldo (Canadian-Italian) consortium. The second 700 MWe unit had been built by an AECL-Ansaldo-SNN management team, and entered commercial operation in October 2007 (WNA, 2014). The SNN, Societatea Nationala Nuclearelectrica, Romanian state nuclear power corporation established in 1998 was assigned to operate the Cernavoda NPP. The shareholders are the Romanian Government (91%) and Romanian Property Fund (9%). The main shareholder of the Romanian Property Fund is the Ministry of Economy and Finance (66 %), the rest are private shareholders.

4.10.2 New Units and Financing of the Nuclear Power Plant

As the original plan was to build five Units at Cernavoda, but only two were constructed, the current plan aims at construction of Units 3 and 4 at Cernavoda site. There are currently no plans to complete Unit 5 at this time. There are building foundations from 1980s at the Cernavoda site for the construction of Units 3 and 4, as the decision to stop construction of Units 2-5 was made in 1991. As Romania have well-developed nuclear infrastructure, including heavy water plant, fuel fabrication plant, uranium production, and technically qualified and experienced staff (Rotaru, 2012) and operation experience, the plan to further develop nuclear capacities is expected, logical and predictable.

The procurement process for the construction of Cernavoda NPP Units 3 and 4 started in 2002 with the Unit 3 only. As the outcomes were unconvincing, SNN created a project joint venture EnergoNuclear SA with SNN to complete both 720 MWe units in a €2.5 billion project and then operate them. Twelve potential investors were selected from 15 initial bidders and eventually binding offers from six companies were accepted: ArcelorMittal of Romania, CEZ of the Czech Republic, Electrabel of Belgium, Enel of Italy, Iberdrola of Spain, and RWE Power of Germany (WNA, 2014).

In 2010-2013, all of these companies pulled out of the project for mainly commercial reasons and sold their stakes to SNN. SNN was thus a sole owner of the EnergoNuclear SA and it became clear that it could not raise this share of the funds[1], and new bidding was opened in 2011, unfortunately

[1] The total costs at that time were expected to be about €4 billion.

with no bids received[2]. In May 2014, a vendor equity agreement with the China General Nuclear Power Group (CGN) to hold 51% in the EnergoNuclear SA (while SNN will hold the remaining minority of 49%) was closed (WNA, 2014). This agreement was eventually followed with a new public tender in August 2014, where the CGN was the only company to submit a non-binding bid with the September 9, 2014 being deadline for the contract to build the two new reactors. In October 2014, CGN has been designated as the "selected investor" for the development of units 3 and 4 at Romania's Cernavoda nuclear power plant. A letter of intent has been signed to complete the two units (“CGN to invest”, 2014). Meanwhile, CNPEC has signed a "binding and exclusive" cooperation agreement with Candu Energy Inc for the construction of two more reactors at the Cernavoda NPP in Romania (“Cernavoda 3&4”, 2014). The construction project of reactors 3 and 4 is supposed to be worth €6.45 billion (“China Nuclear Power”, 2014). Also Moldova's partnership in the project is discussed (see Moldova case study for details).

However, the memorandum of cooperation with the Chinese also contained previously unknown points, such as the equipment and labour would come from China and Chinese demand for long-term governmental guarantees (contract for difference). The whole deal is therefore not certain yet, as Chinese presented new requirements that are being discussed at the moment. Romanian Government is of course reluctant to offer guarantees because there is in reality no need for electricity

[2] Some information suggest that the SNN, Societatea Nationala Nuclearelectrica, Romanian state nuclear power corporation was poorly managed so far and that they have problems with negotiating and receiving loans from private banks. This might also be among the reasons it were only the Chinese who eventually came with money.

from the Units 3 and 4. Also, some information suggest problems with water supply, especially in dry months. Nicolae Ceaușescu's original plan was to displace thousands of people and to create an artificial water reservoir for the Units 3 and 4. This plan is of course unrealistic today.

To sum up, the CGN is the investor in the Cernavoda NPP Unit 3 and 4 projects, the CGN subsidiary CNPEC (China Nuclear Power Engineering Co) is the constructor of the units, and the Industrial and Commercial Bank of China provided the finances to the investor. The design of the Units 3 and 4 will be the Canadian CANDU and as the CGN has no experience with CANDU design, the construction and the commission is to be overseen by the Canadian Candu Energy Inc, the owner of the CANDU technology and design. In 2014, Unit 3 is reported to be 53% complete and unit 4 to be 30% complete, and the construction should end in July 2019 (WNA, 2014).

Also, there is some evidence that a second nuclear power plant is planned to start construction in 2020 and the Romanian authorities are currently looking for the best suited nuclear technology. The French EPR has been considered so far and Piatra Neamț was understood to be the best location for a nuclear power station based on the EPR technology (“Romanians ponder”, 2008; “Old fashioned”, 2008). This idea of a second NPP is in the very beginning of the process and no further development has been registered. The reason might also be the fact that current Romania's generation capacities exceed consumption, and further development of these capacities would have negative impact on the competitiveness of some Romanian electricity production options. Another reason might also be the French willingness to sell Mistral-class military ships to Russian Federation even after the Crimea crisis, which led to huge debates in Romania and froze the discussions about the second NPP with French technology.

4.10.3 The Front End of the Nuclear Fuel Cycle

The end of the delivery of uranium metal to the USSR in 1963 did not mean the end of the uranium extraction industry in Romania. On the contrary, in 1960s, the follower company of Sovrom Cuarțit, the Organizatia Expeditia Geologica worked on important geological surveys, where a lot of new uranium deposits were found, the Crucea-Botușana and the Tulgheş-Grințieş being the most important ones (Dumitrescu, 2010). During the socialist era, many deposits, both underground and open-cast, were mined (e.g. Avram Iancu, Dobrei, Natra, Ciudanovița, Băița). Băița, closed in 2009, was the biggest mine in Romania and was also the first to be opened in the 1950s by the Soviet Union. Nowadays, only Crucea-Botușana mines are still mined (together with the Rožná underground mine in the Czech Republic, these are the last two operating uranium mines in Europe). As Romania has yet not reported its production to OECD Nuclear Energy Agency, the Agency estimates the production is 80 tons of Uranium metal annually (OECD NEA & IAEA, 2014, p. 61). The Crucea-Botușana mines are mined over 40 years and they are almost depleted. The closure of the mines is planned to 2015. Therefore, the state-owned Compania Nationala a Uraniului S.A. Bucuresti (CNU) is planning to develop the small Tulgheş-Grințieş deposit in the East Carpathian mountains about 100 km south of Crucea-Botușana at a cost of EUR 91 million (WNA, 2014). The investment will most probably be covered from the state budget

and mainly by the CNU (Euratom Supply Agency, 2014, p. 12). It is an advanced project, as the feasibility study was already conducted. Authorities assess an annual exploitation of 124,000 tons over a 108 month long project (Stroe, 2013).

The extracted uranium has been since 1977 transported to Feldioara Processing Plant, where uranium dioxide has been produced ever since. The uranium dioxide produced is then transported to the Nuclear Fuel Plant (FCN) Pitești, where the CANDU fuel bundles are fabricated. The facility is recognized by the Atomic Energy of Canada Limited (AECL, nowadays known as Candu Energy Inc) as an authorized CANDU fuel manufacturer, the only supplier of this fuel in the Word outside Canada (Dumitrescu, 2010).

The domestic uranium production covers the domestic uranium demand. Cernavoda 1 has been using 105 tons of natural UO2 fuel per year; the domestic production of the fuel bundles fully covers the demand. In 2003, the production was doubled to 46 fuel bundles daily in preparation for unit 2 commissioning (WNA, 2014). We can thus clearly infer that Romania is self-sufficient in the uranium fuel production and supply.

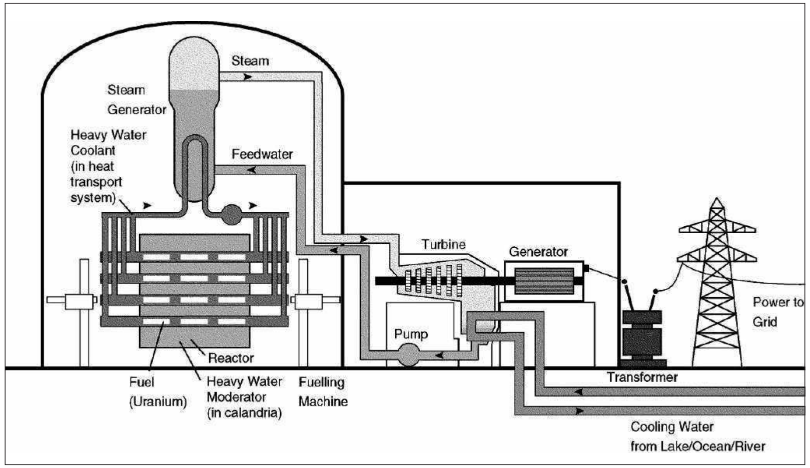
4.10.4 The Service Part of the Nuclear Fuel Cycle

Even though the Russian VVER-440 design was also considered in the past, eventually, the CANDU design was selected. The decision was not done because of the actual need of the nuclear power plant, but rather due to the efforts to politically move away from the USSR during Nicolae Ceaușescu's rule. Also, Ceaușescu's denouncement of the Soviet invasion to Czechoslovakia in 1968 led to the end of Soviet-

Romanian cooperation in the nuclear sector. He thus started to play the "Western" card to secure Western technology for Romania. The CANDU design has many structural similarities with PWR design, with the most visible difference that the power plant operation consists of only two circles, as the first and second one is jointed (see Table 4.10.2). Unlike with PWR, the CANDU design uses heavy water as regulator. Heavy water absorbs less neutrons, thus is able both to moderate nuclear reaction and secure criticality, and non-enriched fuel can be used. The Danube River is used as a reservoir for cooling water in the cooling circle. The reactor design originated in Canada, but was sold to and is used also in India, South Korea, Romania, Pakistan, Argentina, and China. Heavy water is produced within Romania, in ROMAG-PROD Heavy Water Plant in the city Drobeta Turnu Severin.

The Romanian nuclear sector is relatively new, but very well organized. All the nuclear related institutions and bodies work under the Ministry of Economy and Finance, with the exception of independent control body (CNCAN, National Commission for Nuclear Activities Control), which is subordinated to the prime minister. The Cernavoda NPP and FCN Nuclear Fuel Factory are parts of the SNN Company, and the SNN together with Waste Management Agency (ANDRAD), Nuclear Agency (NA) and Romanian Authority for Nuclear Activities (RAAN) are subordinated to the Ministry of Economy and Finance. RAAN controls and coordinates the work of the ROMAG-PROD Heavy Water Plant, SITON Center of Design and Engineering for Nuclear Projects and INR Institute for Nuclear Research (Romanian Authority for Nuclear Activities, n.d.).

Tab. 4.10.2: The CANDU Reactor Scheme



Source: *Nuclear Engineering*

Romania has also quite a history of nuclear energy development originally based on the cooperation with the USSR. The cooperation started with creation of the joint venture Sovrom Cuarțit Company to extract uranium. Even though the lifetime of the company was only 4 years (1951-1956), the USSR had received 17,228 tons of uranium metal until Romania bought out the Soviet stake in the company in 1961 (Cioroianu, 2005, p. 70). After the dismantlement of the Sovrom Cuarțit, the cooperation flourished and USSR assisted with the construction of the VVR-S research reactor in Măgurele, U120 cyclotron and other equipment (Gheorghe, 2012, p. 10-11). In late 1960s, Romania started to court various Western governments and firms active in the nuclear industry.

The reason was the poor quality of Soviet equipment and the fact the USSR was reluctant to share its technology with Romania as the USSR was delaying the delivery of nuclear technology to all Eastern European allies at that time fearing of nuclear proliferation (Gheorghe, 2012, p. 13).

Tab. 4.10.3: Nuclear Units in Romania

Reactor	Type	Power Output	Status	End of life-cycle
Măgurele*	VVR-S	2 MWt	Decommissioning	2002
Măgurele**	Sub Critical Assembly	-	Shut down	2006
Măgurele**	RP-0	0 MWt	Decommissioned	-
Pitești***	TRIGA II	14 MWt	Operating	2025
Cernavoda 1	CANDU 6	706.5 MWe	Operating	2026
Cernavoda 2	CANDU 6	706.5 MWe	Operating	2037
Cernavoda 3	CANDU 6	720 MWe	Planned	-
Cernavoda 4	CANDU 6	720 MWe	Planned	-
Second NPP	-	2,400 MWe	Proposed	-

* It is a research reactor built in 1957 based at Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN HH). The reactor was shut down in July 1997.
** The sub critical assembly "HELEN" is owned by the Faculty of Physics, University of Bucharest. The Zero Power Reactor RP-0 belongs to the Polytechnic University of Bucharest.
*** It is an American research reactor manufactured by General Atomics built in 1980 and based at Institute for Nuclear Power Research in Pitești.

Source: compiled by T. Vlcek from open sources.

Eventually, even though an agreement on construction of VVER-440 design NPP at Olt River was never cancelled, Nicolae Ceaușescu decided to deal with the unwillingness to share the technology simply with finding partnership in the West. And shortly after the energy crisis connected with the closure of the Suez Canal in 1967, Romania established that the CANDU reactor was the most efficient option[3] (Gheorghe, 2012, p. 15, 29).

Also, in 1982 a contract was signed with the Soviet Union to build a VVER-1000 nuclear power plant, which would have three 1,000 MWe reactors. The preparatory work even began in March 1986 for construction of a nuclear plant at Piatra Neamț, to be equipped largely by the Soviet Union (Federal Research Division of the Library of Congress, n.d.). Piatra Neamț is a city approximately 100 km from the current Moldovan border. But these plans appeared unattainable and the plan was scrapped.

