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Nuclear energy in the Czech Republic and Central and Eastern Europe

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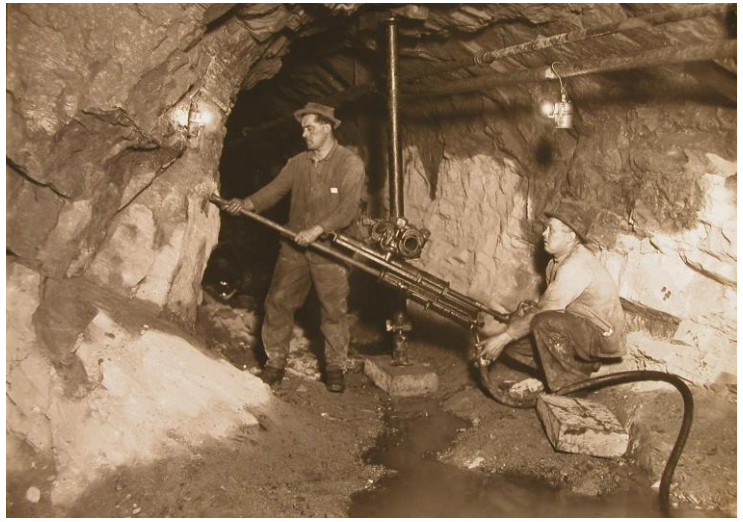
Contents

- History of the Czech Nuclear Industry and Uranium Mining
- Nuclear Fuel Cycle in the Czech Republic
- State Energy Policy and NPP Fleet Development Experience
- Nuclear Energy in CEE

History

- Rich history of uranium mining connected to Jáchymov
  - 1843 Jáchymov
  - 1892/1902 Polonium/Radium
  - 1910 State factory
  - 1912 World monopoly
  - 1918 Nationalization
  - 1930s Loss of primacy
  - 1938 Munich
  - 1945 Agreement with USSR
  - 1948-1953 (Act. No. 247)
- 164 deposits were located and investigated for uranium of which 66 were mined (Pribram, Rozna, Straz, Hamr, Jachymov, Zadni Chodov, Vitkov II, Olsi, Horni Slavkov, Okrouhla Radoun)
- In 1946-2000 107,080 tonnes of uranium mined (6th in the world)



Pracovní tábory pro rozvratníky
jsou připraveny

V Kladně, Pardubicích a Karlově Varech byly již zřízeny kárné tábory.
Obchody, živnostenská oprávnění, byty, motorová vozidla atd. budou rozvratníkům odebírány.

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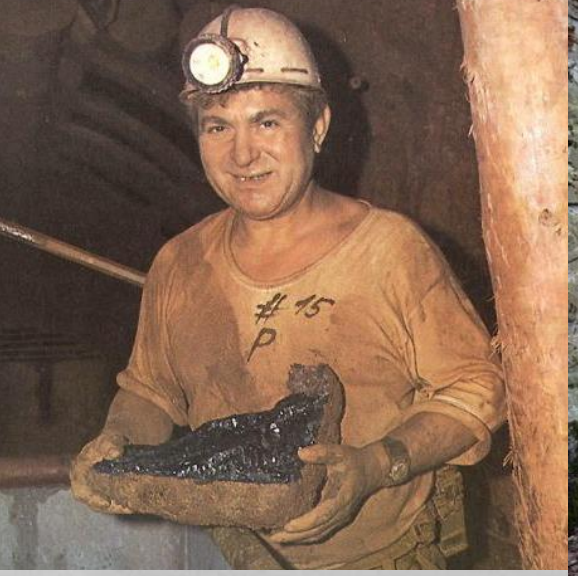
- 1989 attenuation program, shortly after 2 of 16 deposits mined (Stráž pod Ralskem, Dolní Rožínka)
- 1995 mining terminated at the last deep underground mine Hamr I (Stráž pod Ralskem, 13.2 mt)
- 1995 In-Situ Leaching mining terminated (Ralsko, 15.6 mt)
- 2007 Government approved continuation of mining and processing of uranium in Rožná mine for the period of economic feasibility
- 2017 Mining at Rožná mine terminated on April 27, it was the last uranium mine in Europe

Stages of Czech uranium mining after World War II

	Years	Characteristics
1	1946 – 1950s	Restoring of old mines in the Jáchymov district, carrying out exploration work in traditional ore districts, the discovery of deposits in Horni Slavkov and Pribram
2	1950s – 1965	Intensive exploration works
3	1965 – 1975	Intensive mining in the found locations from the previous stage, i.e. in the Krusne hory, Tachovsko, Zelezne hory, Krkonose, Rychlebske hory, Ceskomoravska vysocina a Ceskolipsko
4	1976 – 1988	Further uranium exploration and opening of new mines, major mining operations in the Ceska Lipa
5	1989 – today	The final attenuation phase of the uranium mining, setback program

Source: Majer, 2004, s. 229; Loucká, 2004, s. 227, 330.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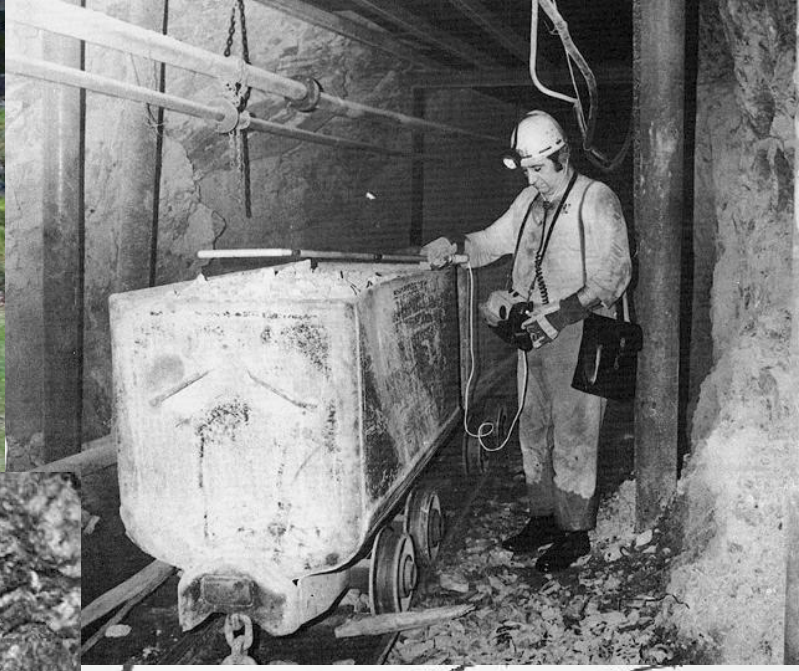
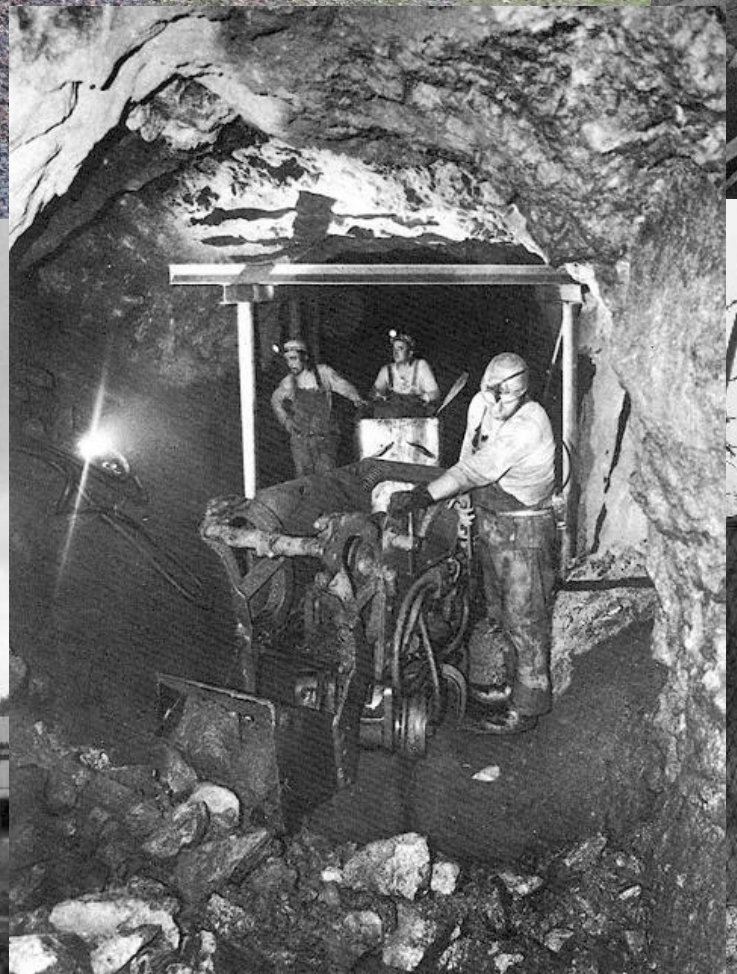


