The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2245-11

# Joint ICTP-IAEA Advanced School on the Role of Nuclear Technology in Hydrogen-Based Energy Systems

*13 - 18 June 2011*

## IAEA Initiatives on Hydrogen Related Activities

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# IAEA Initiatives on Hydrogen Related Activities

KHAMIS, Ibrahim

**Department of Nuclear Energy**

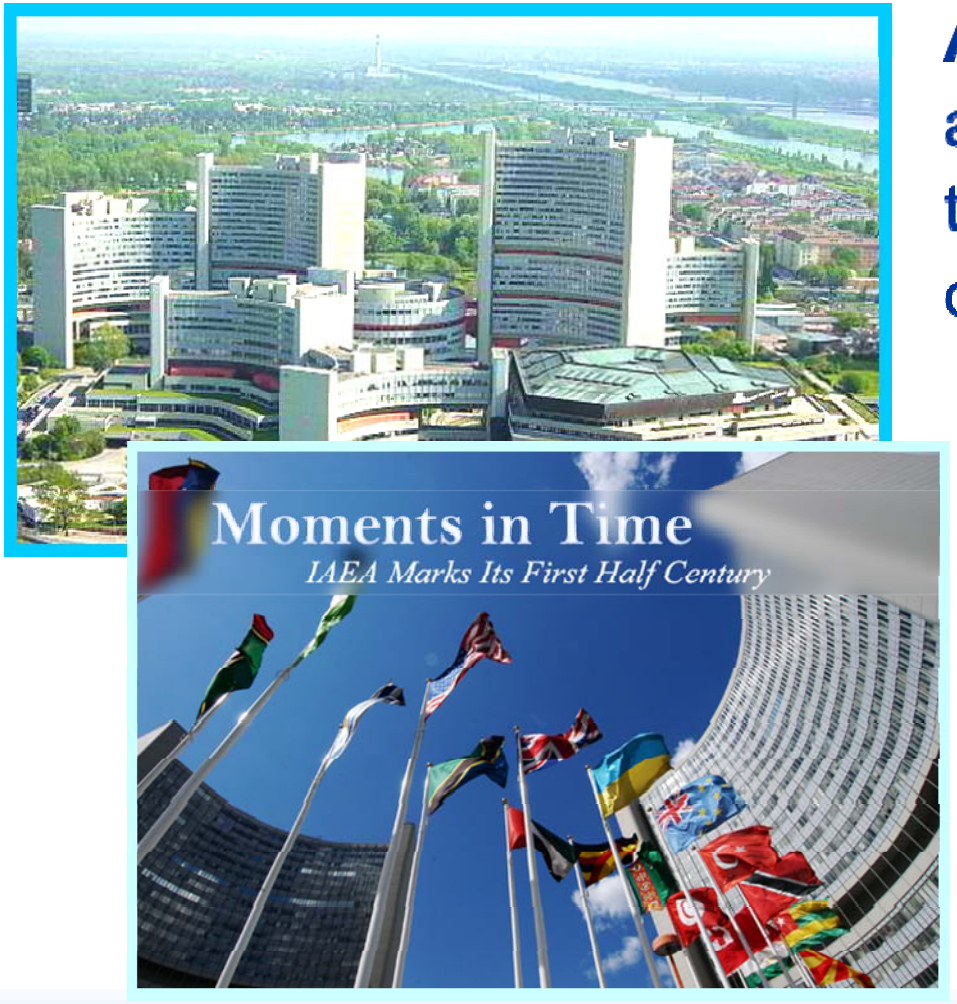
# Contents

- Introducing IAEA: Role & Structure & Pillars
- Hydrogen & Need for Nuclear Energy
- Insight of IAEA Member States
- IAEA activities on nuclear hydrogen
- Conclusion

**The International Atomic Energy Agency** (IAEA)

is an independent intergovernmental, science and technology-based organization, in the United Nations family, that serves as the global focal point ***for nuclear cooperation***

