New Electricity Generating Installations - Czech Experience

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Abstract

Economically and technically are analysed alternatives for new electricity generation installations (GEN III+ NPPs, finalization of NPPs under construction, lifetime extension of existing NPPs, coal plants and gas plants. Described are experienced with NPP Temelín (lessons learned from its design, construction, start-up and resent operation and service experience) and new Czech Energy Policy, where the nuclear energy is an important source for electricity generation. Discussed is also impact of potential trading with CO2 limits and strategy on minimization of dependence on energy from politically unstable regions. Underlined is important role of preparation of young generation for safe and reliable long term operation of NPPs. General recommendation is to orient on finalization of NPPs under construction, lifetime extension of existing NPPs and long term orientation on new generation of NPPs (GEN III+ and GEN IV).

1. Introduction

In 21[st] century, energy, aside of its obvious role in human life and all human activities, has become a key strategic and political issue. Its shortage can undermine social and economic stability of whole regions and nations. Greenhouse gases accompanying utilisation of fossil fuels present global threat for mankind. What more the large size of investments and lifetime of electricity generation installations require strong state regulation and establishing of long-term energy policy.

Nuclear energy is one of the options which promises sustainable electricity production, therefore Czech Republic has a stable commitment to nuclear power.

This paper summarises:
- Our cost estimation for new electricity generating installation for Czech Republic conditions,
- Experience gained with finalization of NPP Temelin and
- Newly approved Czech Energy policy.

Because of similarity of Czech and Bulgarian energy sector conditions we are trying to apply our experience for the decision-making on Belene NPP finalization.

2. New power plants economy

Feasible alternatives for extension of existing electricity generation capacity:
- Construction of new installations
- Finalization of interrupted projects advantages:
    - No time required for new site development
    - No loses of already spent finances
    - Elimination of expenditures for liquidation of already built facilities
- Service life extension of units in operation in majority of cases this option is the most advantageous one:
    - Necessary improvement and reconstructions can be performed partly without interrupting operation
    - Expenditures are substantially lower than for new investments

  problem is whether the technically feasible improvements will be sufficient to meet existing requirements (efficiency, safety, waste and emissions).

If new installation is necessary, what type?:
- Fossil (coal and gas)
    - Current technologies have high efficiency (coal 42-45% for supercritical steam, gas - 50-60% with combined cycle)
    - Coal is acceptably mainly for domestic resources due to high transport costs
    - Gas in the majority of cases is imported from unstable regions

  - Greenhouse gases can become an expensive problem
  - Coal burning produce large amount of waste (ash) with potential high cost of transport and deposition
- Nuclear
  - Relatively low efficiency 33-35% of current technology (generation III and III+), realistic target for generation IV (50%)
  - Low fuel cycle costs, with high potential for spent fuel recycling and depleted uranium utilisation in generation IV
  - Negligible greenhouse gases
  - No commercially available deep repository for high level waste
- Renewables
  - Hydropower – very good solution, but geographically limited
  - Biomass – acceptable as supplementary source due to land limitation
  - Wind, PV etc. is without strong subsidies uneconomical, can play only marginal role

Comparison of electricity generation cost for different solution is in the following graphs.