4.10.5 The Back End of the Nuclear Fuel Cycle

The used fuel from the Cernavoda NPP is cooled in Spent Fuel Storage Bay (SFB) next to the reactor with the capacity for ten years of operation for one unit (Radu, n.d., p. 115) and then stored in interim storage units[4]. The Interim Dry Spent Fuel Storage Facility (DICA) at Cernavoda NPP location is a modular construction[5] with the first module operational from 2003, second from 2006, third from 2008, fourth from 2011 etc., with the final profile of 27 modules. Altogether, this storage capacity is enough for 50-80 years of storage for 2 CANDU Units (Rotaru, 2012, p. 24). At the end of 2002, after 6 years of plant operation, the inventory was of 30,344 spent

[3] During the following negotiation period, the USA equipped Romania with different nuclear technology, including TRIGA II research reactor
[4] There are other repositories in Romania for low and intermediate level waste, such as the location Băița-Bihor at the former uranium mine Băița operational since 1985.
[5] A concrete monolith module of the MACSTOR type, a system designed by Atomic Energy of Canada Limited (see Andrei, Glodeanu, Talmazan & Radu, n.d.).

fuel bundles, which means an annual production of 5,000 spent fuel bundles per Unit (Andrei, Glodeanu, Talmazan & Radu, n.d., p. 283). Obviously, another Dry Spent Fuel Storage Facility will be constructed for the Units 3 and 4.

The Spent Fuel Final Disposal Facility (SFDF), e.g. the deep underground depository, is planned to be developed later as the capacity of the interim storage is adequate. The plan is to open the facility in 2050 and fill it with spent fuel until 2075, when it should be closed (Radu, n.d., p. 115). There are 15 locations that were taken into consideration for future geological analysis.

Romania has got experience also with decommissioning of nuclear facilities with decommissioning of Măgurele VVR-S reactor, Sub Critical Assembly and RP-0 reactor, and with decommissioning of depleted uranium mines. The National Agency for Radioactive Waste (ANDRAD) together with the Ministry of Economy and Finance are responsible for the Decommissioning process of nuclear facilities, and these agencies have responsibly prepared very detailed plans and scenarios for the future including financing.

Tab. 4.10.4: Romanian Nuclear Sector Examination

Indicator	Description
Is there nuclear producing capacity present in the country?	Yes, Cernavoda NPP (CANDU design, 2 Units of 706.5 MWe each)
Is there a project to expand the capacity? What is the status of the project?	Yes, financing resolved, negotiations reaching their end
How was the project procured?	Openly, without Russian bid
Who is the contractor in charge of the project?	China General Nuclear Power Group
How is the financing secured?	The contractor received a loan from the Industrial and Commercial Bank of China

Who is the operator of the facility?	Societatea Nationala Nuclearelectrica (91% Romanian Government, 9% Romanian Property Fund, of which 66% Ministry of Economy and Finance, and 34% private shareholders) for Cernavoda 1 and 2; EnergoNuclear SA (51% China General Nuclear Power Group; 49% Societatea Nationala Nuclearelectrica) for Cernavoda 3 and 4
Are there enough home-based experts to run the facility safely?	Yes
Who is/will be in charge of decommissioning?	National Agency for Radioactive Waste together with the Ministry of Economy and Finance
Who provides nuclear fuel and under what conditions?	Romanian Nuclear Fuel Plant Pitești, licensed and authorized CANDU fuel manufacturer by Candu Energy Inc
What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	No operational issues; path dependency inherent as Nuclear Fuel Plant Pitești or Canadian Candu Energy Inc are the only CANDU fuel type producers worldwide
Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	Romania houses working capacities for the whole nuclear fuel cycle and is therefore fully self-sufficient
How is used fuel treated and who is in charge of this?	The used fuel is stored in the Interim Dry Spent Fuel Storage Facility (DICA) at Cernavoda NPP, the DICA is owned and operated by Societatea Nationala Nuclearelectrica

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4.11 Country Case Study: Slovak Republic

Tomáš Vlček

4.11.1 Introduction

Slovakia is a country that shares common history with the Czech Republic until 1993, when Czechoslovakia was peacefully dissolved into Czech and Slovak Republic. Even though separated, the two Republics are still very close partners. The country entered the EU in 2004 and its economy and citizens' will allowed for the adoption of Euro in 2009.

Slovakia is fully dependent on imports of crude oil from the Russian Federation via the Druzhba pipeline. As seen in Table 4.11.1, the imports of crude oil reached 146% in 2011. This happened due to the fact that Slovakia houses the Slovnaft, a.s. refinery in Bratislava with 5.5 Mt/y design capacity. The ownership structure of the Slovnaft refinery is 98.4% Hungarian MOL Rt and 1.6% other legal and physical entities (Slovnaft, a.s.). The transport sector accounts for half of all oil used in Slovakia (OECD & IEA, 2014, p. 392). The petroleum products are partly supplied to neighbouring states, especially the Czech Republic and Hungary.

Slovakia is also almost fully dependent on natural gas imports from Russian Federation via the Yamal pipeline. Less than 3% of demand is covered by domestic production. Table 4.11.1 shows over 100% imports of gas in 2011; this is due to the fact that some gas is imported to be stored in the country's underground natural gas storages in the Láb complex. The capacity of this facility in Western Slovakia is 3.02 bcm (OECD & IEA, 2014, p. 401).

Both crude oil and natural gas are also transported via the Druzhba and Eustream pipelines through Slovakia to the Czech Republic.

Tab. 4.11.1: Key Energy Statistics

Source	Consumption	Imports	TPES share	Electricity Generation share
Crude Oil	4.09 Mt	146%	35.9%	2.0%
Natural Gas	5.64 bcm	105%	26.7%	11.0%
Coal (all types)	7.47 Mt	68%	21.4%	14.1%
RES	-	-	7.7%*	19.1%*
Nuclear Energy	-	-	23.5%	53.8%
* Biofuels and waste stand for 5.5% of TPES share and 2.9% of Electricity Generation share; hydro stands for 14.5% of Electricity Generation share Note: 2011 data				

Source: ***U.S. Energy Information Administration; International Energy Agency***; compiled and calculated by T. Vlcek

Slovakia produced 28.66 TWh of electricity in 2011 and produces 28 TWh annually on average. The import/export values are more or less coping with one another; the average import is 10.1 TWh and export is 9.3 TWh (International Energy Agency). The sovereign company in terms of its market share is Slovenské elektrárne, a.s. operating 68% (5,739 MWe) of the total installed capacity in the country (8,431 MWe) and produced 21.93 TWh in 2011, making it 77% of the total electricity production (Slovenské elektrárne, a.s.). The company is owned by Italian Enel Produzione S. p. A. (66%) and the Ministry of Economy through the National Property Fund of the Slovak Republic (34%). Due to mother company's debt, the

Italian Enel Produzione S. p. A. decided in summer 2014 to sell its share in Slovenské elektrárne, a.s. (Holeš, 2014b)

The following Table 4.11.2 shows the key power plants in the Slovak Republic besides the nuclear power plants. As seen in Table 4.11.1, nuclear energy produces more than half of the country's electricity consumption and is therefore the most important source of electricity. There are currently four operating units in Jaslovské Bohunice NPP and Mochovce NPP with two more being under construction at Mochovce site. The current total installed capacity in nuclear reaches 1,950 MWe. The nuclear energy sector is analyzed further in the text.

Tab. 4.11.2: Key Power Plants in the Slovak Republic

Power Plant	Owner	Installed Capacity	Connected to the Grid	Fired on
Gabčíkovo HPP	Vodohospodársky podnik, š.p.	746.54 MWe	1992-1996	Water
Čierny Váh PSHPP	Slovenské elektrárne, a.s.	734.4 MWe	1982	Water
Vojany 1 TPP	Slovenské elektrárne, a.s.	440 MWe	1965-1967	Hard coal
Vojany 2 TPP	Slovenské elektrárne, a.s.	440 MWe	1973-1974	Gas
Nováky B TPP	Slovenské elektrárne, a.s.	440 MWe	1964, 1976	Brown coal
Note: HPP = Hydroelectric Power Plant; PSHPP = Pumped Storage Hydroelectric Power Plant; TPP = Thermal Power Plant				

Source: compilation by T. Vlcek.

Besides nuclear power plants, the remaining electricity generation capacity is well diversified. There are basically only five more centralized power plants with bigger cumulative

capacity. Slovakia has been developing its hydroelectric potential, so two of them are Gabčíkovo Hydroelectric Power Plant (746.54 MWe) and Čierny Váh Pumped Storage Hydroelectric Power Plant (734.4 MWe). The Gabčíkovo HPP was originally part of the international Slovak-Hungarian project of Gabčíkovo–Nagymaros Waterworks. Hungaria withdrew from the project in 1977 due to negative environmental effects leaving Slovakia alone to choose whether to abandon the project or to finish it. After several years of negotiation and reconsidering, Slovakia adjusted the project and completed the Gabčíkovo Dam without the Hungarian Nagymaros part in 1992-1996. The Slovak-Hungarian international dispute at the International Court has still not been resolved. The Gabčíkovo HPP is owned by the state enterprise Vodohospodársky podnik, š.p. but operated by Slovenské elektrárne, a.s. In December 2014, it was announced that the Slovak Government terminated the contract between Vodohospodársky podnik, š.p. and Slovenské elektrárne, a.s. for violations of the contract (“Slovenské elektrárne”, 2014). Legal struggle is now expected.

The Čierny Váh PSHPP is the biggest hydroelectric plant in Slovakia and is also a very important part of the electricity supply system. It assists the TSO greatly as it is used as a primary regulation of the power balance. Vojany TPP and Nováky TPP are the country's fossil fuel power plants being fired on hard coal, brown coal, natural gas and heat fuel oil. Together their installed capacity is 1,398 MWe. Besides all these power plants, there are many decentralized small units around Slovakia, for example, several tens of small hydroelectric power plants followed by some photovoltaics, wind power plants and biofuels.

4.11.2 New Units and Financing of the Nuclear Power Plant

Originally, the Mochovce NPP was supposed to be equipped with four VVER-440/V-213 units, but due to the lack of finances, the construction of the units 3 and 4 was stopped in 1992. In 2006, Italian Enel Produzione S. p. A. acquired 66% stake in Slovenské elektrárne, a.s. and came with an investment plan to enhance nuclear capacities. The plan was eventually incorporated in the 2006 Energy Policy and 2008 Energy Security Strategy. These documents envisaged completion of Mochovce NPP 3&4 (+880 MWe); uprate of Jaslovské Bohunice V2 NPP and Mochovce NPP 1&2 (+180 MWe) and eventually uprate of newly constructed Mochovce NPP 3&4 (+60 MWe). In 2024, the operation of a new NPP of 1,200 MWe is also proposed (Ministerstvo hospodárstva SR, 2008, p. 106).

The Mochovce NPP 3&4 were partially built and the project was thus a real completion. In 2007, Slovenské elektrárne, a.s. concluded a revolving credit line for seven years in the amount of EUR 800 million and the major shareholder announced its intend to invest over EUR 3 billion in Slovakia, of which approx. EUR 1.7 billion will be used for the completion of units 3&4 of the Mochovce NPP (Slovenské elektrárne, a.s., 2008, p. 19). The total cost was in November 2014 finally authorized at EUR 4.63 billion, the whole sum is covered exclusively with the company's own financial resources ("Akcionári schválili", 2014).

In July 2008, the European Commission approved the completion of the units and in June 2009, contracts were signed with the original suppliers of the unfinished parts. The contracts were signed with Škoda JS a.s., ZAO AtomStroyExport and Slovak suppliers Výskumný Ústav

Jadrovej Energetiky, a.s. (VÚJE), Enseco a.s. and Inžinierske Stavby a.s. for more than EUR 370 million to supply the remaining nuclear island equipment (beyond that delivered 20 years earlier), with part of the instrumentation and control (I&C) systems being from Siemens AG. Contracts for engineering, construction and project management of the conventional island were signed with ENEL Ingegneria & Innovazione S.p.A., involving the use of Doosan Škoda Power s.r.o. steam turbines (WNA, 2014). The completion of the project was originally due in 2012 and 2013, but has been postponed several times, currently to November 2016 and 2017. The main reason was the implementation of new safety measures after the Fukushima Daiichi accident ("Úrad jadrového", 2014).

In 2008, plans for a new NPP were announced and it was decided that it will be a new reactor at Jaslovské Bohunice NPP site. A project company Jadrová energetická spoločnosť Slovenska, a. s. (JESS) was established in 2009, with 51% share for Jadrová a vyraďovacia spoločnosť (JAVYS), fully owned by the Slovak Ministry of Economy (Ministerstva hospodárstva SR), and 49% share for ČEZ Bohunice a.s. fully owned by the Czech company ČEZ, a.s. (Jadrová energetická spoločnosť Slovenska, a. s.) At that time, the Czech 2008 tender for the Temelín NPP contained an option for up to three more reactors; one of them was intended for Slovakian Jaslovské Bohunice NPP.

In 2010, potential vendors were invited to send information about their projects. At the end of the year, six information packages were received: Westinghouse Electric Company LLC

[1] Joint venture of AREVA SA and Mitsubishi Heavy Industries, Ltd.