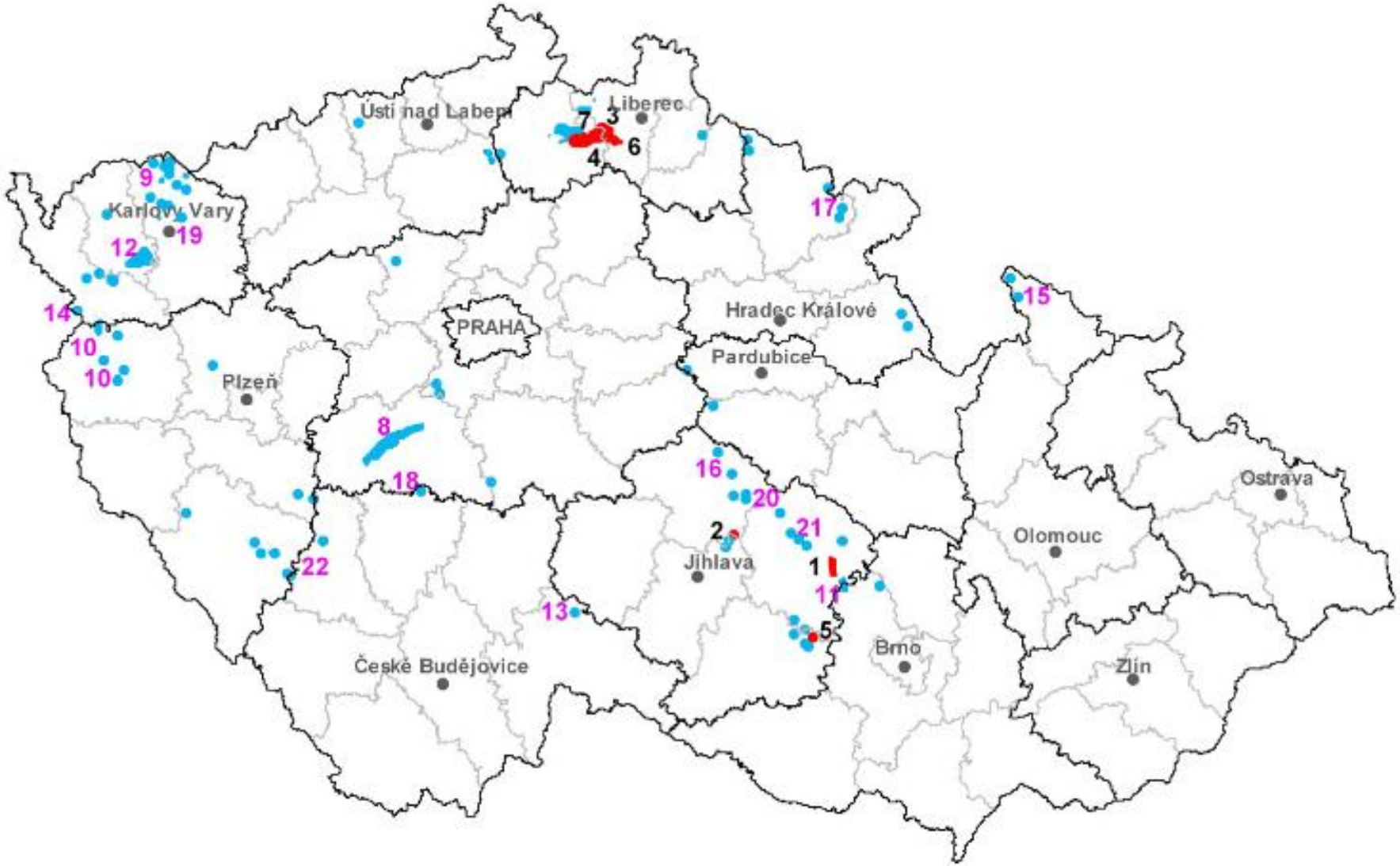


Uranium

- 232 t in 2013 produced
- 128 t in 2016 produced
- 56 t in 2017 produced
- 34 t in 2018 produced

- DIAMO, s. p.

- 59.5 kt produced worldwide in 2017



Source: Česká geologická služba

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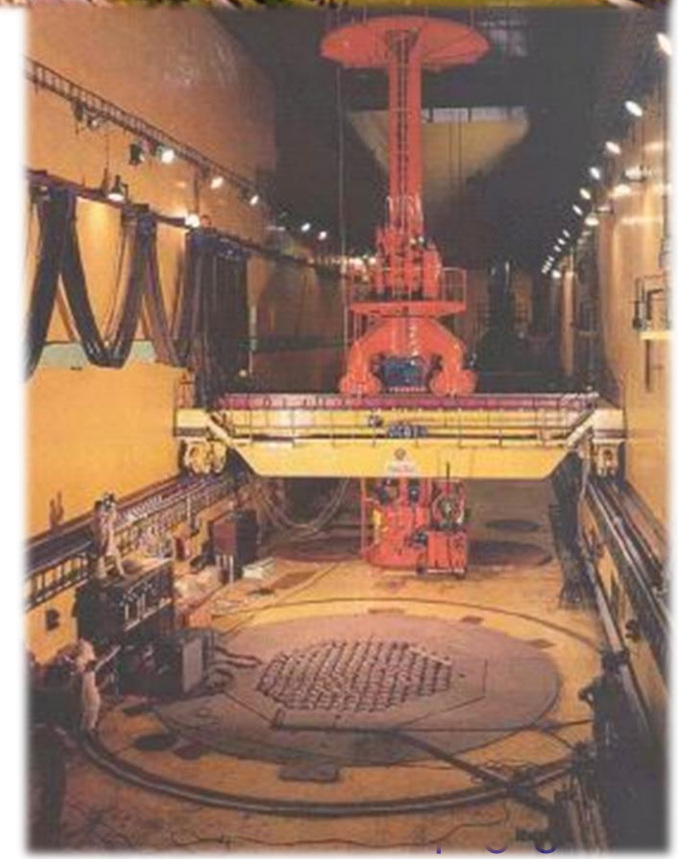
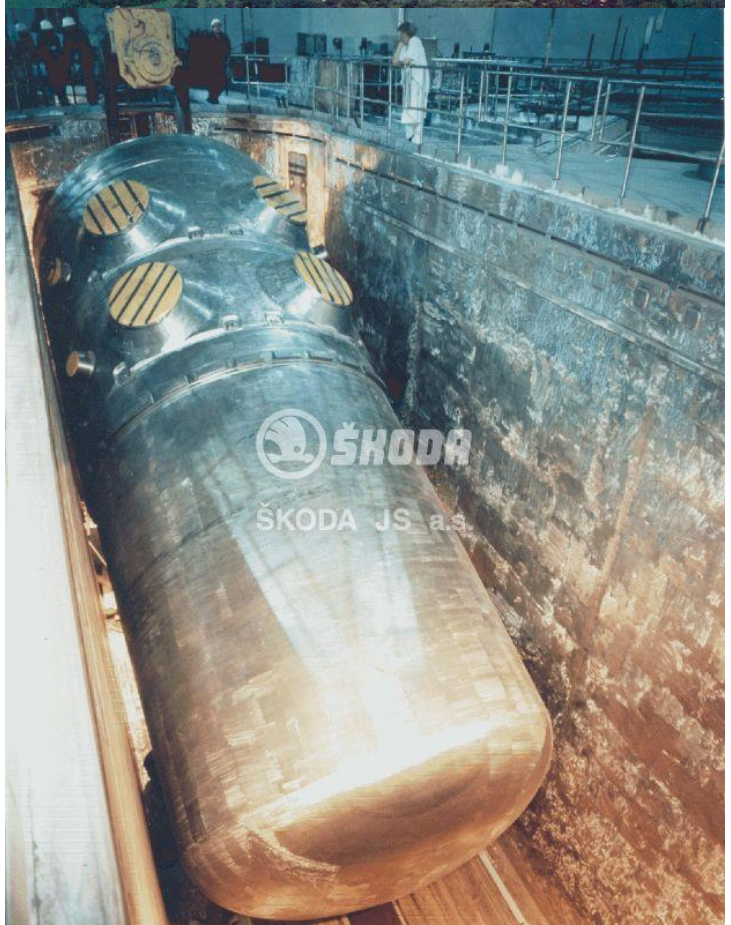
History

- 1945 CSSR-USSR uranium supply agreement
- 1955 Agreement on Nuclear research Institute in Řež
- 1956 CSSR-USSR Agreement on Soviet aid in the A1 construction
- 1958 Jaslovské Bohunice A1 construction started
- 1972 NPP operation commenced
- 1972 First accident
- 1977 Second accident
- 1970 Agreement CSSR-USSR on the construction of 2 NPPs (Voronezh VVER 440 type V 230 of 440 MWe for Bohunice identified as V-1 and Dukovany V-2)
- 1975 V 2 shifted to EBO, EDU with 4 units of V-213 type



