Development of nuclear energy and position on small reactors in the Czech Republic

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Nuclear Research Institute Rez plc

International Conference on
Prospects of Small Nuclear Reactors and Renewable Energy for the Baltic States by 2020 and beyond
3 March, 2011, Druskininkai, Lithuania

Content of the presentation

- Nuclear facilities in the Czech Republic
- Current plans for new builds in the Czech Republic
- Implementation of new nuclear units in the CR
- Feasibility of implementation of small reactors
- Position on implementation of small reactors in the Czech Republic
- Significant opportunities associated with implementation of small reactors in the Czech Republic
- Issues associated with implementation of small reactors in the Czech Republic
- Summary

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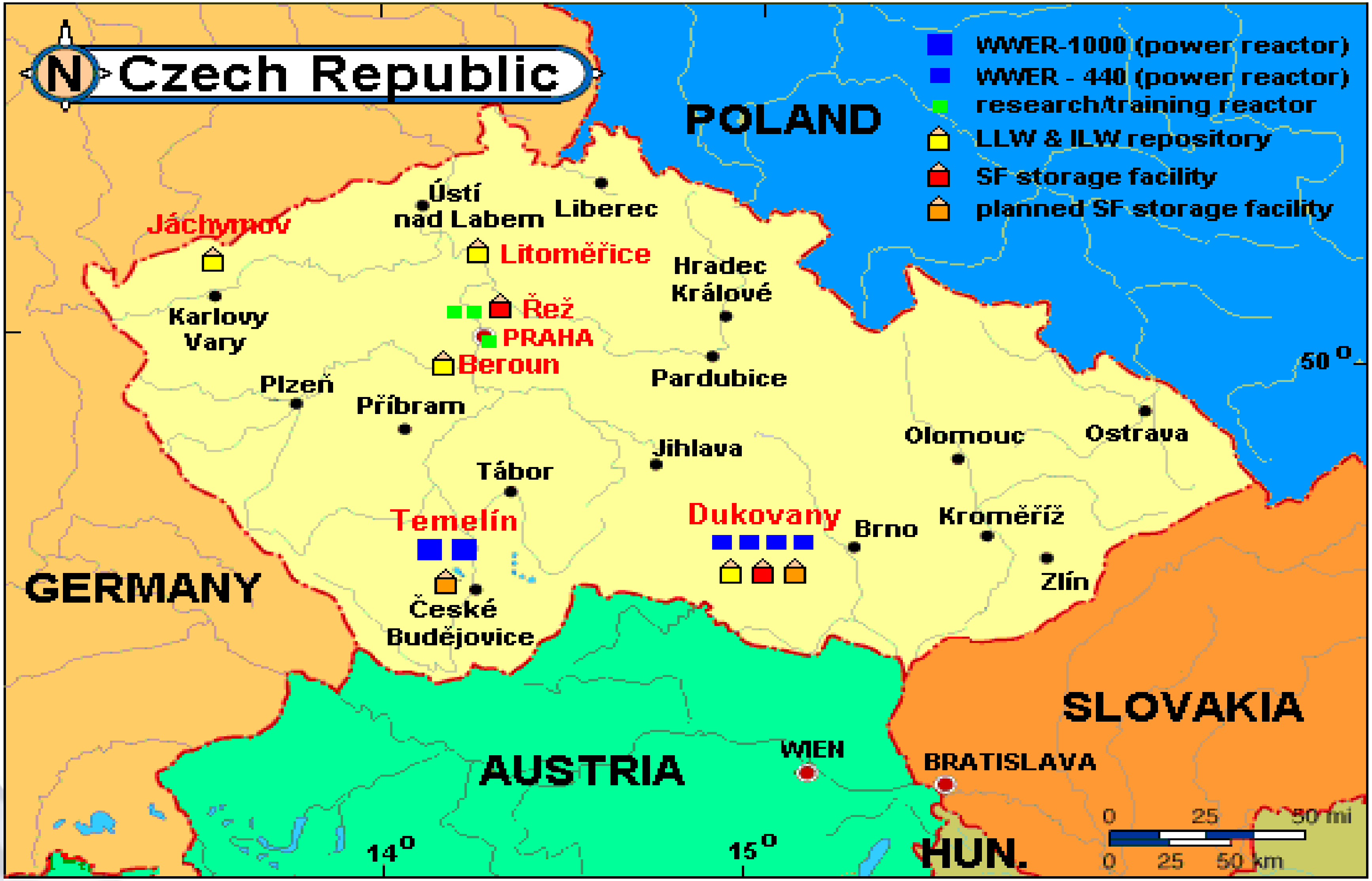
Nuclear facilities in the Czech Republic

COUNTRY PROFILE



Country profile

- 50 years of nuclear experience
- Running 6 nuclear units for up to 15 years
- Favourable public opinion
- ~30 % of electricity produced in NPPs
- Existing country energy strategy relying on significant role of nuclear power in the energy mix
- CEZ – major state owned utility interested in further expansion of its nuclear fleet

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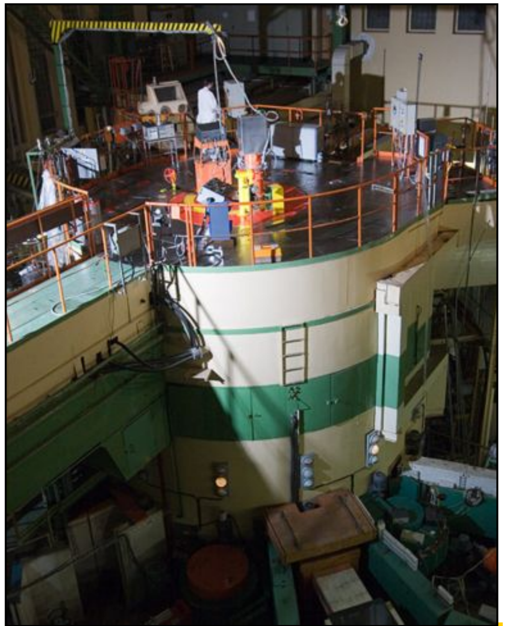
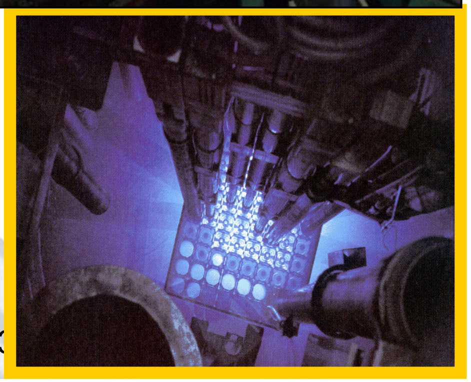
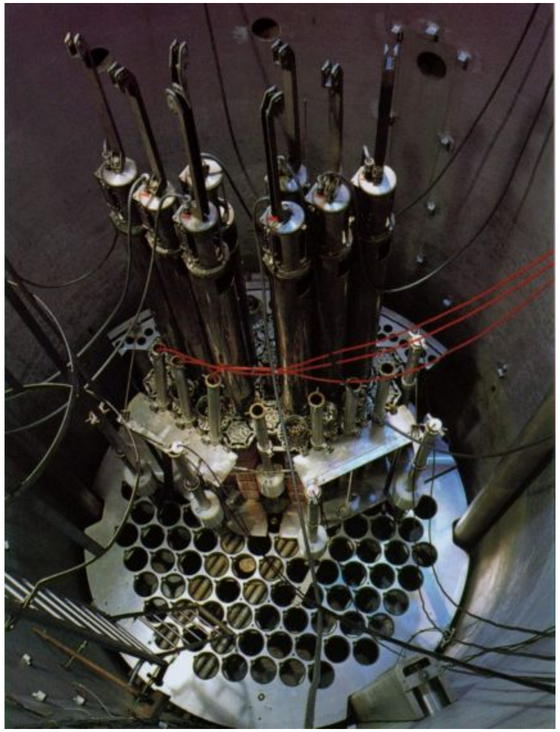
RESEARCH REACTORS

NRI Řež Plc.
LVR-15
(max. power 10 MWt)





NRI Řež Plc.
LVR- 0 – zero power research reactor, modified fuel of WWER – 440, 1000 type; measurements of basic physical fuel parameters



Czech Technical University, Prague
VR – 1 (zero power, 19,7% 235U)

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NPP Dukovany in operation

- VVER 440 - 213, 4 units
- PWR, 6 loops, 2 turbines
- Pressure-suppression containment
- 1375 MWt, 440 MWe
- In operation since 1985 -1987

→dry interim storage of spent fuel (cask-type, CASTOR),
→regional shallow land repository of radioactive waste to accommodate all low and intermediate radioactive wastes from both nuclear power plants

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Temelín NPP in operation

- VVER 1000 – 320, 2 units
- PWR, 4 loops, 1 turbine
- Full-pressure containment
- 3000 MWt, 1000 MWe
- Construction since 1986
- Operation since 2003-2004

→dry interim storage of spent fuel (cask-type, CASTOR) under construction

RADWASTE AND SPENT FUEL STORAGE FACILITIES (DUKOVANY SITE)

