International Atomic Energy Agency

IAEA Activities for Innovative Small and Medium Sized Reactors

Presentation by V. Kuznetsov
(NENP/NPTDS)

The 1st COE-INES International Symposium,
INES-1, 31 Oct.-4 Nov. 2004, Tokyo, Japan

International Atomic Energy Agency

Renewed interest in many Member States in the development and application of Small and Medium Sized Reactors (SMRs).

In the past, the trend in nuclear power reactor technology development showed an emphasis towards large reactors due to the economics of scale, which produced reactor designs on to 1600 MWe.

Development of SMRs points into the opposite direction, i.e. towards smaller outputs with an equivalent electrical output of less than 700 MWe.

Small sized reactor: 0-300 MWe

Medium sized reactor: 300-700 MWe

Arguments supporting SMRs:

- Population growth and economic development in today's developing countries which often have insufficient infrastructure and small electricity grids;
- Many developing countries have limited funds for investment, the more so as comes to funds in hard currency
- In developed countries, electricity market deregulation is calling for larger flexibility of power generation, siting and applications
- SMRs are of particular interest for near-term (seawater desalination) and advanced future non-electrical applications (hydrogen production, other process heat applications)

International Atomic Energy Agency

Arguments supporting SMRs:

- Learning from a small prototype plant may be a necessary step in reaching the final goal of wide-scale deployment of innovative technology

The renewed interest in many Member States in the development and application of Small and Medium Sized Reactors (SMRs) is reflected in the increased activities of the IAEA’s (the Agency’s) Nuclear Power Technology Development Section (NPTDS) for this trend.

IAEA-TECDOC-936 "Terms for Describing New Advanced Nuclear Power Plants"

Advanced designs = evolutionary designs and *innovative designs*

an *evolutionary design* is defined as an "advanced design that achieves improvements over existing designs through small to moderate modifications, with a strong emphasis on maintaining design proveness to minimize technological risks"

an *innovative* design as the design "that incorporates radical conceptual changes in design approaches or system configuration in comparison with existing practice" and would, therefore, "require substantial R&D, feasibility tests and a **prototype or demonstration plant** to be implemented"

Why innovative SMRs?

There is a need in the innovation that may facilitate solutions for one or several issues that are currently accepted as critical for further deployment of nuclear power in the subject areas of:

economics

environment

safety

waste management

proliferation resistance and physical protection

infrastructure

contribution to sustainable development

A. Status Report on Innovative SMR Designs (1)

Deliverable: **TECDOC in 2005**

1. Consultancy Meeting: **15-17 March 2004**
2. Technical Meeting: **07-11 June 2004**

TECDOC with Proceedings is under Preparation

3. Contracts

Status Report on Innovative SMR Designs (2)

New Design Description Outline

- 6 subject areas
- fuel cycle options
- non-technical factors and arrangements
- lists and **cross-cuts of enabling technologies**,

applications, special features, design & regulatory status, deployment timelines, design evolution since the last IAEA Status Report (IAEA-TECDOC-881, 1995)

Status Report on Innovative SMR Designs (3)

- **Innovative SMRs (52 inputs from 13 Member States for 4 Reactor Lines)**

➢ Innovative Water Cooled SMRs (7 groups, 24 inputs)

➢ Innovative Gas Cooled SMRs (3 groups, 7 inputs)

➢ Innovative Liquid Metal Cooled SMRs (5 groups, 16 inputs)

➢ Non-conventional SMRs (5 groups, 5 inputs)

