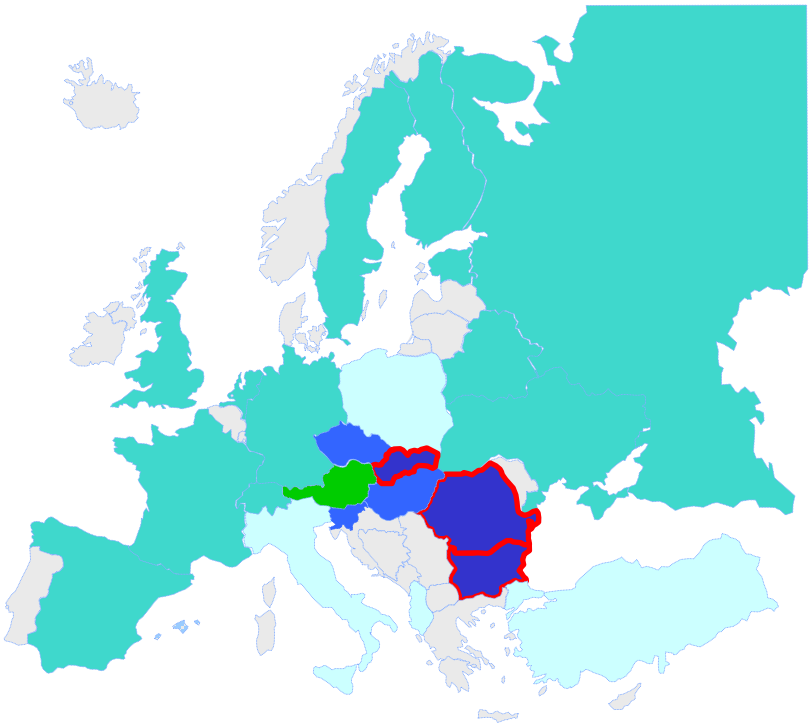
Nuclear Renaissance in Central Europe

David Gilchrist,
ENEL Area Tecnica Nucleare

Nuclear Power in Central Europe



Czech Republic

DUKOVANY
TEMELIN

Slovakia[2]

BOHUNICE 34
MOCHOVCE 12

MOCHOVCE 34

Hungary

PAKS NPP

Bulgaria

KOZLODUY

BELENE

Slovenia

KRSKO

Romania

CERNAVODA 12

CERNAVODA 34

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European Commission – and other politics

- Security of Soviet Reactors after Cernobyl and collapse of USSR - G7/G8 Meetings
- TACIS & PHARE Safety Enhancement programmes - €nB of EU funds 'round tripping'
- EU expansion and accession criteria – "Aquis Communautaire"
- Shutdown of "unsafe" Soviet reactors – namely VVER **230** - Kozloduy, Bohunice
- Regional energy consumption initially declines then recovers
- Old Coal & Lignite power plants subject to CO2 caps
- Energy shortage throughout Central and Eastern Europe
- Electricity is State Priority (after national security)

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SLOVAKIA – ENEL Slovenske Elektrarne

Plant	Installed capacity	Employees	Operation from
EBO 3&4	880*	1594	1984-85
EMO 1&2	880	1480	1998,2000
EVO	880	964	1965-67
ENO	518	973	1954-55
VE	2373**	666	1936

ELEKTRÁRNE

* Excluding EBO V1 units (1&2) which are not owned/operated by SE

**Including the Gabcikovo hydro plant which is not owned, BUT operated by SE

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Slovakia – brief history

- 1993 – Czechoslovakia splits in Velvet Revolution:
  - Czechs get Dukovany, Temelin, Skoda and UJV- Rej & Regulator
  - Slovakia gets Bohunice, Mochovce and Vuje

- Bohunice centre of Czechoslovakian nuclear operational competence since 1957
- A1 Bohunice “own design unit” HWGCR shutdown after core damage in 1977

- VVER 230 units 1 & 2 at EBO commissioned 1978/80 – being closed

- VVER 213 units 3 & 4 at EBO commissioned 1984/85 – Major Upgrades nearly finished

- VVER 213 units 1& 2 at EMO commissioned 1998/2000 – First to match western standards

- VVER 213 units 3&4 mothballed – 1991 – Construction completion contracts to be signed soon, start-up 2013 / 2014

SLOVENSKÉ ELEKTRÁRNE

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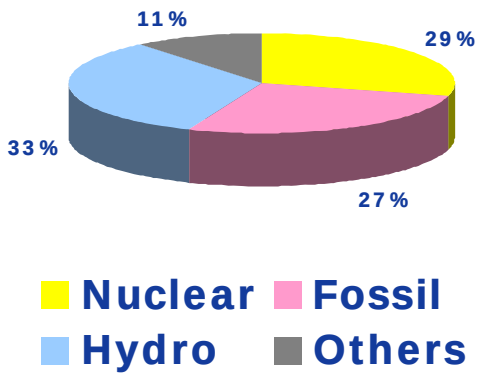
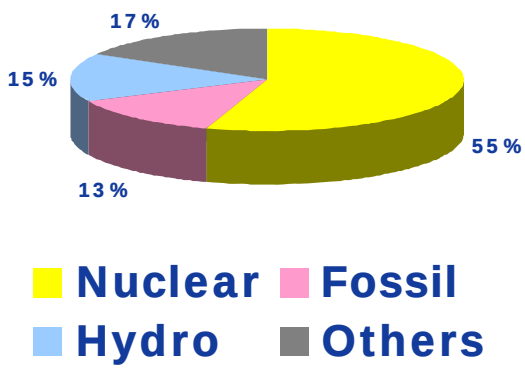
Nuclear Power in Slovakia

- Slovakia is one of four european countries with more than **50%** nuclear electricity generation
- Slovakia was one of the first countries to develop nuclear power with programmes going back **50** years
- Approx. **5,500** people are employed either directly or indirectly in nuclear activitity in Slovakia – total population: 5,4M
- Nuclear has a high level of public acceptability and is rooted in the culture with know-how at all levels including public institutions, engineering companies and the education system.

Installed Capacity



Generation



SLOVENSKÉ ELEKTRÁRNE

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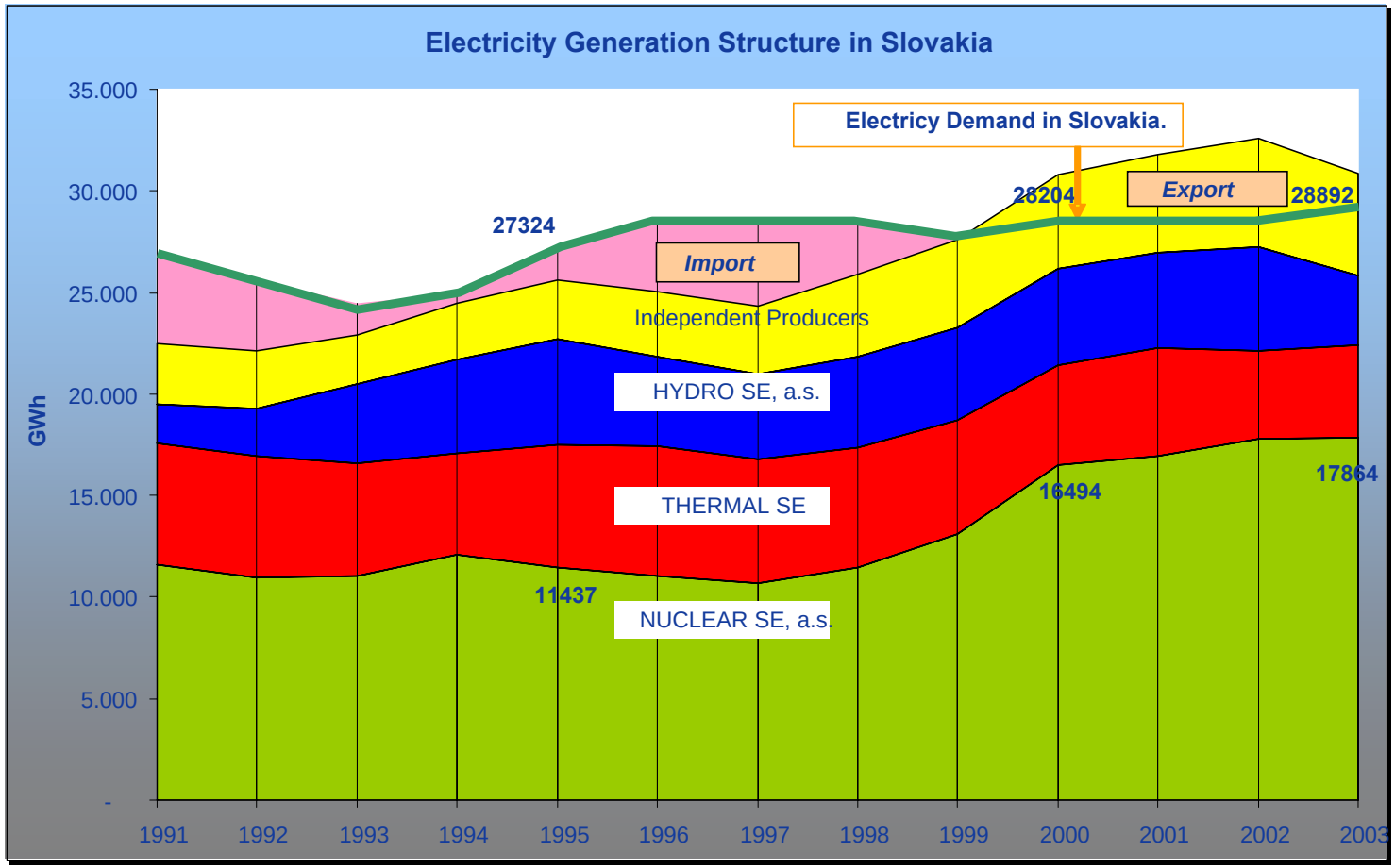
Slovakian Electricity Independence - history