# International Atomic Energy Agency (IAEA)




**Atoms for Peace (1953)**
addressed by D.Eisenhower, to the 470th Plenary Meeting of the UN GA

- **Founded 1957**
- HQ in Vienna, Austria
- **151 Member States**
- 6 Departments
- 2200 Staff
- About 300 MEuro Budget
- www.iaea.org

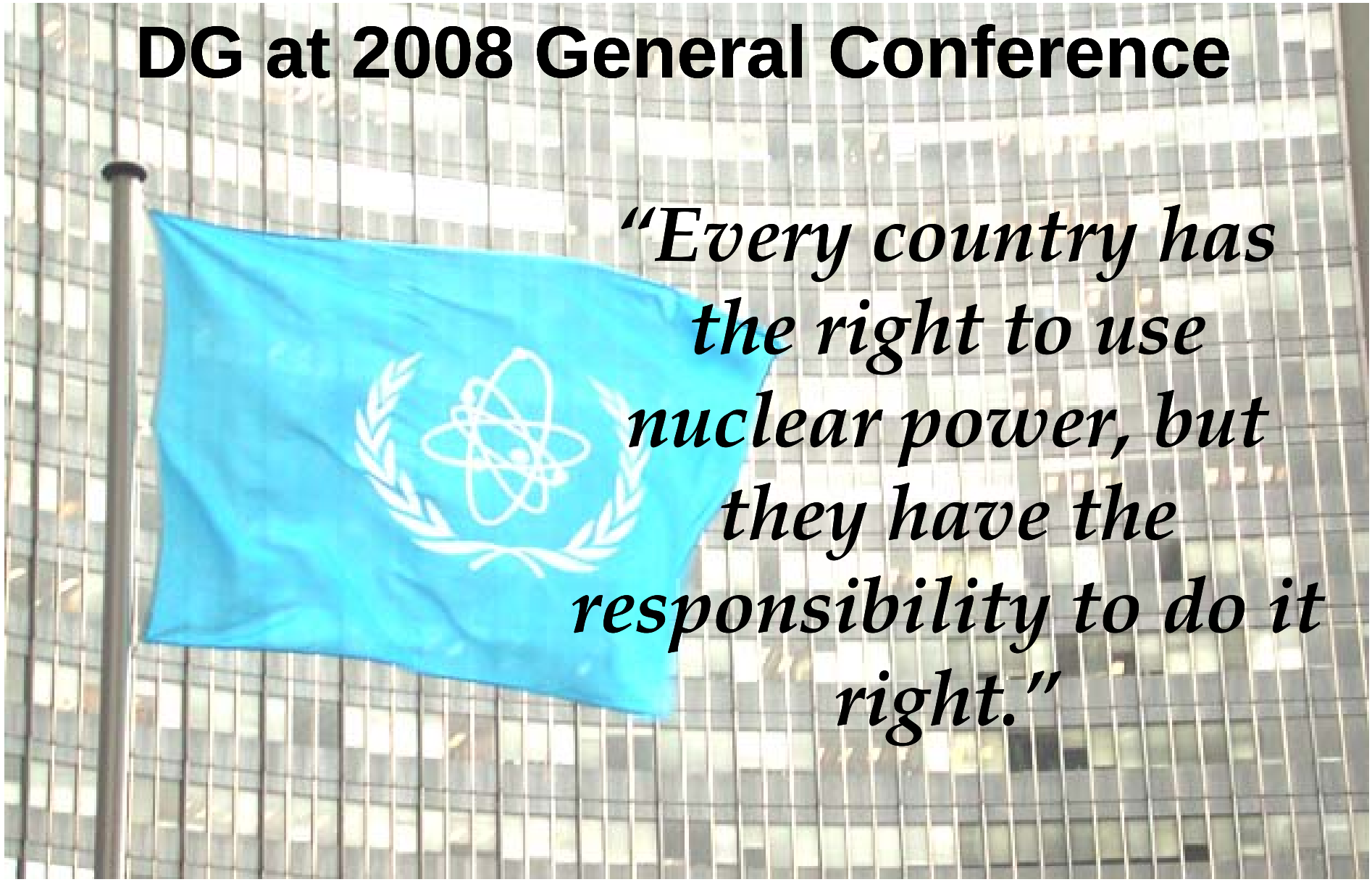
# IAEA and Nuclear Power

***"The Agency has a key role to play in ensuring that this expansion in nuclear power takes place in an efficient, responsible and sustainable manner.***