History

- 1978 EBO V1 connected
- 1984 EBO V2 connected
- 1982-1999 Mochovce NPP construction based on COMECON agreement on the development of nuclear energy
- 1998-1999 only 2 Units connected, due to lack of funding Units 3 and 4 construction started in 2008
- 2019 (July) Unit 3 99% completed, Unit 4 86.5% (originally 2013 vs. 2020)
- 1978 Temelín NPP decision (4x 1,000 Mwe VVER 1000 type 320)
- 1986 construction started
- 1989 re-decided to construct only 2 Units
- 1990 IAEA analysis



History

- 1993 alterations to the original design made by Westinghouse in cooperation with IAEA and SÚJB (information and control systems added, electrical modifications carried out, cabling, reactor core and fuel elements replaced)
- 1990s Austrian resistance
- 2000 (December 12) Melk Agreement
  - Czech Republic agreed to the EIA according to Western standards
  - The Czech Republic has agreed with direct information system, which will inform of all events at NPP Temelín
  - The Czech Republic agreed that Austria has established a monitoring station close to the NPP
  - It was agreed on closer cooperation between the two countries in energy research, improvement and effective systems for renewable energy
  - Both countries agree to respect the rules on free movement of persons and goods
  - Both countries have agreed to support the EU enlargement
- 2001 (November 29) Brussels´ Protocol
  - Every State has the sovereign right to their own energy policy

History

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Nuclear Fuel Cycle

- 1990s sales to Slovakia ended
- 2000 domestic production covered 93% of demand
- 2009 sales to ČEZ ended, final product has been purchased
- 2017 sales to international market (France, Russia...) ended

- DIAMO Processing Plant in Dolní Rožínka
- Czech contribution to global production was minimal, decreasing from 1.3% in 2003 to 0.1% in 2017
- uranium yield 0.16%, uranium concentrate final product

- Russian company OAO TVEL (daughter of Rosatom) supplies fuel for Dukovany and Temelín NPPs

Nuclear Fuel Cycle

- European Energy Security Strategy (May 2014) - utilities to diversify their nuclear fuel supply sources
- Euratom opened call NFRP-16-2015 to support the licensing of Western nuclear fuel for reactors in VVER units in December 2013, with an application deadline of November 2014 - won by Westinghouse Electric Company LLC led group (€2 million in backing from the EU)
- The Euratom Supply Agency understands the importance of the security of supply, mandating that there should always be at least two alternative fuel designs from two different suppliers qualified for each reactor

Front end fuel cycle costs of 1 kg of uranium as UO_2 fuel (2017 costs, source: WNA)

Uranium	8.9 kg U_3O_8	$ 68 per kg	**$ 605**	**43%**
Conversion	7.5 kg U	$ 14 per kg	**$ 105**	**8%**
Enrichment	7.3 SWU	$ 52 per SWU	**$ 380**	**27%**
Fabrication	1 kg	$ 300 per kg	**$ 300**	**22%**
Total			**$ 1390**	**100%**

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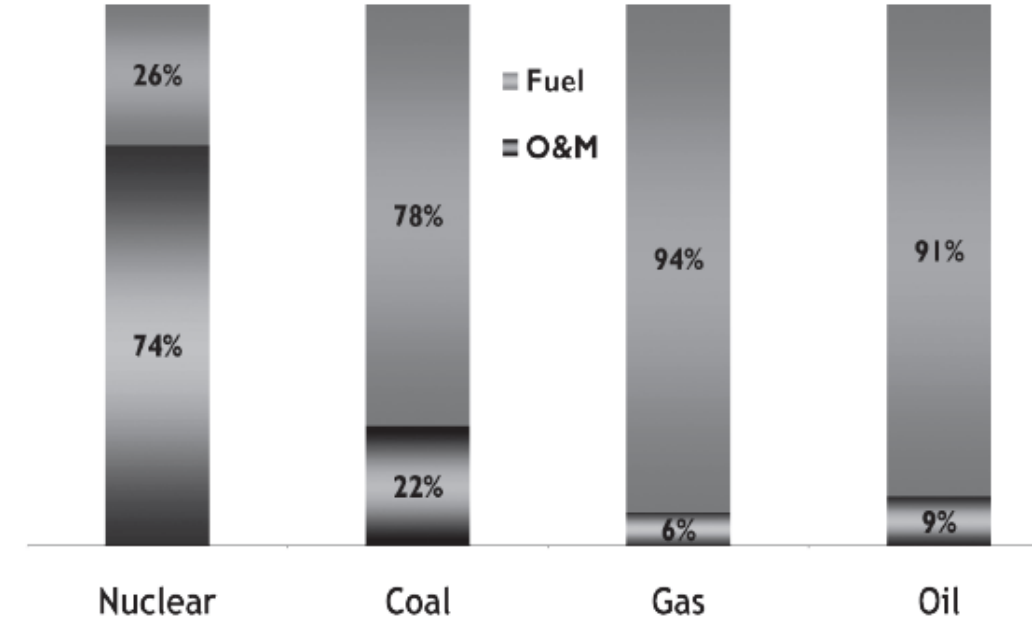
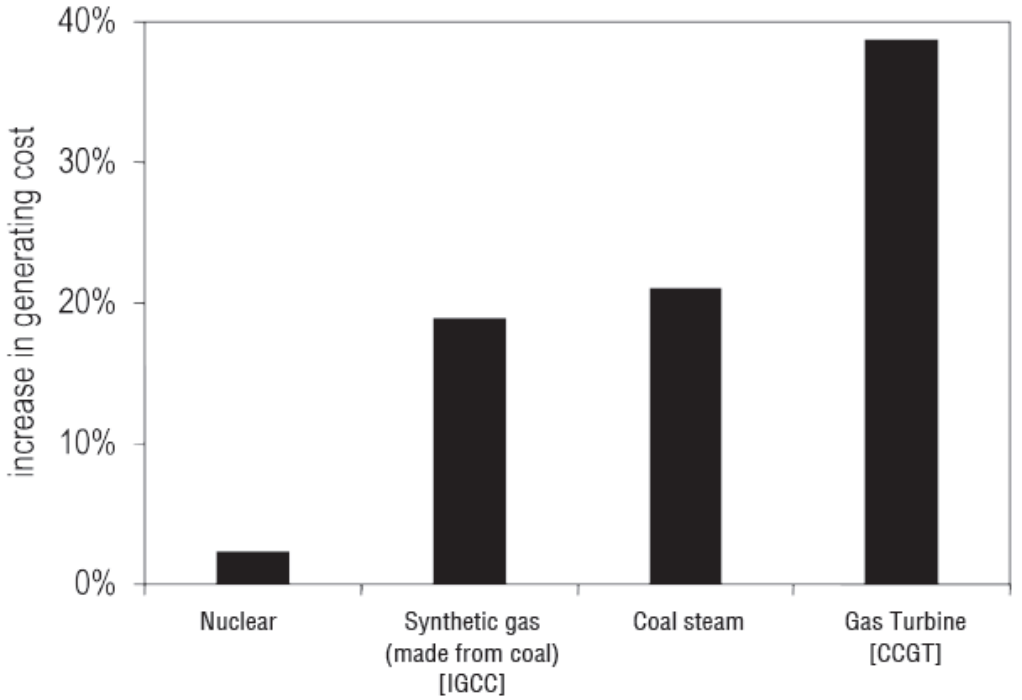
Nuclear Fuel Cycle

The reactor fuel buyers fight hard to save every last cent because this is cost they feel they can influence. It has however minor role on the NPP operating costs.

Impact of 50 % increase in fuel costs on generating costs

Source for figures: Global Energy Decisions, ERI, Inc.; IEA WEO 2006; in Steve Kidd, 2010, Nuclear Fuel: Myths and Realities





Nuclear Fuel Cycle

Difference to every other step:

1) Fabrication is a highly specialised service rather than commodity (barrier for newcomers enetring the market)
2) TVEL offers full front end process as a product (i.e. fuel) vs. steps in the fuel cycle
3) Main technology (NPP) suppliers are also main fuel producers
4) Fuel is manufactured according to public tenders specifing the product in details
5) VVER technology was developed paralelly with western technology (legacy of cold war)
6) Markets were opened 25 years ago with no experience on both sides
7) The nuclear fuel quality is critical for NPP production. The financial implications of reduced plant performance would quickly outweigh any benefit from potentially lower fuel prices

Operating VVER Design Nuclear Units Outside the Russian Federation (as of January 2019)