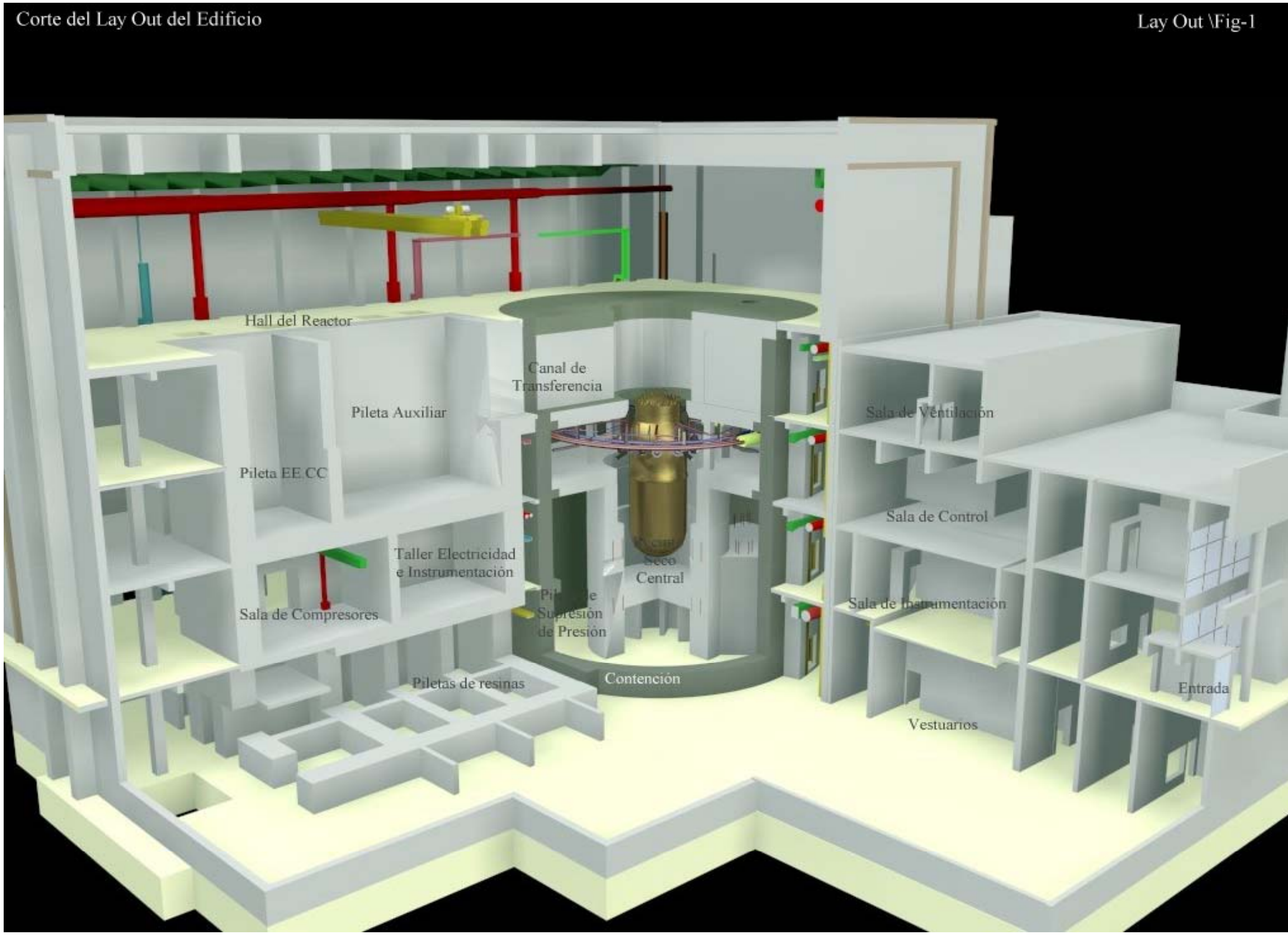


Fig. 1. Plant layout of CAREM (Argentina)

B. Report on Small Reactors without On-Site Refuelling

Deliverable: **TECDOC in 2005**

1. Consultancy Meeting: **15-17 March 2004**
2. Technical Meeting: **07-11 June 2004**
3. Contracts

This Report will be Volume 2 of the Status Report on Innovative SMR Designs

23 out of **52** inputs for the Status Report on Innovative SMR Designs are **Small Reactors without On-Site Refuelling**