"…***countries should be able to introduce nuclear power knowledgeably, profitably, safely and securely. ."***

**Yukiya Amano, Director General**

# DG at 2008 General Conference



*"Every country has the right to use nuclear power, but they have the responsibility to do it right."*

# Role of the IAEA

- Involves ALL countries
- Special focus on:
  - Training developing countries
  - Sharing information
  - Catalyse research, development and innovation
- ***Means to achieve goals***
  - Training workshops, technical meetings
  - Collaborative research activities
  - Produce reports/documents

# What does IAEA do?

- **Standards and Guidance**
- **Reviews and Services**
- **Capacity Building**
- **Knowledge Networks**
- **Forum for communicating & sharing lessons learned**


Safeguards
Safety & Security
Nuclear Applications
Nuclear Energy
Technical Cooperation

# The Nobel Peace Prize 2005

"for IAEA effort to prevent nuclear energy from being used for military purposes and to ensure that nuclear energy for peaceful purposes is used in the safest possible way"

# Pillars of the IAEA


- **Promoting Science & Technology**

  the world's focal point to mobilize peaceful applications of nuclear science and technology for critical needs in developing countries

- **Promoting Safeguards & Verification:**

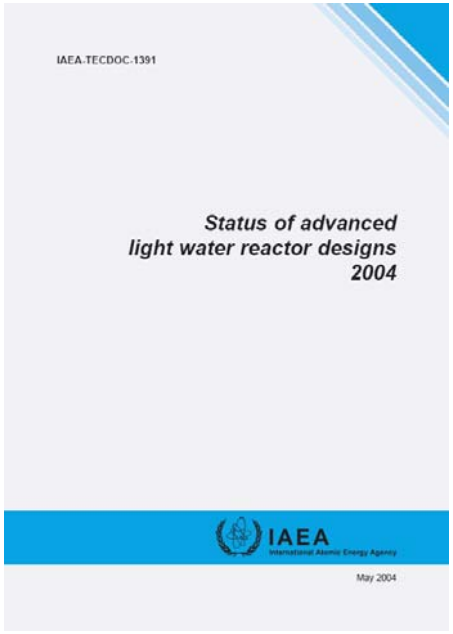
  the world's nuclear inspectorate

- **Promoting Safety and Security**

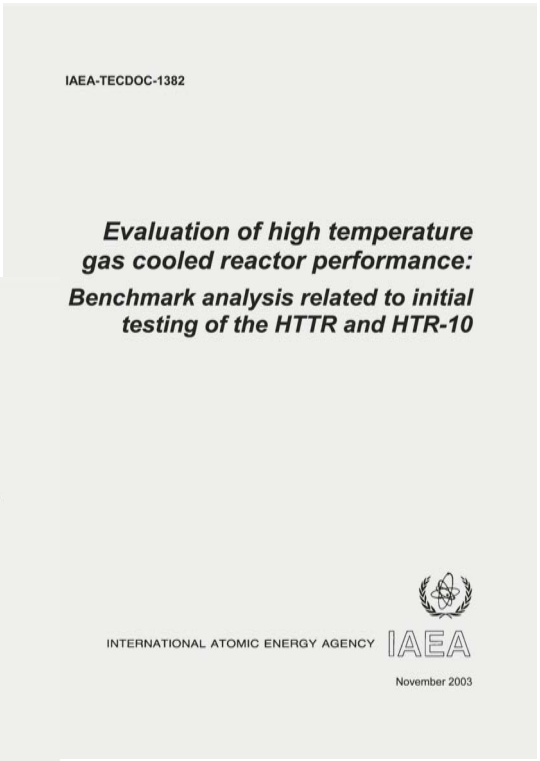
  helps countries to upgrade nuclear safety and security