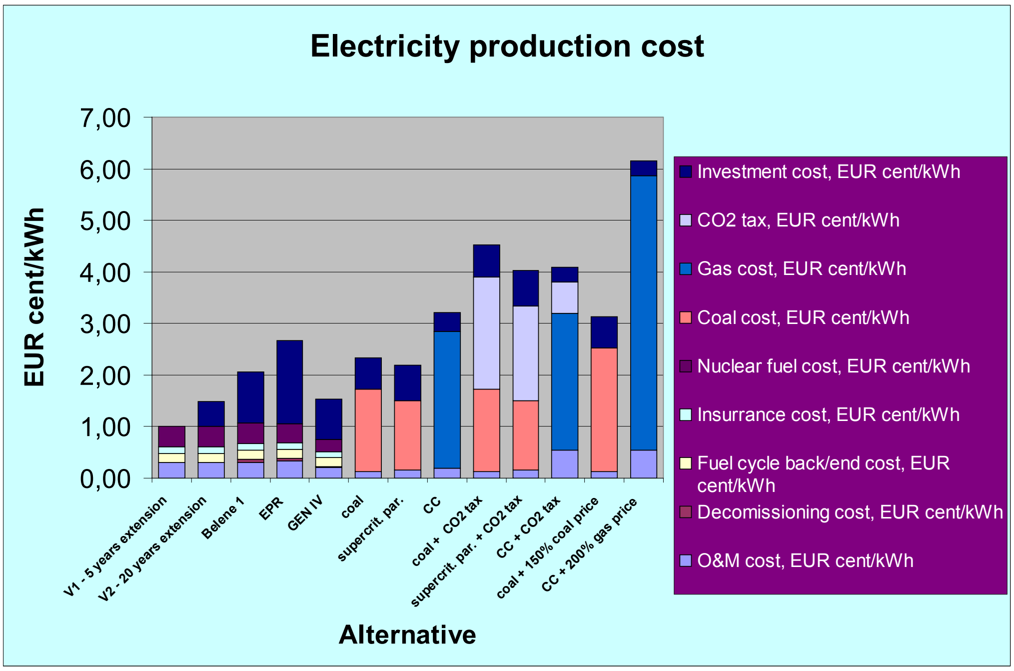

Fig. 1. Comparison of nuclear and fossil power plants

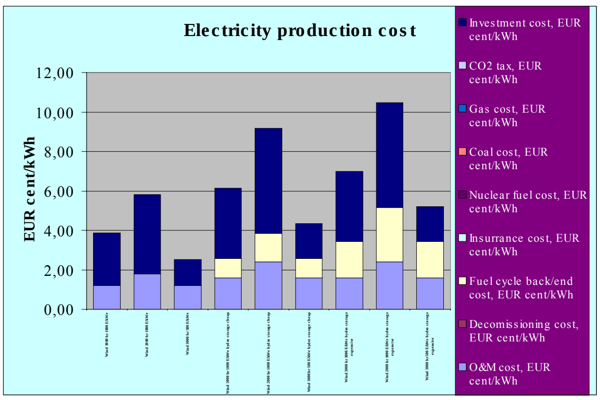

Fig. 2. Wind power plants

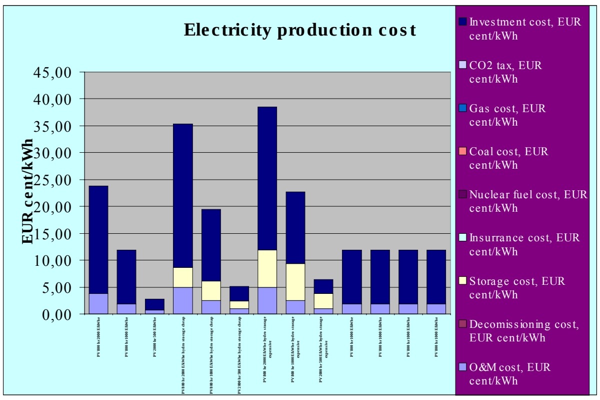

Fig. 3. PV power plants

3. Experiences with NPP Temelín

Commissioning of NPP Temelin unit 1 in 2002 and unit 2 in 2003 was a big technical, economical and political achievement. The construction of Temelin NPP started in 1986 after Construction permit was granted. The construction process coincided with political (and economic) changes which had significant impacts on plant construction, including even questioning its political acceptability.

Nuclear Power Plant Temelín - Milestones

1986	Construction permit issued
1987	Start of construction of the plant operation buildings
1990	Units 3 a 4 cancelled
1993	Signature of contracts between ČEZ and Westinghouse for delivery of nuclear fuel and of the I &C system
1995	Modification of the contracts between ČEZ and ŠKODA Praha
1995 - 1998	Cabling replacement
1997	Delivery of the nuclear fuel by Westinghouse
1998	Signature of contract amendments among ČEZ, ŠKODA Praha and Westinghouse
04/2000	Non-active hot testing of Unit 1
07/2000	Fuel loading of Unit 1
10/2000	First criticality of Unit 1
03/2002	Fuel loading of Unit 2 (05/2002 First criticality of Unit 2)
06/2002	Unit 1 trial operation
04/2003	Unit 2 trial operation

The Temelin was basically constructed within the following main contracts:

- EGP PRAHA (Nuclear Research Institute Řež) General Designer
- ŠKODA PRAHA General Supplier of Technology
- Hochtief VSB General Supplier of Civil Construction
- Westinghouse I&C Supply
- Westinghouse Fuel Supply

Many domestic and foreign companies participated in the NPP Temelin construction under this umbrella, the details are in the following table.