SHALLOW LAND REPOSITORY

INTERIM SPENT FUEL STORAGE

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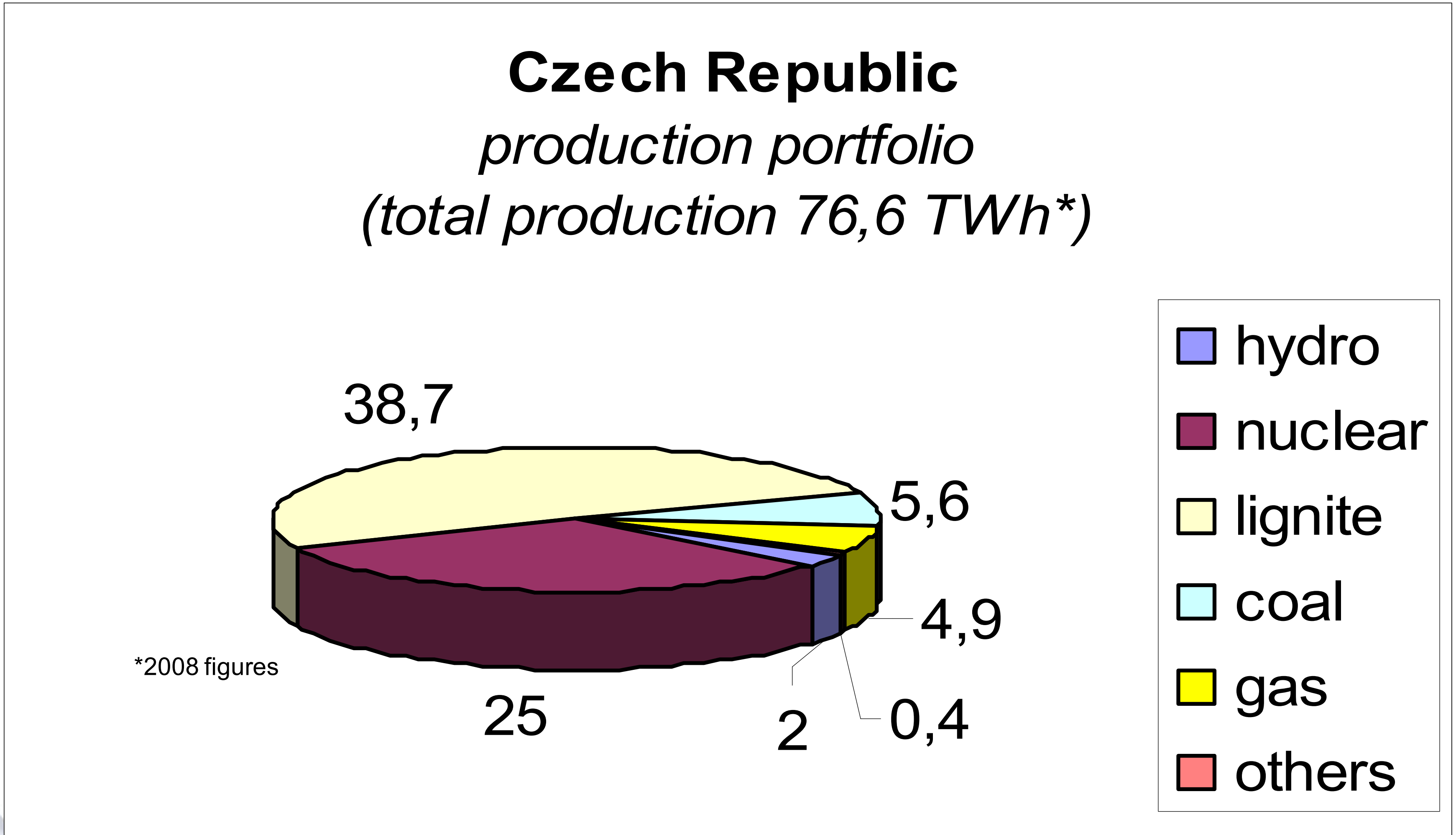
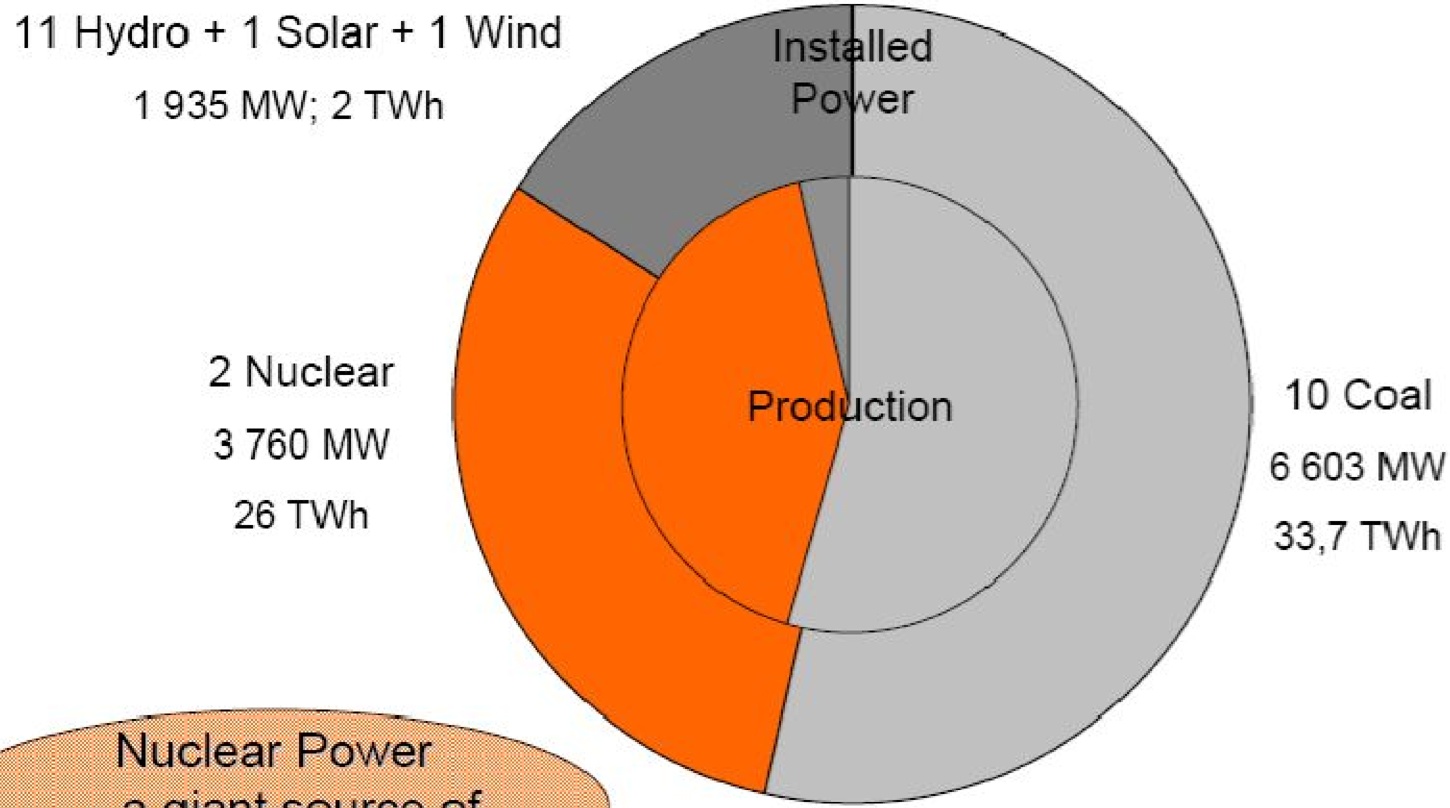
PRODUCTION PORTFOLIO IN THE CR



*2008 figures

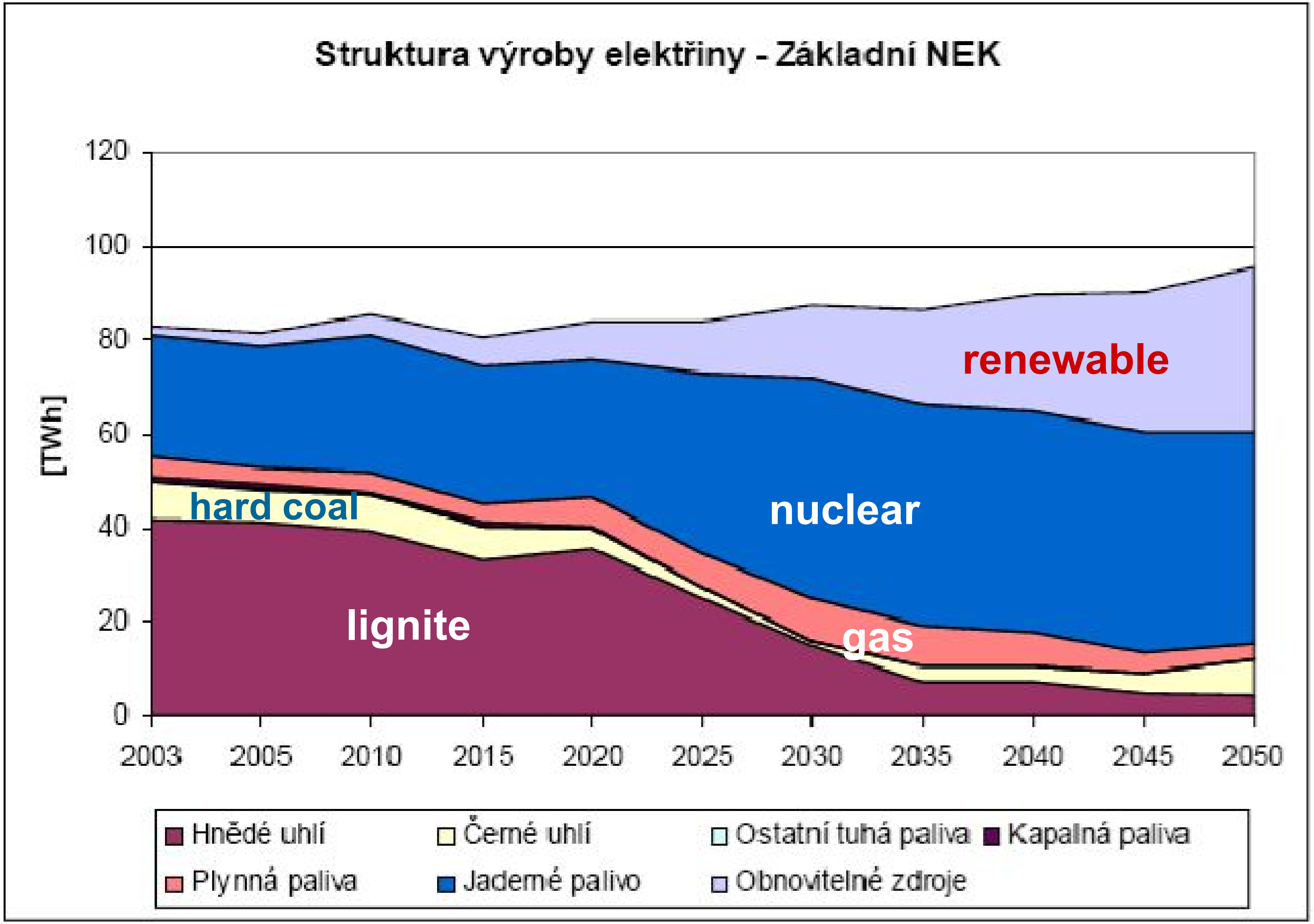
CEZ electricity production in the CR



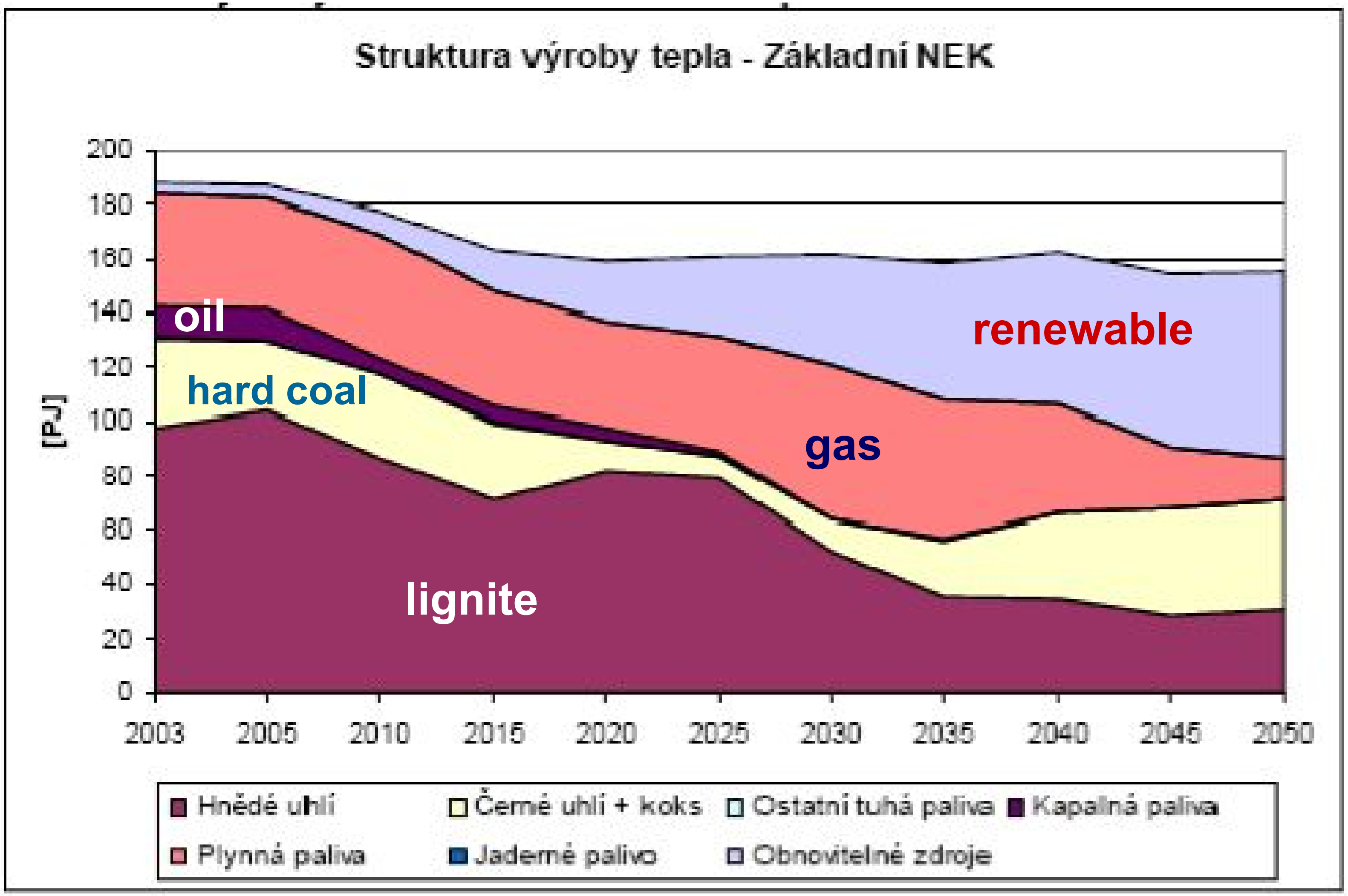
Nuclear Power
– a giant source of energy!