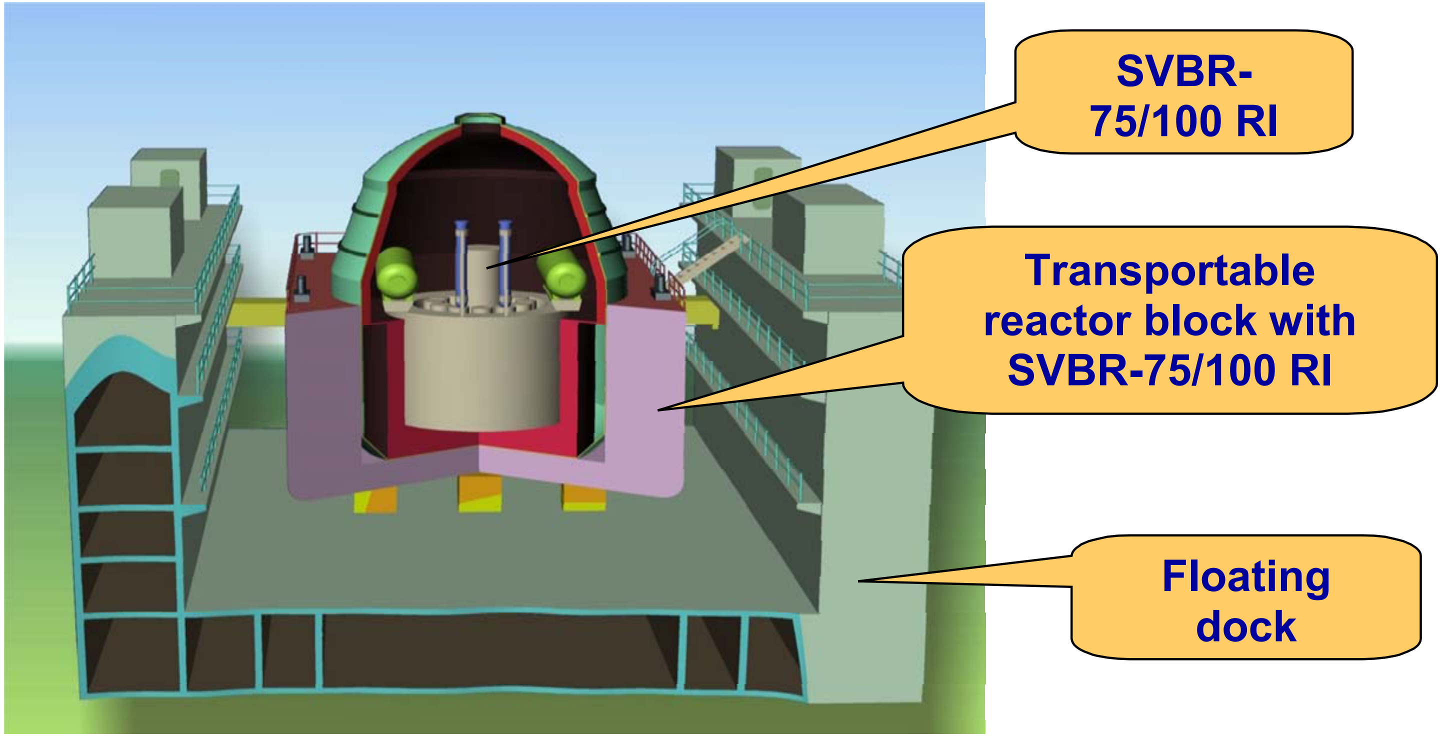


Fig. 2. Floating NPP option is being developed not only for small PWRs, but also for lead-bismuth cooled reactor SVBR-75/100 (75-100 MWe, integral design, IPPE, Russia [8]), which is currently in the detailed design stage and is thoroughly based on 80 years of operation experience of its marine prototypes

C. Coordinated Research Project "Development of Small Reactors without On-Site Refuelling" (2004-2007)

Deliverable: **TECDOC in 2007**

Objective:

to increase the capabilities in IAEA MS to achieve progress in the development and deployment of Small Reactors without On-Site Refuelling by formulating major requirements for Small Reactors without On-Site Refuelling and increasing international cooperation for the development of key enabling technologies for such reactors.