List of Temelin NPP Key Suppliers

Country	Company	Delivery
Czech Republic	Energoprojekt Praha (Nuclear Research Institute Řež)	General Designer
	Škoda Praha	General Contractor for Technology
	Hochtief	General Contractor for the civil part of NPP
	Škoda JS	Reactor vessels, special systems, final delivery of the "Nuclear Island"
	Škoda Turbíny	1000MW Turbogenerator
	Vítkovice	Steam generators, pressurizers
	Královopolská RIA	Auxiliary systems of the Primary Circuit
	První brněnská ABB	Turbines for feed water pumps
	Sigma	Pumps
	Modřanská potrubní	Piping, valves
	ZVVZ Milevsko	Air-conditioning systems
	EZ Praha	Deliveries and installation of electric technical equipment
	ORGREZ SC Brno	Full - scale simulator
Hungary	GANZ Budapest	Refueling machine
Austria	PKE	Technology for the plant physical protection
	PHILIPS	Chemicals
	NALCO chemical ELIN	Electricity equipment
France	ALCATEL CABLE	Incombustible cables for Temelin NPP safety systems
	Lyon	Radioactive waste processing technology

	FRAGEMA SGN	Fuel assembly leak-proof surveillance system
Italy	ANSALDO	Refueling machine control system
Germany	AEG AG	Electrical switchboards and supplies
	SEMPEL	Valves
Switzerland	Switzerland ABB	Electrical supplies
	CERBERUS	Electronic Fire Alarm System
	SULZER	Pumps
United Kingdom	CADCENTRE Ltd.	Computers, software
USA	USA WESTINGHOUSE	Instrumentation and Control system, nuclear fuel
	DATA SYSTEMS & Solutions	I&C independent verification and validation
	SORRENTO Electronics	Radiation and monitoring system

In the course of "prolonged" Temelin construction, the original Russian series design of VVER 1000/320, was subject of permanent modifications, starting with changes decided on before construction, decided by ČEZ during construction as reaction on to IAEA generic recommendations, and accepted recommendations of many review mission on Temelin NPP.

Main design upgrading measures

- Instrumentation & control system replacement
- reactor core design and fuel replacement
- radiation monitoring system replacement
- plant diagnostic system replacement
- plant electrical part upgrading - replacement of original cabling for incombustible and fire non-propagating cables , electric protection replacement, addition of two diesel generators, accumulator battery capacity increase etc.
- plant mechanical parts replacement or modification (pumps, valves..)
- containment hydrogen recombiners installation
- fire extinguishing equipment reconstructed, alarm system installed
- radioactive waste treatment equipment and method changed

Other upgrading measures

- new safety analysis reports prepared including LBB and ATWS analysis (US NRC RG 1.70)
- probabilistic safety assessment report prepared and safety monitor developed (updated in 2003)
- new accident management approach applied, operation modes changed
- symptom based emergency operating procedures, severe accident management guidelines, emergency plan, technical support centre build
- new operational personal training system applied and full scope and display simulators built
- western reactor core management adopted

Czechoslovak atomic legislation was even before 1986 very similar to US Rules and Regulations applied in nuclear area. In the course of construction many requirements were accepted to make the plant acceptable also for neighbouring countries and EU.

Temelín NPP acceptability and legal basis

- Czechoslovakia /Czech Republic nuclear legislation
    - Act 28/ 1984 and other nuclear legislation mainly based on of 10CFR 50 (legislation update 1997)
    - Other US codes and standards as well as those of IAEA, France, Germany etc.
- Temelin NPP modification programme
    - Accelerated after 1989
    - Several safety reviews organized by IAEA, Halliburton NUS, TUV....
    - Contracts with Westinghouse under the condition of licensability in country of origin
- EU accession process and political pressure
    - Nuclear safety in candidate states questioned and politicised
    - „Report on Nuclear Safety in the Context of EU Enlargement" – June 2001

- 25 basic IAEA nuclear safety principles, recommended for implementation to the safety authorities in candidate countries (Court of Auditors February 1999 report)
- Nuclear package in preparation and discussion within EU

As a result of ČEZ policy of transparency, the Temelin NPP hosted such a number of safety related missions and reviews as none of other NPP everywhere.