Current plans for new builds in the Czech Republic

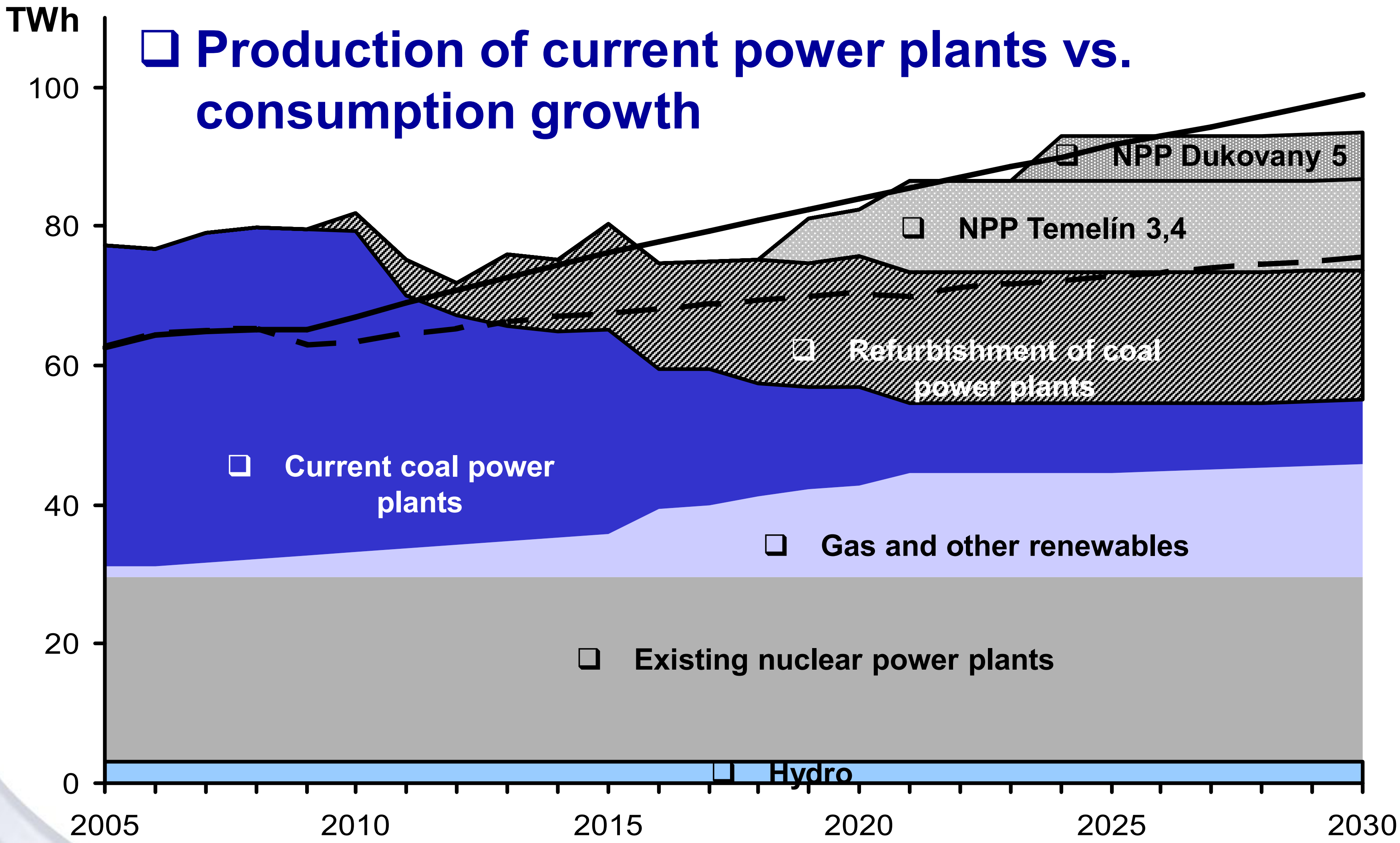
Structure of electricity production in the CR



Structure of heat production in the CR



New units Temelin 3,4 and Dukovany 5 could cover future electricity need



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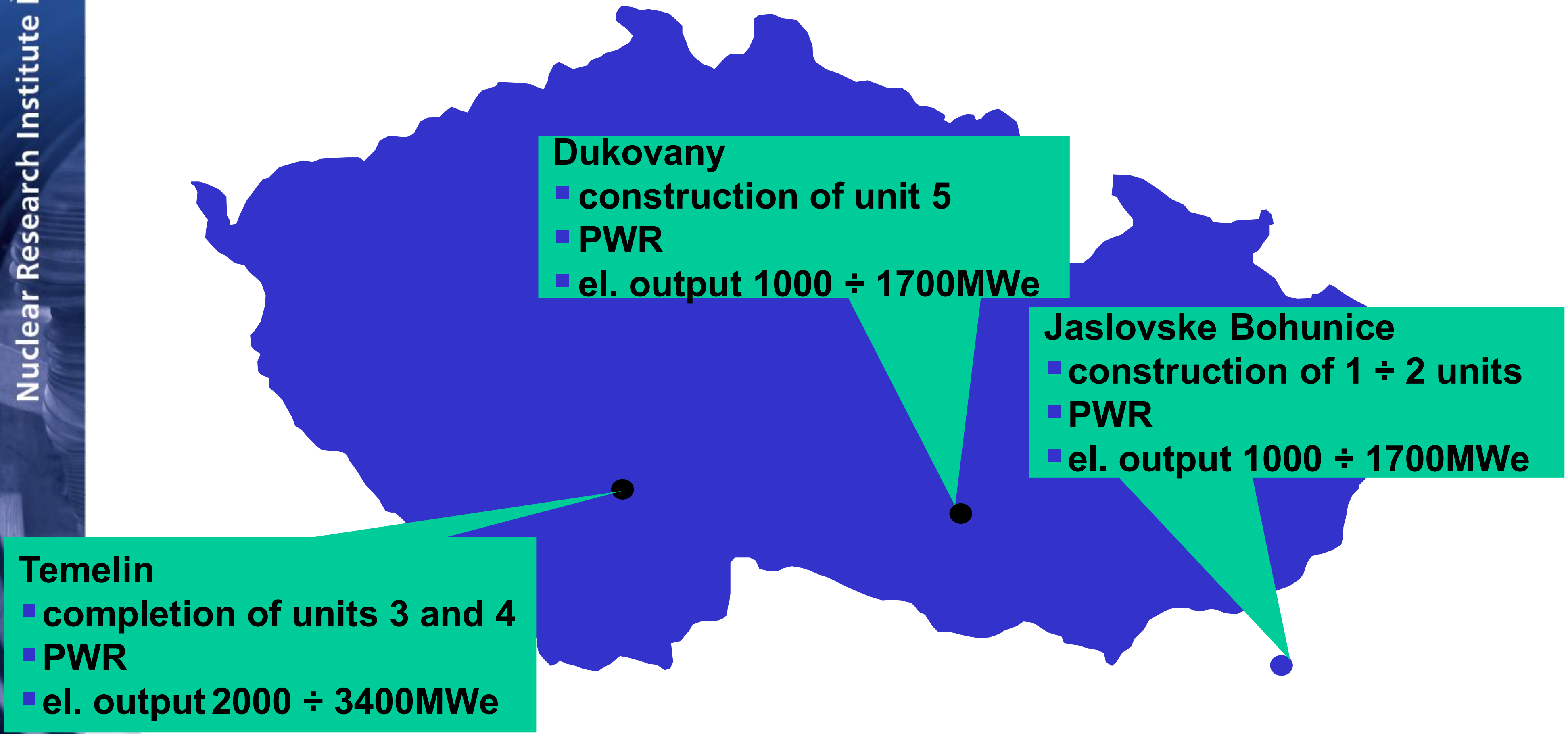
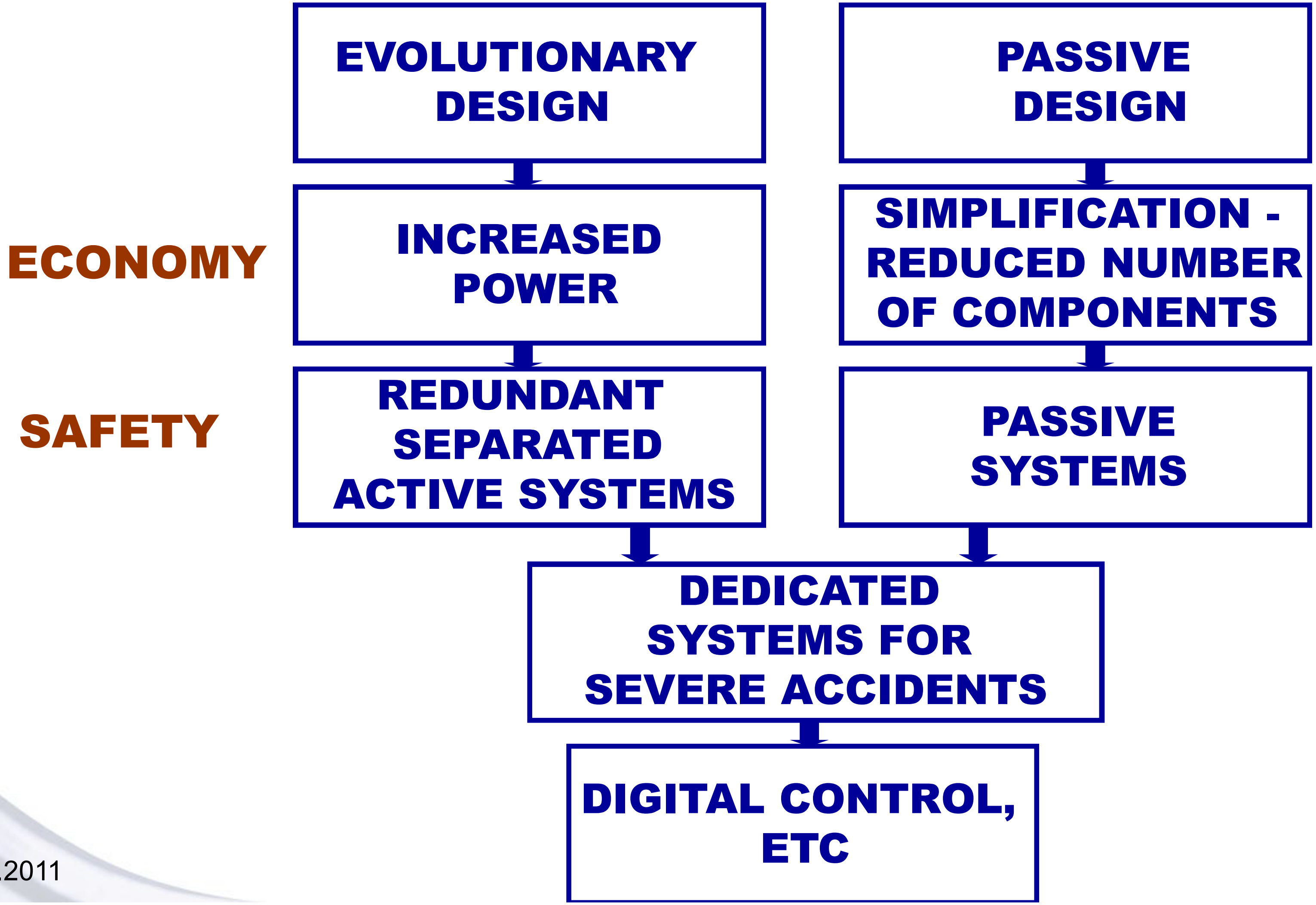
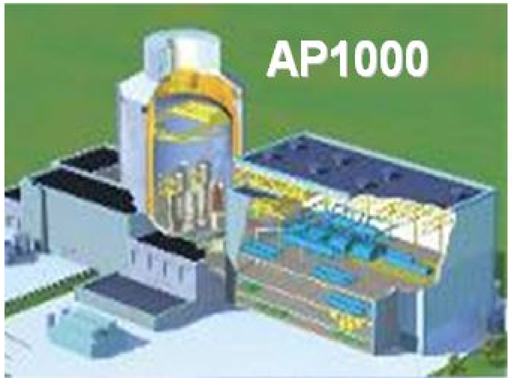
Current plans of nuclear projects of CEZ, a.s.