Operating VVER Design Nuclear Units Outside the European Union

Country	Reactor	Type	In Operation from	End of Life-Cycle	Fuel Supplier	Fuel Contract Until
Armenia	Metsamor 2	VVER-440/V-270	1980	2026	OAO TVEL[B]	2026
Belarus	Astravets 1	VVER-1200/V-491	2019	2079	OAO TVEL	2079
	Astravets 2	VVER-1200/V-491	2020	2080	OAO TVEL	2080
China	Tianwan 1	VVER-1000/V-428	2006	2046	CNNC Jianzhong Nuclear Fuel Company, Ltd.	2046[E]
	Tianwan 2	VVER-1000/V-428	2007	2047	CNNC Jianzhong Nuclear Fuel Company, Ltd.	2047[E]
	Tianwan 3	VVER-1000/V-428M	2017	2057	OAO TVEL	2025[E]
	Tianwan 4	VVER-1000/V-428M	2018	2058	OAO TVEL	2025[E]
India	Kudankulam 1	VVER-1000/V-412	2013	2073	OAO TVEL	2073[F]
	Kudankulam 2	VVER-1000/V-412	2016	2076	OAO TVEL	2076[F]
Iran	Bushehr 1	VVER-1000/V-446	2011	2071	OAO TVEL	2021
Ukraine	Rivne 1	VVER-440/V-213	1980	2030	OAO TVEL	2030[G]
	Rivne 2	VVER-440/V-213	1981	2031	OAO TVEL	2030[G]
	Rivne 3	VVER-1000/V-320	1986	2036	OAO TVEL	2030[G]
	Rivne 4	VVER-1000/V-320	2004	2034	OAO TVEL	2030[G]
	Khmelnitsky 1	VVER-1000/V-320	1987	2017[A]	OAO TVEL	2030[G]
	Khmelnitsky 2	VVER-1000/V-320	2004	2034	OAO TVEL	2030[G]
	South Ukraine 1	VVER-1000/V-302	1982	2023	OAO TVEL/WH EC LLC	2025[G]
	South Ukraine 2	VVER-1000/V-338	1985	2025	Westinghouse EC LLC	2025[G]
	South Ukraine 3	VVER-1000/V-320	1989	2019	Westinghouse EC LLC	2025[G]
	Zaporizhzhya 1	VVER-1000/V-320	1984	2025	OAO TVEL/WH EC LLC	2030[G]
	Zaporizhzhya 2	VVER-1000/V-320	1985	2026	OAO TVEL	2030[G]
	Zaporizhzhya 3	VVER-1000/V-320	1986	2027	OAO TVEL/WH EC LLC	2030[G]
	Zaporizhzhya 4	VVER-1000/V-320	1987	2028	OAO TVEL/WH EC LLC	2030[G]
	Zaporizhzhya 5	VVER-1000/V-320	1989	2019	OAO TVEL/WH EC LLC	2030[G]
	Zaporizhzhya 6	VVER-1000/V-320	1995	2025	OAO TVEL	2030[G]

Operating VVER Design Nuclear Units Outside the Russian Federation (as of January 2019)

Operating VVER Design Nuclear Units Inside the European Union

Country	Reactor	Type	In Operation from	End of Life-Cycle	Fuel Supplier	Fuel Contract Until
Bulgaria	Kozloduy 5	VVER-1000/V-320	1987	2027	OAO TVEL	2020
	Kozloduy 6	VVER-1000/V-320	1991	2019[A] (+10)	OAO TVEL	2020
Czech Republic	Dukovany 1	VVER-440/V-213	1985	not set[H]	OAO TVEL	2028[D]
	Dukovany 2	VVER-440/V-213	1986	not set[H]	OAO TVEL	2028[D]
	Dukovany 3	VVER-440/V-213	1986	not set[H]	OAO TVEL	2028[D]
	Dukovany 4	VVER-440/V-213	1987	not set[H]	OAO TVEL	2028[D]
	Temelín 1	VVER-1000/V-320	2000	2020	OAO TVEL	2020
	Temelín 2	VVER-1000/V-320	2002	2022	OAO TVEL	2020
Finland	Loviisa 1	VVER-440/V-213	1977	2027	OAO TVEL	2027[C]
	Loviisa 2	VVER-440/V-213	1980	2030	OAO TVEL	2030[C]
Hungary	Paks 1	VVER-440/V-213	1982	2032	OAO TVEL	2032[D]
	Paks 2	VVER-440/V-213	1984	2034	OAO TVEL	2034[D]
	Paks 3	VVER-440/V-213	1986	2036	OAO TVEL	2036[D]
	Paks 4	VVER-440/V-213	1987	2037	OAO TVEL	2037[D]
Slovak Republic	Jaslovské Bohunice V2 1	VVER-440/V-213	1984	2024	OAO TVEL	2021
	Jaslovské Bohunice V2 2	VVER-440/V-213	1985	2025	OAO TVEL	2021
	Mochovce 1	VVER-440/V-213	1998	2028	OAO TVEL	2021
	Mochovce 2	VVER-440/V-213	2000	2030	OAO TVEL	2021
	Mochovce 3	VVER-440/V-213+	2019	2049	OAO TVEL	2024[I]
	Mochovce 4	VVER-440/V-213+	2020	2050	OAO TVEL	2025[I]

Alternative Fabricators of VVER Design Nuclear Units Fuel				
Reactor Type	**Company**	**Previous Experience**	**Current Contracts**	**Operational experience and Limitations**
VVER-440	Westinghouse Electric Company LLC*	Nova E-3 fuel type for Loviisa NPP Unit 1 (Finland) in 1998-2007	-	The fuel performed in accordance with expectations during operation. BNFL signed a contract with Finnish NPP operator IVO and Hungarian Paks NPP in 1996 for the design, development, licensing and supply of test fuel assemblies for the VVER-440 reactor at Loviisa NPP. At the same time, Hungarian Paks NPP was considering using an alternative supplier for at least one reactor. But no BNFL fuel was ever loaded into Hungarian reactors (likely because of the Hungarian-Russian contract for fuel supply until the end of plant´s life-cycle) and BNFL´s fuel was licensed in Hungary only until 2008.
VVER-1000	Westinghouse Electric Company LLC	VVANTAGE-6 fuel type for Temelín NPP (Czech Republic) in 2000-2009; VVANTAGE-6 (TVS-W) fuel type for South Ukraine NPP (Ukraine) in 2009-2014; TVS-RW fuel type for South Ukraine NPP since 2015	South Ukraine NPP (Ukraine) until 2020	Temelín NPP experienced massive malfunctions related to the geometric stability of the fuel that eventually led to premature unloading of all of Westinghouse's fuel assemblies despite financial losses, and replacement with TVEL fuel. Problems with fuel recurred in Ukraine to a lesser extent, but still enough to cause a lengthy unscheduled outage at two of the units, which eventually led to technological adjustments to the fuel and consequent relabeling to Robust (TVS-RW).
	China National Nuclear Corporation (CNNC)	-	Tianwan NPP (China) until the end of plant´s life-cycle	As part of the 2008 contract with TVEL and CNNC, TVEL sold production technology for TVS-2M fuel for VVER-1000 units. China's Yibin fabrication plant will thus produce the fuel for Tianwan Units 1 and 2 and future Units 3 and 4 (currently under construction) from fourth refuel onwards. The contract is for Tianwan NPP only.
VVER-1200	-	-	-	-

* This contract was operated by British Nuclear Fuels Limited (BNFL), owner of Westinghouse Electric Company LLC between 1999 and 2006. All Westinghouse's nuclear power business was restructured by BNFL, including ABB Group's nuclear power business, bought and merged into Westinghouse in 2000. In 2007, BNFL sold Westinghouse Electric Company LLC to Toshiba Corporation and Toshiba sold shares of the company to minorities (20% to The Shaw Group and 3% to Ishikawajima-Harima Heavy Industries Co. Ltd.; later in 2007 10% to Kazatomprom) leaving the Japanese company with 67% share. When BNFL bought Westinghouse, it was decided that the reload fuel for Loviisa NPP Unit 1 would be assembled via a manufacturing license by Enusa Industrias Avanzadas, S.A. in Spain instead of at Westinghouse´s Springfields plant in UK.

Source: public sources; company information; compiled by T. Vlček.

Nuclear Fuel Cycle

- Potentially the biggest single obstacle to fuel market diversification is the license.
- The Euratom funding noted earlier is targeted directly at diversifying the VVER-440 fuel market by qualifying a second supplier for the EU's VVER-440 reactor fleet. The program will chiefly focus on establishing the methods and methodology required to license a VVER-440 fuel design.
- The Euratom funding is targeted directly at diversifying the VVER-440 fuel market by qualifying a second supplier for the EU's VVER-440 reactor fleet.
- The Dukovany NPP in the Czech Republic, the Loviisa NPP in Finland, and the Paks NPP in Hungary all have lifetime fuel contracts with OAO TVEL for all their VVER-440 units. Only at the Jaslovské Bohunice and Mochovce NPPs in Slovakia do the contracts expire in 2021.