(AP1000 PWR of 1,117 MWe), ATMEA S.A.S.[1] (ATMEA 1 PWR of 1,100 MWe), Mitsubishi Heavy Industries, Ltd. (Mitsubishi Advanced PWR of 1,700 MWe), Consortium MIR.1200[2] (MIR 1200 of 1,200 MWe), Korea Hydro & Nuclear Power[3] (Advanced Pressurised Reactor-1400 of 1,400 MWe) and AREVA SA (PWR EPR 1600 of 1,600 MWe).

The material received was used for the feasibility study prepared in 2012 by Ústav jaderného výzkumu Řež, a.s., which stated that the location is suitable for up to 2,400 MWe of new installed capacity and a turnkey option is the most preferable. It was also said that all the offered technologies are suitable for the location. In September 2013, the work proceeded with the start of EIA process that should end in the second half of 2015 (Jadrová energetická spoločnosť Slovenska, a. s.).

Originally, the project was meant to be financed by the stakeholders of the project company, e.g. the Jadrová a vyraďovacia spoločnosť (JAVYS) and the Czech company ČEZ, a.s. In August 2010, the newly-elected centre-right government said it was keen for the Bohunice project to proceed, but would not offer any financial support for it (WNA, 2014). The Czech company eventually started to aim at withdrawal from the project, since they focused on the Czech Temelín NPP tender, and also because of its unsuccessful Balkan investments. In January 2013, Jadrová a vyraďovacia spoločnosť (JAVYS); ČEZ, a.s.; ČEZ Bohunice a.s.; and Jadrová energetická spoločnosť Slovenska, a. s. (JESS) signed a memorandum of understanding with Rosatom, as this company showed, in 2012, an interest to

[2] Consortium of the companies ŠKODA JS, a. s., from the Czech Republic, Atomstrojexport, a. s., from the Russian Federation (a daughter company of the Russian company ZAO Atomstroyexport) and OKB Gidropress, a. s. from the Russian Federation.
[3] Subsidiary of Korea Electric Power Corporation KEPCO.

be both technology provider and an investor in this unit (ČEZ Bohunice a.s., 2014, p. 10). The ČEZ, a.s. offered its 51% stake to Rosatom; the planned sell was supported by the Slovak government. However, Rosatom possibly sought a BOO (build-own-operate) arrangement, and also a guaranteed long-term electricity price of EUR 60-70 /MWh, which the Minister of Economy Tomáš Malatinský was unwilling to provide (Mitev, 2013), and therefore the transaction was scrapped.

Slovaks eventually stopped the negotiations with Russians at the end of 2013, as Rosatom insisted on a guaranteed electricity price, and even though promised, no other proposal was provided. Shortly after, at the beginning of 2014, Rosatom stopped insisting on guaranteed prices and it is now prepared to consider any form of support from the Slovak side, which will ensure that a project is economically viable way for investors as well as for creditors (Holeš, 2014a). Also, the new Minister of Economy of Slovakia Pavol Pavlis, who entered the office in July 2014, is inclined to offer electricity price guarantees.

The new Jaslovské Bohunice II NPP should be operational after 2025. However, the negotiations and investor seeking is complicated, and financing of the new NPP is not secured. Other non-Russian subjects are interested as well (for example French and Slovak presidents discussed potential cooperation in nuclear energy in October 2013), but they were not disclosed and no official offer was received (Dargaj, 2014).

4.11.3 The Front End of the Nuclear Fuel Cycle

The Slovak Republic shares common history with the Czech Republic as until 1993 the countries were coupled in Czechoslovakia. Therefore the uranium mining history is also common. Because the uranium deposits were richer in the Czech lands, uranium has never been really mined in Slovakia, except as a byproduct in molybdenum and copper mining or during some geological research (Rizman, 2009, p. 5). Uranium was therefore to some extent extracted in the Novoveská Huta deposit near the city Spišská Nová Ves, where 6,340 tons of uranium in 0.099 grade uranium ore is now deposited (Bartalský, Kuestermeyer & Novotný, 2012, p. 12). Other deposits include Kurišková – Jahodná, Kluknava, Kálnica – Selec.

However, there is a plan for opening a new deposit Kurišková near the city of Košice in east Slovakia. A Preliminary Feasibility Study conducted by American Tetra Tech, Inc. gave evidence of 15,831 tons of economically exploitable uranium deposited in Kurišková (Ludovika Energy s.r.o.). Currently, detailed geological and technical research by the company Ludovika Energy s.r.o. takes place and this will be eventually followed by a feasibility study, EIA, and potential licensing procedure. The amount of resources will be enough for 50 years of Slovak needs, as Slovak demand is 300 tons of uranium annually (Bartalský, Kuestermeyer & Novotný, 2012, p. 24), which is an important incentive for further work on this deposit. The European Uranium Resources Ltd., 50% owner of both projects in Novoveská Huta and Kurišková (the other 50% owns Forte Energy NL), decided in April 2014 to sell their shares to Australia's Forte Energy NL for USD 8.5 million plus a 1% production royalty (Bacal, 2014).

The reason might be the fact that the outlined development is not certain, as strong opposition emerged not only in local authorities and NGOs, but also in the Slovak Parliament, where two members of the parliament (SDKÚ-DS party) submitted

in April 2014 a proposal for country-wide ban for uranium mining with local referendum approved exceptions. They later withdrew their proposal because the Minister of Environment Peter Žiga with the mayor of Košice Richard Raši succeeded with their initiative to impose a general uranium mining ban in the whole territory of the Slovak republic by a law. The government agreed on this amendment of the law in May 2014, and since June 2014, there has been a compulsory prerequisite for uranium mining – a positive compulsory referendum in affected municipalities ("Uranium mining amendment", 2014). Without this referendum it is forbidden by law to mine uranium in Slovakia. As people in the affected municipalities in east Slovakia are generally against uranium extraction, it will be very difficult to successfully complete the two abovementioned uranium projects.

As Slovakia does not have capacities in the Front End of the Nuclear Fuel Cycle, it purchases the final product (uranium fuel) directly from the producer. Slovakia signed a contract with Russian TVEL in 2008, and according to this contract, TVEL is the provider of fuel until 2015 with an option to prolong the contract. The Government has however discussed the possibilities of reducing dependency on Russian nuclear fuel, and in November 2014, information about signing a contract for uranium fuel supply with a non-Russian company emerged without any further details. ("Vymenit´ ruské", 2014; Ehl, 2014) Later the contract was publicly specified as a contract for the supply of enriched uranium only and this product will still be processed into nuclear fuel elements by TVEL. The supplies began in 2015. (Carney, 2014; Vilikovská, 2014) Unofficial information suggests that the new supplier of enriched uranium is AREVA SA.

4.11.4 The Service Part of the Nuclear Fuel Cycle

There are two nuclear power plants operating in the Slovak Republic with a total of four pressurized water reactors cooled and moderated by light water. The Jaslovské Bohunice NPP is located in western Slovakia near the Czech and Austrian borders. The V1 Units were shutdown because of Austrian political pressure during the EU-accession period[4], therefore only the V2 Units are currently in operation. Jaslovské Bohunice NPP is equipped with two VVER-440/V-230 pressurized water reactors (2x 505 MWe), which had provided their first electricity in 1984-1985. The second nuclear power plant Mochovce in southern Slovakia is equipped with two VVER-440/V-213 pressurized water reactors (2x 470 MWe) and has been operating since 1998 and 2000. The new units at Mochovce site should be operational in 2016 and 2017. Both of the power plants were constructed with Soviet assistance end employs Soviet design VVER reactors.

The Slovak Republic (or Czechoslovakia) has also experience with its own reactor design. Between 1958 and 1972, the Czechoslovak KS-150 design Jaslovské Bohunice A1 NPP had been constructed by domestic companies with Soviet support. Since 1972, the A1 NPP had generated electricity until its shutdown in 1977 due to a nuclear accident (INES 4). Human error was behind the 1977 accident, with rector meltdown that eventually led to NPP shutdown. This also means that the Czech and Slovak experts have quite an experience with decommissioning and nuclear accident mitigation.

[4] With EUR 437 million compensation from the EU for the first seven years after the shutdown.

Tab. 4.11.3: Nuclear Units in the Slovak Republic

Source	Consumption	Imports	TPES share	Electricity Generation share
Crude Oil	4.09 Mt	146%	35.9%	2.0%
Natural Gas	5.64 bcm	105%	26.7%	11.0%
Coal (all types)	7.47 Mt	68%	21.4%	14.1%
RES	-	-	7.7%*	19.1%*
Nuclear Energy	-	-	23.5%	53.8%

* Biofuels and waste stand for 5.5% of TPES share and 2.9% of Electricity Generation share; hydro stands for 14.5% of Electricity Generation share
Note: 2011 data

Source: open sources, compiled by T. Vlcek.

Speaking about the life-cycle of the nuclear units, they were all designed and licensed for 30-year operation. As the two units of Jaslovské Bohunice V2 reached its planned life-cycle, the operator requested in 2013-2014 at the Úrad jadrového dozoru SR (Nuclear Regulation Office of the Slovak Republic) an extension of the life of the two units for another thirty years and a positive decision is expected. In fact, the operator counts that all the nuclear units will be operating for 60 years.

The VVER-440/V-230 model at Jaslovské Bohunice V1 was not equipped with containment structure and this was one of the safety deficiencies and the main reasons Slovakia had to shut down the V1 NPP in accordance with the Accession Treaty to the European Union. The Unit 1 was therefore shutdown in December 2006 and the Unit 2 in December 2008. During the natural gas crisis January 2009 caused by Russia–Ukraine gas disputes, the Slovak Government announced that the EU it will restart the NPP to mitigate the effects of the crisis (Filo, 2009). However, as the cut-off of Russian gas supplies was mitigated by reverse flow from the Czech Republic, the Jaslovské Bohunice V1 NPP was not restarted.

4.11.5 The Back End of the Nuclear Fuel Cycle

After at least 3 years of cooling, the spent fuel in a pool they are transported to the wet-type Interim Spent Fuel Storage (MSVP, Medzisklad vyhoretého paliva) at the Jaslovské Bohunice site. Spent fuel from both of the country's nuclear power plants is stored there. Even though the current capacity is 14,112 fuel assemblies, this will be enough only until 2021 (with respect to the new Units 3 and 4 at Mochovce). Plans for expansion are therefore being considered, as well as plans for construction of another Interim Spent Fuel Storage in Mochovce to avoid unnecessary transportation of spent fuel. The ISFS construction in Mochovce should commence in 2016.

The whole Back End of the Nuclear Fuel Cycle is managed by the company Jadrová a vyraďovacia spoločnosť (JAVYS), fully owned by the Slovak Ministry of Economy (Ministerstva hospodárstva SR). This company thus also operates the Jaslovské Bohunice MSVP. It is also responsible for the safe storage of non-fuel radioactive wastes; therefore, it operates the storages at Jaslovské Bohunice and Mochovce sites, and since its construction in 2001, also the Republic Radioactive Waste Storage (RÚ RAO, Republikové úložisko rádioaktívnych odpadov) for industrial low- and medium-level waste (Jadrová a vyraďovacia spoločnosť).

Tab. 4.11.4: Slovak Nuclear Sector Examination

Indicator	Description
Is there nuclear producing capacity present in the country?	Yes, Jaslovské Bohunice V2 NPP with two VVER-440/V-230 reactors (2x 505 MWe) and Mochovce NPP with two VVER-440/V-213 (2x 470 MWe)
Is there a project to expand the capacity? What is the status of the project?	Yes, the EIA procedure will be finished in second half of H2 2015, investor and technology provider is sought
How was the project procured?	The public procurement process has not yet been opened, direct negotiations with technology suppliers and investors in one are preferred
Who is the contractor in charge of the project?	Jadrová energetická spoločnosť Slovenska, a. s. (51% Jadrová a vyraďovacia spoločnosť, fully owned by the Slovak Ministry of Economy; 49% ČEZ Bohunice a.s. fully owned by the Czech company ČEZ, a.s.)
How is the financing secured?	Originally from contractors, currently strategic investor is sought
Who is the operator of the facility?	Unclear, either Jadrová energetická spoločnosť Slovenska, a. s. or Slovenské elektrárne, a.s.
Are there enough home-based experts to run the facility safely?	Yes
Who is/will be in charge of decommissioning?	The operator together with Jadrová a vyraďovacia spoločnosť (fully owned by the Slovak Ministry of Economy) overseen by Úrad jadrového dozoru SR (Nuclear Regulation Office of the Slovak Republic)
Who provides nuclear fuel and under what conditions?	OAO TVEL under the contract from 2008; since 2015 undisclosed non-Russian company has started supplying the fuel, unofficial information suggests the new supplier is AREVA SA
What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	No issues, as OAO TVEL is the traditional manufacturer and supplier of VVER-reactor fuel, path-dependency was expected, however, breached by the new undisclosed fuel supplier

Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	None except for spent fuel storage
How is used fuel treated and who is in charge of this?	The whole Back End of the Nuclear Fuel Cycle is managed by Jadrová a vyraďovacia spoločnosť (JAVYS), fully owned by the Slovak Ministry of Economy; standard procedure with Interim Spent Fuel Storage at the Jaslovské Bohunice site; plans for expansion as well as for construction of another one in Mochovce; deep final underground depository planned

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4.12 Country Case Study: Ukraine

Tomáš Vlček

4.12.1 Introduction

Ukraine declared its independence for the first time in the turbulent times after the February Revolution in the Russian Empire in 1917. The following Ukrainian war for independence ended with partition of Ukraine among Poland, USSR and Ukrainian SSR. The Ukrainian SSR withstood all the political changes in the world and lasted until the breakup of the USSR in 1991. In December 1991, three officials; Ukrainian president Leonid Kravchuk; Chairman of the Supreme Council of the Republic of Belarus Stanislav Shushkevich, and President of the Russian Federation Boris Yeltsin, signed the Belavezha Accords, dissolving the Soviet Union and establishing the Commonwealth of Independent States instead.