Nuclear Power Technology Development Section Activities for Innovative SMRs in 2004-2005

C. Coordinated Research Project “Development of Small Reactors without On-Site Refuelling”. Activities (1)

- Identification and prioritisation of the enabling technologies, concepts and designs of Small Reactors without On-Site Refuelling to be addressed in the CRP

- Identification of requirements and broader specifications for NPPs with Small Reactors without On-Site Refuelling for selected representative regions

C. Coordinated Research Project "Development of Small Reactors without On-Site Refuelling". Activities (2)

- Review of the approaches to ensure lifetime core operation without refuelling, including benchmark analysis for long-life cores of several concepts of Small Reactors without On-Site Refuelling
- Review of the inherent safety and passive safety design options for Small Reactors without On-Site Refuelling and comparative analysis of selected accident scenarios, including the operation of passive reactivity regulating systems and passive decay heat removal systems

Definition of Small Reactor without On-Site Refuelling

The term “refuelling” could be defined as the “removal and/or replacement of either fresh or spent, single or multiple, bare or inadequately confined nuclear fuel cluster(s) or fuel element(s) contained in the core of a nuclear reactor”.

With this the infrequent replacement of well-contained fuel cassette(s) in a manner that prohibits clandestine diversion of nuclear fuel material is permitted.

Sources:

1. Consultancy Meeting: **15-17 March 2004**
2. Technical Meeting: **07-11 June 2004**

Features of Small Reactors without On-Site Refuelling

(1) Small Reactor without On-site Refuelling should have the following essential features:

1.1. Capability to operate without refuelling for a reasonably long period consistent with the plant economics and energy security;

1.2. Minimum inventory of fresh and spent fuel being stored at the site outside the reactor during its service life;

1.3. An enhanced level of safety, consistent with the scale of global deployment of such reactors, through wider implementation of inherent and passive safety features and systems;

Features of Small Reactors without On-Site Refuelling

(1) Small Reactor without On-site Refuelling should have the following essential features:

1.4. Economic competitiveness for anticipated market conditions and applications;

1.5. Difficult unauthorized access to fuel during the whole period of its presence at the site and during transportation, and design provisions to facilitate the implementation of safeguards;

1.6. Capability to achieve higher manufacturing quality through factory mass production, design standardization and common basis for design certification.

Features of Small Reactors without On-Site Refuelling

(2) Small Reactor without On-site Refuelling may have the following additional desirable features:

2.1. Factory fabrication and fuelling to facilitate delivery of a sealed core to the plant site;

2.2. Capability to survive all postulated accident scenarios, including those caused by natural or human-induced external events, without requiring emergency response actions arising out of unacceptable radiological consequences in the public domain and without compromising the transportability of reactor back to the manufacturers;

Features of Small Reactors without On-Site Refuelling

(2) Small Reactor without On-site Refuelling may have the following additional desirable features:

2.3. An overall reactor and fuel cycle enterprise that is highly unattractive for weapons purposes, e.g. offering limited overall amount of material, high degree of contamination providing noticeable radiation barriers, incorporating fuel forms that are difficult to reprocess and/ or types of fuel that make it difficult to extract weapons-grade fissile material;

2.4. A variety of applications, including generation or co-generation of electricity, heat, potable water, or hydrogen production;

Features of Small Reactors without On-Site Refuelling

(2) Small Reactor without On-site Refuelling may have the following additional desirable features:

2.5. A variety of options for siting, including those close to population centres, as well as remote and hardly accessible areas, dispersed islands, etc;

2.6. Simplified operation procedures and robustness with respect to human errors;

2.7. Minimum reliance on sophisticated local infrastructure;

2.8. An overall reactor and fuel cycle enterprise that contributes to effective use of resources in a sustainable way.

D. Review of Passive Safety Design Options for SMRs

Deliverable: **Draft TECDOC in 2005**

1. Consultancy Meeting: **to be defined**
2. Technical Meeting: **06-10 June 2005**
3. Contracts

E. Review of Experience and Options Relevant for Validation, testing and Demonstration of Passive Safety Systems for SMRs