Design approaches for new reactors



Candidate projects for new builds in CR - PWRs with > 1000 MWe



Westinghouse

MITSUBISHI HEAVY INDUSTRIES, LTD.

AREVA

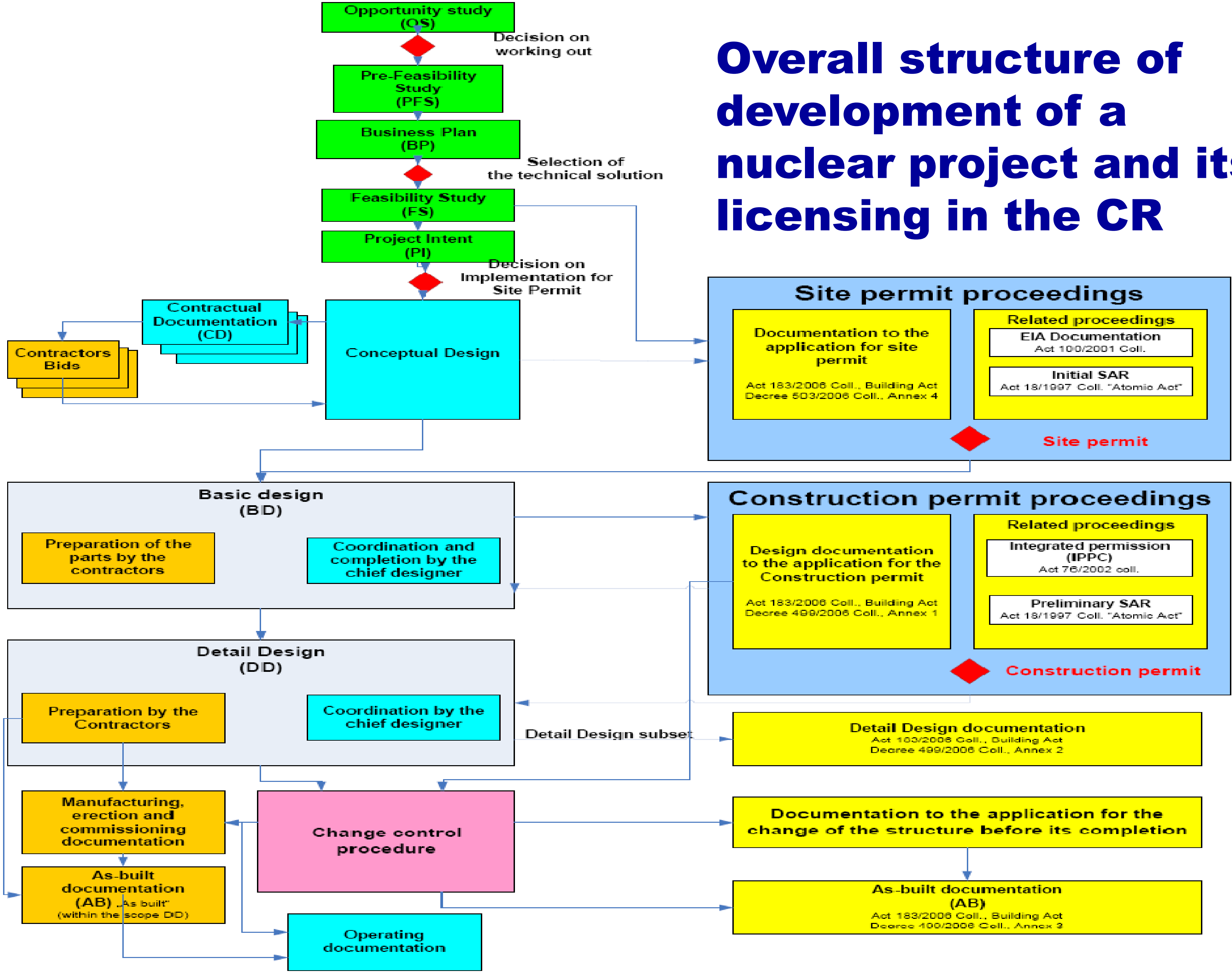
ATMEA

ACЭ·ASE

KHNP

Implementation of new nuclear units in the Czech Republic

Overall structure of development of a nuclear project and its licensing in the CR



Legislative system

- The basic legal regulations governing the licensing and approval process for nuclear installations are:
  - Civil Construction Act (No. 186/2006 Coll.);
  - Atomic Act (No. 18/1997 Coll.) and related Decrees (e.g. on QA, Design, Operation);
- Other important regulations in this area are:
  - Administrative Procedure Act (No. 500/2004 Coll.);
  - State Inspection Act (No. 552/1991 Coll.);
  - Environmental Impact Assessment Act (No. 100/2001 Coll.)

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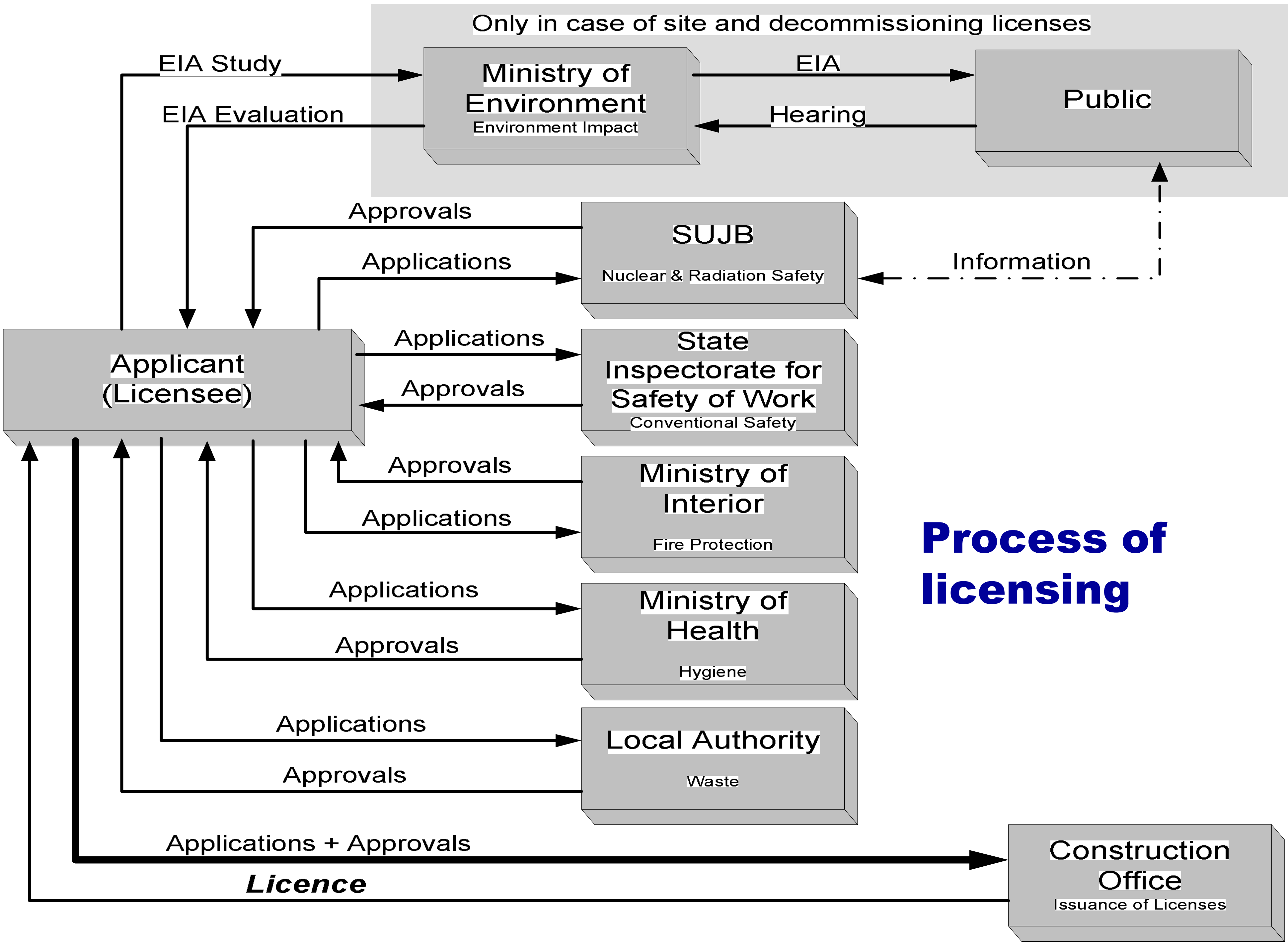
Process of licensing



Documents to be developed by the utility

UTILITY

- Communication with vendors → **Bid invitation specification**
- Communication with Ministry of Environment → **Environmental Impact Assessment**
- Communication with Nuclear Regulatory Authority → **Initial Safety Analysis Report**

- **All these documents should be consistent**
- **Quite complicated to achieve, in particular if the reactor type is not selected yet**

Siting proces in the CR

– 1st step: EIA process

precondition of next approvals

plan : 2011 / 2012 (delay expectable, critical path)

– 2nd step: SITING APPROVAL

by State Office for Nuclear Safety (SONS)

Quality Assurance Program approval as a precondition

approval based on evaluation of Initial Safety Report

– 3rd step: TERRITORIAL DECISION

by Building (Construction) Authority

What has been already done for Temelin 3,4 - BIS

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– Preparation of Bid Invitation Specification (BIS) documentation (based on EUR), tender organization
  - August 2009 – public tender announced
  - March – June 2010 –consultation meetings with 3 potential vendors
– Next process
  - 2011 release of final BIS documentation
  - 2012 vendor selection process
  - 2013 contract signature
  - 2022 commissioning

Environmental impact assessment (EIA)

- July 2008 – CEZ, a. s. issued intent announcement EIA
- February 2009 – CEZ, a. s. received comments from the Czech Republic, Austria, Germany
- April 2010 – EIA finalization
- May 2010 - EIA handover to the Ministry of Environment
- June 2010 – Ministry of Environment publishes EIA
- Currently and in next months : comments, consultations with Austria, Germany, Poland, then expert opinion, public hearing and final statement of Ministry of Environment

Siting process in the CR
Initial safety report

Content of Initial Safety Report (Atomic Act No. 18/1997)