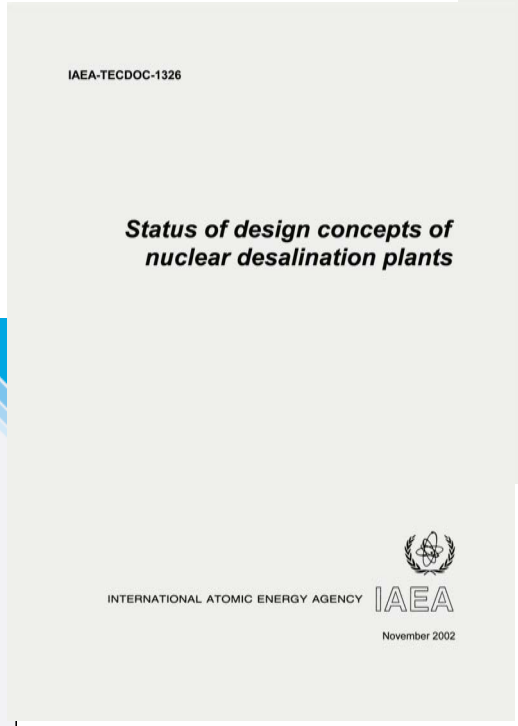
**IAEA's 50 Years of Atoms for Peace (2007)**