The political struggle between presidential candidates Viktor Yanukovych (pro-Russian) and Viktor Yushchenko (pro-Western) eventually led to massive protest (Orange Revolution) and abdication of the elected president Viktor Yanukovych. However, at the end of Yushchenko's presidential mandate, one of his closed allies, Yulia Tymoshenko, turned against Yushchenko and ran for president. Even though she did not succeed, the country was politically harmed and Viktor Yanukovych became the president. This eventually led to a political switch from heading towards the EU to closer ties with Russia. This was again followed by a public protest and the power struggle continued. Two more presidents changed in the office (Oleksandr Turchynov and the current one Petro Poroshenko) and the country went to another crisis in 2014, when Crimea was annexed through Russian military intervention. The crisis burst out into civil war and the fighting continues in Eastern Ukraine until today. The country is still neither unified, nor stable.

Tab. 4.12.1: Key Energy Statistics

Source	Consumption	Imports	TPES share	Electricity Generation share
Crude Oil	14.2 Mt*	55%*	7.2%	0.3%
Natural Gas	64.6 bcm	69%	37%	9.5%
Coal (all types)	64.1 Mt	20%	32.8%	38.2%
RES	-	-	2.1%	5.7%**
Nuclear Energy	-	-	18.7%	46.3%
* 2010 data ** Hydro stands for 5.6% of Electricity Generation Share Note: 2011 data				

Source: *U.S. Energy Information Administration; International Energy Agency*; compiled and calculated by T. Vlcek

Speaking about fuel imports, the country is dependent on crude oil and natural gas imports. Speaking in percentage, the dependence is relatively lower than in many other CEE countries (55% and 69% respectively); however, speaking in absolute numbers, the consumption is high (14.2 Mt of crude oil and 64.6 bcm of natural gas in 2011), thus the import dependency is high as well. Crude oil is imported via the Druzhba and Prydniprovski oil-trunk pipelines from the Russian Federation to Ukrainian refineries (see Table 4.12.2). However, due to the current political and economical situation, only one of the seven refineries in Ukraine is operational – the Kremenchuk refinery.

Tab. 4.12.2: Ukrainian refineries

Refinery	Owner	Capacity
Odessa	VTB Bank OAO	2,8 / 3,9
Lysychansk	TNK-BP	7,2 / 16,0
Kherson	Continuum Group	? / 7,1
Kremenchuk	Privat Group (57 %), Naftogaz of Ukraine (43 %)	8,0 / 18,6
Drohobych	Privat Group (75 %), Naftogaz of Ukraine (25 %)	2,0 / 3,3
Nadvirna	Privat Group (74 %), Naftogaz of Ukraine (26 %)	2,2 / 4,0
Shebelinka	UkrGazVydobuvannia	1,0 / 1,2
Note: capacity in Mt/y; first figure is technical (maximal available) capacity, the second is installed capacity		

Source: *LUKOIL oil company; OECD & IEA, 2012*, p. 142; *„Oil Processing Industry of Ukraine"*, n.d.; compiled by T. Vlček

31% of domestic consumption of natural gas is covered from the domestic sources. The main natural gas fields are Dashava in the West and Krestiche and Shebelinka in the East. There is also major potential in underexplored Ukrainian sectors of the Azov and Black Seas as well as in the onshore areas of the Crimean Peninsula. Very promising are also unconventional natural gas sources that could exceed 11.5 Tcm (Ministry of Energy and Coal Industry of Ukraine, 2012, p. 18-21). Driven by the idea of diversification of natural gas supplies, the Naftogaz of Ukraine[1] (НАК Нафтогаз України) signed a USD 3.65 billion contract with China Development Bank Corporation for investment programs into coal gasification

[1] Owned fully by Ministry of Energy and Coal Industry of Ukraine.

facilities in Luhansk, Donetsk and Odessa (Alic, 2013). The facilities are to be constructed by China National Chemical Engineering Corporation (CNCEC). Even though there are only several exclusively natural gas-fired power plants in Ukraine (700 MWe CHP-5 and 500 MWe CHP-6 in Kiev and 540 MWe CHP-5 in Kharkiv), as primary use of natural gas is for heating and cooking, the country will save 1.64 Bcm annually (Revina, 2012, p. 8).

The following Table 4.12.3 shows the key power plants in Ukraine besides the nuclear power plants. As seen in Table 4.12.1, nuclear energy constitutes 46.3% of the country's electricity generation share and is therefore the most important source of electricity. There are currently fifteen operating units in four nuclear power plants, all operated by DP NNEGC National Nuclear Energy Generating Company Energoatom (Державне підприемство Національна атомна енергогенеруюча компанія Енергоатом) fully owned by the Ministry of Energy and Coal Industry of Ukraine. The current total installed capacity in nuclear reaches 13,835 MWe. The nuclear energy sector is analyzed further in the text.

Besides nuclear power plants, the second most important source for electricity generation is coal with 38.2% on electricity generation share. 31,800 million tons of proven coal reserves at the end of 2012 ranks the country as No. 7 in the world (Euracoal, 2013) and as No. 2 in Europe (DTEK, 2014, p. 23). The most important is the Donetsk Basin in the East, followed by Lviv and Dnipro Basins. As of December 2012, more than 350 legal entities operated in the coal, lignite and peat production, processing and agglomeration sectors in Ukraine, of which approximately 250 produced and processed hard coal

(Euracoal, 2013). The coal sector is an important part of Ukrainian energy sector, the government plans to further support development of its coal production capacities as well as the portfolio of coal-fired power plants by both modernization and new construction. The largest coal miner as well as the largest private energy company in Ukraine is DTEK, which produces nearly half of the total country's coal production.

Tab. 4.12.3: 1000+ MWe Power Plants in Ukraine

Power Plant	Installed Capacity	Fuel	Operator	Construction Year
Krivorozhskaya TPP	2,820 MWe	Coal, Gas	OJSC Dniproenergo	1965-1973
Pridneprovskaya TPP	1,765 MWe	Coal, HFO	OJSC Dniproenergo	1959-1966
Kurakhovskaya TPP	1,487 MWe	Coal, Gas	Vostokenergo LLC	1972-1975
Zuyevskaya TPP	1,245 MWe	Coal	Vostokenergo LLC	1982-1988
Uglegorskaya TPP	3,600 MWe	Coal, Gas	OJSC Centrenergo	1972-1977
Starobeshivska TPP	1,775 MWe	Coal, Gas	OJSC Donbasenergo	1961-1967
Burshtynska TPP*	2,300 MWe	Coal, Gas	OJSC Zapadenergo	1965-1969
Zmiyevskaya TPP	2,200 MWe	Coal, Gas	OJSC Centrenergo	1960-1969
Trypilska TPP	1,800 MWe	Coal, Gas	OJSC Centrenergo	1969-1972
Luganskaya TPP	1,150 MWe	Coal, Gas	Vostokenergo LLC	1963-1969
Ladyzhinska TPP	1,800 MWe	Coal, Gas	OJSC Zapadenergo	1970-1971
Zaporiska TPP	3,600 MWe	Coal, Gas	OJSC Dniproenergo	1972-1977
Danipro HPP	1,504 MWe	Water	VA UkrHydroEnergy	1947-1980

* The Burshtynska TPP is vital for ensuring electricity exports to Hungary, Slovakia and Romania as it operates within the Burshtyn Energy Island integrated in ENTSO-E. The export capacity is 650 Mwe.
Note: TPP = Thermal Power Plant; HFO = Heavy Fuel Oil; HPP = Hydroelectric Power Plant; OJSC = Open Joint-Stock Company

Source: *Global Energy Observatory*

Ukraine produced 194.9 TWh of electricity in 2011 and produces 189 TWh annually on average. The country is a net exporter, the average electricity exports value is 6.6 TWh (International Energy Agency). Electricity is exported mainly to Hungary and Belarus, to some extent also to Moldova and Poland. Negligible amounts go to Romania and Slovakia. The electricity sector is divided into seven main companies covering the whole country; these are OJSC Kyivenergo, OJSC Dniproenergo, Vostokenergo LLC, OJSC Centrenergo, OJSC Donbasenergo, OJSC Zapadenergo, and VA UkrHydroEnergy, The country is dominated in terms of its market share by DTEK, Ukrainian leader in coal and energy markets. The company owns 72.4% in OJSC Kyivenergo, 73.3% in OJSC Dniproenergo, 100% in Vostokenergo LLC and 72.19% in OJSC Zapadenergo. The second most important subject is the Energy Company of Ukraine (НАК Енергетична компанія України) as it owns shares in these companies as well (78.29% in OJSC Centrenergo, 25% in OJSC Donbasenergo and 100% in VA UkrHydroEnergy).

4.12.2 New Units and Financing of the Nuclear Power Plant

Following the recent decision for life extension of Rivne 1 and 2 and South Ukraine 1 and 2, the key Ukrainian topic in nuclear sector today is the life extension of operating units. In the following years, units Rivne 3, Khmelnitsky 1, South Ukraine 2 and 3, and Zaporizhzhya 1-5, will come to their 30-year design life and the operator is fully focused on the life extension process. Lifetime extension of Ukrainian NPPs is envisaged by February 2014 state

Energy Strategy of Ukraine for the period up to 2030, and is considered as high priority activity by DP NNEGC Energoatom.

Currently, there are Khmelnitsky units 3 and 4 under construction. The construction of units 1 and 2 started in 1981 and 1983, but the works were stopped as part of Ukrainian Moratorium on new nuclear plant construction in 1990. Units 1 and 2 were finished in 2004 shortly after the moratorium was lifted. Units 3 and 4, of which the construction started in 1985-1986, were however left unfinished – unit 3 was completed from 75% and unit 4 from 28%, according to DP NNEGC Energoatom (Sklyar, 2013, p. 17). The Information and Analytical Survey (IAS) of the Feasibility Study (FS) however described the degree of completion as 35-40% for unit 1 and 5-10% for unit 2 (Backer, Wallner, Hirsch, Indradiningrat & Andrusevych, 2013, p. 6).

In 2005-2006, government decided to focus on finishing these two units, as well as to focus generally on nuclear power plants enhancement as part of reaction measures for problems with natural gas supply from Russia. The 2006 nuclear power strategy involved building and commissioning 11 new reactors with the total capacity of 16.5 GWe (and 9 replacement units totaling 10.5 GWe) to more than double the nuclear capacity by 2030 (WNA, 2014). This strategy was strongly corrected several times to current emphasis on life-extensions and around 2-5 GWe of new nuclear units by 2030.

Five potential suppliers were invited to participate in the tender in 2008, Russian OAO OKB Gidropress (ОАО ОКБ “Гидропресс”); Czech ŠKODA JS, a. s.; American Westinghouse Electric Company, LLC; Korea Electric Power Corporation KEPCO; and French Areva SA. Only OAO OKB

Gidropress and Korea Electric Power Corporation KEPCO however submitted their bids, and in October 2008, it was stated that the OAO OKB Gidropress' reactor facility VVER-1000 V-392 was chosen as the reactor facility for new power units (Backer, Wallner, Hirsch, Indradiningrat & Andrusevych, 2013, p. 35-37). In February 2011, Russian ZAO AtomStroyExport and Ukrainian SE AtomProektInzhiniring (ВП Атомпроектінжиніринг, subdivision of DP NNEGC Energoatom) signed an agreement in Kiev to complete the reactors, and the following year, the Ukrainian Parliament adopted legislation to create a framework to finance the project, which included 80% of the funds coming from Russia (Schneider & Froggat, 2014, p. 138; "Contract agreement", 2011). The logic of the agreement is that Russia will provide loan for 80-85% of the total costs estimated at EUR 3.7 billion. The rest will be provided by Ukraine. However, Ukraine and Russia haven't yet agreed on the government guarantees for this loan, nor on the interest rate. One of the main conditions for the loan was a government guarantee that the Ukrainian side has not granted to the necessary extent. As a result, Sberbank offered Energoatom a credit for priority effort to implement the project on commercial terms, to which the Ukrainian side did not agree ("Russia to credit", 2012; "Further construction", 2011). There has been generally no progress in the matter since 2012, and the current Russia-Ukraine relations do not imply that the issue will be resolved soon.

This idea was confirmed in August 2014, when DP NNEGC Energoatom stated that Ukraine will not cooperate with Russia in building new power units at Khmelnitsky NPP. Yuri Nedashkovskiy, president of DP NNEGC Energoatom

stated that Russian participation is not even considered from now on and that there are other financing options, such as long-term electricity export contracts to Europe. According to him, a "completely new attitude" towards nuclear power is adopted and he supports the idea of building new reactors using technology of Western design ("Украина решила", 2014; "Ukraine to sign", 2014). This was demented by Russian side stating that the two parties are still negotiating over the Ukraine's Khmelnitsky Nuclear Power Plant (Sweet, 2014).

Unfortunately, the most recent development in this issue is strongly affected by disinformation and propaganda of both sides in the conflict. The Ukrainian turn away from Russia can be observed since September 2014, when Ukraine and Westinghouse Electric Company, LLC started negotiating the possibility of privatization of nuclear power plants in Ukraine. The operator of the power plants DP NNEGC Energoatom could be privatized, which would allow for foreign investment and nuclear energy development. This most up to date plan was developed by Ukraine Prime Minister Arseniy P. Yatsenyuk and Pavlo M. Sheremeta, Ukrainian economist and former Minister of Economical Development and Trade ("Westinghouse хочет", 2014).