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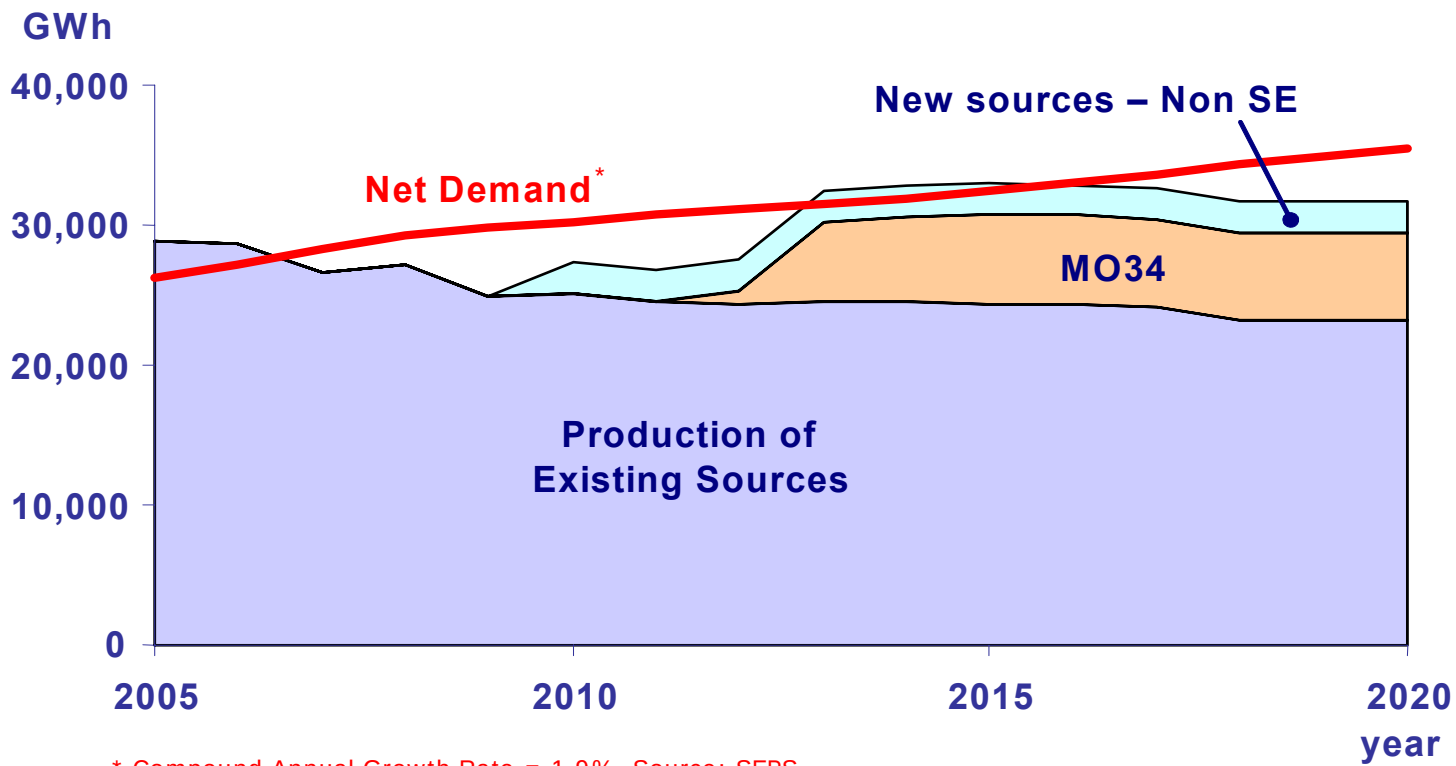
Slovakian Electricity Independence - future



* Compound Annual Growth Rate = 1.9%. Source: SEPS

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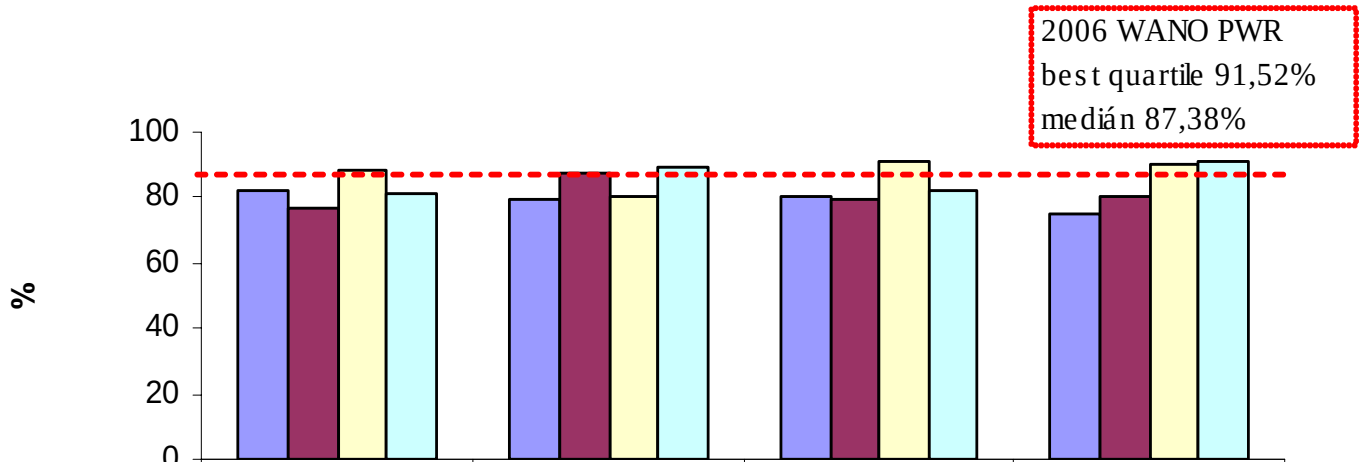
Slovak Nuclear Operational performance

Unit Capability Factor



	R 2004	R 2005	R 2006	R 2007
EBO 3	81.97	79.49	80.73	75.04
EBO 4	76.95	87.32	79.27	79.97
EMO 1	88.58	80.75	90.72	90.06
EMO 2	81.60	89.45	82.07	91.33

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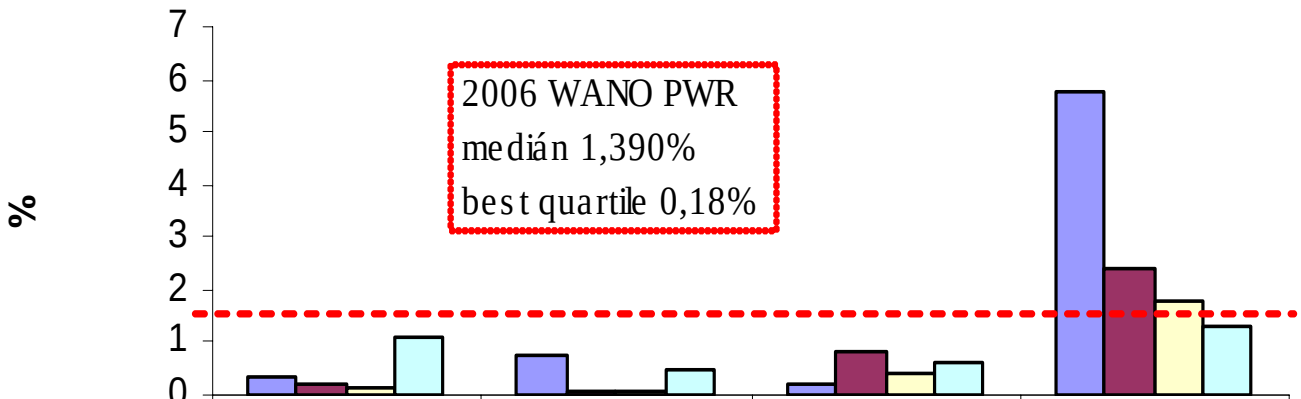
Slovak Nuclear Operational performance

Unit Capability Loss Factor



	R 2004	R 2005	R 2006	R 2007
EBO 3	0.32	0.73	0.24	5.79
EBO 4	0.18	0.05	0.85	2.39
EMO 1	0.13	0.08	0.40	1.78
EMO 2	1.11	0.45	0.60	1.33

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VVER is a very good NPP:

UNIT NAME	World rank*	PWR rank	VVER rank
Brokdorf 1	1	1	–-
Emsland 1	2	2	–-
Sizewell B 1	4	3	–-
Maanshan 2	5	4	–-
Qinshan 2-2	7	5	–-
Tomari 2	10	6	–-
Ulchin C 6	11	7	–-
Balakovo 3 – VVER 1000	12	8	1
Beznau 1	13	9	–-
Yonggwang B 4	14	10	–-
Mochovce 1 – VVER 440	16	12	2

(* WANO 2007 Composite Index – 400+ units)

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View of Bohunice Site

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View of Bohunice V1

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View of Bohunice V2

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Bohunice V2 Main Control Room