Nuclear Fuel Cycle

- Finally, we may expect the instalment of Lead Test Assemblies in a VVER-440 reactor in the near future. It may occur either at Ukraine's Rivne NPP, since Westinghouse already has a commercial presence in Ukraine, or at Slovakia's Jaslovské Bohunice and Mochovce NPPs.
- The Slovak Government has discussed the possibility of cutting dependency on Russian nuclear fuel, and in November 2014, information emerged about a contract for uranium fuel supply being signed with a non-Russian company
- Additionally, in 2014 Slovakia began a diversification effort targeting not only uranium enrichment, but also nuclear fuel manufacture, crude oil and natural gas infrastructure, and military equipment based on Resolution 146 of the Committee of the Slovak Republic National Council for Defence and Security

Nuclear Fuel Cycle

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	VVER 440, V 213 type	2,040	5,776	1985 – 1988	ČEPS	400	Slavětice
	2	510	VVER 440, V 213 type						
	3	510	VVER 440, V 213 type						
	4	510	VVER 440, V 213 type						
Temelín Nuclear Power Plant	1	1,082	VVER 1000, V320 type	2,164	6,240	2000-2002	ČEPS	400	Kočín
	2	1,082	VVER 1000, V320 type						
ÚJV Řež	LR-0 (TR-0)	5 kWt	VVER 440/1000-	-	-	1972	-	-	-
	LVR-15 (VVR-S)	10 MWt	LVR	-	-	1957	-	-	-
FJFI ČVUT Praha	VR-1 Vrabec	100 Wt	-	-	-	1990	-	-	-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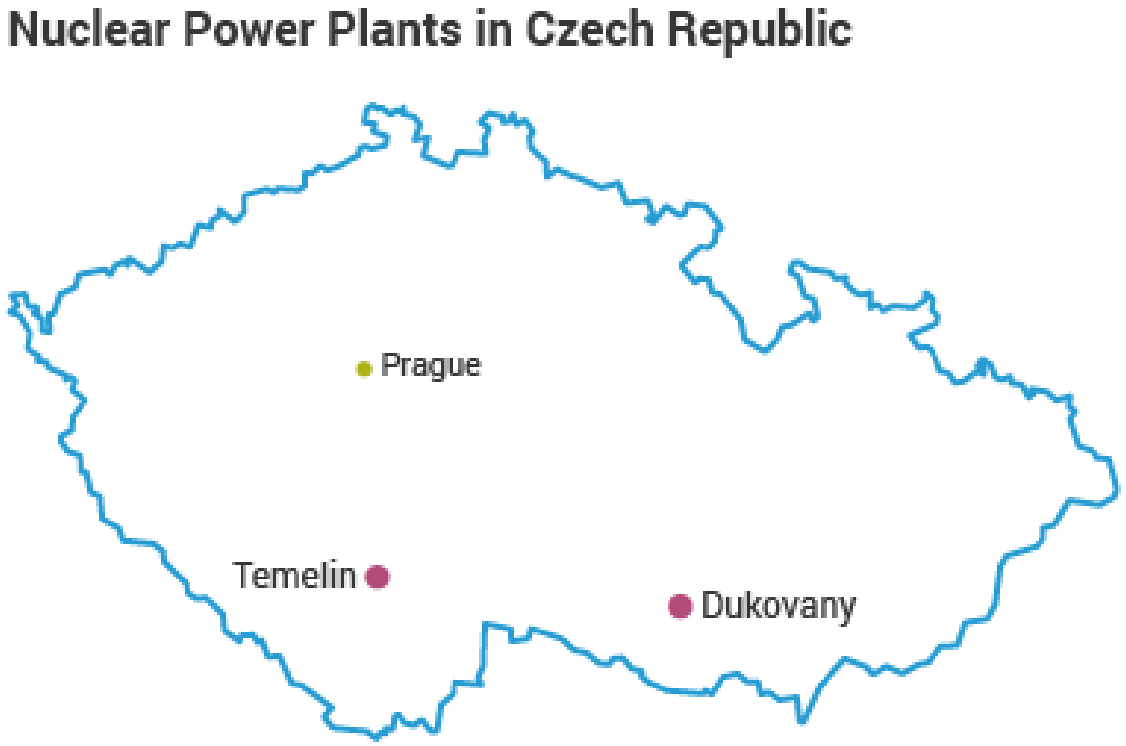
Nuclear Fuel Cycle

- All operational reactors constructed by Škoda JS
- Service and maintenance by domestic companies



Source: World Nuclear Association

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Nuclear Fuel Cycle

- In the **first phase**, the fuel is actively cooled in a pool next to the reactor. After around 10 years they are put into dry containers and passively cooled in interim storages. Dukovany NPP annually produces less than one container of spent fuel. Temelin NPP annually produces two full containers of used fuel. The dry interim storage facility is constructed to store fuel for about 80 years.
- The **second phase**, i.e. transport phase, is/will be provided by rail.
- The **third phase** is the underground geological repository
  - 2020 Selection of two locations
  - 2025 Primary and backup location selection by the Government
  - 2050 Construction start
  - 2065 Operation

Nuclear Fuel Cycle

- Underground geological repository
  - Phase I (until 2015) selection stage
  - Phase II (2015-2025) exploratory stage
  - Phase III (2025-2050) detailed research
- Locations for construction
  - **Březový potok u Pačejova**
  - Čertovka u Lubence
  - **Horka u Budišova**
  - **Hrádek u Rohozné**
  - Čihadlo u Lodhéřova
  - Magdaléna u Božejovic
  - Kraví hora
  - Na Skalním (near Dukovany)
  - **Janoch (near Temelín)**
- Construction CZK 36.7 billion
- With operating costs and containments

  CZK 111.4 billion

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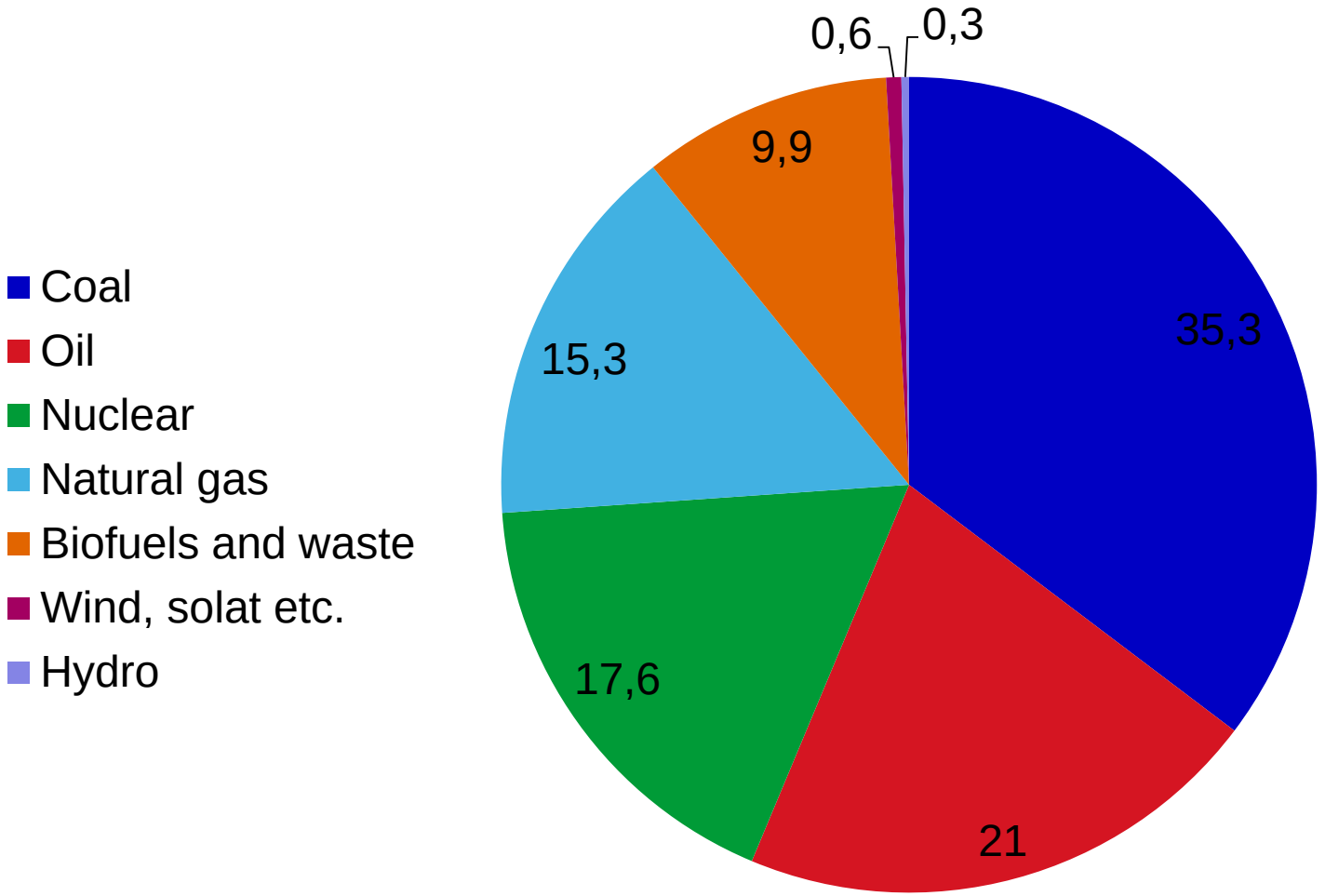
Nuclear Fuel Cycle

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 reprocessing
Location	Spent fuel pools in the Dukovany and Temelín nuclear power plants	Storage in the Dukovany and Temelín nuclear power plants, backup repository Skalka	Deep geological repository
Responsible	ČEZ, a. s.		SÚRAO
Supervised by	State Office for Nuclear Safety		
Financial means	Corresponding budget ČEZ		Nuclear account (ČEZ contributions)
Source: Otčenášek, 2005, p. 540; modified by T. Vlček.			