4.12.3 The Front End of the Nuclear Fuel Cycle

Ukraine has got several decades of experience with uranium mining. It started in 1944 with the first deposits discovery. Subsequently, the Pervomayskoye and Zheltorechenskoye uranium deposits were mined out in 1967 and 1989 respectively. In the mid-1960s, the explorations revealed deposits in the Kirovgrad region that have been mined until today. Currently, three mines are in operation (Ingulsky with Michurinskiy and Centralny deposits, Smolinskiy with Vatutinskiy deposit and Novokonstantinovskiy mine with the deposit of the same name) with uranium concentration ranging between 0.1% and 0.17%. The recoverable resources are 160,816 tons of uranium. Also, there are plans to begin operation of the Safonovskiy deposit in the Safonovskiy mine in 2015 with 2,248 tons of uranium in 0.02% grade uranium; and the Severinskiy-Podgaytsevskiy deposit in the Severinskiy mine in 2020 where 48,120 tons of uranium in 0.1% grade uranium ore is now deposited (OECD & IAEA, 2014, p. 426-427).

The Vostochnyi mining-processing combinat VostGOK (Східний ГЗК, Державне підприємство "Східний гірничо-збагачувальний комбінат"), fully owned by the Ministry of Energy and Coal Industry of Ukraine, is the only body operating in the uranium production and processing. The annual average uranium production of 940 tons of uranium concentrate has recently started to be exceeded by 1,000 tons annually.

The first Ukraine uranium processing plant, the Pridneprovskiy Chemical Plant (PCP) in the town of Dneprodzerzhinsk, is connected with the first deposits discoveries. It was constructed in 1948 and uranium ore from the Pervomayskoye and Zheltorechenskoye uranium deposits was processed there. After mining out the mines, the PCP stopped uranium processing in 1991. The company developed zirconium production technologies and have processed zirconium from a mine near the city of Volnogorsk, the only zirconium mine in the former Soviet Union. Zirconium is used for fuel rods production and the mine with the processing plant has the capacity to meet

all of Ukraine's zirconium requirements. In 1959, a second uranium processing plant (VostGOK) was constructed in the city of Zheltiye Vody. The plant capacity is 1.5 Mt/y of uranium ore (OECD & IAEA, 2014, p. 428) and it is the largest facility in the former Soviet Union's military industrial complex.

Uranium fuel has always been provided by the Russian OAO TVEL. However, as the country's uranium production is quite significant, domestic uranium concentrate is send to the Russian Federation for enrichment and fuel fabrication. Domestic uranium production currently covers 30% of domestic requirements, but the expansion in uranium production due to new mines openings is expected to meet the uranium requirements for the Ukrainian nuclear fleet by 2014-2015 (OECD & IAEA, 2014, p. 430).

Ukraine has planned to construct the facilities for domestic uranium fuel production since early 1990s (Levine, 1995, p. 896). Obviously, the fact that Ukraine houses extensive uranium and zirconium production played its part in these plans. There is, however, no enrichment plant in Ukraine, which is why Ukraine joined in October 2010 the new JSC International Uranium Enrichment Centre at Russian Angarsk in Siberia. The company is now owned by Rosatom State Atomic Energy Corporation (70%), JSC NAK Kazatomprom (10%), JSC Armenian NPP (10%) and Ukrainian State Concern "Nuclear Fuel"[2] (10%) (JSC International Uranium Enrichment Centre). The Ukrainian State Concern "Nuclear Fuel" aims at preparation of domestic nuclear fuel elements production and fuel assembly fabrication.

[2] Государственный концерн "Ядерное топливо" under the Ministry of Energy and Coal Industry of Ukraine.

Ukraine's State Concern Nuclear Fuel apparently sells natural uranium to IUEC, which enriches it at Russian plants. Then IUEC sells the enriched uranium to the OAO TVEL, which fabricates fuel assemblies and supplies them to NNEGC Energoatom. The remaining nuclear fuel required for Ukraine's nuclear power plants is purchased directly from OAO TVEL. The contracted volume is reported to be 60,000 SWU/yr, proportional to the Ukrainian shareholding, which covers approximately 3% of Ukraine requirements (WNA, 2014; Safirova, 2014, p. 47.5). However, as the capacity of Ukrainian share of IUEC is very low, NNEGC Energoatom signed a long-term contract with OAO TVEL for all 15 reactors. The contract was signed in June 2010 for 20 years, as Rosatom had offered a substantial discount to Ukraine if it signs up with TVEL for 20 years. Ukraine is OAO TVEL's biggest foreign client, totaling to 55% of its exports (WNA, 2014). Ukraine has historically been sending its used fuel to Russia for storage or reprocessing and has no long-term storage facility for high-level waste (Schneider & Froggat, 2014, p. 138).

Westinghouse Electric Company LLC supplies VVER design fuel assemblies to Ukraine as well. Although the price of the contract was not published, the logic is obvious. The Ukrainian political decision was clearly to diversify the supply of nuclear fuel even at higher costs. The contract was signed in 2008 and Westinghouse supplied a total of 630 fuel assemblies for the South Ukraine NPP (“More Westinghouse”, 2014). And although there were similar problems (manufacturing defects in the fuel led to a lengthy unscheduled outage at two units) with the diversified fuel as in the Czech Republic's case, after the

Russian annexation of Crimea, the contract with Westinghouse was extended until 2020 (“Ukraine signs”, 2014; “Westinghouse significantly”, 2014; WNA, 2014). So far, no figures or details on the quantities of fuel or the number of reactors involved were presented.

The mentioned Ukrainian State Concern "Nuclear Fuel" is active in building nuclear fuel fabrication plant in Ukraine. It was in 2010 when tender for joint venture to build a plant to manufacture VVER-1000 fuel assemblies was announced. OAO TVEL and Westinghouse Electric Company LLC bid to build this plant, and in September 2010, OAO TVEL was selected by the decision of the Cabinet of Ministers of Ukraine. It is likely that the OAO TVEL has won because it offered to transfer all the nuclear fuel manufacturing technologies from nuclear fuel elements filling and fuel assembly to the production of medicine and powder to the joint venture. The joint venture (Private Joint-Stock Company Nuclear Fuel Production Plant) thus comprises of OAO TVEL (50% -1) and State Concern "Nuclear Fuel" (50% +1) and the construction has been underway near the village of Smolino since 2012. In 2015, it is planned to put the assembly into operation, and by 2020, the plant will commence its own production of fuel pellets. Once operational, it will produce around 400 fuel assemblies annually. However, delays might occur, as the construction was delayed already in 2014 due to shareholders' disagreements and financial issues.

4.12.4 The Service Part of the Nuclear Fuel Cycle

There are four nuclear power plants operating in Ukraine with a total of fifteen pressurized water reactors cooled and moderated by light water. The Rivne NPP with two VVER-440/V-213 units (415 and 420 MWe) and two VVER-1000/V-320 units (2x 1,000 MWe); and the Khmelnitsky NPP with two VVER-1000/V-320 units (2x 1,000 MWe) are located in Western Ukraine. The other two plants are located in Southern Ukraine. These are the South Ukraine NPP with three VVER-1000 units of V-302, V-338 and V-332 types (3x 1,000 MWe); and the Zaporizhzhya NPP with six VVER-1000/V-320 units (6x 1,000 MWe). The Zaporizhzhya NPP is the biggest nuclear power plant in Europe. All of the units were constructed with Soviet assistance end employs Soviet design VVER reactors.

All units are operated by DP NNEGC National Nuclear Energy Generating Company Energoatom (Державне підприемство Національна атомна енергогенеруюча компанія Енергоатом) fully owned by the Ministry of Energy and Coal Industry of Ukraine.

There are also two research reactors in Ukraine. The 10 MWt VVR-M reactor is located at Kiev Institute for Nuclear Research of the National Academy of Sciences of Ukraine. The reactor is scheduled for shutdown in 2015 followed by decommission. The very small IR-100 research reactor at the Naval Engineering School in the Sevastopol National University of Nuclear Energy and Industry in Crimea has been recently seized by the Russian Federation. Also, in 2012, the construction of Experimental Neutron Source at the Kharkov Institute of Physics and Technology began with US technological assistance.

Tab. 4.12.4: Nuclear Units in Ukraine

Reactor	Type	Power Output	Status	End of life-cycle
Chernobyl 1	RBMK-1000	800 MWe	Permanent shutdown	2000
Chernobyl 2	RBMK-1000	1,000 MWe	Permanent shutdown	1991
Chernobyl 3	RBMK-1000	1,000 MWe	Permanent shutdown	2000
Chernobyl 4	RBMK-1000	1,000 MWe	Permanent shutdown	1986
Rivne 1	VVER-440/V-213	415 MWe	Operating	2030
Rivne 2	VVER-440/V-213	420 MWe	Operating	2031
Rivne 3	VVER-1000/V-320	1,000 MWe	Operating	2016
Rivne 4	VVER-1000/V-320	1,000 MWe	Operating	2034
Khmelnitsky 1	VVER-1000/V-320	1,000 MWe	Operating	2017
Khmelnitsky 2	VVER-1000/V-320	1,000 MWe	Operating	2034
Khmelnitsky 3	VVER-1000/V-392B	1,000 MWe	In construction	-
Khmelnitsky 4	VVER-1000/V-392B	1,000 MWe	In construction	-
South Ukraine 1	VVER-1000/V-302	1,000 MWe	Operating	2023
South Ukraine 2	VVER-1000/V-338	1,000 MWe	Operating	2015
South Ukraine 3	VVER-1000/V-320	1,000 MWe	Operating	2019
Zaporizhzhya 1	VVER-1000/V-320	1,000 MWe	Operating	2015
Zaporizhzhya 2	VVER-1000/V-320	1,000 MWe	Operating	2016
Zaporizhzhya 3	VVER-1000/V-320	1,000 MWe	Operating	2016
Zaporizhzhya 4	VVER-1000/V-320	1,000 MWe	Operating	2017
Zaporizhzhya 5	VVER-1000/V-320	1,000 MWe	Operating	2019
Zaporizhzhya 6	VVER-1000/V-320	1,000 MWe	Operating	2025
Kiev	VVR-M	10 MWt	In termination	2015
Sevastopol	IR-100	200 kWt	Suspended	?

Source: *Mykolaichuk, 2011; DP NNEGC Energoatom; State Nuclear Regulatory Inspectorate of Ukraine*, 2013, p. 39; *International Nuclear Safety Centers of Ukraine*; open sources; compiled by T. Vlcek.

Speaking about the life-cycle of the nuclear units, they were all designed and licensed for 30 years operation. As many of the units achieved the 30 years of operation or are about to achieve, the life extension is one of the key targets of the nuclear units' operator. Lifetime extension of Ukrainian NPPs is envisaged by state Energy Strategy of Ukraine for the period up to 2030, and is considered a high priority activity by DP NNEGC Energoatom. The Rivne 1 and 2 have been extended by 20 years by State Nuclear Regulatory Inspectorate of Ukraine (Державна інспекція ядерного регулювання України) in 2010, and the South Ukraine 1 has been extended by 10 years in 2013. Actions for life extension of South Ukraine 2 and Zaporizhzhya 1 and 2 have been implemented since 2012. The Zaporizhzhya 1 was disabled for 96 days at the end of 2014 and Zaporizhzhya 2 and 5 will be disabled from February 2015 for 110 and 107 days respectively ("Ukraine will disable", 2014; "The power unit?", 2014). These outages are in line with the implementation of the planned activities associated with the prolongation of the life of these units. The requirement of a new license for these units might be problematic due to the lack of investment and potential EU pressure on closing the power plant.

4.12.5 The Back End of the Nuclear Fuel Cycle

The country's spent fuel management is specific, as the spent fuel is partly stored on site and partly removed to Russian Federation for storage. Speaking about the Zaporizhzhya NPP, after cooling down the spent fuel in a pool, the spent fuel is stored in an interim dry storage facility on site (new facility for treatment solid radioactive waste will be commissioned in

2015). There is also a wet interim storage facility at Chernobyl NPP site (together with the whole Industrial Complex for Solid RW Management) for storage of high-level wastes from Chernobyl NPP and other sources. However, the spent fuel from all other Ukrainian NPPs is removed to the Russian Federation, according to the contract with OAO TVEL, at a cost to Ukraine of over USD 100 million per year. From 2011, high-level wastes from reprocessing Ukrainian fuel are to be returned from Russia to Ukraine to be stored in Ukrainian Central Spent Fuel Storage Facility (CSFSF) (WNA, 2014). However, this has been most likely postponed as the CSFSF is not commissioned yet. These high-level wastes are stored in the interim storage facility (ISF-1) at Chernobyl NPP, where another one (ISF-2) is currently under construction.

It was the Strategy for Radioactive Waste Management in Ukraine adopted in 2009 that envisaged the construction of CSFSF. The Construction of the centralized storage facility of the State Specialized Enterprise "Centralized RW Management Enterprise" (Державне спеціалізоване підприємство Центральне підприємство з поводження з радіоактивними відходами) was originally planned to take place in March 2011, but commenced in August 2014, and is being built with the financial support of the Department of Energy and Climate Changes of the United Kingdom and the European Commission. The final design capacity of the facility will allow storage of 16,530 used fuel assemblies, including 12,010 VVER-1000 assemblies and 4,520 VVER-440 assemblies (IAEA Contact Expert Group, 2012; WNA, 2014). The company is subordinated to Ukrainian State Corporation RADON (ДК УкрДО "Радон") that collects, transports, conditions, and stores temporarily radioactive waste from all non-nuclear cycle enterprises, which produce radioactive waste in the course of their activities. USC RADON consists of Scientific and technical center and 6 facilities for storage and management, processing, decontamination etc. in Lviv, Kyiv, Kharkiv, Odessa, Donetsk and Dnipropetrovsk.