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Aerial View of Mochovce

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NE

Control Room Mochovce

NSKÉ
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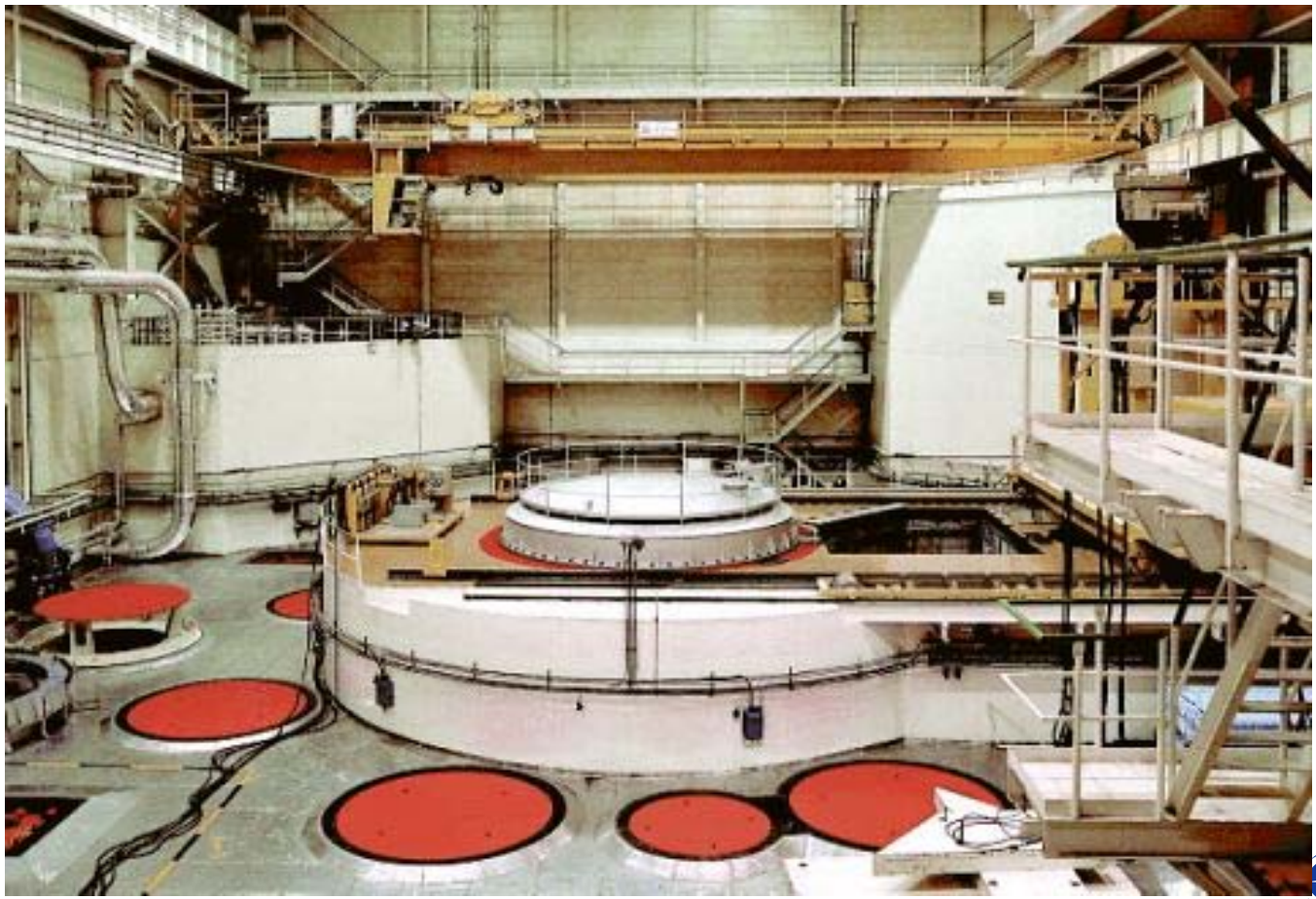
Turbine Generator Hall

VVER Reactor Hall



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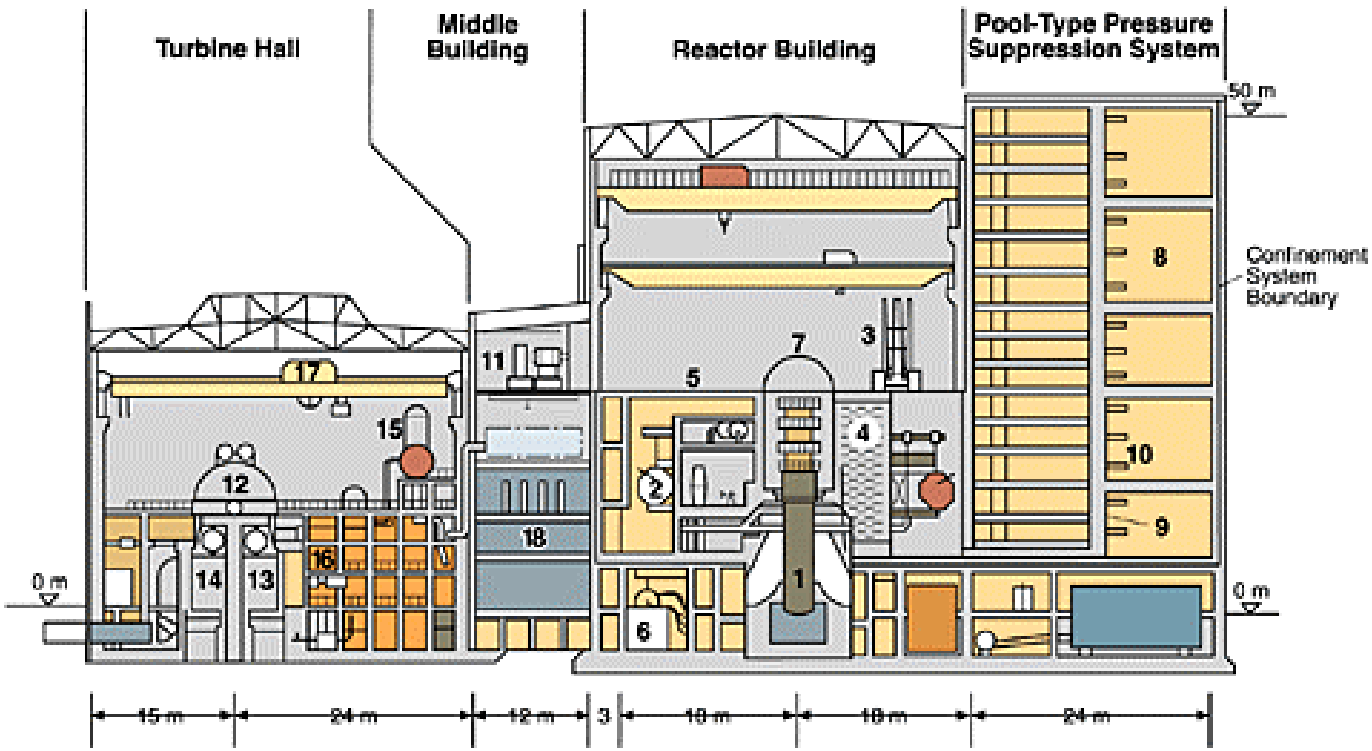
VVER Cross Section

VVER-440/213 Plant Layout



1. Reactor pressure vessel
2. Steam generator
3. Refuelling machine
4. Spent fuel pit
5. Confinement system
6. Make-up feedwater system
7. Protective cover
8. Confinement system
9. Sparging system
10. Check valves
11. Intake air unit
12. Turbine
13. Condenser
14. Turbine block
15. Feedwater tank with degasifier
16. Preheater
17. Turbine hall crane
18. Electrical instrumentation and control compartments

This illustration shows a vertical "cut" through containment with bubble condenser tower.

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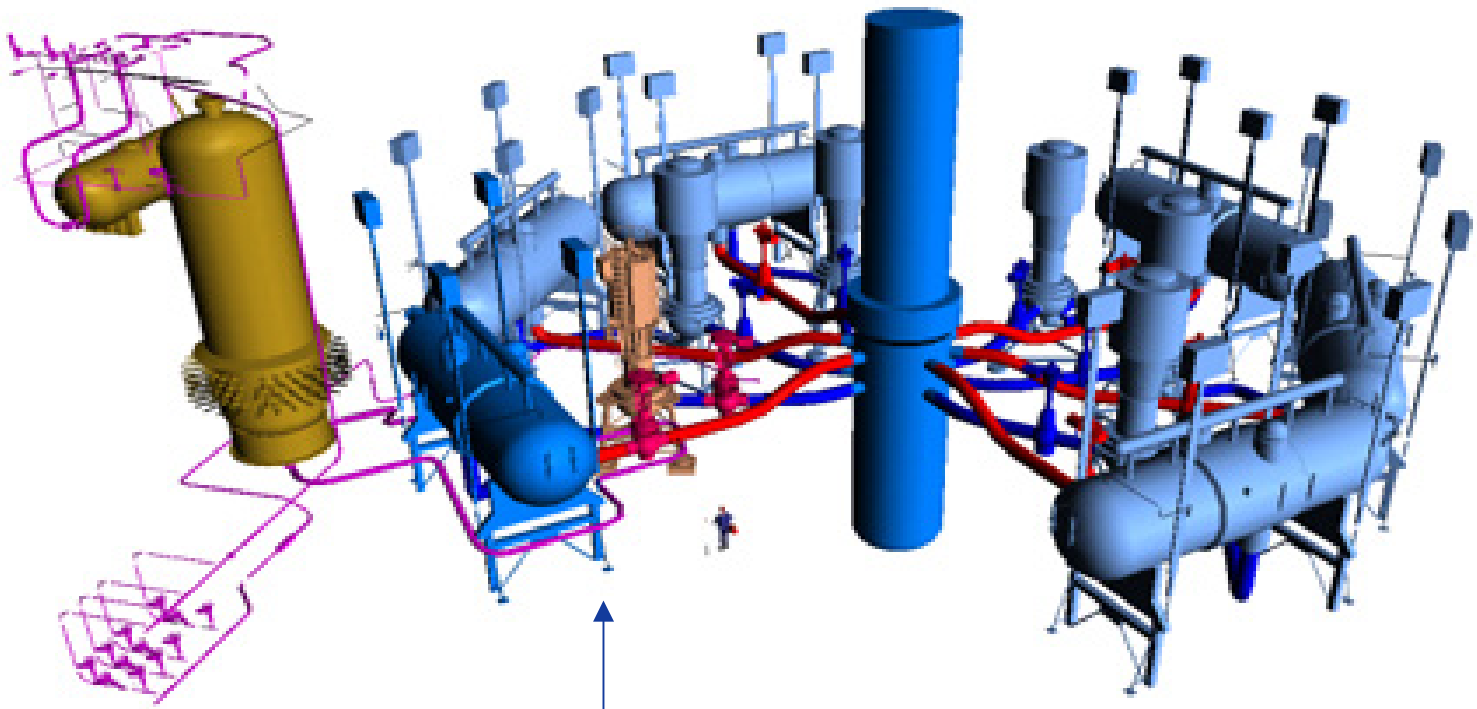
VVER NSSS 3D schematic