Total Primary Energy Supply 2018



Indicative Corridors for Czech Republic's Energy Sector in 2040			
Structure of Brutto Electricity Generation		**Structure of Energy Mix**	
Nuclear	46 – 58 %	**Nuclear**	25 – 33 %
RES and secondary sources	18 – 25 %	**RES and secondary sources**	17 – 22 %
Natural Gas	5 – 15 %	**Gaseous fuels**	18 – 25 %
Coal	11 – 21 %	**Solid fuels**	11 – 17 %
		Liquid fuels	14 – 17 %
Source: Ministerstvo průmyslu a obchodu, 2014, p. 44			

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State Energy Policy

Raw material policy of the Czech Republic in the field of mineral resources and their resources 2017

- mine out the rest of exploitable resources at Rožná by 2017
- select the best alternative mining location and proceed with required feasibility, economic and environmental studies and legal steps
- use the time window (25 to 30 years) for R&D of mining and processing technology
  - Brzkov and Věžnice, exploration in 1976-1990, assumption of 3,100 tons of metal (1992), buried within the reduction program after ten years of exploration and mining preparation
  - mining can bring DIAMO miners back to work for about 16 years (900 people works in DIAMO)
  - Prime minister Sobotka at the end of March 2014 supported the intention of the company and presented it to the Government
  - Resolution of the Government of December 2014 No. 1086 ordering the Minister of Industry and Trade to start the preparation of new uranium mining in Brzkov through DIAMO
  - DIAMO is however unable to prove that there is uranium, The Ministry of the Environment has repeatedly extended the deadline for submitting documents (now by mid 2020)

State Energy Policy

State Energy Policy 2015

- nuclear fuel to make 46-58% of electricity production in 2040
- nuclear fuel to make 25-33% of TPES in 2040
- maximization of heat supply from nuclear power plants
- reserves of nuclear fuel for four years (by nuclear power plant operators)
- extending the life of the Dukovany NPP to 50 years and, if possible, up to 60 years
- new NPP (up to 2,500 MWe) in the years 2030-2035
- decision on the nuclear waste repository until 2025
- promotion of nuclear energy as a low carbon technology contributing to the transition to low carbon energy within the EU
- inclusion of nuclear fuel in the system of state material reserves

State Energy Policy

Action Plan for the Development of Nuclear Energy in the Czech Republic 2015

- focus on EDU (max 1x 1,200 MWe, or 2x 1,200-1,400 with EDU shutdown)
- investment model (August 2019), the investment model of a 100% subsidiary of ČEZ (Dukovany II Power Plant) and a contract with the state (CEZ will be able to obtain a loan under the same favorable conditions as the state borrowed; the state will guarantee the stability of the legislative environment); 70 % of finances should be covered by the State
- it will be necessary to discuss with the EC the model chosen in relation to the rules of the EU's internal market
- completion by 2036, cost 140-160 billion CZK
- 2019 EIA
- 2021 zoning decision

State Energy Policy

Action Plan for the Development of Nuclear Energy in the Czech Republic 2015

- **Further plans**
- tender announcement expected in 2022
- during January-February 2017, the MPO consulted six potential suppliers
  - Rosatom (Russia) VVER 1200
  - **EdF (France) EPR 1650 MWe**
  - **Westinghouse (USA/Canada) AP1000**
  - **KHNP (South Korea) APR1400**
  - China General Nuclear Power (China) Hualong 1 1080 MWe (merger of CPR-1000 and ACP1000)
  - Areva + Mitsubishi (France, Japan) Atmea 1 1100 Mwe
- 2019 plan expected in 2022 supplier selection, in 2029 construction start, in 2036 completion; price 300 billion CZK for 2 units
- in 2020 ČEZ announced 55 CZK billion investment to keep EDU operational for 25-27 years
- 2021 new discussion on financing (100% by State)
- 3/2021 – China excluded and CEZ will contact selected candidates to submit summary information by the end of November this year on how they will meet the safety requirements for suppliers of a new NPP
- 4/2021 – Russia excliuded after the Vrbětice case

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NPP Fleet Development Experience

- August 2009 - May 2014 first tender experience (start-up 2024, price CZK 200-300 billion for 2 Units)
- more than 6,000 pages employing over 11,000 criteria to be met by the bidders
- each bidder provided the Czech side with documentation exceeding 10,000 pages
- Westinghouse, Areva, Russian consortium (Skoda JS, ASE, Gidropress)

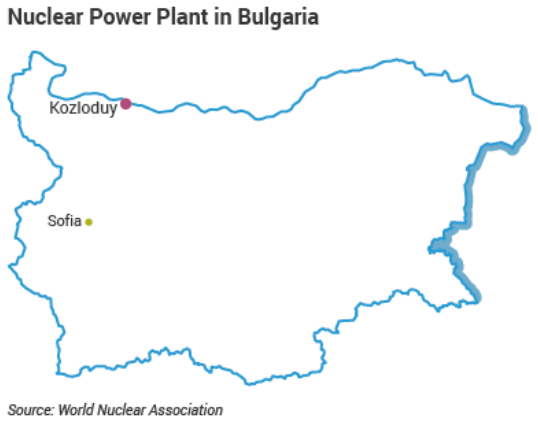
- cancelled for the Government was not willing to offer any kind of guarantees
- the price of electricity in 2009-2014 decreased by 60% (4/2014 - the price of € 34/MWh, historical minimum)
- CO_2 allowances were worth about 113 CZK (€ 4.2), the plan was at least 15-20 euro
- operation of EDU became a more pressing problem

Nuclear Energy in CEE

- **Nuclear countries**: Bulgaria, Czech Republic, Hungary, (Lithuania), Romania, Slovakia, Ukraine

- **Newcomers**: Belarus, (Poland)

Bulgaria



- Kozloduy 5 and 6 (2x VVER 1000 V 320) in operation
- plans since the late 1970 and early 1980s to build two new units at the Kozloduy NPP site and units at the Belene site
- the Belene NPP project, where Atomstroyexport won the procurement procedure as part of a broader consortium, restarted in 2008, was definitely aborted in 2012
- Atomstroyexport claimed EUR 1.2 billion in damages for the aborted Belene project, won the arbitrage for EUR 550 million
- Kozloduy NPP 1-4 was shut down in 2002 and 2006 as the outcome of the accession negotiations with the EU (non-upgradable VVER-440 V-230 models)
- Kozloduy NPP unit 7 planned, Westinghouse as the technology supplier for the Kozloduy 7 unit was accepted as geopolitically more favourable than the Russian offer
- Financial problems, Westinghouse unwilling to participate financially

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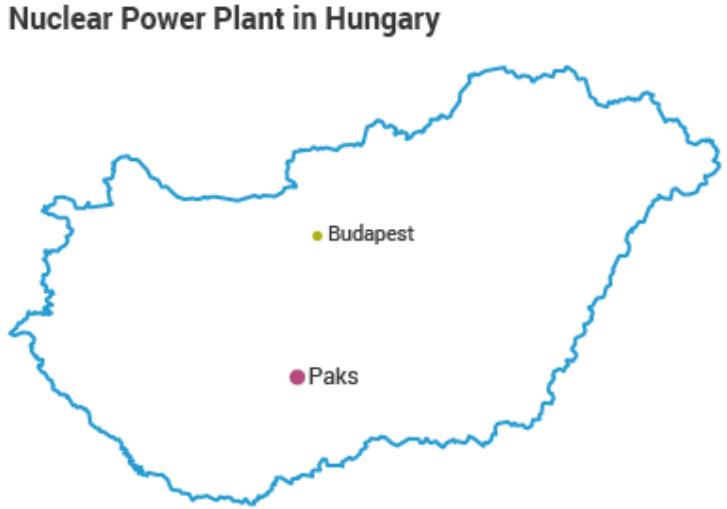
Hungary



Source: World Nuclear Association

- Paks NPP 1-4 (4x VVER 440 V 213) in operation
- the current construction plans build upon 1980s plans preparations for VVER design
- decision to construct 2 units of VVER-1200 (Paks 5 and 6) was taken
- contract was signed in January 2014 with Rosatom without procurement
- EUR 10 billion loan to co-finance the project was offered by the Russian Federation (the Russian side was allegedly the only one prepared to offer financing to support the project) – 80% of the EUR 12 billion project
- Hungary to repay the loan over 21 years of operation, starting in 2026 even without the construction completed
- fuel is to be supplied solely by Rosatom for the first 10 years of operation (cut from 20 by ESA)
- EC also opened a state aid investigation into the project financing for Paks II, but in March 2017 the EC approved it, as being in line with state aid rules
- EC also expressed concerns about compatibility with EU public procurement rules but cleared the matter in November 2016
- construction of service buildings started in June 2019