- general project information
- detailed site evaluation
- technical concept description
- preliminary evaluation of impact on population and environment
- envisaged decommissioning method
- physical protection issues
- quality assurance for siting and quality principles for next stages

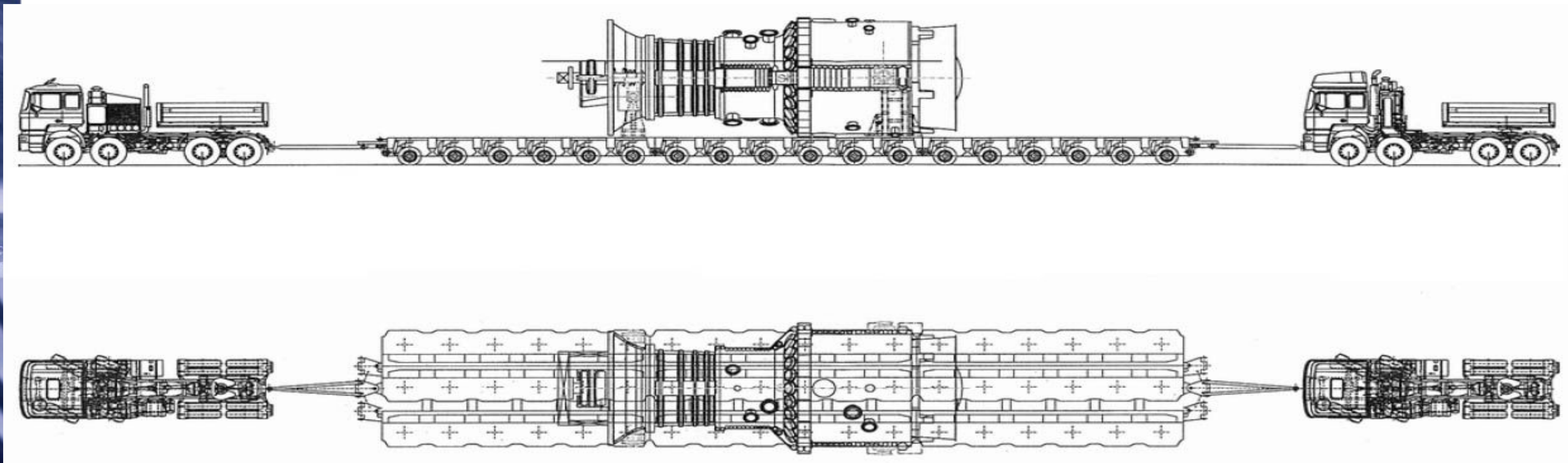
Nuclear regulatory body requires to keep the same structure of the safety reports throughout the project life time => ENVELOPE APPROACH

Siting – current challenges

- Reactor type is not selected yet, siting approval as well as EIA process is executed for „envelope of PWR GENERATION III, III+“
- Czech legislation and also international standards (IAEA, WENRA, etc.) for new builds are in the development process; this brings uncertainty and also possible changes of licensing base in the future (it is not enough just to follow current requirements and rules, we have to predict future ones)
- Safety report is being drafted now- consistency of ISR & EIA & BIS documentation must be maintained

What has been already done for Temelin 3,4 – technical studies

- Market investigation 2006, communication with potential vendors 2006 - 2008
- Electrical grid issues studies
- Study of related investments needed at site and in the surroundings
- Study of heavy component transportation



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Estimated time for construction of a new unit is ~13 years!

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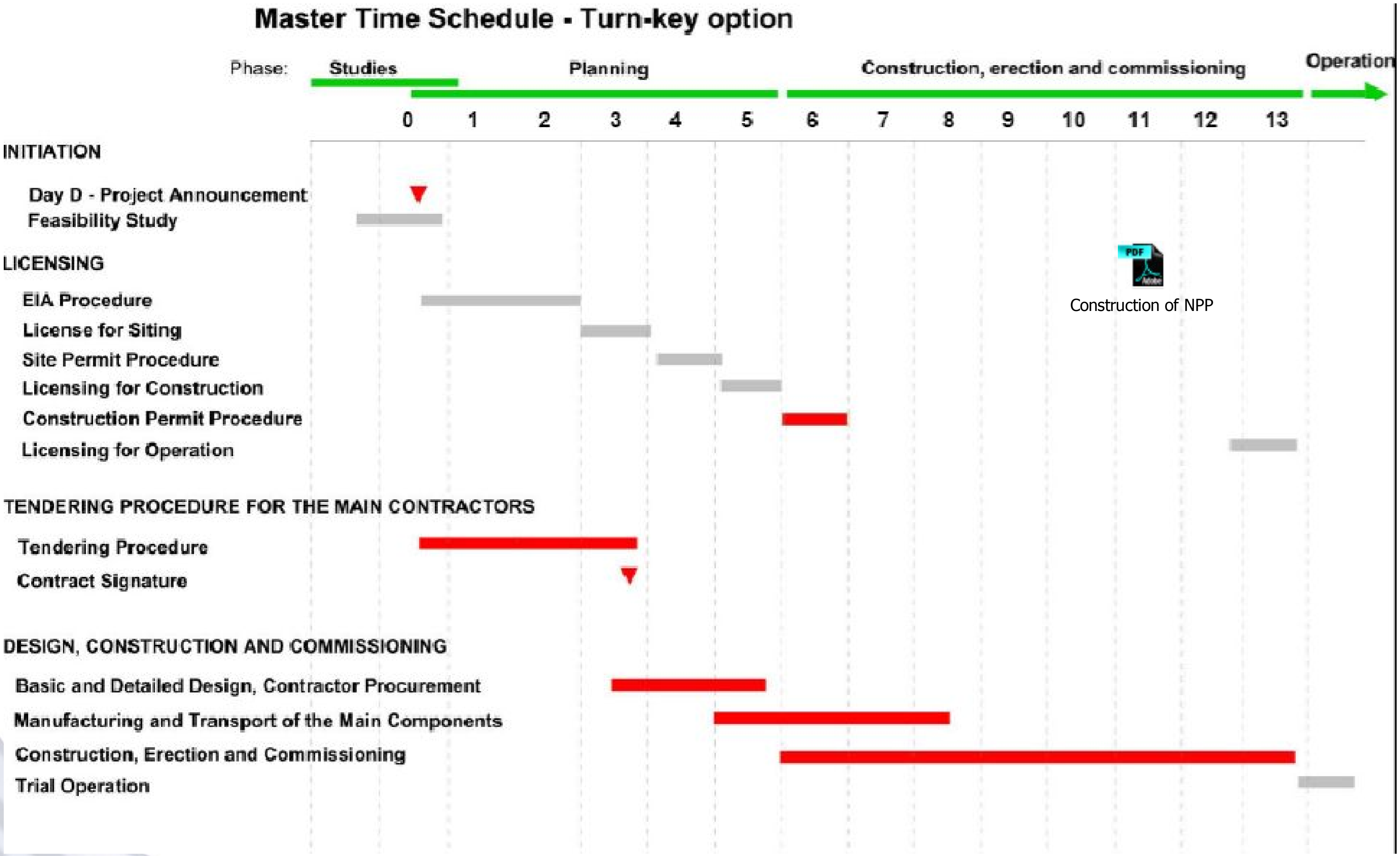

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Feasibility of implementation of small reactors

(based on IAEA work and a presentation delivered by Mr. V. Kuznetsov of IAEA in UJV Rez)

Definitions (IAEA-TECDOC-1451, 2005; IAEA-TECDOC-1485, 2006; IAEA-TECDOC-1536, 2007)

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Small Reactors: < 300 MW(e)
Medium Size Reactors: <700 MW(e)

Of the 436 NPPs operated worldwide 134 are with SMRs; of the 45 NPPs under construction 10 are with SMRs

About 50 concepts and designs of advanced Small and Medium Sized Reactors (SMRs) are being developed in *Argentina, China, India, Japan, the Republic of Korea, Russian Federation, South Africa, USA, and several other IAEA member states*

Small and Medium Sized Reactors:

- **Reactors with conventional refuelling schemes (partial core refuelling in batches, on-line refuelling, pebble bed transport)**
- **Small reactors without on-site refuelling (SRWOR)- refueling interval from 5 to 30+ years**

Target users for SMRs in Near Term

Use of SMRs is largely defined by their ability to address the needs of those users that for whatever reason cannot benefit from large NPPs; this can be changed in the future

- Countries with small electricity demand/ small electricity grids < 5,000 MW(e) peak load
- Countries with limited investment capability (attractive investment profile through incremental capacity increase)
- Settlements and energy intensive industrial sites in remote off-grid locations (permanent frost, islands, remote draught areas, etc.)

Advantages of small reactors

- More appropriate for small grids (less impact on stability)
- Less demanding new grid connections
- Possibilities for modular increase of plant power
- Enhanced simplicity, safety, reliability
- Smaller inventory of radioactivity, consequently smaller emergency zone (not necessarily when compared to modern Generation III designs)
- More flexibility for site selection
- Smaller capital cost, easier financing
- Shorter construction time
- Reduced complexity in design and needed manpower

Advantages of small reactors

- Broader applicability of passive systems and inherent safety
- Suitability for non-electric multi purpose applications, flexibility in applications
- Long refuelling interval (for some designs)
- Factory fabricated and fuelled core (reactor) provided
- Less severe security issues (but for many sites, unstable regions)
- Reduced possibilities for proliferation/misuse of nuclear material
- Easy transportation of components on site
- Potential for construction of many units

Many options for selection of a reactor type

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- **Choice of the neutron velocity**
  - thermal (2 km/s) : high fission probability for a couple of nuclei (^{233}U, ^{235}U, ^{239}Pu…)
  - fast (20'000 km/s) : low fission probability – for all heavy nuclei
- **Choice of the fissile nucleus (which can fission immediately)**
  - ^{233}U, ^{235}U, ^{239}Pu
- **Choice of the breeding substance (nuclei that can become fissile)**
  - ^{238}U, ^{232}Th
- **Choice of the chemical form of the nuclear fuel**
  - oxide, metal, carbide, nitride
- **Choice of the moderator (light atomic nuclei)**
  - liquid: light water H_2O, heavy water D_2O
  - solid: graphite
  - nothing – if the neutrons shall remain fast
- **Choice of the coolant**
  - liquids (H_2O, D_2O, molten salts)
  - liquid metals (Na, Pb/Bi)
  - gases (He, CO_2)
- **Choice of the number of barriers**
  - 2 or 3 confinement barriers
- **Choice of the fuel cycle**
  - open, closed for selected elements, fully closed

Many options for selection of a reactor type

- Geometry of the fuel:
  - 1D = rods in a square or hexagonal arrangement,
  - 2D = plates,
  - 3D =pebbles…;
- Different temperatures and pressures of the primary coolant;
- Geometric disposition of the coolant: pool, loop, tubes…
- Choice of a secondary loop and of its coolant
- Choice of power conversion system
- Choice of final heat sink : sea, river, air cooling tower (natural or hybrid)