Number of coolant loops: 6

Steam pressure: 4.6 MPa

Feedwater temperature: 223 ºC

Steam temperature: 260 ºC

Steam production rate: 452 tons/h

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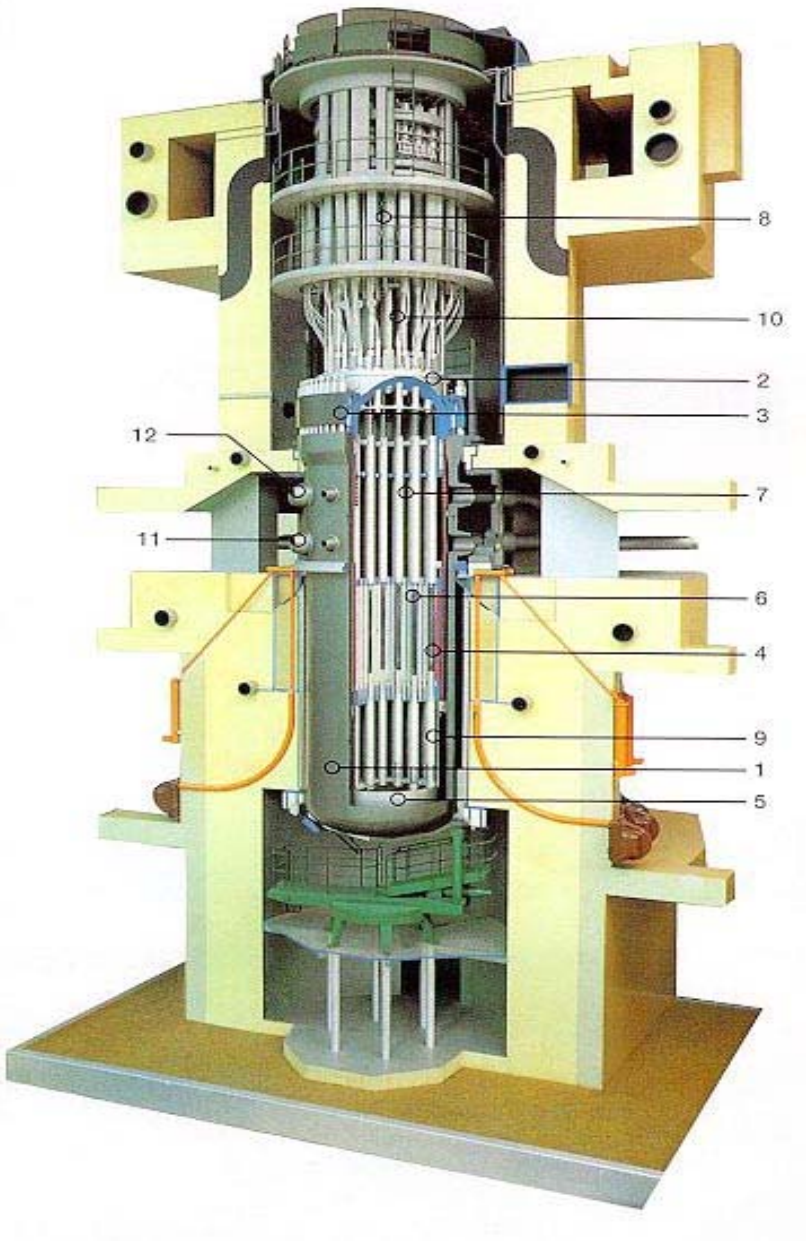
VVER 440/213 Reactor



1 – reactor pressure vessel,

2 – vessel closure head,

3 – free flange,

4 - core barrel,

5 – core barrel bottom,

6 – reactor core,

7 – core hold-down,

8 – upper block,

9 – protection tubes with dumpers,

10 – control rod drives,

11 – inlet nozzle,

12 – outlet nozzle

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Outage – Open Reactor

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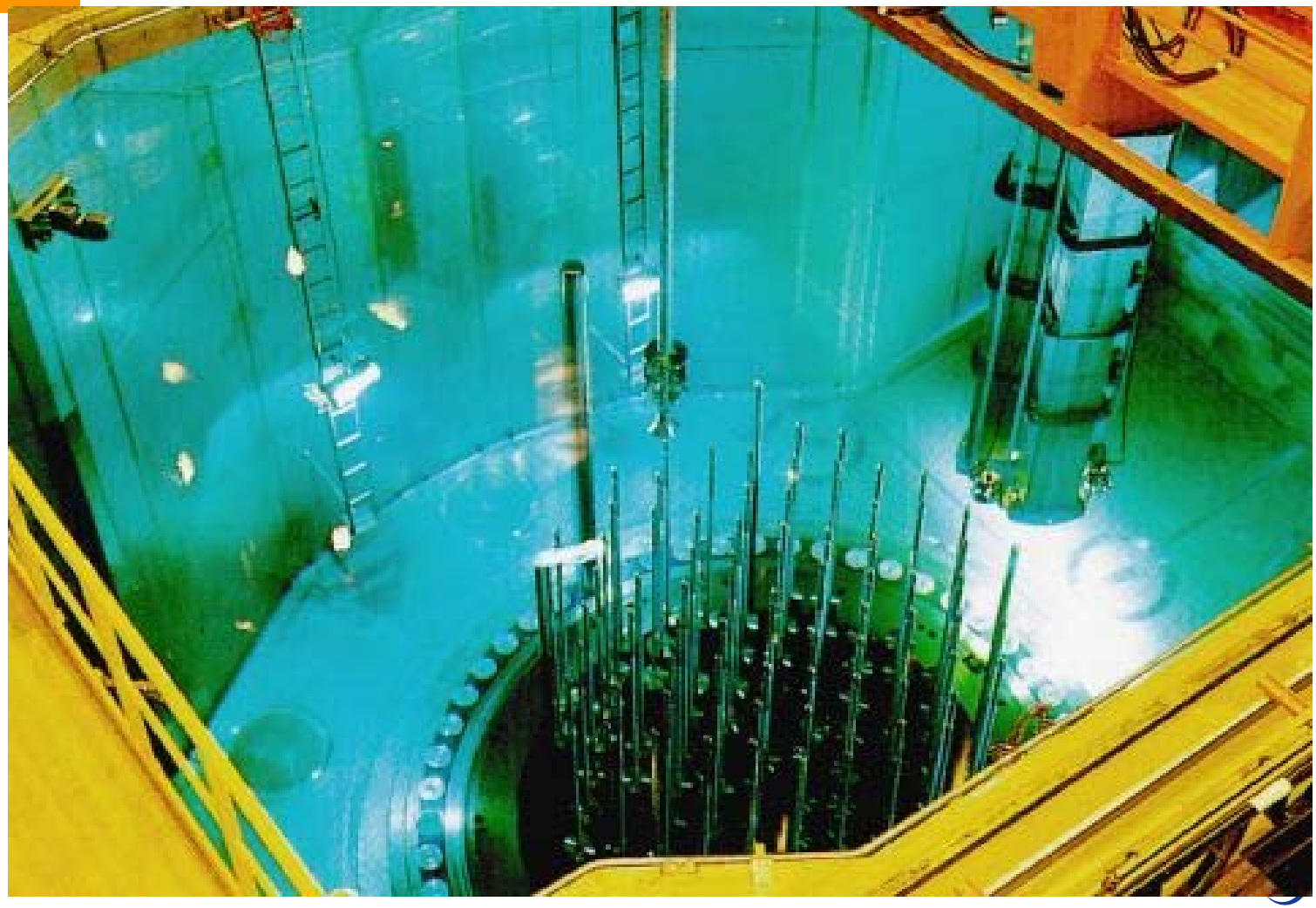
Refuelling



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Control Rod Penetrations

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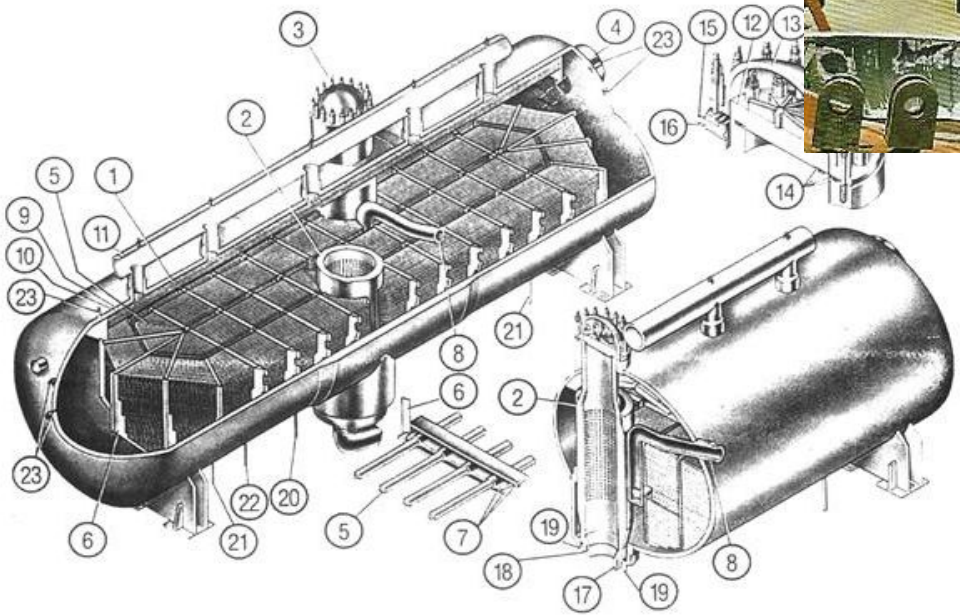
Steam generator