More than 20 IAEA safety missions and several other international missions was organized on Temelin NPP

- Site safety review mission and follow up 4/1990, 6/1992, 6/1994
- PRE - OSART mission 4 - 5 / 1990
- Design review mission 6 -7 / 1990
- Pre - OSART mission follow - up 2 / 1992
- Quality Assurance Review (QARAT) mission 3 - 4 / 1993
- LBB Application review mission 5/1993, 12/1993, 2/1994, 12/1995
- Fire safety mission 2 / 1996
- Probabilistic Safety Assessment review missions 5 / 1995 & 1 / 1996
- Safety issues of WWER 1000 resolution review mission 3 / 1996
- Physical Protection Assurance mission - IPPAS 9 / 1998
- Operational Preparedness & Plant Commissioning Review 2 / 2000
- Pre - OSART mission 2 / 2001
- Safety issues of WWER 1000 resolution review - follow up 11 / 2001
- IPPAS (International Physical Protection Advisory Service) 4 / 2002
- Site Seismic Hazard Assessment - expert mission 3 / 2003

The following paragraphs present the most important findings and conclusions (presented at: M.Holan: Temelin NPP in the European Context. Annual Meeting on Nuclear Technology 2004.) .

IAEA Mission on Safety Issues Resolution (1996)

- It is recognized that the Czech Electric Company (CEZ) has made a large effort to improve the design of Temelin independently of the identification of safety issues by the IAEA. The organization of their actions in terms of the IAEA issues was only a convenient way to demonstrate that all of the issues are being taken into consideration.
- The adoption of Western technology and practices for part of the scope of supply (e.g. fuel, I&C, radiation protection, accident analysis) has helped to solve a large number of safety issues identified for WWER-1000/320 NPPs. In several cases, the combination of Western and Eastern technology has led to safety improvements in comparison with international practices.

TEMELIN NPP Design Safety Review Missions HALLIBURTON NUS AUDIT- 1992

- Temelin can be licensable, but licensibility could not be assured unless the audit team´s technical and programmatic recommendations are implemented

Design Safety Review Missions ENCONET Consulting (Austria) - 1998

- After modifications are fully implemented, Temelin NPP will be a much safer plant than originally designed and much more safer than some of the already operating WWER 1000 plants
- The process of compatibility was specifically assured by selecting prudent practices acceptable in the Western countries.

2001 - IAEA Safety Issues Resolution
Follow up Mission Conclusions

- Most of issues are resolved which follow the intent of the IAEA recomendation.
- Only a few issues has not yet been met in full. However all these issues have been addressed and measures are at an advanced stage of implementation to complete their resolution.
- The status of these issues is judged not to preclude the safe operation of the Temelin NPP.
- It was also mentioned that in some fields, the Temelin NPP safety exceeds the usual safety standards.

WENRA Assessment - October 2000
Report on Nuclear Safety in EU applicant countries

- CR Regulatory regime and regulatory body status

The status is comparable with Western European practice. A well-defined licensing process according to Western practice is in place

- Nuclear power plant safety status
  The safety improvement programme for TEMELIN units 1-2 is the most comprehensive one ever applied to a VVER-1000 reactor. Standard Western practices were used to integrate Eastern and Western technologies and to deliver the corresponding authorisations...... A few safety issues still need to be resolved. If these are resolved, TEMELIN units 1-2 should reach a safety level comparable to that of currently operating Western European reactors.

COREPER approved in June 2001 the „Report on Nuclear Safety in the Context of Enlargement“ which gave several recommendations

The safety improvement programme for the Temelin units has been the most comprehensive so far for this reactor type.