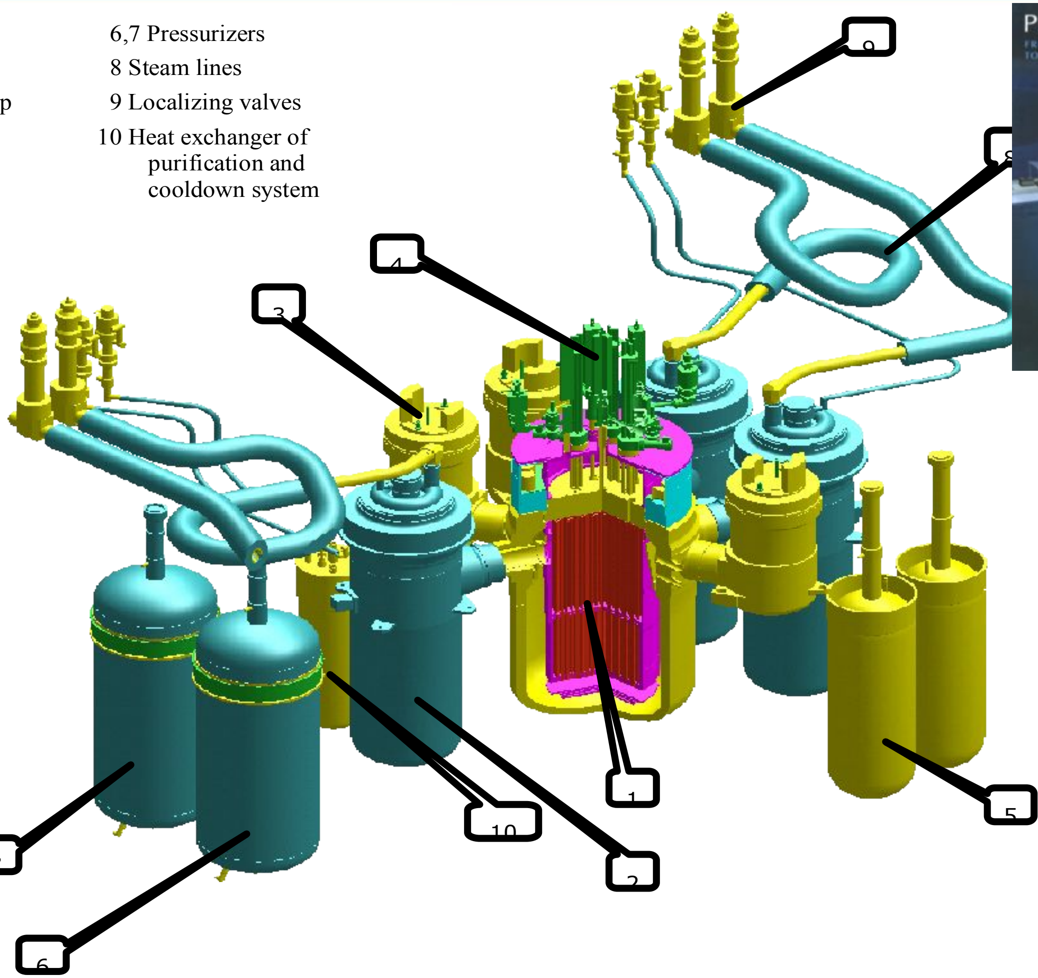
- **Many thousands of theoretical options for a reactor type are possible**
- **Selection of reasonable number of reactor types for further development necessary**

Design and Licensing Status of SMRs (IAEA)

Licensing status	No formal licensing process	Preliminary licensing process	Full licensing process
Detailed design	SVBR-75/100	CAREM-25 AHWR ABV-3, ABV-6	KLT-40S SMART
Basic design	PBMR-400, KLT-40S VBER-150, RIT-150	IRIS SAKHA-92	
Conceptual design	HTR-PM, ELENA, NIKA-70, UNITHERM, RUTA-0,SCOR, SSTAR, STAR-LM, STAR-H2, VKR-MT, PFPWR50, FBNR, SSPINOR, CHTR, HTR-F, VHTR (Generation-IV), MARS, (IAE Kurčatov) CANDLE		

Pressurized Water Reactor KLT-40S - Marine Reactor Derivative (150 MWt)

1 Reactor
2 Steam generator
3 Main circulating pump
4 CPS drives
5 ECCS accumulator
6,7 Pressurizers
8 Steam lines
9 Localizing valves
10 Heat exchanger of purification and cooldown system



Modular layout of the KLT-40S reactor plant (OKBM, Russian Federation).

PWRs with Integrated Primary Circuit System – SMART (KAERI, Korea)

System-integrated Modular Advanced Reactor

- 330 MW(th) with a cogeneration option (unit power is under review);
- Since 1997, KAERI has been developing the integrated modular advanced reactor
- Targets: Licensing start-up – soon; FOAK – 2014

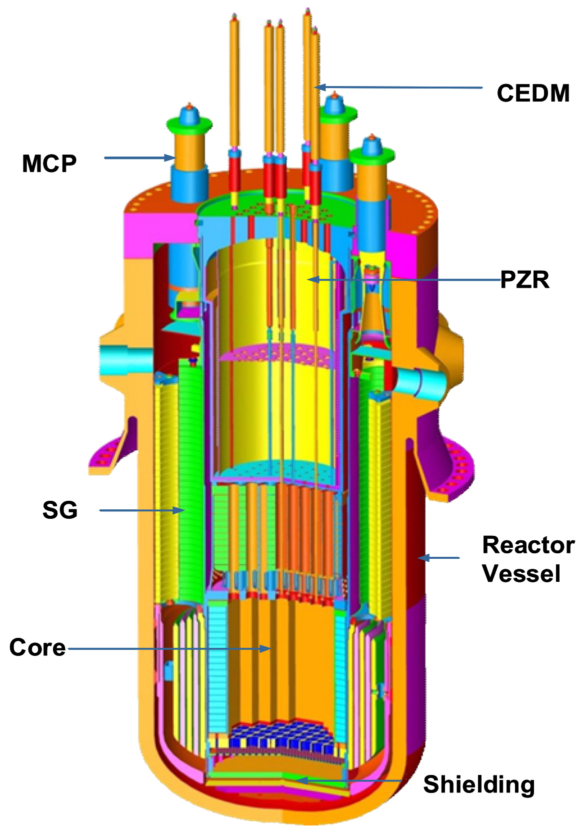
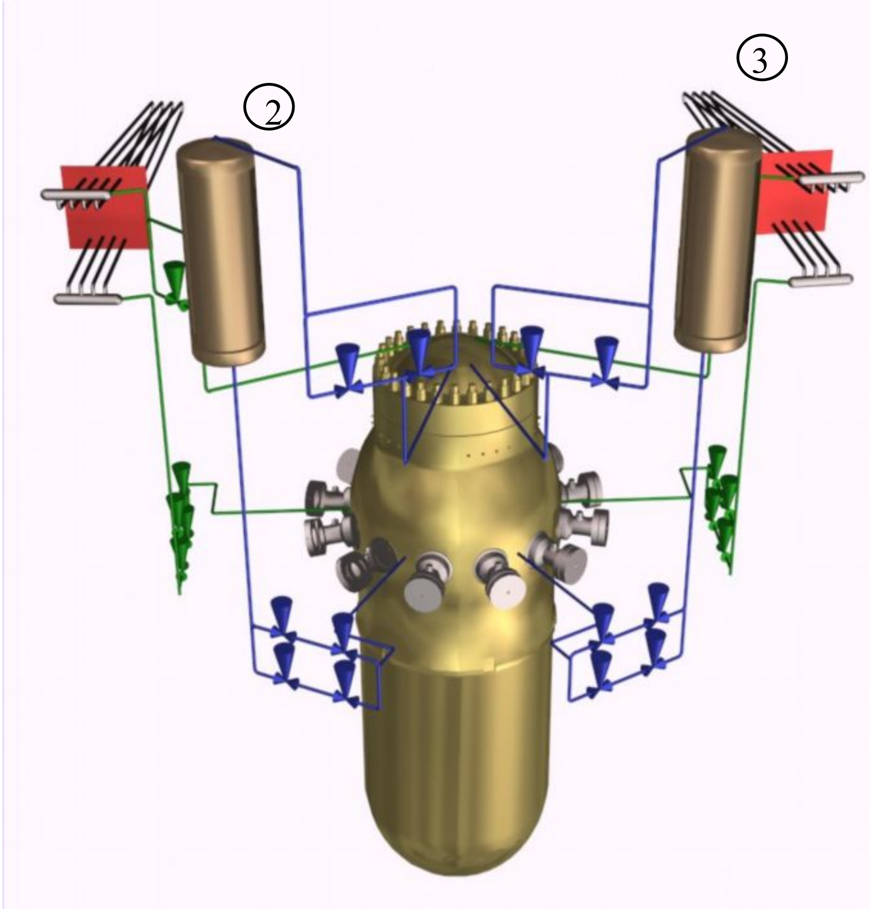


FIG. I-1. SMART reactor.

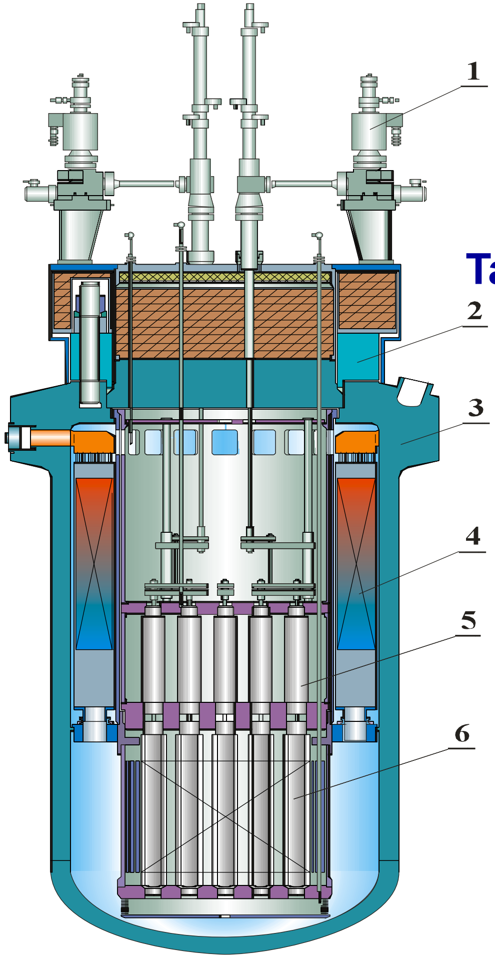
PWRs with Integrated Primary Circuit System – CAREM (CNEA, Argentina)



Central Argentina de Elementos Modulares (CAREM)

- Construction of a prototype ~ 100 MWt, 27 MW(e) (CAREM-25) goes first.
- Targets: Licensing – started; CAREM-25 – 2011; Commercialization (150, 300 MW(e)) to follow.