1. Consultancy Meeting: **to be defined**
2. Technical Meeting: **17-21 October 2005**
3. Contracts

Proposals for P&B 2006-2007 (1)

New

Sub-programme A.1.4. Common Technologies and Issues for SMRs

1. Cooperate in International Symposium on Non-Electrical Applications of Nuclear Power (in coordination with A.5.02/4)

2. Review options to break the economy of scale for SMRs and hold a Technical Meeting in 2007

3. Review common enabling technologies for SMRs and hold a Technical Meeting in 2006

Proposals for P&B 2006-2007 (2)

Sub-programme A.1.4. Common Technologies and Issues for SMRs

4. Coordinate a CRP on the identification of competitive technological options for SMRs (2006-2009) – approved.

Proposals from MS:

- *Dynamic system simulations for systems with small reactors and Regional Fuel Cycle Centres*
- *Development of Methodology and Approach to Revise the Need for Relocation and Evacuation Measures Unique to Nuclear Reactors*

MAJOR FINDINGS AND CONCLUSIONS (1)

- Multiple R&D on-going many Member States cover a variety of SMR design and safety approaches targeted at near-, medium- and longer-term deployment

- They also cover the expanded range of energy products, including potable water, district heating, process heat and hydrogen production

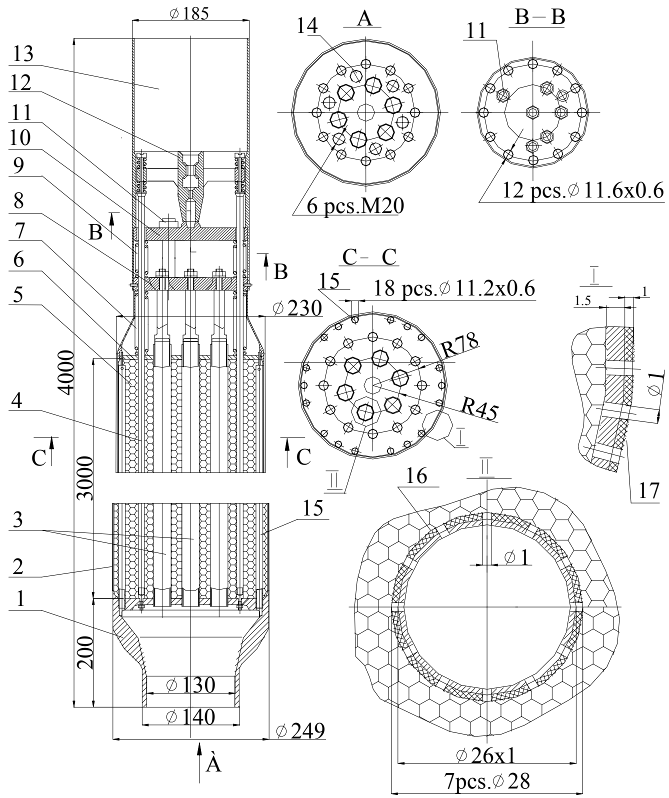
MAJOR FINDINGS AND CONCLUSIONS (2)