- General recommendations on plant safety improvement programs
  Those are followed in case Temelin already
- Specific recommendations:
  - type I - highest priority for consideration in the accession proces
    Protection against high energy pipe breaks
  - type II - implementation in more flexible time frame
    Qualification of Safety and Relief valves
    The Comprehensive Safety Case Comprehensive Safety Case introduced

German view and attitude to Temelin

- Germany and the CR cooperation is based upon the bilateral agreement from 1990.
- Scores of questions from Germany citizens was answered
- The Federal Government had financed in 2000 a project on safety assessment of safety issues of Temelin design
  - reactor pressure vessel
  - information & control system
  - reactor core design
  - containment
  - safety analysis
  - others

Conclusion of GRS assessment

- The analysis has shown that the design - independent safety requirements of the German guides and standards are largely fulfilled by the concepts and safety measures provided in NPP-T for the elimination of the known deficiencies of standard VVER-1000 plants.
  As for the identified deviations, the regulations of other Western countries, in particular the US regulations of the US-NRC, are followed in most cases in line with the demands of the licensing authority and according to the application documents submitted by the applicant.
- Two issues only left finally for further investigation
- The representatives of GRS did not detect any safety faults as they said at the Eurosafe Forum in Köln am Rein in November 2000.

Austria attitude and view to Temelin NPP

- Austria and CR cooperation is based upon the similar bilateral agreement from 1989 (originally from 1977)
- Austria Federal Government aimed to stop Mochovce and later intended to stop Temelin
- Vienna Technical University professors expressed in 1995 their realistic statement to Mochovce during anti-nuclear campaign
- Council of Ministers released „Action plan“ - Anti-nuclear Policy in the European Context in July 6,1999
- The Melk protocol signed in December 2000 and related process finished in November 2001 in Brussels
- Atominstitute of Austrian Universities and Austrian Nuclear Society issued positive assessment report to Temelin in 2001
- The „Anti-Temelin“ referendum organized in 2002

Melk protocol and related process

- Protocol signed between Austria and CR with participation of EC in December 2000 which contains VIII chapters

- Especially IV.- Safety Issues and V.- EIA chapters are important
- Trilateral expert group was established in SI area and met several times since February till May 2001 and discussed all Austria concerns
- Austria specified 29 issues in „blue book", CR answered all in „white book" and EC concluded all work by summarising report in June 2001after final expert meeting in Brussels
- Austria prepared later own Technical Position Paper („black book") changing its Brussels position. This report was refused by EC expert group leader
- The Commission was established in Czech Republic for EIA preparation with Austria, Germany and EC observers
- EIA extended report in accordance with Council Directives 85/337/EEC and 97/11/EC and related Standpoint report was prepared and public hearing in Vienna was organised
- All Melk process was closed by Concluding Statement in November 2001 in Brussels
- Seven items from safety issues area and 21 environmental measures was specified for further discussion and monitoring in the frame of Czech - Austria Bilateral agreement.

IAEA Nuclear Safety Convention
Conclusions of Czech National Report 1999 review:

- The new nuclear legislation complies with international standards.
- The SUJB is an independent authority as required by the Convention.
- Positive statements regarding approaches to nuclear safety level improvements of nuclear power stations

Conclusions of Czech National Report 2002 review:

- Nuclear safety situation in CR is in compliance with the CNS intent

Result of this immense effort of the CEZ and of many national and international organisations, especially IAEA, was confirmation that nuclear safety of NPP Temelin corresponds to the state-of-the art and therefore this plant is acceptable for operation in EU.

Nevertheless, we should mention that the process of changes implementation in the whole course of plant construction had a very negative impact on the project duration (both during construction and start-up), costs escalation and demands on general designer. The situation with Unit 2 was quite different because the lessens learned with unit 1 were implemented into design already during planning phase. Delays of unit 2 were caused mainly by waiting for decisions for unit 1. As an example can serve comparison of start-up test duration for Units 1 and 2.