The state managing body for USC RADON is the State Agency of Ukraine on Exclusion zone management (Державне агентство України з управління зоною відчуження). This company is in charge of management of RW processing including long-term storage and disposal in Chernobyl Exclusion Zone and is also in charge of the implementation of the state policy for RW management.

Deep geological repository is planned in Ukraine without specific data as the new Central Spent Fuel Storage Facility is planned for at least 50 years of operation.

Tab. 4.12.5: Ukrainian Nuclear Sector Examination

Indicator	**Description**
Is there nuclear producing capacity present in the country?	Yes, 4 nuclear power plants with a total of 15 reactors; Rivne NPP (2x 505 MWe VVER-440/V-213 and 2x 1,000 MWe VVER-1000/V-320 units), Khmelnitsky NPP (2x 1,000 MWe VVER-1000/V-320 units), South Ukraine NPP (3x 1,000 MWe VVER-1000 of V-302, V-338 and V-332 types), Zaporizhzhya NPP (6x 1,000 MWe VVER-1000/V-320 units)
Is there a project to expand the capacity? What is the status of the project?	Khmelnitsky 3 and 4, tender was won by OAO OKB Gidropress, however, due to Crimea crisis, the project was cancelled and other Western options are investigated, especially with Westinghouse Electric Company, LLC
How was the project procured?	Publicly, openly, five potential suppliers were invited (Russian OAO OKB Gidropress; Czech ŠKODA JS, a. s.; American Westinghouse Electric Company, LLC; Korea Electric Power Corporation KEPCO; and French Areva SA); OAO OKB Gidropress and Korea Electric Power Corporation KEPCO eventually submitted their bids and in October 2008, OAO OKB won the tender
Who is the contractor in charge of the project?	DP NNEGC Energoatom fully owned by the Ministry of Energy and Coal Industry of Ukraine
How is the financing secured?	Russian loan for 85% of total costs, however, due to Crimea crisis, the project was cancelled and other Western options are investigated, especially with Westinghouse Electric Company, LLC
Who is the operator of the facility?	DP NNEGC Energoatom fully owned by Ministry of Energy and Coal Industry of Ukraine
Are there enough home-based experts to run the facility safely?	Yes
Who is/will be in charge of decommissioning?	The operator together with State Agency of Ukraine on Exclusion zone management
Who provides nuclear fuel and under what conditions?	Ukraine's State Concern Nuclear Fuel sells natural uranium to IUEC in Russia for enrichment, OAO TVEL fabricates fuel assemblies and supplies them to DP NNEGC Energoatom; as the Ukrainian share of IUEC capacity is very low, NNEGC Energoatom signed a long-term contract until 2030 with OAO TVEL for all 15 reactors with a substantial discount; Ukraine's diversification efforts led to Westinghouse Electric Company LLC supplying VVER design fuel assemblies for the South Ukraine NPP, the contract with Westinghouse was extended until 2020 after the Russian annexation of Crimea

What is the experience with the fuel being currently used? Is there any rationale or path-dependency behind the current contract?	Some Westinghouse's fuel manufacturing defects led to a lengthy unscheduled outage at two units of the South Ukraine NPP
Is there any part of nuclear fuel industry present in the country? If so, how it contributes to country's nuclear fuel cycle?	Uranium production currently covers 30% of demand, opening of Safonovskiy and Severinskiy-Podgaytsevskiy deposits should cover the whole demand; VostGOK uranium processing plant in Zheltiye Vody has 1.5 Mt/y of uranium ore processing capacity; Pridneprovskiy Chemical Plant produces zirconium (used for fuel rods) has the capacity to meet all of Ukraine's zirconium requirements; the State Concern "Nuclear Fuel" (50% +1) together with OAO TVEL (50% -1) is constructing nuclear fuel fabrication and fuel assemblies plant at Smolino, it should be in operation by 2020 with production of around 400 fuel assemblies annually, delays are likely to occur
How is used fuel treated and who is in charge of this?	Used fuel from Zaporizhzhya NPP is stored in interim dry storage facility on site; spent fuel from all other Ukrainian NPPs is removed to Russian Federation according to the contract with OAO TVEL at a cost to Ukraine of over USD 100 million per year and the high-level wastes from reprocessing Ukrainian fuel was to be returned from Russia to Ukraine to be stored in Ukrainian Central Spent Fuel Storage Facility (CSFSF); CSFSF construction commenced in August 2014; ISF-1 and ISF-2 (under construction) interim storage facility at Chernobyl NPP are used for storage as well; different companies are in charge, but all fully owned by the State

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4.14 Summary of findings

4.14.1 The Sector of Nuclear Energy in Central and Eastern Europe[1]

Tomáš Vlček

As stated above, the aim of the research was to provide an in-depth analysis of Russian operations in the nuclear sector of Central and Eastern Europe. The research sought to unearth whether Rosatom subscribes to specific patterns of conduct with regard to business environment and if so, what are the determining factors of such behaviour. To meet the goals of the study, the following hypothesis was formulated: „Russian state-owned energy companies in the natural gas and nuclear sectors act in order to maximize their influence and market share in CEE markets and strengthen Russian geopolitical leverage and positioning in this region." This section is aimed to address the nuclear sector, i.e. conduct of Rosatom and its subsidiaries in the region of Central and Eastern Europe. The general findings addressing the hypothesis are described below with specific subsections dedicated to findings characterizing the conduct of Rosatom and its subsidiaries in cases under scrutiny. A secondary goal was to identify the behavioural determinants of Russian SOEs and how they differ according to various environments.

In the nuclear sector, Rosatom is positioned as the dominant provider of nuclear technology and fuel supplies to the region, in large part stemming from the Soviet legacy in CEE countries.

[1] The chapter is partially based on the article previously published in the International Journal of Energy Economics and Policy journal in October 2015, where preliminary outcomes of the research were presented. (Vlček & Jirušek, 2015)

Compounding this challenge, nuclear energy is one of the major sources of power generation in CEE. Given the long-time, near monopoly of Russian nuclear technology/design in the region and plans to expand further the nuclear capacity of select CEE countries, the sector requires careful monitoring from both a technical and security-minded perspective. The behaviour of this Russian energy giant in Asia was also examined, due to the region's rise to be the new centre of gravity in the global energy environment and, as such, can offer valuable comparisons to the conduct of these companies in CEE.

The nuclear energy sector has a number of structural differences when compared to crude oil, natural gas or coal; most typically it is not dependent on certain infrastructure and the uninterrupted flow of energy supplies. These supplies are also of different nature than those in the gas sector. These wide differences, including safety and other technical concerns, alter the behaviour of commercial actors in this space and make it somewhat more difficult to detect strategically motivated behaviour. Accordingly, the research team developed a specific approach to assess the potential risks associated with three different stages of the nuclear plant life-cycle: (1) the initial stage when the plant is being planned and financing is being secured; (2) the three sub-stages of the nuclear fuel cycle; and the (3) the final stage which is the decommissioning of the facility. The research team examined these three stages individually in order to identify potential risks of strategically motivated conduct of Russian companies. In the case of nuclear fuel, its origin, supply sources, usage and waste management were taken into account. The main findings of this exercise are below.

Finding 1: All Roads Lead to Rosatom

Although the research was aimed at the operations of Rosatom State Atomic Energy Corporation (Федеральное агентство по атомной энергии России, РосАтом), the evidence shows Rosatom operating directly in only three countries (Bulgaria, Hungary and Slovakia). Rosatom is the contractor of a new nuclear power plant (NPP) only in Hungary. However, Rosatom's network of subsidiaries is extensive and the bulk of the Russian Federation's nuclear portfolio is executed through these subsidiaries which include, ZAO AtomStroyExport, OAO OKB Gidropress, OAO TVEL and others. The Table 14.4.1 below helps illuminate the network of companies that ultimately reports to Rosatom.

All the companies JSC NIAEP, JSC Atomenergoprom, OAO TVEL, OJSC Atomenergomash are fully controlled by Rosatom, and therefore we can use the expression "Rosatom" even when speaking about these companies. In 1992-2008, Rosatom existed as the MinAtom - Ministry for Atomic Energy of the Russian Federation (МинАтом, Министерство по атомной энергии Российской Федерации). According to the law adopted by the Russian parliament and signed by Vladimir Putin in 2007, the MinAtom was transformed to one of six current Russian state corporations. The company was renamed to Rosatom State Atomic Energy Corporation and is subordinated to the Government of Russian Federation.

Tab. 4.14.1: Ownership Structure of Russian Nuclear Energy Companies

Company	Shareholders	Share (%)
Rosatom State Atomic Energy Corporation	Government of Russian Federation	100
ZAO AtomStroyExport	Rosatom State Atomic Energy Corporation AO VPO Zarubezhatomenergostroy OAO TVEL OAO Gazprombank	78.5362 9.4346 1.3303 10.6989
OAO OKB Gidropress Experimental Design Bureau	OJSC Atomenergomash	100
OAO TVEL	OJSC Atomic Energy Power Corporation Atomenergoprom	100
JSC NIAEP	OJSC Atomic Energy Power Corporation Atomenergoprom	100
JSC Atomic Energy Power Corporation Atomenergoprom	Rosatom State Atomic Energy Corporation	100
JSC Inter RAO UES	Rosneftegaz Group FGC UES Group Minorities* INTER RAO Capital Norilsk Nickel Group VEB RusHydro Group	27.63 18.57 16.65* 13.93 13.21 5.11 4.92
OJSC Atomenergomash	OJSC Atomic Energy Power Corporation Atomenergoprom CJSC AEM Leasing INTERNEXCO GMBH OFEJSC Techsnabexport LLC Energomashkompleks	80.6296 2.3673 9.0896 2.8481 0.0453
* Minority shareholdings include ZAO AtomStroyExport, OJSC Rosenergoatom Concern, Rosatom Securities Limited. All these companies are part of the Rosatom which owns a 13.42% stake in JSC Inter RAO UES through these minorities.		

Source: compiled from open sources by T. Vlček

Finding 2: Path Dependency is an Important Factor

Evidence of relatively strong path dependency was found in the nuclear sectors of the CEE countries. Of the twelve countries analyzed, six house a nuclear power plant on their soil and all plan to expand current capacity or construct new NPPs. The six countries referenced are Bulgaria, the Czech Republic, Hungary, Romania, Slovakia and Ukraine. Bulgaria proved to be an anomaly in that it has two VVER-1000 units in operation and yet awarded Westinghouse Electric Company LLC the contract for the construction of Kozloduy 7, despite previous experience with only Russian technology. All of the other countries referenced have followed the path dependency related to previously implemented nuclear technology.

Historical experience in the construction, commissioning and operation of reactors as well as downstream industries, education and training systems factor heavily in tender decisions. These ties to selected technology and infrastructure are a strong prerequisite for future decisions in public tenders. The existence of a nuclear power plant of one kind in the country is a strong factor for decisions about constructions of a new NPP of the same kind. The Russian Federation therefore has a better business starting position in CEE nuclear sectors due to historical and structural reasons. While it is generally the case that Rosatom is strongly advantaged in these tender scenarios, historical experience can also have the opposite effect.

The operating phase is also dependent on a sufficient number of well-trained staff able to operate the facility. The uninterrupted development of a country's nuclear sector can greatly assist in maintaining this vital know-how. From this perspective, securing operation of nuclear units within a country is often key to Rosatom's future business development for the contractor as well as the customer country's preferences. Russian companies generally have the advantage of long lasting cooperation with countries in the region and know-how related to the nuclear units in the region built according to Russian design.

In the decommissioning phase, no threats directly related to Russian involvement were identified. The decommissioning process is regulated by strict rules of treatment of the potentially hazardous materials. Although the amount of waste produced by nuclear plants is usually not an issue in terms of quantity, the question of its ultimate storage remains, as generally little has been done in terms of building final depository underground storages. It is thus rather a question of competence and capacity of particular state authorities to act in order to deal with this issue.

Finding 3: Russian Nuclear SOEs Adapt to the Specific Needs and Conditions of the Operating Country

The enormous cost of every NPP construction project makes such business extremely attractive for contractors given the limited number of such projects worldwide. The financial burden of such projects, however, often requires contractors to offer large-scale, low-cost financing packages in order to win tenders or be selected on a sole-source basis (i.e. with no tender process – a standard Russian sales goal). Smaller countries such as Slovakia, the Czech Republic and Hungary (not to mention the Baltic States) cannot hope to shoulder these multi-billion-dollar price-tags on their own. Quite understandably, in such situations contractors try to decrease the risk of financial loss or at least to secure their position in terms of future revenues by employing various financing schemes. In certain cases, they are also obliged to secure financing of the project appropriate to their share in the joint-venture as, for instance, in the case of Bulgaria.

Rosatom is a very flexible and adaptive entity when it comes to addressing the exact needs and conditions of the prospective sovereign client. Sales techniques and options that are widely accepted – and are also used by Russia – include: vendor investments (favored in the Czech Republic); strategic investment in the project itself (e.g. sharing the financial burden in exchange for a stake in the project and future (as took place for the Czech Temelín NPP and Romanian Cernavoda NPP); providing financial loans through national and/or private banks (as in the cases of the Bulgarian Kozloduy NPP, Ukrainian Khmelnitsky NPP and Hungarian Pakś NPP); and the turnkey option (exercised for the Belarusian Ostrovets NPP and the Slovakian Jaslovské Bohunice NPP). Indeed, Rosatom was the first contractor to arrange payment for the entire construction phase of an NPP project.