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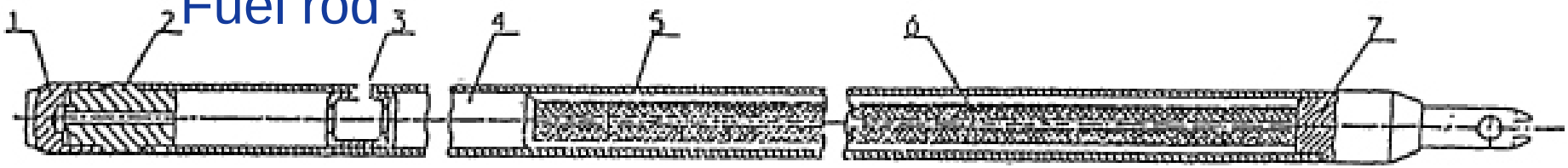
VVER Nuclear Fuel

UO2 Fuel pellets

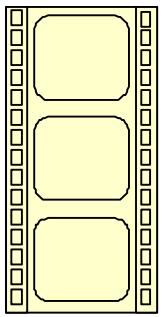
fuel assembly

Fuel rod



Mochovce 3 4

Construction Area



Reactor hall

Turbine hall

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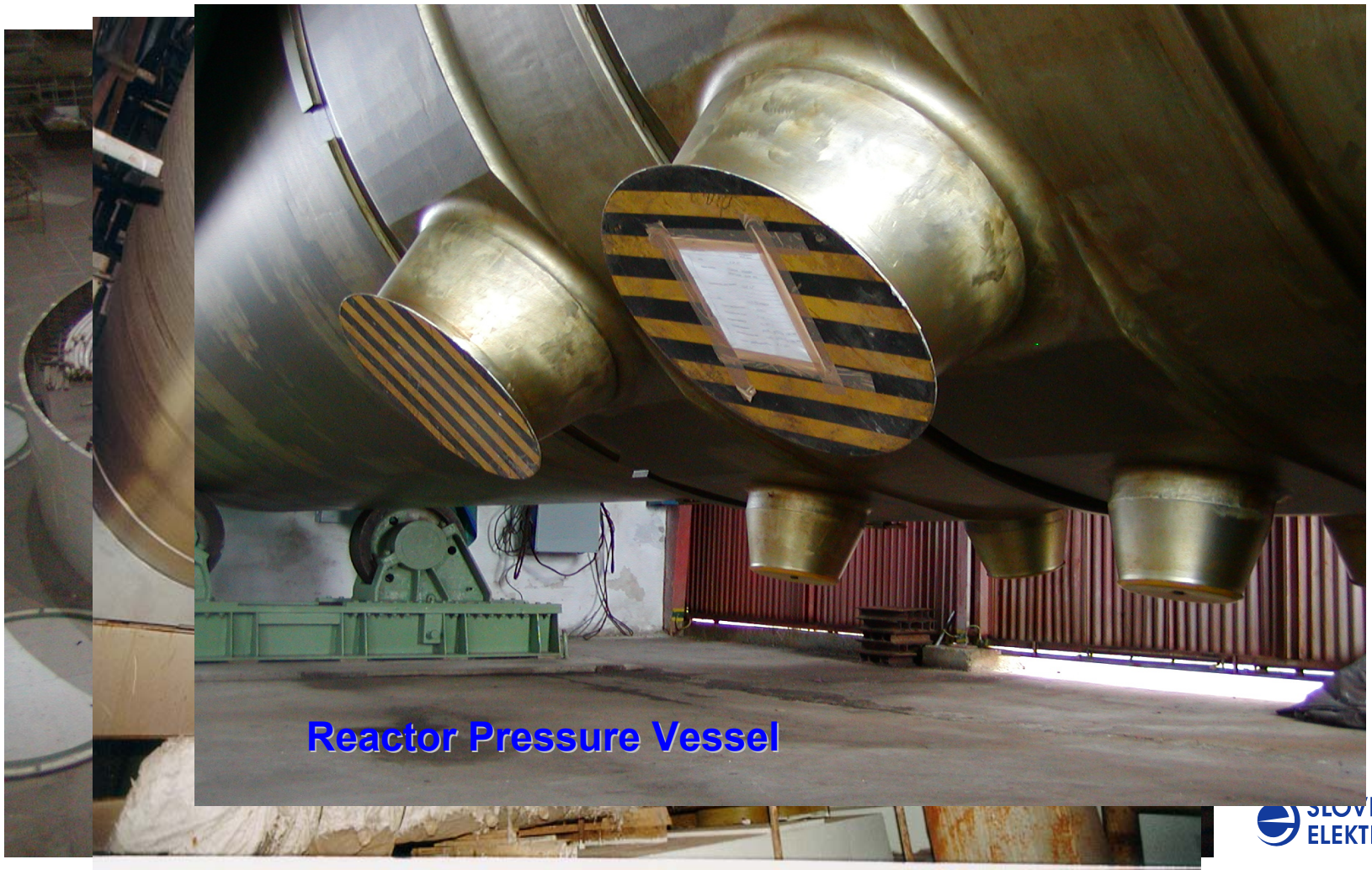
Mochovce 3 4 Components & structures



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Mochovce 3 4: Safety Improvements

Overall review of the original Basic Design in order to introduce **further safety improvements:**

- Further **increase** in accidental events **safety margins** (CDF reduction);
- **Severe accidents management** specific measures, in order to **preserve** the radioactive products containment **barriers' integrity:**
  - **Reactor pressure vessel**
  - **Containment**
- **Improvement** of the **Instrumentation and Control System** and of the **Operator Interface,** in order to improve the operator response in any operating condition;
- **Improvement** of **area events protection** (fire, flood, etc.);
- **Improvement** of **radiation protection** and **monitoring** system.

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Mochovce 3 4 Programme

2006–2007 Feasibility Study

- ✓ **Review of Basic Design**
- ✓ **Finalisation of authorisations**
- ✓ **Environmental Impact Study**
- ✓ **Evaluation of existing assets**
- ✓ **Contract strategy**
- ✓ **Budget and schedule**
- ✓ **Operational model and costs**
- ✓ **Fuel Cycle**
- ✓ **Decommissioning Strategy and Costs**
- ✓ **Financing model**
- ✓ **Business model & Sensitivity Analysis**
- ✓ **Risk analysis**

2007–2008 Site Preparation, Contract Preparation

- ✓ Separation between Mochovce 1-2 and 34 construction site
- ✓ Preparation of **Infrastructure** & **Logistics**
- ✓ Access Control
- ✓ Preparation of **documentation: technical** / **commercial** / **legal** for main **contracts**

2008–2009 Finalisation of Main Contracts

- ✓ **Nuclear Island**, **EPCM** for **Conventional**, **Instrumentation &Control**, Simulator, Steam Turbines, Civil Works, Erection All Risk, etc

2008–2013/14 Plant completion

- ✓ **Re-start site construction**
- ✓ **Commissioning**
- ✓ **Start Commercial Operations** (COD)

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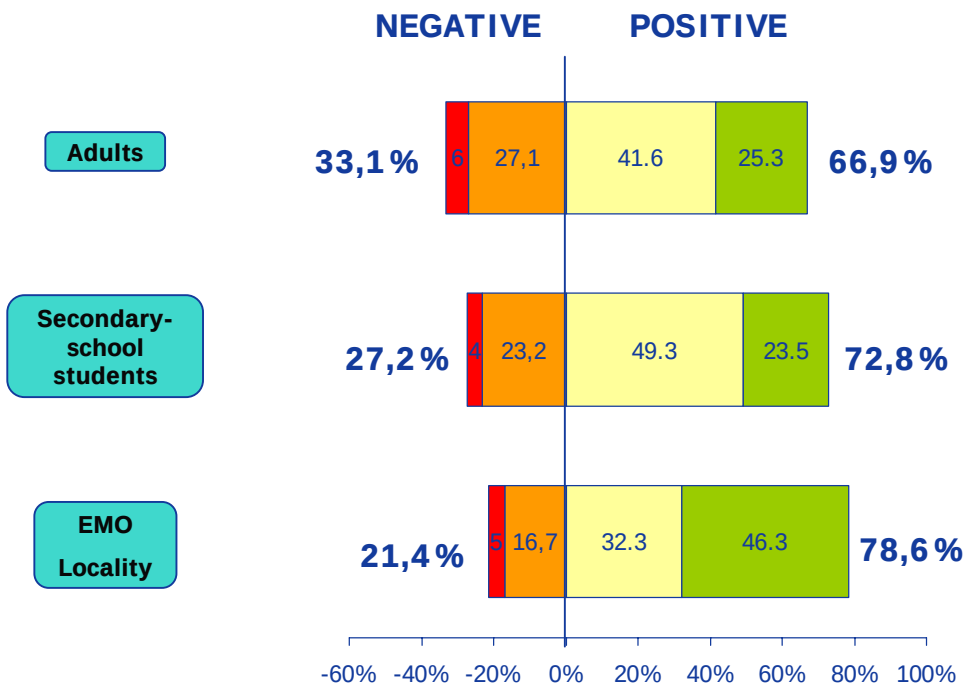
Mochovce 3 4 – public acceptability