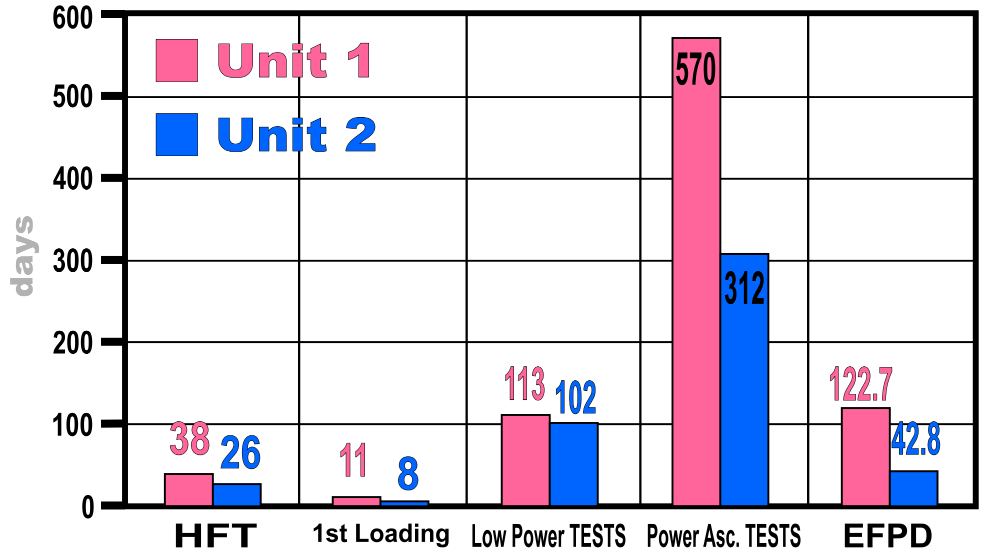

Fig. 4. Comparison of start-up test duration for Units 1 and 2

Both commissioned Temelin units now operate safely, reliably and economically with excellent operational records comparable to other European NPPs. It is planned that the plant service life will be 40 years as a minimum, with appropriate engineering effort extension up to 60 years is viable.

4. Czech Energy Policy

The State Energy Policy is one of the basic components of the economic policy of the Czech Republic. It reflects the state's responsibility for creating conditions for reliable and permanently safe supplies of energy at acceptable prices and for creating conditions for its efficient use that will not threaten the environment and will comply with the principles of sustainable development. The state fulfils this legal responsibility by establishing the legislative framework and rules for the operation and development of energy sector.

The energy policy is based on a vision which comprises:

I. MAXIMUM INDEPENDENCE

- Independence from foreign energy sources
- Independence from energy sources from risky regions
- Independence from reliability of supplies from foreign sources

II. MAXIMUM SAFETY

- Safety of energy sources including nuclear safety
- Reliability of supplies of all kinds of energy
- Reasonable decentralisation of all energy systems

III.SUSTAINABLE DEVELOPMENT

- Environmental protection
- Economic and social development

Energy Policy defines the following main goals

- Maximum efficiency
- Assurance of an appropriate structure of the primary energy consumption
- Assurance of maximum environmental friendliness of energy consumption
- Finalization of transformation and liberalization of energy market

Energy policy was prepared based on analysis of several scenarios of sector development up to 2030.

Alternative scenarios under consideration were:

- White – reference one
    - All existing rules and limitations without changes
- Green – higher consumption of domestic resources
    - Lifting limits for brown coal mining
    - Additional NPPs
    - Strengthening support for renewables
- Black – higher consumption of imported hard coal
    - Non-lifting limits for brown coal mining
    - Increased consumption of primary energy resources covered by hard coal import
- Red – higher consumption of natural gas
    - Non-lifting limits for brown coal mining
    - Increased consumption of primary energy resources covered by natural gas import
- Blue – higher share of nuclear energy
    - Non-lifting limits for brown coal mining
    - 3 new NPP units at Temelin site
- Yellow – highest share of nuclear energy
    - Non-lifting limits for brown coal mining
    - Several new NPP units (total capacity around 5 000 MWe)

Comparison of some analyses of different scenarios impacts are presented in the following graphs.

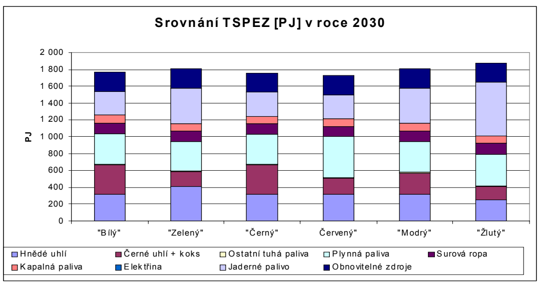

Fig. 5. Comparison of Primary energy resources consumption in 2030 according to different scenarios