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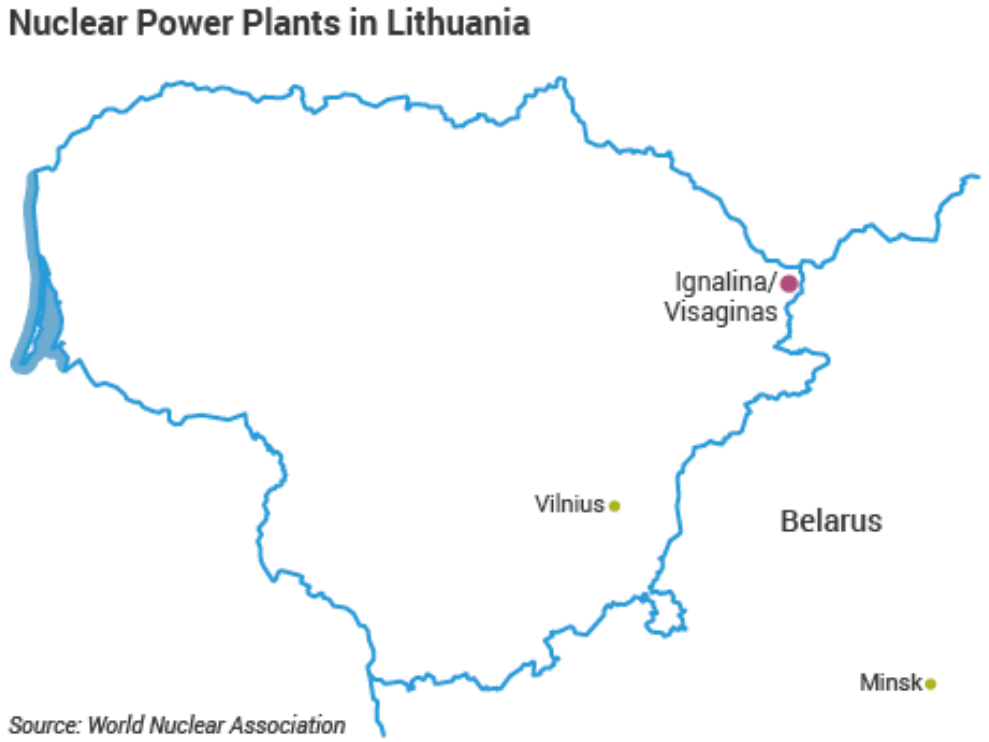
Lithuania



- two RBMK Units of 1,500 MWe each (later derated to 1,300 MWe)
- commenced in 1983 and 1987
- third commissioned in 1985, suspended after Chernobyl
- Ignalina 1 closed down in 2004
- Ignalina 2 closed down in 2009
- the NPP generated 70% of Lithuania's electricity

- by the time Lithuania applied to join the EU it was required to close them both down due to strong EU concerns about the RBMK reactor

- EU agreed to contribute towards decommissioning costs and some compensation,with support continuing to 2020

- Visaginas NPP project from 2007

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Romania

Source: World Nuclear Association

- Cernavoda NPP 1-2 (2x CANDU 6 650 MWe) in operation
- original plan was to built 5 Units at Cernavoda, but only two were constructed
- two CANDU 6 units are planned now
- 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
- in 2010-2013 all of these companies pulled out for commercial reasons
- 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
- in May 2019 CGN and SNN signed a preliminary investors agreement for the project with a view to setting up a joint venture company with 51% CGN equity
- Unit 3 is expected in 2031, Unit 4 to start construction in 2024
- 2/2020 Prime minister announced the country will no longer cooperate with China, USA will finance the project

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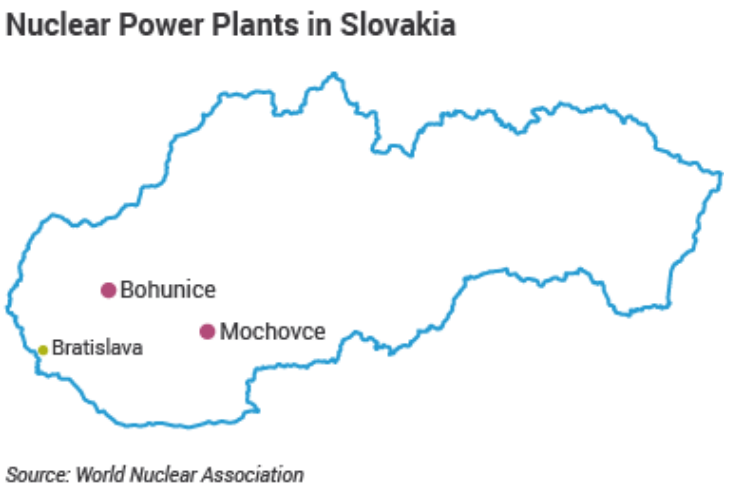
Slovakia



Source: World Nuclear Association

- Jaslovské Bohunice V2 (2x VVER 440 V 213) in operation
- Mochovce 1-2 (2x VVER 440 V 213) in operation
- Mochovce NPP units 3 and 4 are under construction (completion) since 2009 (expected start-up in 2021 and 2023)
- contracts were signed in June 2009 with the original suppliers of the unfinished parts (Škoda JS a.s., ZAO AtomStroyExport, Výskumný Ústav Jadrovej Energetiky, a.s., Enseco a.s., Inžinierske Stavby a.s.), Siemens AG, ENEL Ingegneria & Innovazione S.p.A., Doosan Škoda Power s.r.o.
- in 2008 plans for a new NPP were announced and it was decided it will be at Bohunice NPP site; six information packages were received (Westinghouse, ATMEA, Mitsubishi, MIR.1200, KHNP, AREVA)
- 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 - majority withdrew, Rosatom offered BOO, wanted guarantees
- since 2014 situation complicated though works on the project are proceeding (EIA, approvement by the Ministry of Environment, work on criteria for the selection of a nuclear technology supplier); EIA in 2016

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Ukraine

- NPPs generate about half of Ukraine's electricity

- **in operation:**
- Khmelnitski 1-2 (2x VVER 1000 V 320)
- Rivne 1-4 (2x VVER 440 V 213, 2x VVER 1000 V 320)
- South Ukraine 1-3 (3x VVER 1000 V 302/338/320)
- Zaporozhe 1-6 (6x VVER 1000 V 320)

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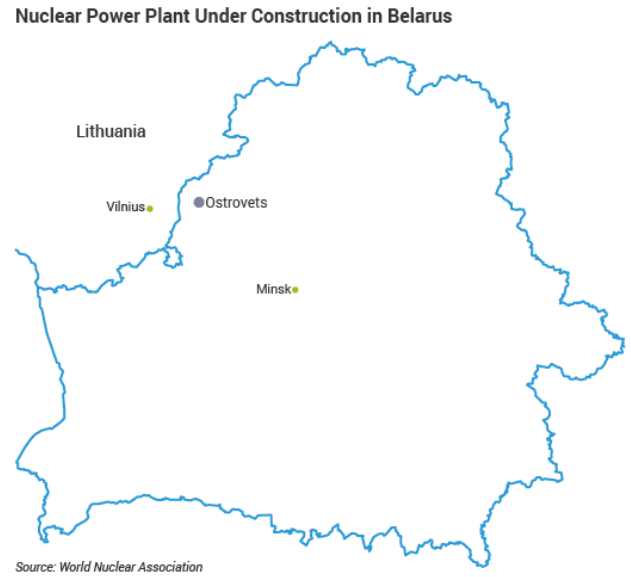
Ukraine

- in 2005-2006 Government decided to focus on finishing Khmelnitski 3 and 4 (construction stopped in 1990 with 75% and 28% work complete)
- five potential suppliers were invited to participate in the tender in 2008, Gidropress, ŠKODA JS, Westinghouse, KEPCO, and Areva ; only Gidropress and KEPCO however submitted their bids and in October 2008, won by Gidropress (VVER-1000 V-392)
- 80% of the funds coming from Russia (loan for 80-85% of the total costs estimated at EUR 3.7 billion, the rest will be provided by Ukraine); Ukraine and Russia never agreed on the government guarantees for this loan, nor on the interest rate, and after Crimea crisis (March 2014) the project was definitelly stalled
- Ukraine and Westinghouse negotiated possible privatization of nuclear power plants in Ukraine
- in August 2016 Energoatom signed an agreement with KHNP, one objective of which is to cooperate on the completion of Khmelnitski 3&4 (the other is Ukraine-EU 'energy bridge' project, exporting power from Khmelnitski 2 to Poland)

Belarus



- dependence on Russian Federation in natural gas (66% TPES)
- 98% of electricity prodced from natural gas
- decision to construct a nuclear power plant in 2006
- site (Astravets) was selected after consultations with experts from the IAEA, Russia, Ukraine and other countries, and approved by IAEA missions in 2008
- four proposals have been received in 2008 from ASE, Westinghouse-Toshiba, Areva and China Guangdong Nuclear Power Corporation
- for different reasons the letter 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
- two units of VVER 1200 V 491 are under construction (Unit 1 start-up in November 2020, Unit 2 in 2021)
- Russian loan of USD 10 billion is for 25 years to finance 90% of the contract between ASE and the Belarus Directorate for Nuclear Power Plant Construction