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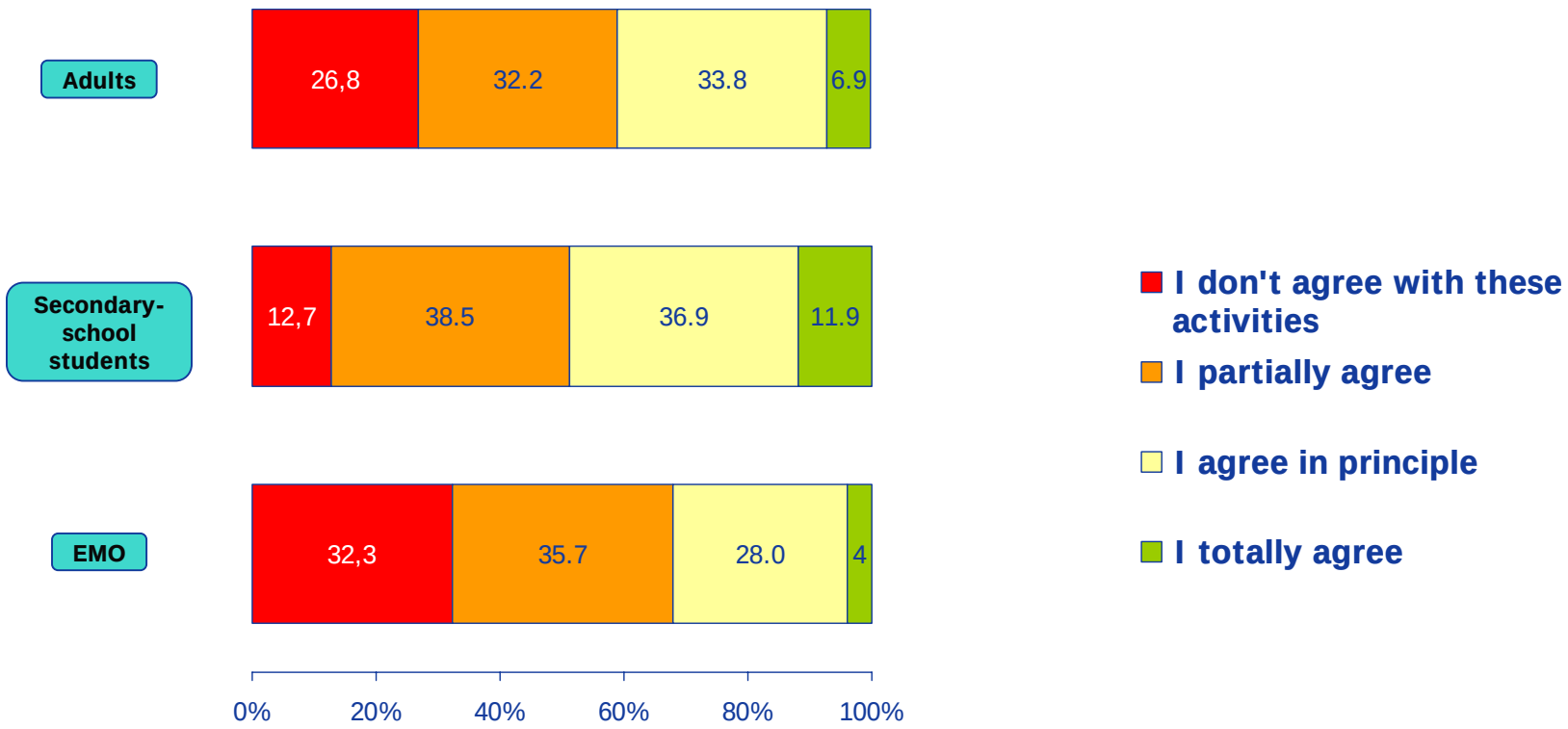
Mochovce 3 4 – public attitude to protests



Western Neighbours - Austria

- Possibly most anti-nuclear member of EU
- Not signatory to Vienna or Paris Convention
- Sustained objections to Mochovce, Temelin
- Obligatory consultee under ESPOO*

* European Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment; as amended by Council Directives 97/11/EC and 2003/35/EC; Convention on Environmental Impact Assessment (EIA) in a Transboundary Context, ESPOO, 1991.

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BULGARIA

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Bulgaria - History

•Construction of first two VVER 230 commenced in April 1970 at Kozloduy and were put into commercial operation in 1974 & 1975

•1973 construction of further two units began with start up 1980

•1982 Units K5 and K6 (VVER-1000/V-320 reactors) began with start up 1988

•Construction at Belene began in 1987 but suspended in 1991 due to political and economic reasons

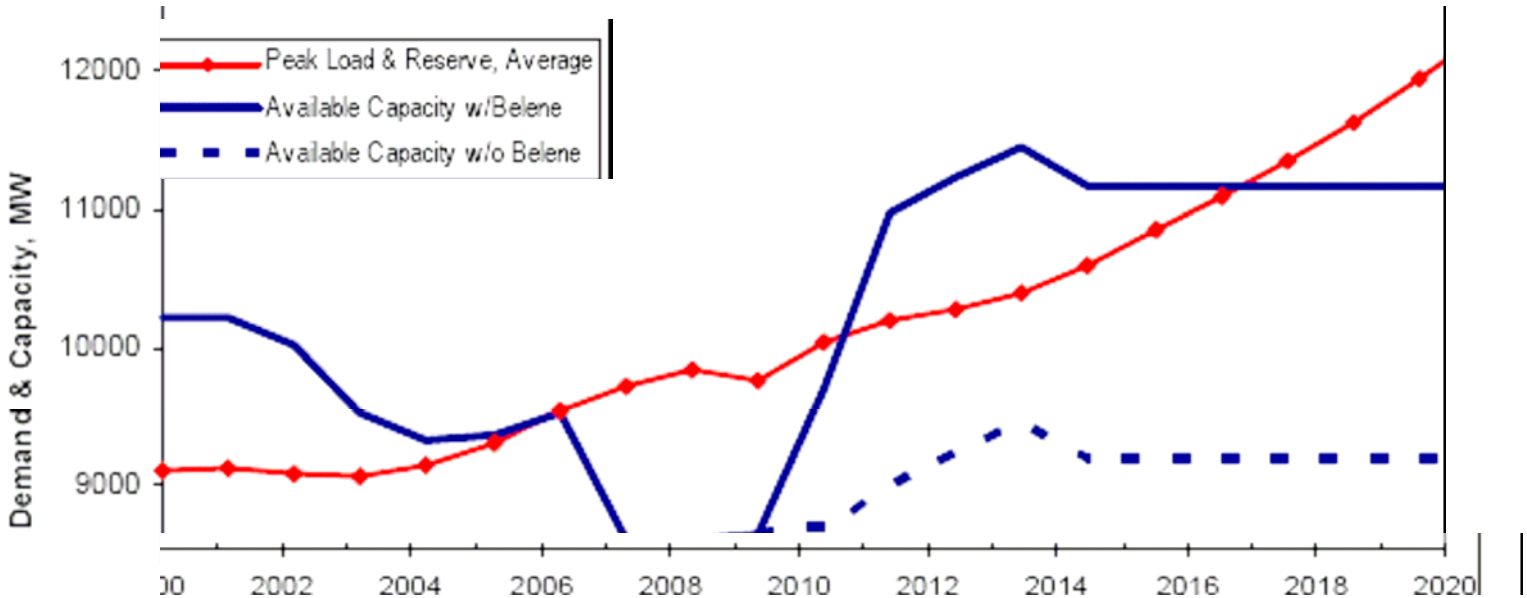
•1993 Kozloduy site capacity was 3,760 MW.

•Units K1 and K2 were shutdown in 2002 and K3 and K4 in 2006.

•K5 and K6 likely to continue to 2030 and beyond

Sources: various

Bulgaria – Capacity & Reserve



Source: NEK

Kozloduy

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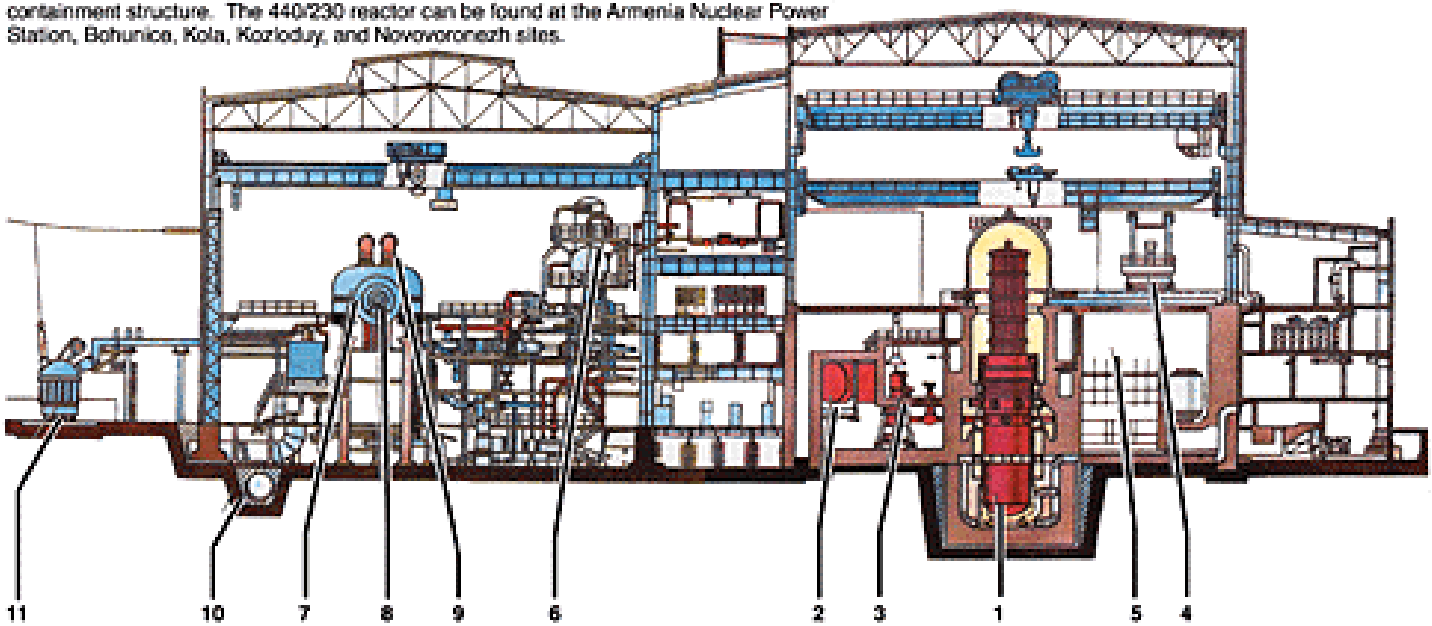
Kozloduy VVER-440 Model 230 Plant Layout

The VVER reactor is a pressurized, light-water cooled and -moderated reactor similar to Western pressurized water reactors (PWRs). There are three predominant models in operation, the VVER-1000 and two versions of the VVER-440.

The VVER-440/230 reactor was the initial civilian model of the Soviet PWR. It is similar to Western PWRs in that it uses low-enriched uranium oxide fuel, placed in thin metal-clad rods, to generate heat. The fuel rods are cooled by pressurized light water. The steam to run the turbine generator is produced when pressurized, heated water from the reactor is pumped through steam generators where it transfers its heat to a separate secondary coolant.