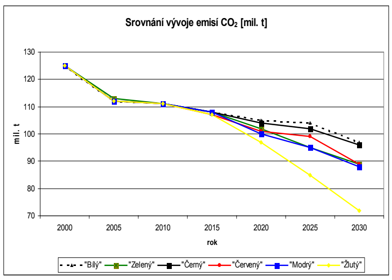

Fig. 6. Comparison of CO2

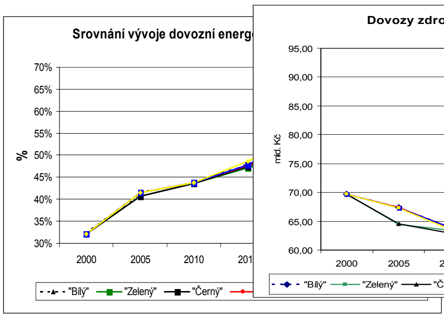

Fig. 7. Comparison of
energy import, %

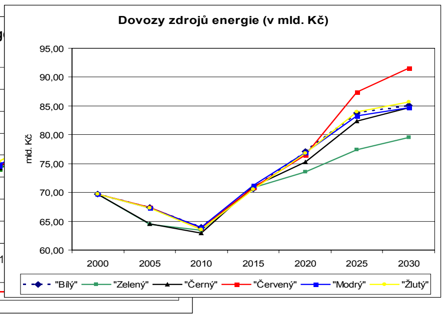

Fig. 8. Comparison of primary energy imports, billon CZK

The accepted main scenario was the green one with higher significance of domestic resources. An important part of this scenario is construction of new NPPs after 2020.

5. Future challenges

Strong commitment to utilisation of nuclear energy should help to resolve the energy problem in our country which is short of primary energy sources and due to the expected economic growth can not avoid increasing energy consumption.

The prerequisite for keeping up with these challenges are long-term reliable and safe operation of existing NPPs. This requires:

- Strong and respected regulatory authority,
- Stable technical infrastructure,
- Motivation of young to enter into education process,
- Transfer of know-how to new generation of engineers and scientists.

Motivation of young generation is contingent on the continued R&D support and international cooperation, these two efforts will also strengthen the national infrastructure.

At present and in near future one of most challenging goals of R&D pursued by multinational effort is preparation of GEN IV NPPs that will fulfil the following targets:

- Increased efficiency up to 50%
- Reduction of investment costs close to the half of that of GEN III plants
- Utilization of U238 and Th232 which can increase the fission resources by two orders of magnitude
- Supply of high temperature heat with potential hydrogen production

6. Conclusions

In the present globalizing world energy is a main strategic commodity. Therefore the EU plans to formulate long term energy strategy with the objectives to assure:

- sustainable,
- secure,
- affordable (economically acceptable), and
- clean

energy supply.

Obviously, this strategy must be reflected in member states energy policies. Czech Republic new Energy Policy declares long-term commitment to nuclear energy and maximum utilization of domestic energy resources, including renewables. Bulgaria, while formulating energy policy, is faced with similar boundary conditions as

Czech Republic and some other EU member states. Finalization of NPP Belene construction is a logical step in this direction.

Based on our experience with NPP Temelin the key aspects to be taken into account during this process can be summarized as follows:
I. What and how to construct:
- Finalize Belene 1 and 2 with maximum utilization of existing equipment (to minimize new investments) and with design modifications already proven and acceptable for EU (to minimize construction time and cost escalation), NPP Temelin design and process of construction was in compliance with these requirements.
- Keep open an option of design reconsideration for Belene 2, depending on economy of potential alternative plant versions proven and available on the market before start-up of the construction.

II. Requirements to the supply model:
- Maximum involvement of Bulgarian engineering capacities to strengthen technical infrastructure for long-term operation support,
- Maximum utilization of local manufacturing and civil construction suppliers.

Split contract model is optimal for fulfilling these requirements.

What the Czech partner can offer to support the NPP Belene finalization:
I. Know-how and experience acquired within construction of two modernized VVER 1000/320 units of NPP Temelin, especially:
- Complete basic and detailed design documentation in digital data base form,
- Two years operation experience feedback of which can be implemented into Belene design,
- The main suppliers of NPP Temelin (one of them ŠKODA JS supplied the key primary components for NPP Belene) formed consortium Aliance ŠKODA to participate in NPP Belene finalization. Aliance ŠKODA is prepared to deliver finalization of whole NPP or partial supplies according to Bulgarian partner requirements, including the corresponding financial resources.

II. NPP Temelin design modifications including Aliance ŠKODA offer have been already presented at several occasions and are available in booklet and CD form.