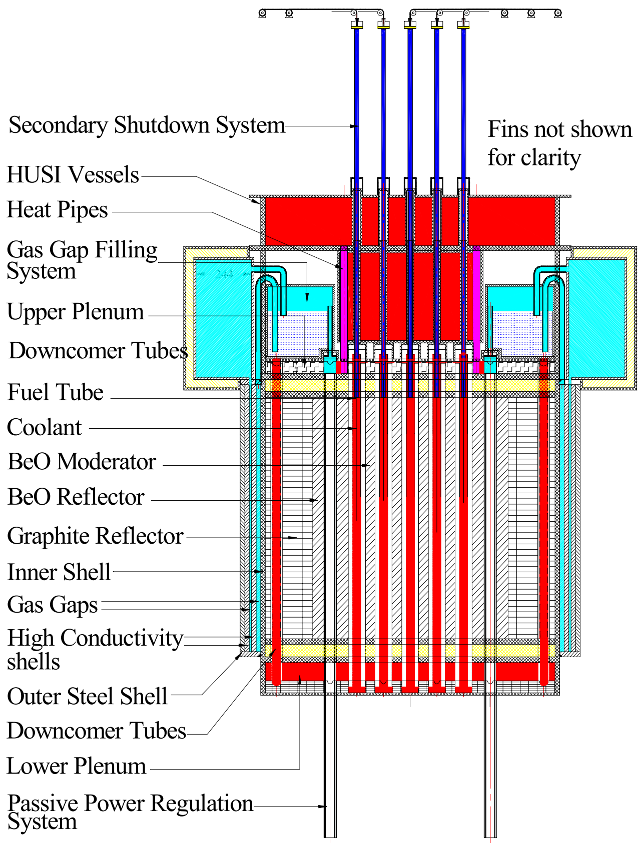
- The need to break the economy of scale is clearly identified as an objective of prime importance for SMRs.
- Several factors arising from the on-going liberalization of energy markets are mentioned as being particularly in favour of NPPs with reactors within the small to medium power range, among them:
  - economy of multiple small modules and corresponding minimized financial risk,
  - diversity of offers and flexibility in the adjustment of design and applications.

MAJOR FINDINGS AND CONCLUSIONS (3)

- To realize the benefits of multiplicity, worldwide market is needed, and one option to expand to worldwide market is international cooperation.

- SMRs have many common technology development issues related to the provision of economic competitiveness, high level of safety and proliferation resistance.





(a) Fuel assembly of VKR-MT (300 MWe BWR Heat and Power Plant with pebble-bed coated particle fuel, VNIIAM – RRC KI, Russia [5])

(b) Core view of CHTR – Compact High Temperature Reactor (0.1 MWth lead-bismuth cooled very high temperature reactor with HTGR type prismatic fuel)

MAJOR FINDINGS AND CONCLUSIONS (4)

- To increase deployment opportunities for SMRs the resolution of several legal, institutional, infrastructure, and public acceptance issues could be important, among them:
- reciprocity of licensing agreements,
- insurance of fuel supply and/or securing increased guarantees of sovereignty through increased refuelling interval,
- simplified licensing procedures, e.g. reduced or eliminated off-site emergency planning and/or simplified licensing of replicate plant construction.

MAJOR FINDINGS AND CONCLUSIONS (5)

- Reduction of the emergency planning requirements is of special interest to designers of both near-term and longer-term SMRs, since it could significantly enhance economic viability and improve public acceptance of such reactors.