Small Marine-Derivative PWR without On-site Refuelling – ABV (Russia)



Designed by OKBM (Russia)
45 MWt, 11 MW(e) per module
Operating experience – available
Design – Licensed in most of its parts
Refuelling interval 10-12 years
Targets: Floating NPPs around 2014-2015

1 – CPS drive	2 – Reactor cover	3 – Reactor vessel
4 – Steam generator	5 – Block of protective tubes	6 – Core

Advanced Light Water Boiling Cooled, Heavy Water Moderated Reactor, Pressure Tube Vertical Type – AHWR (BARC, India) – 300 MWe

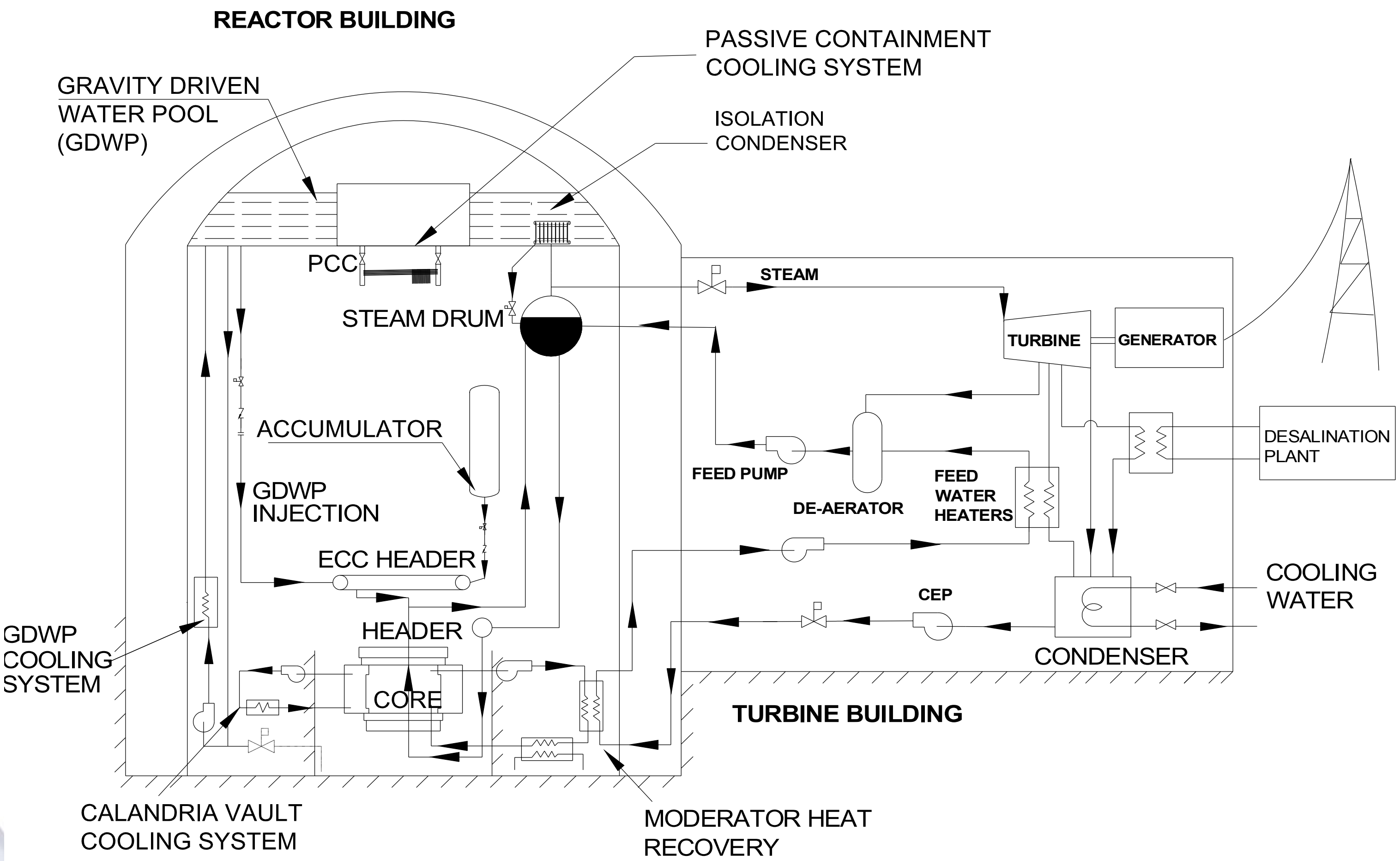
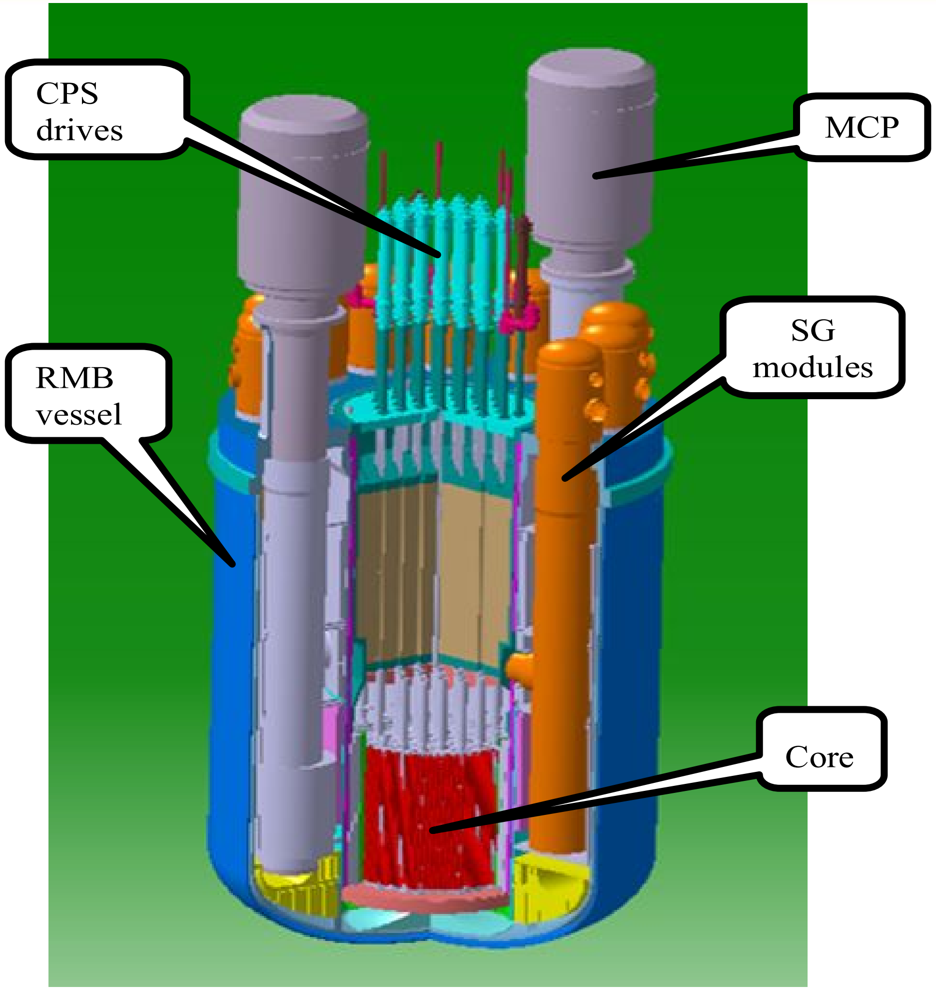


FIG. VI-1. General arrangement of AHWR [VI-1].

Lead-Bismuth Cooled Reactor – SVBR, 100 MWe, refuelling interval 6-9 years



Pb-Bi cooled SVBR 100 reactor of 100 MW(e) with 6-9 EFPY refuelling interval (IPPE-"Gidropress", Russia)

Options for Near-Term Deployment

Reactors with Conventional Refuelling Schemes

PWRs with integrated design of primary circuit

- **IRIS - Westinghouse (USA) + Intl. Team**
- **CAREM – CNEA, Argentina**
- **SMART – KAERI, the Republic of Korea, and several others**

PWRs – marine reactor derivatives

- **KLT-40S *(Floating NPP)* – Rosenergoatom, Russia**
- **VBER-300 *(Land based NPP)* – OKBM + Government of Kazakhstan, Rosatom**

Advanced Light Boiling Water Cooled Heavy Water Moderated Reactors, Pressure Tube Vertical Type

- **AHWR (Designed specifically for *U233-Pu-Th fuel*) – BARC, India**

High Temperature Gas Cooled Reactors

- **HTR-PM – INET, China**

Small Reactors without On-site Refuelling

- **ABV *(Floating NPP)* – OKBM, Russia; *NuScale - NuScale, USA***

Deployment potential of innovative SMRs

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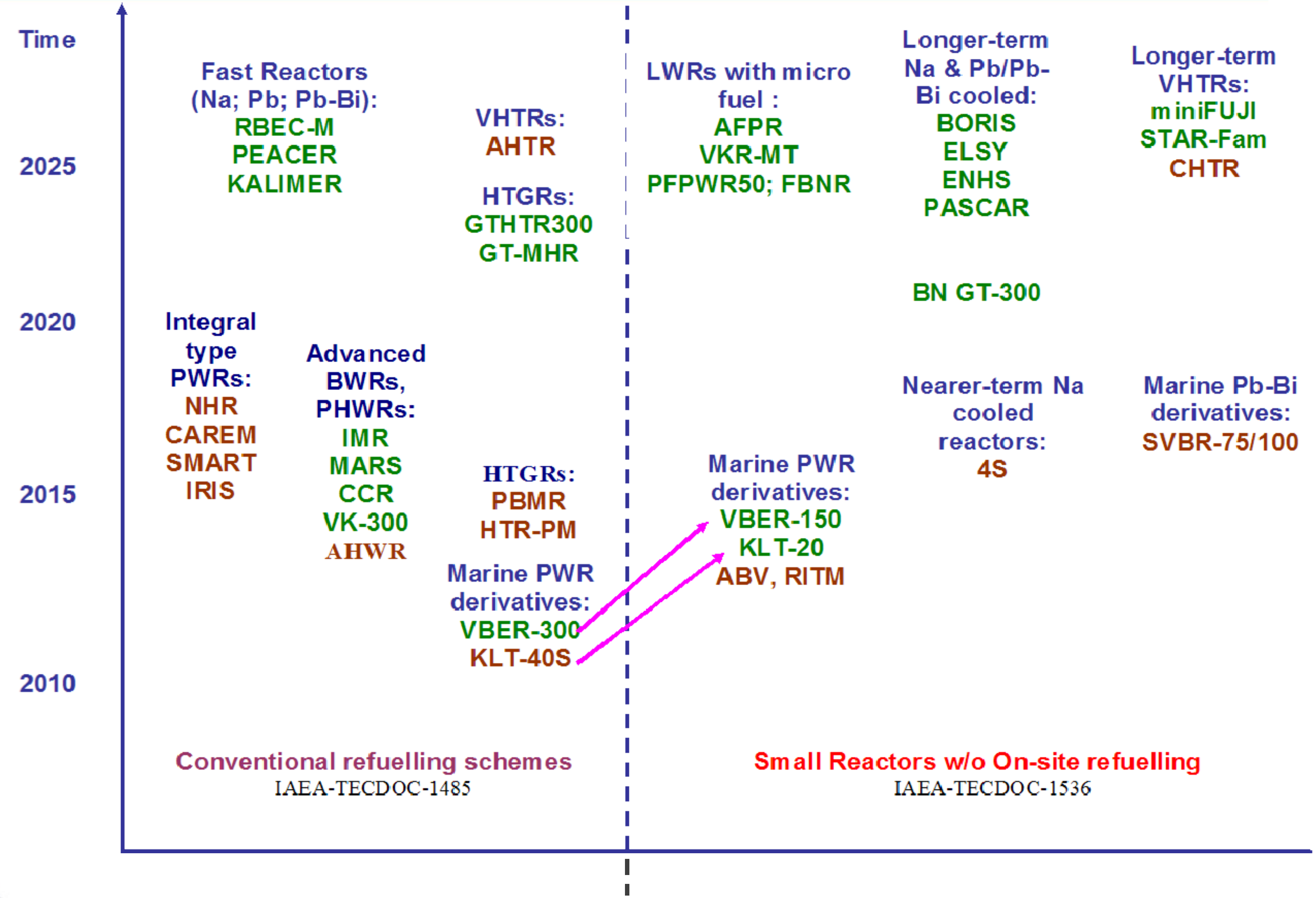

Position on implementation of small reactors in the Czech Republic

Report of Independent commission for evaluation of energy needs for the Czech Republic of 2008

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- Coal reserves will be drastically reduced in next 25 years to about 20 % of current status, and in less than 50 years there will be no more coal reserves
- Essential role of nuclear energy confirmed
- Needs for transition to fast breeders after 2040 recognized
- Use of nuclear energy to non-electric applications identified (central heating, industrial needs, production of hydrogen)
- Lack of primary fuel for central and distributed heating identified as one of the largest risks in mid-term future
- Specific need for small reactors not yet specifically stated in 2008