The steam is routed to the turbine generator, which produces about 440 megawatts of electricity. The VVER-440/230, although similar to Western PWRs, lacks a number of safety features, including fire protection systems, emergency core cooling systems, and a strong containment structure. The 440/230 reactor can be found at the Armenia Nuclear Power Station, Bohunice, Kola, Kozloduy, and Novovoronezh sites.

1. Reactor
2. Steam generator
3. Main circulation pump
4. Refueling machine
5. Spent fuel cooling pond
6. Deaerator
7. Steam turbine
8. Generator
9. Steam pipelines
10. Cooling water pipelines
11. Transformer



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Belene

- Two AES92 (Advanced VVER1000 – Reference Plant: Kudankulam in India)
- Atomstroyexport, AREVA and Siemens

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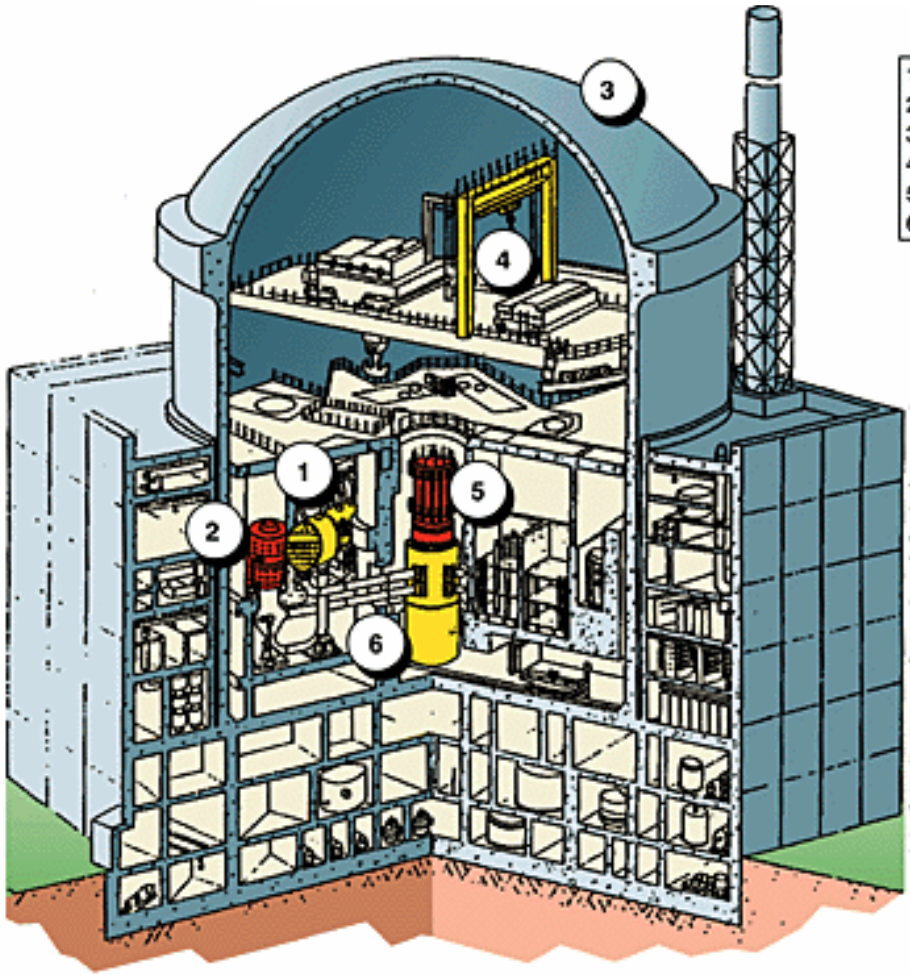
Belene – AES 92



The VVER reactor is a pressurized, light-water-cooled and -moderated reactor similar to Western pressurized water reactors (PWRs). There are three predominant models in operation, the VVER-1000 and two versions of the VVER-440.

The VVER-1000 is the largest and newest of the VVERs. This third-generation design produces about 1000 megawatts of electricity and meets most international safety standards. The VVER-1000 employs safety systems common in Western plants, including emergency core cooling systems and a containment structure. The VVER-1000 can be found at the Balakovo, Kalinin, Khmelnytskyy, Kozloduy, Novovoronezh, Rivne, South Ukraine, and Zaporizhzhya sites.

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Belene - developments

•2004, the Government authorised new nuclear development by the state owned generator Natsionalna Elektricheska Kompania (“NEK”)

•18th of January 2008: Atomstroyexport and NEC signed contract in the presence of the Russian President Vladimir Putin and the Bulgarian President Georgi Parvanov

•€4B turn-key project and provides engineering, supply and construction

•Design meets EUR requirements and has EURATOM Art 41 approval

Source: Sofia Echo

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Belene – but.....

•July 2008: BNP Paribas chooses not to commit any of its own money to fund the project, even though it has been picked to find financing, but will act only as an adviser

•Bankers said that it was unusual for a bank picked to structure finance for such a big project not to make a contribution, and that it sent a message of caution to other prospective financial institutions.

•With the costs of the project rising because of higher commodity prices and financial markets still in the throes of the global credit crunch, banks could be reluctant to get involved.

Source: Sofia Echo

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Did I forget to mention green lobbying ?

Source: Sofia Echo

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Belene – will Russia come to the rescue.....?

“Even Bulgaria's ever optimistic Economy and Energy Minister Petar Dimitrov has had to concede that the country's plans to build a second nuclear power plant at Belene on the Danube River face an uphill struggle to secure financing for construction to begin.”

“July 7, Dimitrov said that funding "could not be secured", still: "There are some candidates, but the most visible one is Vladimir Putin".”

Source: Sofia Echo

ROMANIA

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Nuclear history in Romania

1976 – completion of Romanian-Canadian feasibility study for the CANDU system

1978 – Agreement between ROMENERGO and AECL for CANDU technology

1981 – Contracts with ROMENERGO, Ansaldo (Italy) and General Electric (USA) for the conventional part (BOP) of Unit 1 were concluded

1982 - First Containment Concrete poured

1989 - Romanian revolution; The Cernavodã NPP Unit 1 is 45% complete

1996 - Unit 1 is declared in commercial operation - December

1998 - Societatea Nationala Nuclearelectrica" S A established

2003 - Canadian, Italian , French and USA loan agreements with Societe Generale, Credit Lyonnais and Romanian Bank for Development

2004 - EURATOM Loan approved subject to the implementation of improvements

2007 - 300 days of continuous operation at Unit 1

2007 - Unit 2 reaches full power during commissioning tests

2007 - Official inauguration of Cernavoda Unit 2 - October 5

Source Nuclearelectrica

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Cernavoda

AECL CANDU 6 Units 1,2,3,4,5

Unit	Reactor	Capacity (MWe)		In-Service Date
		Net	Gross	
1	PHWR CANDU-6	655	706.5	07/11/96
2	PHWR CANDU-6	650	706.5	November 2007

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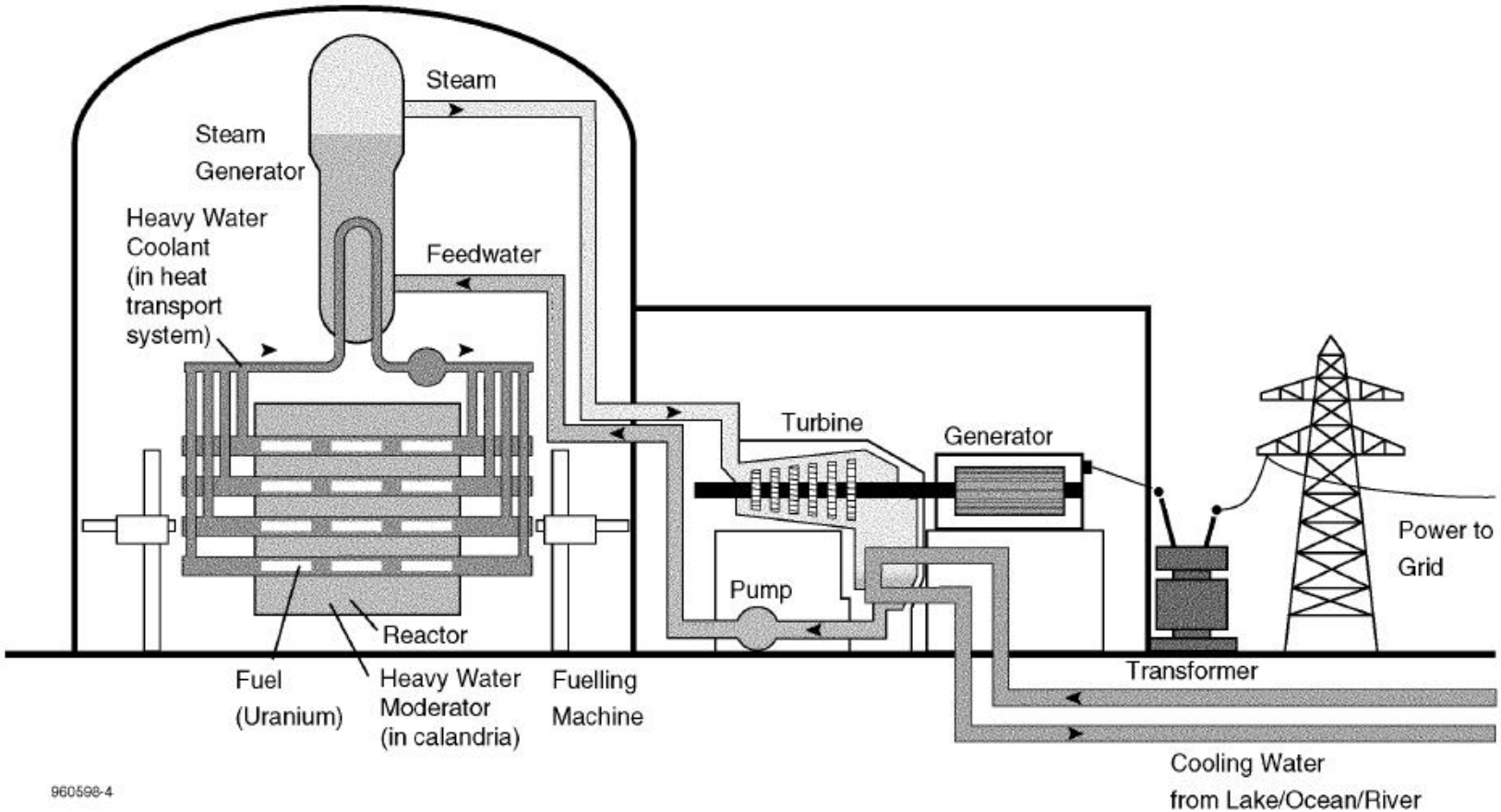
Candu 6