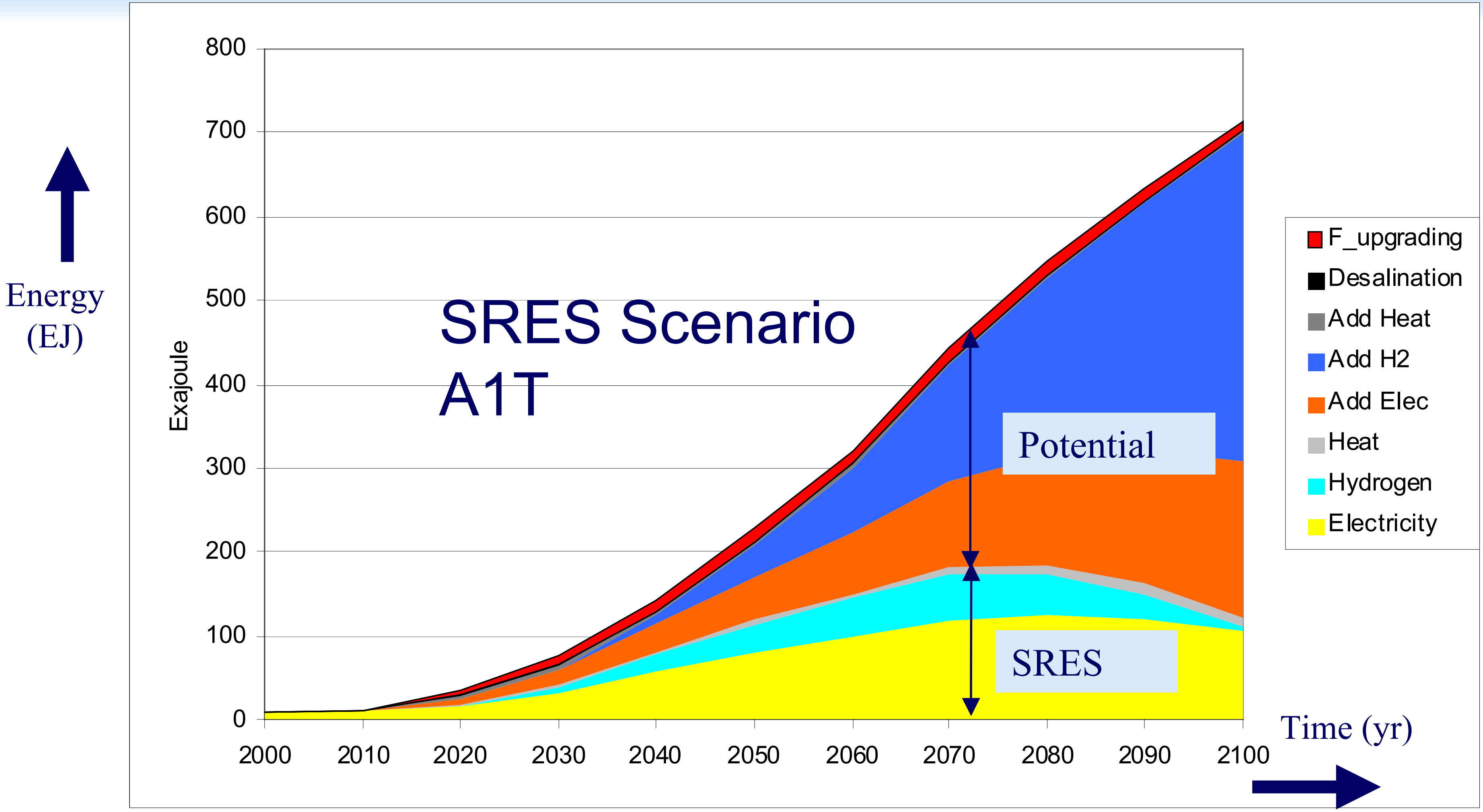
MAJOR FINDINGS AND CONCLUSIONS (6)

- The need of early involvement of regulators to facilitate the process of adjustment of regulatory rules to innovative nuclear reactor concepts is mentioned by many SMR designers worldwide.

To facilitate the preparation of new, technology neutral safety guides and requirements, the designers of IRIS [9] have kept informed the IAEA's Division of Nuclear Installation Safety (NSNI) of their activities from an early stage, and are planning to have an IAEA safety review.

MAJOR FINDINGS AND CONCLUSIONS (7)

- The inputs from Member States indicate that for different countries and regions different solutions for nuclear energy systems with SMRs may be preferable, due to different national or regional constraints. Many of them may be made complementary.
- Detailed evaluation of each particular nuclear energy system with a link to relevant national, regional and global constraints may be required to identify opportunities for SMR deployment.



Potential Global Market for Nuclear Electricity, Hydrogen, Heat and Desalination for A1T IPCC SRES Scenario

MAJOR FINDINGS AND CONCLUSIONS (8)

Reflecting the renewed interest to Small and Medium Sized Reactors,

the Agency will provide an increased support to interested Member States in defining common technology issues and in coordinating selected international R&D efforts for SMRs, as well as in developing strategies for the deployment for such reactors.

THANK YOU!