State energy concept of the Czech Republic of 2010 – Role of nuclear energy

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- Increasing role of nuclear power
- Long term operation of existing units up to 50-60 years
- Accelerate construction of new units, generation III, III+ and generation IV with high level of passive safety and load following capability
- Ensuring sufficient resources of nuclear fuel, development of technologies utilizing plutonium cycle
- Extended use of centralized heat supply from existing and newly built NPP in the time horizon 2030 (including large cities like Brno, Jihlava, Ceske Budejovice, Strakonice)
- In long term horizon (after 2030) considering replacement of existing coal firing sources for central heat supply by small underground nuclear sources with high level of nuclear safety, standardization and pre-fabrication

Public interests in construction of small reactors

- Uncertainty in supply of fossil fuels: Interest in some regions and medium size cities to built small reactors for cogeneration of electricity and heat
- In 2009 the Mayor of Jablonec, a member of the Czech Senate, announced her plans to built in 7 years a small reactor for supplying electricity and heat for 25 000 households, without on-site refuelling
- Recently a private person wrote a letter to NRI asking explanation how to built a small NPP
- Statements by Chairperson of Czech regulatory body
  - It is not a fiction, but at present it is a dream
  - There were several attempts to built a 30-50 MW reactor in the past, which failed due to economical reasons
  - No chance that such reactor will be built in 2015
  - Implementation may be expected in 20-30 years, not before 2025
  - However, new energy crisis can significantly accelerate the process

Opportunities associated with implementation of small reactors in the Czech Republic

Specific background for implementation of small reactors in the Czech Republic

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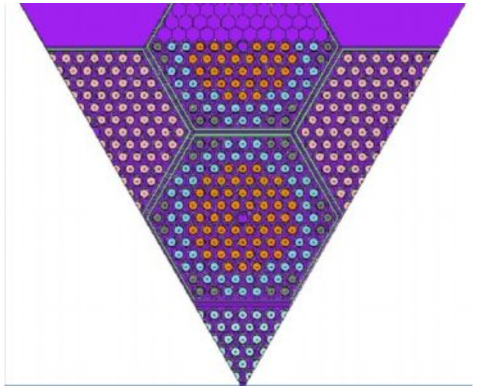
- In the past (70-ties) a number of studies on implementation of nuclear reactors for central heating, but they were not accepted by public
- Recently, growing public interest in large cities for use of reactors for cogeneration heat and electricity
- Background in research, education, design, fabrication of heavy components, plant construction, operation
- Design of all operational NPPs in former Czechoslovakia Czech made
- ~80 % of components for existing NPPs (including RPv, SG, TG, etc - except fuel and RCP) fabricated in CR
- Capabilities for design and fabrication of all major components still available
- Czech engineering and industry can effectively participate in development and implementation of small reactors

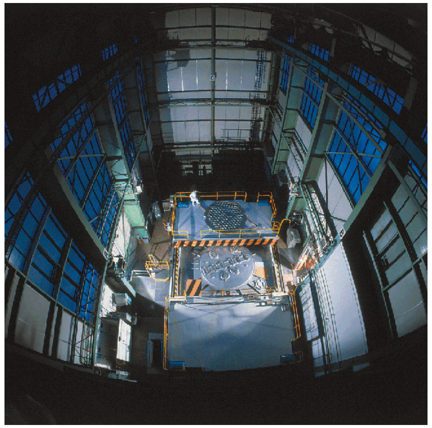
Readiness of Czech engineering and industry to be involved in implementation of small reactors

- From the past, significant experience accumulated with sodium cooled fast breeders, and molten salt reactors
- Experimental loops in currently operating experimental reactors allow for in-pile material testing, and for variety of reactor coolants (sodium, helium, CO_2, supercritical water)
- Major experimental infrastructure aimed at experimental research for new generation of reactors under preparation using European structural funds
- Still available capability for manufacturing nearly all nuclear components, including reactor vessels, control rod drives, steam generators, primary pipes, heat exchangers, turbogenerators, etc
- Development and engineering infrastructure available for all necessary areas, including neutronics, thermal/hydraulics, material structural behaviour, probabilistic safety assessment, radwaste treatment, monitoring, etc available
- Broad international links to EU programmes, France, Russia established
- CR is ready to become an important player in development and implementation of new reactors

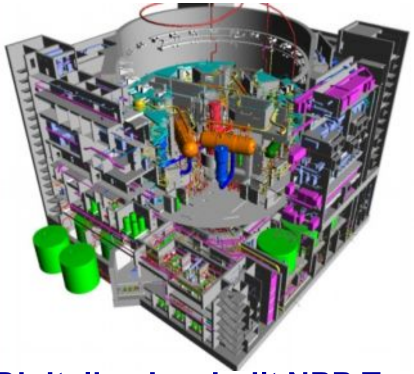
NRI Rez - EXAMPLES OF ACTIVITIES



Criticality analysis using Monte Carlo Method



Neutron physics experiments on LVR-0 reactor



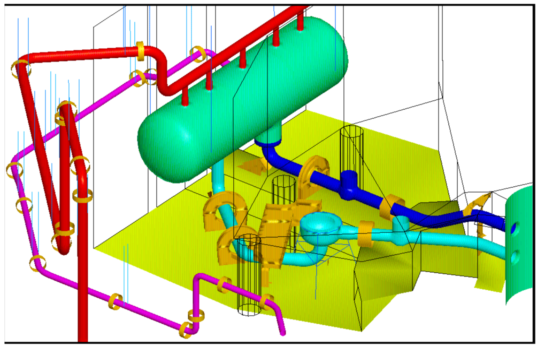
Digitalised as-built NPP Temelín

Qualification of NPP cables

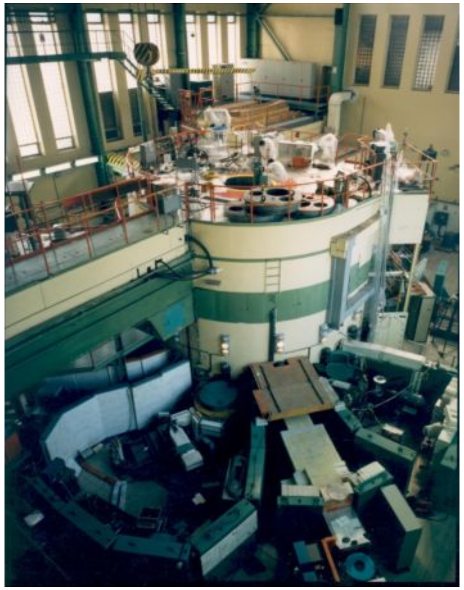
Operation of Pb-Bi loop

Power loop with supercritical parameters of CO2

Demonstration bitumenation unit

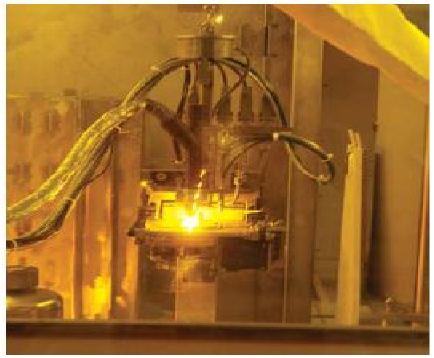


Dynamic analyses of in pipes



Research and irradiation services on LVR-15 reactor

Fossil plant Ledvice 660 MW



Welding for spent fuel repacking

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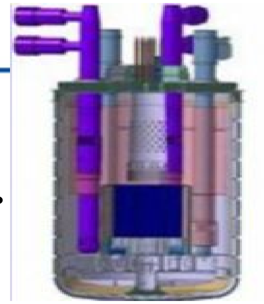
SNETP Road Map for Gen IV Fast Reactors

2008 2012 2020

SFR — Reference technology

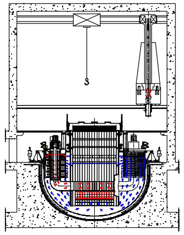


SFR Prototype Astrid (250-600MWe)

LFR

GFR

Alternative technology



ETPP European Technology Pilot Plant LFR Demo

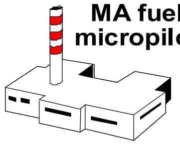
2040: Target for deployment of Gen IV Fast Neutron Reactor

or earlier if new energy needs (electric vehicles, process heat applications)

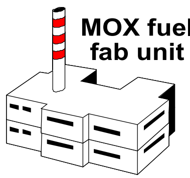
Allegro GFR Demo

- Test bed of GFR technologies
- Innovative fuel qualification and Minor Actinides transmutation
- Test of coupling to heat applications

Supporting infrastructures, research facilities
Irradiation facilities
and fuel manufacturing facilities



MA fuel micropilot



MOX fuel fab unit

Cost : 6 to 10 G€

Czech Republic and UJV Rez – an active member of the SNETP, Involved in development of ALLEGRO reactor

Issues associated with implementation of small reactors in the Czech Republic

Technological issues associated with implementation of small reactors

- At research and development level infrastructure is available for variety of coolant, for both fast neutron and thermal neutron spectra
- At industrial level infrastructure available mainly for pressurized water reactors
- Innovative reactors feature mostly unproven innovative technologies (except water cooled reactors)
- Possible material challenges
- Difficult estimation of component/plant life time
- Innovative fuel cycle
- Security and proliferation issues not completely clear
- Limited knowledge of transient and material behaviour
- Limited set of validated computer codes available
- Limited technological benefit for recipient country in case of factory made facility
- etc

Safety/licensing issues associated with implementation of small reactors

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- In the Czech Republic, licensing of any nuclear installation with more than 50 MWt shall be done according the same set of regulations as any other NPP (Atomic Act and 12 regulations on siting, design, commissioning and operation, physical protection, emergency preparedness, radiation protection, etc)
- Looking for new sites may be a difficult task, if not impossible, unless the legislation will be substantially changed
- Limited experience with new reactor types, all available regulations in Czech Republic based on experience with light water reactors
- Development of technology neutral international safety standards not sufficiently advanced
- Only few of small reactors can be considered as of "proven design" as one of basic safety principles
- Practically no interest both from the regulatory body as well as future operator side to risk building a prototype
- These issues can be successfully resolved in case of strong and stable political and public support

Economical issues associated with implementation of small reactors

- Factors contributing to increasing the cost
  - First of a kind cost
  - Delays in licensing due to limited familiarization
  - Lack of verified designs
  - Uncertainty of life time predictions
  - Small plant output
- Factors contributing to reducing the cost
  - Relatively low total investment
  - Rapid construction
  - Possibility for factory made modules
  - Easy transportation of components, mostly by railway
  - Reduced requirements on emergency planning
- Most probably higher investment cost per installed kWe

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Summary

- Nuclear power in the CR represents a significant component of electricity sector and its role should be further strengthen according the current plans
- In near and medium term development, the nuclear power will be based on pressurized water reactors with unit power above 1100 MWe
- About 50 SMR concepts and designs are being developed within national or international programmes, involving both developed and developing countries. These designs are at very different stages of development. The target dates, claimed by the designers, of readiness for deployment range from 2012 to 2030. These include reactors without on-site refuelling.

Summary

- In the long term, small reactors may become an important source for combined supply of electricity and heat for many countries, including Czech Republic
- Several innovative SMRs have a number of attractive features, including absence of emergency zone, long fuel campaign or even no on-site refuelling, limited security and proliferation risks, but it would be difficult to built them without modifying the current legislation
- Most of SMRs provide for non-electrical applications such as potable water, distric heating or hydrogen production.
- Nuclear sector is prepared to accelerate implementation of SMRs if there will be clear and stable societal order

Summary

- There are a number of issues to be addressed before implementation: public acceptance, development of technology neutral regulations and standards, change of licensing environment including siting, clarification of financial aspects, accumulation of experience with prototypes (proven design)
- The issue of sustainability including availability of resources of nuclear fuel should be taken into consideration
- Czech Republic has large potential to contribute to research, development, design and industrial implementation of small reactors. There is also full capability to develop a complete design with co-generation option utilizing any of the reactor designs

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