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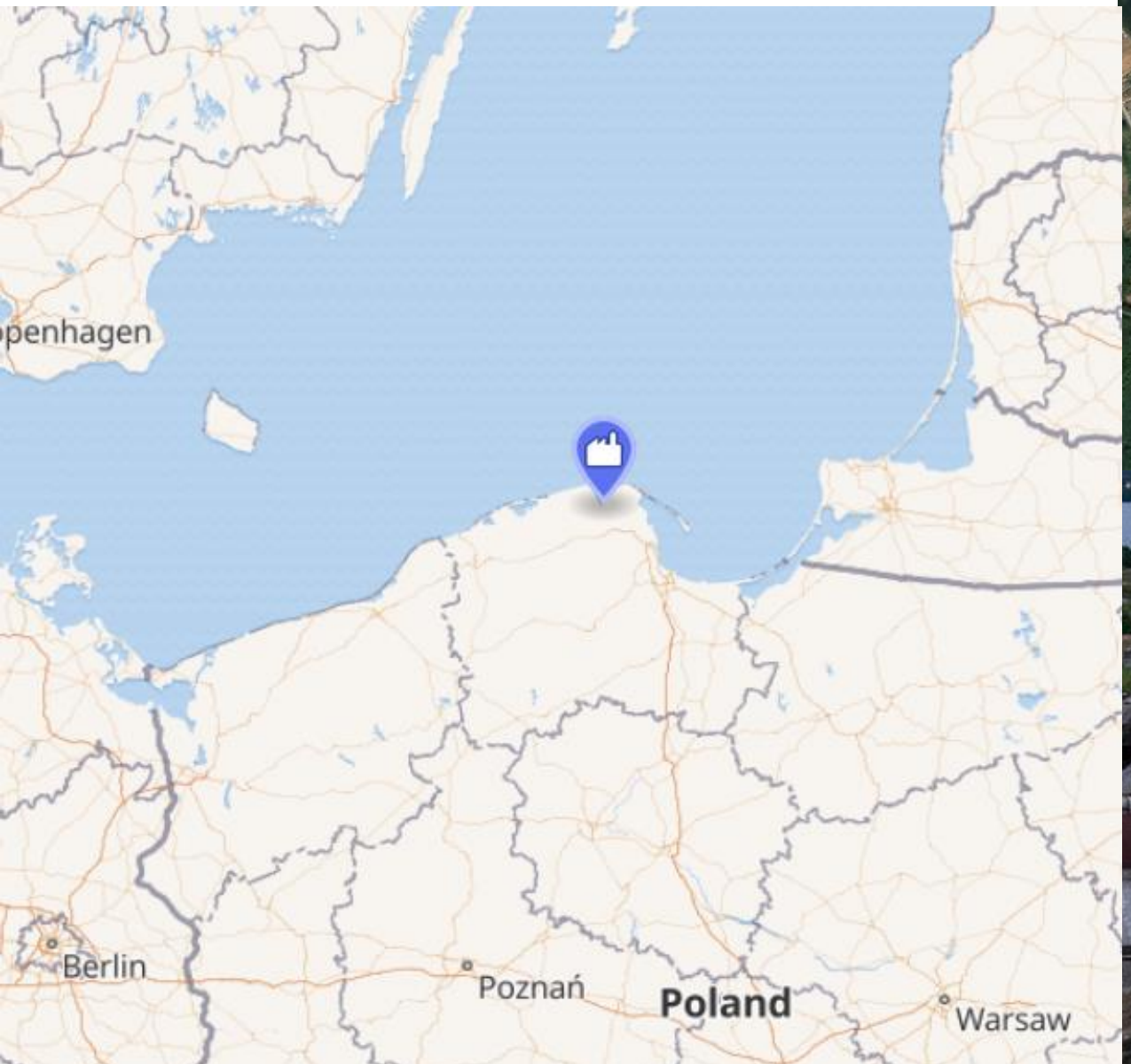
Poland

- decision in 2005 to immediately introduce nuclear power (environmental reasons)
- many successive plans, however delayed
- creation of the National Atomic Energy Agency (Panstwowa Agencja Atomistyki, PAA), which will oversee construction of the plants
- in May 2019 Energy Policy of Poland until 2040 was published (6-9 GWe, of which 1-1.5 GWe operational in 2033)
- each successive unit to follow every two years, replacing coal-fired generation
- in June 2019, Poland signed a bilateral agreement on civil nuclear cooperation with the USA
- Żarnowiec selected as primary location, Bełchatów mentioned as possible second location
- however Choczewo (15 km from Żarnowiec) and Gniewino (10 km from Żarnowiec) targets of localization and environmental studies of PGE EJ1 (to be completed in 2020)
- strong public support (67% favour construction of reactors to strengthen Poland's energy security)

Poland

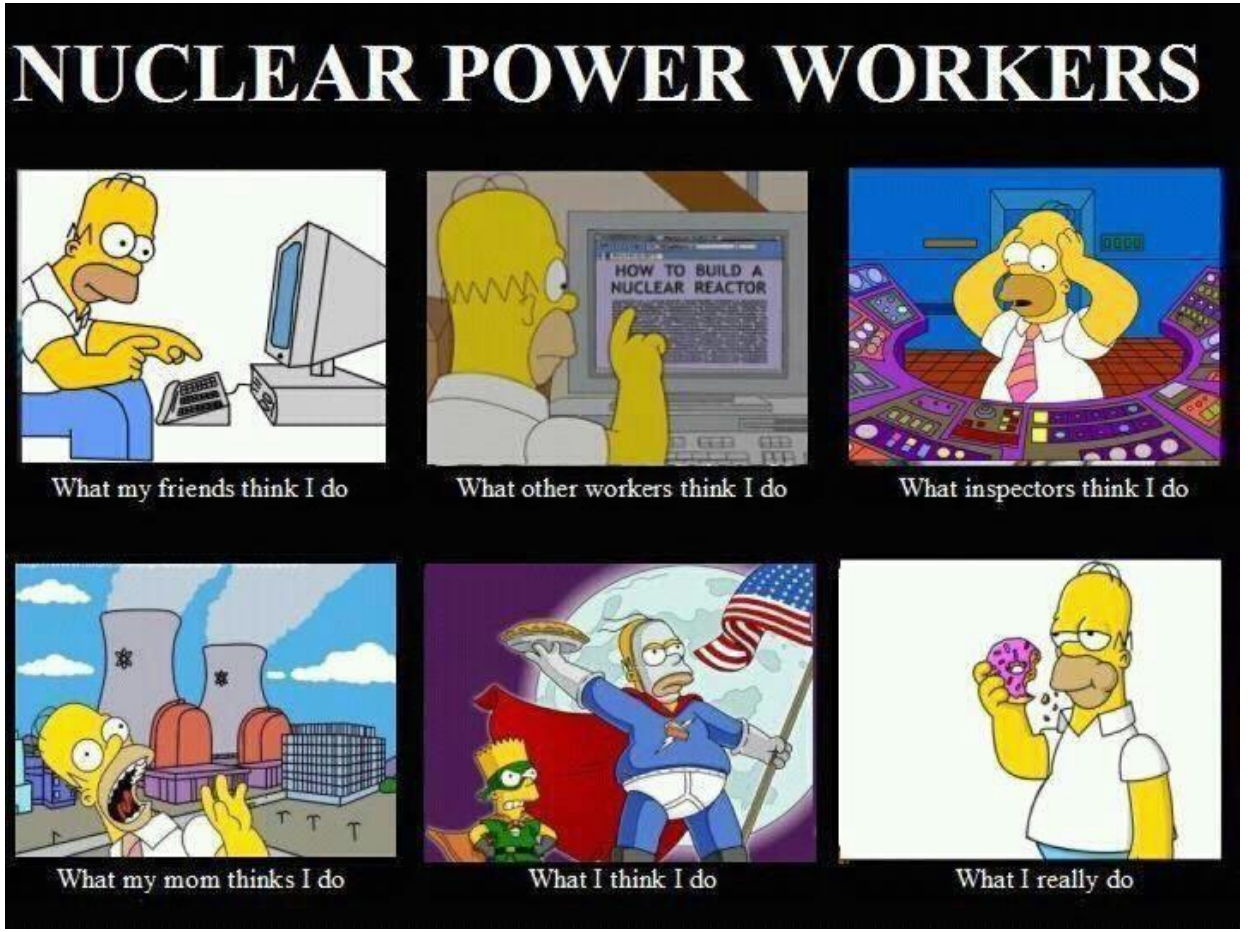

penhagen
Berlin
Poznań
Poland
Warsaw


Żarnowiecka
Kartoszyno
Spokojna
Żarnowiecka
Kaszubska
Żarnowiecka

Summary

- developed and reliable nuclear industry in CEE
- committment to maintenance and further development
- financial aspects the key limitation
- dependence on previous historical patterns (path dependencies)
- dependence on fuel from TVEL (not necessarily on Soviet/Russian technology or Russian service/maintenance)

Thank you for your attention.



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