Steam
Steam Generator
Heavy Water Coolant (in heat transport system)
Feedwater
Turbine
Generator
Power to Grid
Pump
Reactor
Transformer
Fuel (Uranium)
Heavy Water Moderator (in calandria)
Fuelling Machine
Cooling Water from Lake/Ocean/River
960598-4

Candu 6 performance

Unit	Location	In service date	Gross output	Lifetime UCF*
Point Lepreau	Canada	Feb. 01, 1983	680 MWe	83,2 %
Wolsong 1	Korea	Apr. 22, 1983	679 MWe	85,8 %
Gentilly 2	Canada	Oct. 01, 1983	675 MWe	80 %
Embalse	Argentina	Jan. 20, 1984	648 MWe	88,5 %
Cernavoda 1	Romania	Dec. 02, 1996	706 MWe	87,3 %
Wolsong 2	Korea	July 1, 1997	715 MWe	89,1 %
Wolsong 3	Korea	July 1, 1998	715 MWe	90,5 %
Wolsong 4	Korea	Oct. 1, 1998	715 MWe	92,3 %
Qinshan 1	China	Dec. 31, 2002	728 MWe	82,7 %
Qinshan 2	China	July 24, 2003	728 MWe	93 %

Source IAEA PRIS

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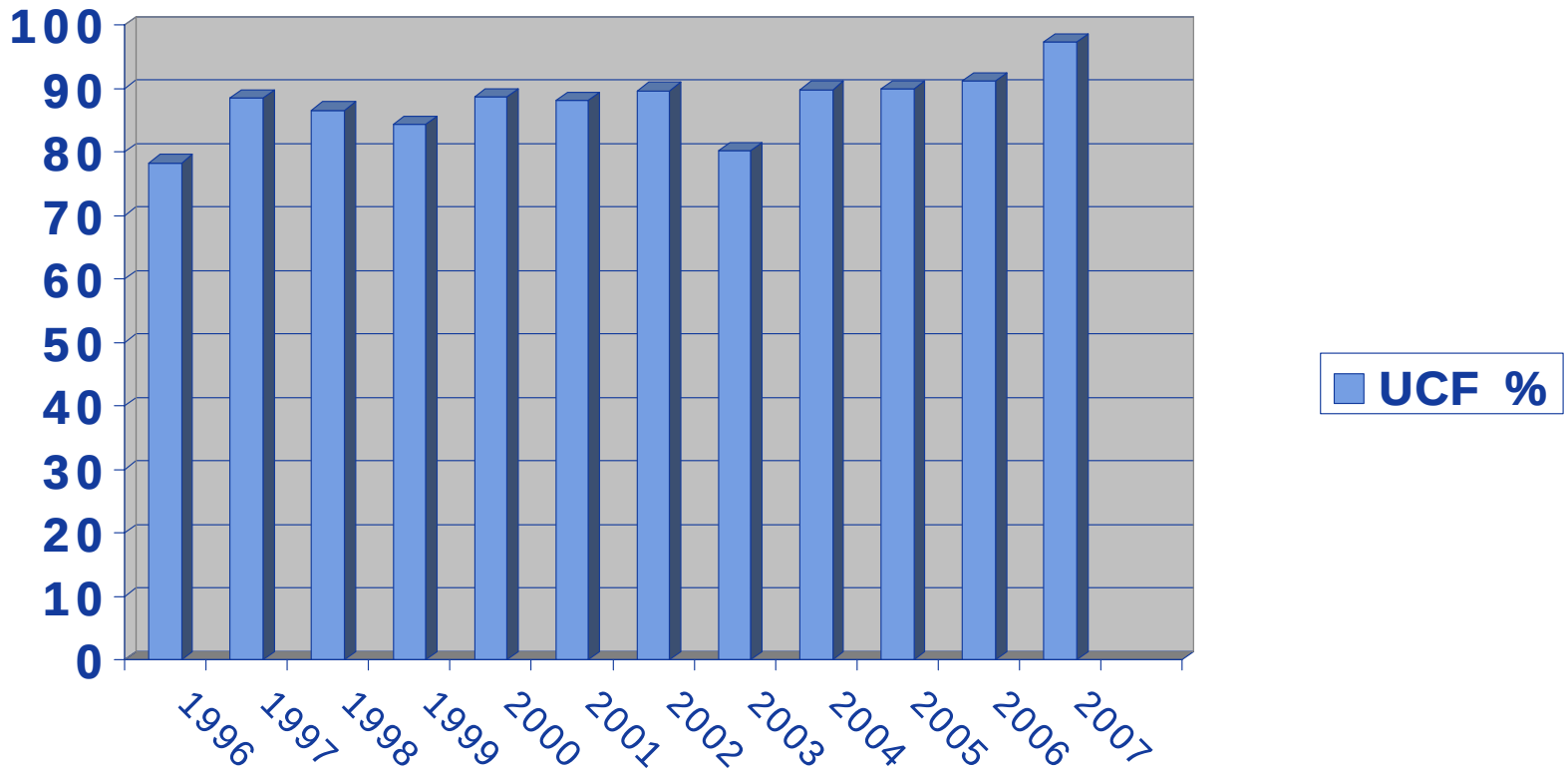
Cernavoda Unit 1 performance



Source IAEA PRIS

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Cernavoda 3 4 - tendering process

•2006 tender launched - 16 companies interested, including Enel, E.ON, Iberdrola and RWE, as well as a consortium between Canada's AECL and Ansaldo (This consortium built Units 1& 2).

• 2007 - Government changes strategy over the financing of the project.

•Aug. 2007 Romanian government re-launches tender for Units 3 & 4 at Cernavoda, (start up around 2014-2015).

•Deloitte and Touche feasibility study estimated costs at €2.2B

•Proposed ownership structure:

- Nuclearelectrica 20%,
- Enel, RWE, Electrabel, CEZ, Iberdrola and ArcelorMittal – 80%.

•Winter 2007/08 due diligence takes place

•Project company to have been established in May 2008

Source: CNNMoney.com - August 03, 2007

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Cernavoda 3 4 – tendering process

•June 2008 – Prime Minister Calin Popescu-Tariceanu announces that Nuclearelectrica will hold a minimum of 51 pct, in the Cernavoda 3 and 4 project company, funds to be sourced from State

•July 2008 - Nuclearelectrica seeks Competition Council clearance – State Aids issue

•Electrabel indicates a “huge delay” against the scheduled deadline because of the change

•Nuclearelectrica states that several other European companies are interested in participating in the project, if any of the investors withdraw.

Sources: Financiarul, The Diplomat, Bucarest

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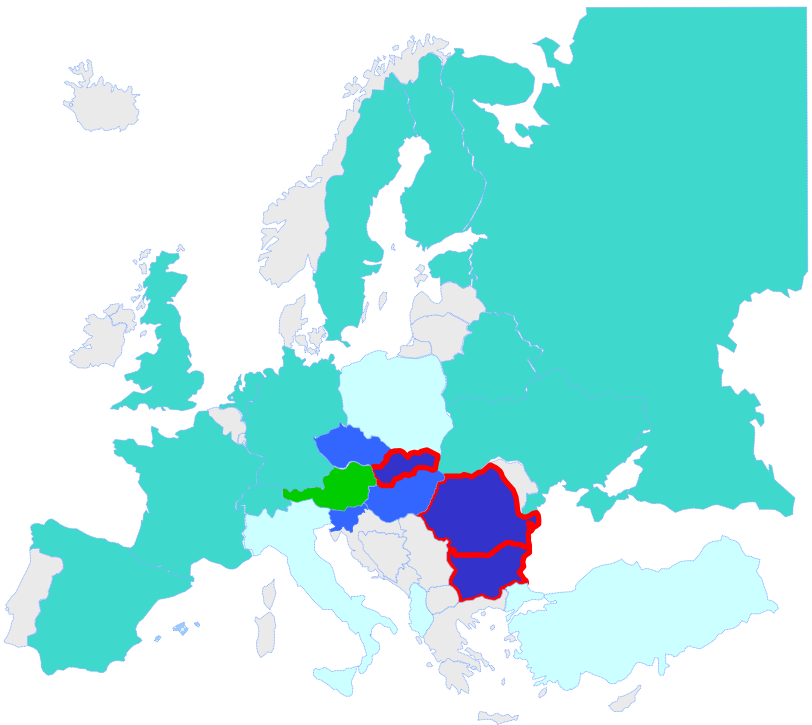
Nuclear Progress in Central Europe ?



Slovakia[2]

BOHUNICE 34
MOCHOVCE 12

MOCHOVCE 34

Bulgaria

KOZLODUY

BELENE

Romania

CERNAVODA 12

CERNAVODA 34

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Central Europe – some observations

- **Strong Government and Public support for Nuclear**
  - » Drivers: Energy Independence, economics and national competences
- **Cash Shortages / EU barriers against State investment**
- **“Strategic Investors” sought after -**
  - » Much interest but so far little cash invested
- **Strong expectation of State control over generation projects and prices**
- **Unfamiliarity with western capital project disciplines**
- **Weak Grid infrastructure limits Unit Capacity to 1GWe max – EPR is too big**
- **Does the “Uranium Curtain” still exist ?**

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