Quite recently a new type of contract has been introduced to the nuclear industry, namely the "Build-Own-Operate" (BOO) model or "Build-Own-Operate-Transfer" (BOOT). Rosatom markets this type of contract to "newcomers" that require an elaborate support structure. This sales model was applied in the case of Turkey's Akkuyu NPP, which will be that country´s first nuclear power generating facility. In the BOO model, the contractor builds the plant and also operates it, while serving as the principal owner. Although it defies logic at some level, in effect, to turn over a strategically-sensitive national asset like a nuclear power complex to another country – particularly one like Russia – some states are content, via the BOO model, to exchange favorable financing for merely hosting the facility on its soi[2].

Among the several potential dangers of this scheme include the sovereign client becoming a "hostage" of the contractor who will be operating the facility. The popular view, however, is that the contractor would never abuse its position, as it could estrange potential future clients. This is especially true given the fact that Russians claim the BOO scheme is the best way to attract newcomers to the nuclear club. (Sokolov, 2013)

The BOO contracts is certainly a proof of Russian strive to penetrate new markets with more open public procurement procedures and to root into these regions to exploit these countries' potential path dependency in the future. A little desperation might be seen in this strategy, as Rosatom takes the risk of not being paid for their constructions and services. The principal loan is usually to be paid including interest in fixed time (usually 10-20 years), however, when the construction of the NPP faces delays, it becomes difficult for operating countries to pay the loan within the original time. This is likely the reason why other nuclear companies worldwide do not plan to react to Russian BOO contracts with their versions of similar contracts.

As mentioned, Rosatom operates through many different subsidiaries, in part to blur its identity, as illustrated in Finding 1. Although some of these subsidiaries were, no doubt, formed as a consequence of commercial circumstances, others were established to assist with Rosatom's reputational challenges.

[2] Under the "Build-Own-Operate-Transfer" variant the facility is transferred to the state after certain, previously agreed, period of time.

Finding 4: The Sector is Strongly Driven by Economics

Generally, the nuclear sector offers limited opportunities to exert influence because of the specific nature of the sector itself which shapes the behavior of respective actors and provides a framework for operational interaction. In fact, it is primarily the economics of a nuclear power project, driven by extraordinarily high costs of construction and the longevity of the projects (e.g, as many as 30 years or more), that provides Russia, in particular, with substantial advantage in the bidding process. Few, if any, countries and/or companies are able to build and finance an entire nuclear power plant. This makes the initial stage, where financing and identifying a strategic partner takes place, crucial and simultaneously the most sensitive in terms of the potential influence that can be exerted by an external actor.

Given the limited amount of contracts in the nuclear sector and the revenue implications of each one, any attempt to use a nuclear contract as leverage on a particular country would cause substantial damage to any contractor's reputation. This fact diminishes the possibility of a nuclear contractor exerting political pressure over a sovereign client, as contractors with damaged reputations would find themselves in a difficult situation regarding future business prospects worldwide. Rosatom probably calculates that it cannot afford to be found guilty of abusing a particular project to advance its political/strategic goals, as it would essentially harm not only its long term future but also its immediate market capitalization.

Naturally, no one could guarantee that no political pressure may take place during the bidding and procurement processes. The rather scarce contracts are usually worth several billions and it is thus natural that contractors give each potential contract high priority and are often backfired by their home governments by various means (rhetorically, formally by officials during state visits, by foundations and partnership programs, state guarantees, etc.).

The scale of NPPs often requires Head of State attention and bargaining for some of the reasons mentioned above. Financing is the key issue of every project to ensure that initial costs are repaid during a reasonable period of time (i.e. before the life-cycle of the plant comes to an end). This very much depends on the electricity price in the client country, which has been an issue for some time in Europe due to relatively low and unpredictable prices that have undermined the commercial viability of certain nuclear projects. Obviously, this is an overarching concern, not exclusively related to the operations of Russian SOEs. On the other hand, Russian SOEs operating in the sector often come with a model that gives them a sizeable advantage over Western competitors in the sector as described in the following section.

Finding 5: Rosatom Comes with Attractive Financing

There are five countries in which public procurements have taken place or are underway where Rosatom is a player. These are Belarus, Bulgaria, the Czech Republic, Slovakia and Ukraine. Russia has selected financing as its “tip of the spear” in these competitive circumstances, some of which are referenced below. In the case of Belarus, Russia’s Vnesheconombank, provided the Belarusian commercial bank Belvnesheconombank a subsidized USD 6 billion loan for the construction of the Ostovets NPP site in a remote area in the north of the country (Schneider & Froggat, 2014, p. 26). This loan was renegotiated in 2009 and 2011 to end up at USD 10 billion, including investment in new infrastructure. The loan has a term of 25 years and will finance 90% of the total contract cost between AtomStroyExport and the Belarus Directorate for Nuclear Power Plant Construction.

The Bulgarian Belene project, which was originally set to utilize the Russian VVER-1000 design, has been offered a large-scale Russian loan several times to support the AtomStroyExport-led consortium. These offers have, thus far, been rejected for primarily political and security-related reasons. The project was eventually scrapped and attention shifted to a new unit at the Kozloduy site where Westinghouse Electric Company LLC was selected to be the contractor.

In the Czech Republic, two vendor financial offers were made towards the end of the public procurement process for Temelin's 3 and 4 units. Rosatom offered 100% coverage of project costs (through its JSC Rusatom Overseas subsidiary). Westinghouse, in turn, arranged a U.S. Exim Bank credit covering 50% of project costs. This one example speaks volumes about the respective levels of financial competitiveness of the two sides. In the end, no agreements were concluded and ČEZ, a.s. cancelled the whole procurement procedure in April 2014. A major reason for the cancellation was the Czech government's announcement that it will not provide any electricity price guarantees for construction of the NPP. A less public reason could be that Rosatom was set to win the tender, but it was judged too controversial for the Czech government to award Moscow the tender in the midst of the Ukraine crisis.

In the case of Slovakia's Jaslovské Bohunice project, Rosatom expressed the willingness to purchase a 51% stake in the project company Jadrová energetická spoločnosť Slovenska, a. s., thus making it both the technology provider and strategic investor. Rosatom sought a guaranteed long-term electricity price of EUR 60-70 /MWh and possibly a BOO (build-own-operate) arrangement. As the Slovak Minister of Economy, Tomáš Malatinský, was unwilling to meet these conditions, the offer was rejected. The Slovaks eventually ended negotiations with the Russians at the end of 2013, as Rosatom continued to insist on guaranteed electricity prices. Shortly thereafter, at the beginning of 2014, Rosatom changed course abruptly and stopped insisting on a price guarantee. Indeed, it is now prepared to consider any form of support from the Slovak side, which will ensure that the project is economically viable for investors as well as for creditors (Holeš, 2014a). Moreover, the new Minister of Economy of Slovakia, Pavol Pavlis, who entered office in July 2014, is inclined to offer such electricity price guarantees.

Concerning Ukraine, in February 2011 Russia's ZAO AtomStroyExport and Ukrainian SE AtomProektInzhiniring (a subdivision of DP NNEGC Energoatom) signed an agreement to complete reactor units 3 and 4 at the Khmelnitsky site. The following year, the Ukrainian Parliament adopted legislation to create a framework to finance the project, which included a plan to attract 80% of the necessary funds from Russia (Schneider & Froggat, 2014, p. 138; "Contract agreement", 2011). The terms of the agreement were that Russia would provide a loan for 80%-85% of total project cost (estimated at EUR 3.7 billion) and the remainder would be financed by Ukraine. To date, Ukraine and Russia have not agreed on a government guarantee for this loan or on the interest rate. One of the principal conditions for the loan was a Ukrainian government guarantee that has not been granted to the necessary extent. As a result, Sberbank offered Energoatom a credit to implement the project on commercial terms, to which the Ukrainian side has not agreed ("Russia to credit", 2012; "Further construction", 2011). There has been generally no progress in the case since 2012, and current Russia-Ukraine relations do not bode well for the deal being concluded.

Hungary is a rather special case. Rosatom was victorious in providing an expansion of the Pakś NPP complex with no public tender whatsoever. It was rather a classic "backroom" deal concluded by the two Heads of State in a highly secret framework. In fact, the Hungarian Parliament was pressured by the Hungarian Prime Minister to pass legislation making it a crime to reveal the terms and conditions for a 30-year period. A EUR 10 billion loan was offered by the Russian Federation to co-finance the project[3] and the deal was eventually cemented in January 2014, when Hungary entered into an international agreement with the government of the Russian Federation on the cooperation in peaceful use of nuclear energy (Balogh, 2014). The deal will reportedly involve the Russian Federation granting Hungary an interest-only loan at an annual rate of 3.9%, starting in 2014. Once construction is completed in 2026 (the expected operational date), the principal balance will be amortized over 21 years, with an interest rate of 4.5% for the first seven years, 4.8% for the next seven, and 4.95% for the final seven. ("A Brief Summary", 2014; "Kiderultek a reszletek", 2014).

[3] The Russian side was allegedly the only one prepared to offer financing to support the project. The loan equals to 80% of the total costs of the project ("A Brief Summary, n.d.").

Romania also stands aside as the public procurement process was without Russian bid due to the nature of the project. The project is actually a completion of Cernavoda units 3 and 4 on building foundations from 1980s. Analogical is the situation in Lithuania and Poland, where the public procurement process have been without Russian bid, too. Russian bids are not allowed in the public procurement process in these countries, which is related to the business environment.

Finding 6: Business Environment Sets the Operational Framework

Historical ties and traditional policies play an important role in the operational framework of Russian state-controlled companies. The research indicates three categories of "nuclear energy" states in the region. First is the Western-leaning countries of Bulgaria, the Czech Republic, Romania and Slovakia. These countries are enmeshed in EU structures, policies and procedures, making it more difficult for Russia to cut "sweetheart" deals of the type on display in Hungary. The interconnection with EU legislation also reduces the space for shadowy undertakings. EU procurement procedures and related documentation is formulated quite precisely, according to respective regulations and laws, especially those related to promoting fair competition. These positive features of EU integration and involvement in other Western political structures however, is accompanied by a tedious and complicated bureaucracy.

The second category is non-nuclear states that seek to enter the nuclear club, but have more negative relationships with the Russian Federation. These countries include Poland and the

Baltic states. For example, the Lithuanian government explicitly excluded a Russian design in its tender for the Visaginas NPP. Rosatom, through its subsidiary JSC Inter RAO UES, sought to oppose the project by offering its own alternative in Kaliningrad´s Neman NPP announced in 2008. This effort however, was unsuccessful. The actual tender in Poland has not yet been opened, but it is also likely that there will be no Russian contractor or subcontractor allowed to bid on the project due to Polish very strong traditional anti-Russian feeling stemming from historical Russian-Polish relations.

The third category consists of CEE nuclear countries that remain close to the Russian Federation for political, historical and economic reasons. These countries include Belarus and Hungary. Not so long ago, Ukraine would have appeared in this category, but, obviously, not now. These countries favor Russian energy enterprises, and Rosatom in particular. In addition, the business and political environments are more accommodating for Russian companies.

As referenced earlier, special attention is warranted in the case of Hungary. It now fits in this third category, despite its EU membership, for ignoring proper procurement procedures and including state subsidies being granted to MVM Group. The EU has not sought to unwind the Rosatom contract for the Pakś NPP, despite every necessary justification to do so, and instead concentrated on reducing Rosatom's monopoly on nuclear fuel supplies from twenty years to ten years. The decision to grant the project to the Russians was made by the Prime Minister and his closest collaborators without any official procurement procedure or even consultations with other interested parties, industry experts or the public at large.

In sum, Rosatom is most often forced to operate within specific local, political, economic and regulatory frameworks, which means the business and political environment has a great deal to do with determining tender winners and losers and the operations of these facilities. In this regard, the importance of multilateral regimes, especially the EU, is as clear as it is necessary to discipline's Rosatom's behaviour, which is often more strategic, under Kremlin oversight, than it is commercial.

Finding 7: Delays Are Natural Part of the Process

When examining the nuclear industry, one of the key issues is actually the construction itself. To build a nuclear power plant is a complex undertaking that typically takes some five to seven years. Currently in countries such as South Korea and China, construction timetables range from four to six years and in European countries between six and eight years (Nuclear Energy Agency, 2012). Delays and additional work are natural components of the process. For example, the in-service dates of the pilot project of the Westinghouse's AP1000 design at the American Vogtle NPP in Georgia (in the United States) has been recently moved from April 2016 to December 2017 (unit I) and December 2018 (unit II) with additional work costing some $650 million. Rosatom's VVER-1200 design at the Russian Novovoronezh II site has been postponed from the original in-operation date (2012 for unit I and 2013 for unit II) to 2014 for unit I and 2016 for unit II ("2014 startup", 2012). Moreover, this project is likely to be postponed again. AREVA's pilot European Pressurized Reactor (EPR) design at Finland's Olkiluoto-3 site has also been postponed several times. The original date of in-service (2009) has been recently changed once again to the end of 2018. Olkiluoto-3's construction costs were first estimated at 3.2 billion euro. Later in 2012, the CEO of AREVA estimated the overall cost would end up closer to 8.5 billion euro (Rosendahl & De Clercq, 2014).

These are only a few examples of the challenges of NPP construction that have reportedly afflicted some 50 of the 67 reactors under construction in 2014. The delays have stretched from several months to several years. All of the 17 remaining units are currently in their initial stage of construction, making it difficult to assess whether they are on schedule or not (Schneider & Froggat, 2014, p. 34). Either the construction process or the public procurement process, were behind schedule in each of the CEE countries analyzed.

Although the reasons for these persistent delays and cost-overruns are often not made public, they are generally caused by rising material costs, delayed subcontractors´ work, accidents, increasing safety requirements and public opposition. It seems clear that these set-backs are a natural part of the process of building highly complex nuclear units. There was no evidence of any delays motivated by political considerations, but this is not to exclude the possibility.

Such irresponsible actions would mean substantial damage to the contractor's reputation, given the complexity and strategic nature of a nuclear power plant for the client. As there are a limited number of such high cost contracts, the suppliers have to proceed very carefully not to compromise their position for future projects. In this sense, any effort to use delaying tactics concerning a nuclear contract for geopolitical purposes would be perilous for the contractor's reputation in the markets, as was pointed out earlier. That said, Russia's efforts to derail

Lithuania's NPP involved trying to delay the procurement process by introducing its own alternative in Kaliningrad to confuse the process. Should, for example, Rosatom politically manipulate the time of the construction process of its projects, it will likely never get another job overseas. Quite naturally, every contractor aims to highest possible capitalization within each contract, but this is neither exclusively related to a specific companies nor to the Russian ones. Although it is rumored that there were some unusual delays caused by not merely technical difficulties in some cases[4], neither the contractor – and Rosatom is without any doubt no exception – can simply afford to be convicted for misusing the particular project for political goals of the homeland government. Such reputation would make any future projects impossible to reach for such contractor.

Recommended tactic for any contracting party is thus to ensure that the procurement procedure and all the related documentation is formulated very precisely, leaving no room for further "behind-the-scenes" negotiations. Naturally, no one could guarantee that no political pressure may take place during the bidding and procurement processes. The rather scarce contracts are usually worth several billions and it is thus natural

[4] Examples of these alleged non-standard delays are for instance the construction of Iranian Bushehr NPP and situation of the Czech Temelin NPP in early 1990s.

The Iranian Bushehr NPP built by Russian companies was a subject to major delays that prolonged the original construction time to more than three times its original length. It is rumoured that Russians used this opportunity for consolidation and capitalization of their nuclear industry after it was seriously harmed by the collapse of the Soviet Union. Although this may be partially true the major reason for those delays was the vast complexity of this project that was originally built by Germans, then abandoned and damaged during the war between Iran and Iraq (Khlopkov & Lutkova, 2010).

The Czech example relates to the situation when Russian engineers were forced to leave the project of Temelin NPP due to political changes following the fall of communist regimes in CEE countries. The hand-over of the project documentation was in this case slower than it should have been. But again, this was rather caused by the financial situation and the fact that Russian companies were losing their ground in the formerly closely tied economies.

But even if the delays were financially motivated it was no way near political motives which, as stated above, would make a serious and lasting damage to the contractor´s reputation.

that contractors give each potential contract high priority and are often backfired by their home governments with by various means (rhetorically, formally by officials during state visits, by foundations and partnership programs, state guarantees, etc.).

Finding 8: Dependency of Operators of VVER Reactors on OAO TVEL Fuel

Not surprisingly, for the VVER reactor design, the dominant supplier is the Russian company OAO TVEL. This company supplies nuclear fuel for each of the analyzed countries, except for Romania and partially Slovakia and Ukraine. The VVER type fuel assemblies are hexagonal, while the Western reactor fuel employs square-shaped fuel assemblies. Although the VVER type fuel can be produced by Western companies, Russian experience and facilities are difficult to beat in terms of price of the product. Even though Westinghouse[5] and other companies[6] are capable of supplying the client country with VVER design fuel assemblies, they cannot do so at competitive prices[7]. For example, Westinghouse says it could resume VVER fuel rod production with an investment of $20 million, if

[5] The Czech experience: The long-time fuel supplier for the Temelín NPP was the Russian company TVEL. Since 2002, when the plant was launched, to the end of 2009, fuel for the Temelín NPP was supplied by the American company Westinghouse Electric Company, LLC. It is well-known that the fuel rods were deflective in the active zone of reactor at that time. This was caused by the different shape of the fuel assemblies which Westinghouse produced. Hexagonal assemblies for Temelín were initially provided by Westinghouse Electric Company LLC, but the fuel rods suffered from torsion, which resulted in forced operational interruption, limited production and inability to produce electricity at full capacity. These issues occurred mainly due to Westinghouse´s short experience with VVER design fuel assemblies, as they began providing this product only in 1997. In 2010, a selection process for a new supplier took place and was awarded to the Russian TVEL, which submitted a financial offer that was substantially below other offers. TVEL will now be supplying nuclear fuel to the Czech Republic until 2020, and is now the exclusive fuel supplier for both Czech nuclear power plants.

[6] For example, since 2010 part of the nuclear fuel supplies for Chinese VVER design reactors has been produced by Chinese China National Nuclear Corporation.

[7] Westinghouse, for example, now supplies VVER design fuel assemblies to Ukraine. Although the price of the contract was not published, the logic is clear. The Ukrainians made a political decision aimed at diversifying the supply of nuclear fuel even at a higher cost. Although some problems similar to those

allowed back into the market. Such a plan, however, would take at least two years. (Lenoit, 2014) The economies of scale play into the hands of Russian TVEL.

The logic chain is as follows: Westinghouse will reenter the market only if customers can be found; these will be found only if the product is offered at a competitive price; the product will be offered at a competitive price only if the existence of customers allows investment into production capabilities; the investment in production capabilities will be allowed only if customers can be found. Accordingly, the situation resembles a kind of a vicious circle that can be breached but is unlikely to be anytime soon. It is also worth noting that TVEL manufactures nuclear fuel assemblies for Western type reactors as well.

This feature of the nuclear sector is currently being addressed at the EU level, as the European Commission offered a research grant of EUR 2 million for safety analyses, tests and further study into the licensing of other than TVEL-produced nuclear fuel ("Kdo nahradí ruské", 2014). Such an allocation supports the diversification of nuclear fuel supplies and also serves as indirect support of TVEL competitors in the EU market, especially Westinghouse. It is also clear evidence of the fact that political will can change a seemingly unchangeable pattern, at least from a commercial perspective.

In sum, the nuclear fuel cycle does not represent an unworkable, one-sided dependency on Russian supply. This is, in part, because of the global abundance of uranium and a highly competitive uranium market, enabling countries to switch between suppliers more easily. On the other hand,

faced by the Czech Republic have surfaced, after the Russian annexation of Crimea the contract with Westinghouse was extended until 2020, validating the politicization of the decision.

Rosatom's fuel subsidiary has some sizeable advantages over other suppliers stemming from long-term, technology-specific relations with CEE countries, experience and technological compatibility based on the prevalence of nuclear units built according to Russian design. This results in better pricing – also occasionally lowered for political purposes – and generally smoother operation of those fuel assemblies provided. Switching to another provider is possible, but may be accompanied by higher prices and operational difficulties in the early stages.

Finding 9: Spent Fuel Treatment Procedure Poses Only Standard Risks

There are two types of nuclear fuel cycles that differ in the last phase. When the fuel is not reprocessed and is disposed after use, it is called the "open" or "once-through" nuclear fuel cycle. If the fuel is reprocessed, the nuclear fuel cycle is referred to as "closed". Fuel reprocessing is nowadays technically and financially demanding, which only a few countries in the world are willing or able to afford[8]. In the next 50 years, this may become common practice. Currently, nuclear fuel is reprocessed only by countries with a broad portfolio of nuclear power plants (such as France, Russia, UK, Japan and certain others). The fuel is reprocessed only by countries with a broad portfolio of nuclear power plants (such as France, Russia, UK and some others), where it makes economic sense. The global recycling capacity is presently some 5,370 tons annually, which is only around 8.7% of global uranium demand. Far more usual is the open nuclear fuel cycle option.

[8] In 2011, it was only China, France, the Great Britain, India, Japan, Pakistan, Russia and the USA.

After removal from the reactor, three phases of fuel disposal follow. In the first phase, fuel cassettes are actively cooled in a pool next to a reactor. After at least five years they are moved into dry containers and then passively cooled in interim storage facilities. The interim storage units are built with the capacity to last for several decades, at least for a period exceeding the lifespan of the power plant itself. The second phase includes safe transport to the final waste disposal site. The third phase, disposal, is understood to be the final operation, which is why the depository for the spent fuel needs to offer impenetrable protection. None of these phases generally pose a risk related to Russian SOEs.

Constructing a deep geological repository is a very complicated process which requires confident data regarding its locality. In terms of its radioactivity, spent fuel becomes safe at least for 300 years after its removal from a reactor, which is accordingly the period for which a repository has to function without difficulty. In that relation, we can mention an interesting aspect of a nuclear sector, namely that spent fuel also alone protects itself against abuse, because its removal from the protection containers would, during this period, mean a deadly dose of radiation (Vlcek & Cernoch, 2013, p. 137). The possible abuse could be actually a dirty bomb production only (in the "closed" cycle) or also nuclear bomb (in the "open" cycle). Unlike with the reprocessing, storage is always managed by the home country, unless the return of the used fuel to the possession of the producer is not a part of the contract[9]. The risks within the

[9] Currently, this is for example a part of the contract between the Russian Federation and Hungary (Digges, 2014). But the so-called Commercial Nuclear Fuel Leasing might become an interesting future's option, as it might very positively relate with nonproliferation efforts and spent fuel management.

storage are very low given to strict security measures by respective national nuclear safety authority, the Non-Proliferation Treaty and the International Atomic Energy Agency regulations.

A deep geological repository is meant to be a final repository of spent nuclear fuel. It is questionable whether it should be technologically implemented, so as to make it impossible for already deposited waste to ever be picked up again, or to enable deposited waste to be extracted and processed in the far future. Even though experts are rather inclined to the second alternative, because spent nuclear fuel represents a very valuable material which can be used as fresh fuel after being processed or even as fresh fuel without previous processing[10], economic reality suggests the first alternative[11]. The most expensive feature of a repository is its operation, which makes it economically unreasonable to keep a repository open for decades. This means it is better to store spent fuel on a long-term basis in interim storages and only when so decided, to deposit high-activity radioactive waste rather at once, and to do it definitely (opening and using it again would be impossible). A deep geological repository is constructed under the assumption it will work for the next hundred years (Vlcek & Cernoch, 2013, p. 137).

The countries analyzed, can be divided into two basic categories. Those countries in the first category (i.e. Belarus, Bulgaria and Ukraine) send their spent fuel to the Russian

[10] Some of the current fourth generation reactor projects plan to use as a fuel previously spent fuel.
[11] The assumption that using reprocessed fuel is not economically viable under the current conditions (i.e. world abundance of uranium and highly competitive global market) has been also confirmed by, for instance, the updated interdisciplinary MIT study on nuclear energy from 2009 (Deutch et al., 2009) and very little has changed since then.

Federation for reprocessing. It is not actual reprocessing per se, as the same reprocessed fuel is not returned to the country. Rather, as a part of their contracts, the fuel is "leased" and repatriated after use. Only the separated wastes are returned to the country for storage. The states in the second category (i.e. the Czech Republic, Hungary, Lithuania, Romania, Slovakia and partly Ukraine) purchase fuel from Rosatom and spent fuel management is completely done by them. This option is much more common.

So, as part of the Belarusian-Russian contract, for the life of the plant the used fuel will be repatriated to Russian Federation. It will be reprocessed there and the separated wastes returned to Belarus eventually. The same logic is applied in Bulgaria where used fuel is being sent for reprocessing to Russia under the agreement from 2002 for USD 620,000 per ton. Spent fuel from all Ukrainian NPPs, except for Zaporizhzhya NPP, is removed to the Russian Federation according to the contract with OAO TVEL at a cost to Ukraine of over USD 100 million per year, and the high-level wastes from reprocessing Ukrainian fuel was to be returned from Russia to Ukraine to be stored in Ukrainian Central Spent Fuel Storage Facility (CSFSF). The CSFSF facility construction has commenced in August 2014.

The states in the second category (Czech Republic, Hungary, Lithuania, Romania, Slovak Republic and partly Ukraine) actually purchase the fuel and the spent fuel management is completely theirs. This option is much usual. In the Czech Republic, spent fuel is owned by the operator of the nuclear power plants and stored in interim dry storages in the areas of the Dukovany and Temelín NPPs. The used fuel in Hungary is stored in domestic interim and long-term storage facilities of the state owned Public Limited Company for Radioactive Waste Management (PURAM). In Lithuania, the spent fuel is partly stored in storage pools next to the reactors, and partly in dry storage at the Ignalina NPP site. The used fuel in Romania is stored in the Interim Dry Spent Fuel Storage Facility (DICA) at Cernavoda NPP. The whole Back End of the Nuclear Fuel Cycle in Slovakia is managed by Jadrová a vyraďovacia spoločnosť (JAVYS), and there is a standard procedure with Interim Spent Fuel Storage at the Jaslovské Bohunice site with plans for expansion as well as for construction of another one in Mochovce. Used fuel from Ukrainian Zaporizhzhya NPP is stored in interim dry storage facility on site. The facility is always under control of the respective state.

The spent fuel (or back-end) treatment procedure is nothing extraordinary. It is a fairly common procedure and no threats or abuses appear to be related to Russian involvement, as the nuclear fuel cycle is regulated by strict rules due the potentially hazardous materials involved. Although the amount of waste produced by nuclear plants is usually not an issue in terms of quantity, the challenge of its ultimate storage remains. Little has been done in terms of building final underground storage facilities.