# Nuclear Power Technology Development Section

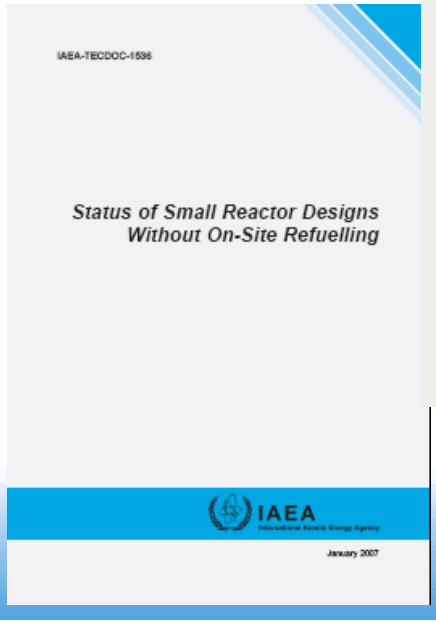




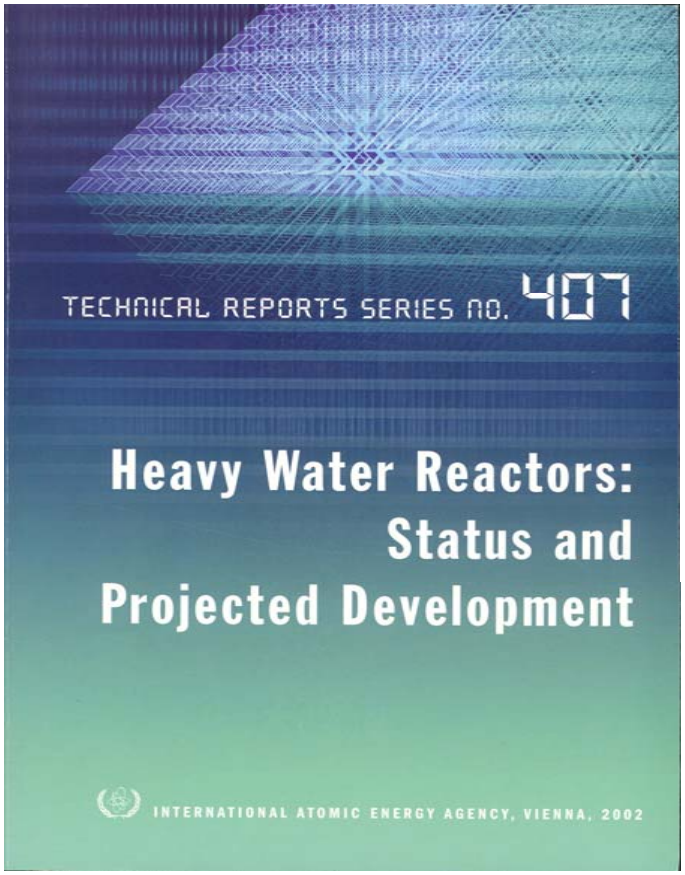


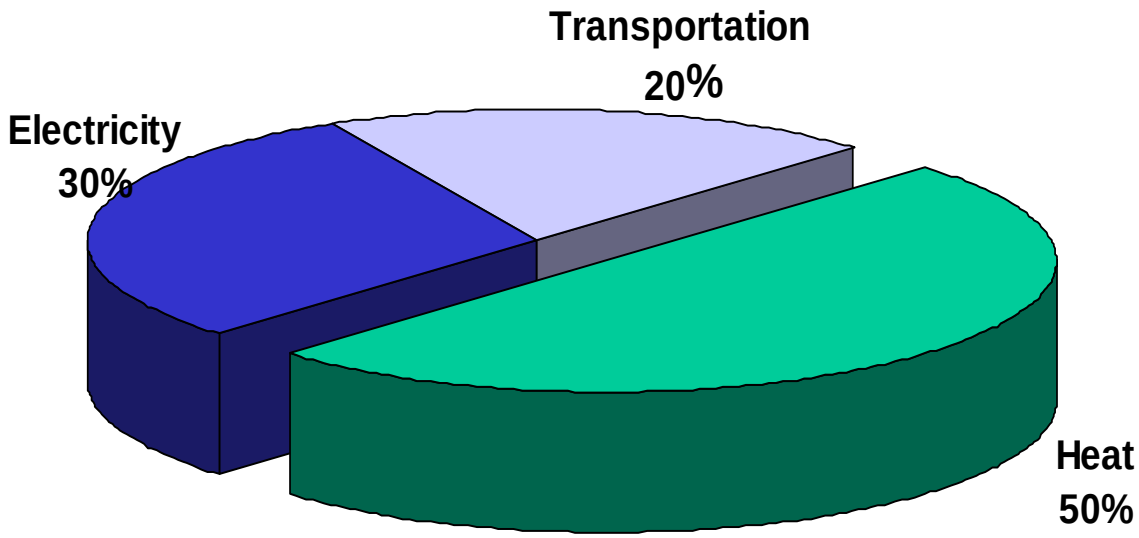


# Nuclear Power Technology Development Section




# Worldwide Energy Consumption by Application




Nuclear could make bigger impact by penetrating heat and transportation sectors

# Hydrogen Demand

- There is an *increased interest* in hydrogen as a carbon-free fuel of future.

- Demand for hydrogen is large and keeps growing (at rate of 6-10 % /year).

- Reforming of hard coal and oil (gasification): 96% of current annual hydrogen production

# Hydrogen Demand

- Total current world demand for $H_2$ : 50-60 Mt/a
  - Ammonia production 40 – 45 Mt/a
  - Methanol 1 – 2 Mt/a
  - Oil refining 10 – 15 Mt/a (growth area)

- $H_2$ for synthetic crude oil upgrading (Canada)

  (2.4 – 4.3 kg $H_2$ per barrel of bitumen)
  - Current: 2.0 Mt/a
  - By 2020: 6.0 Mt/a

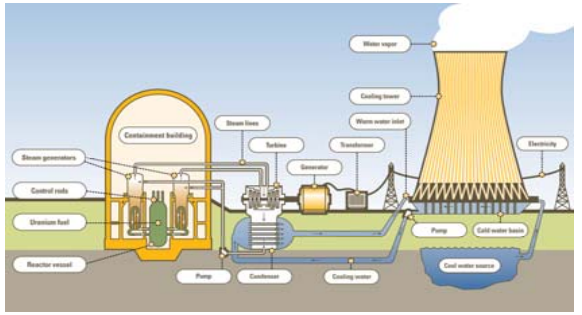
- Hydrogen as a transportation fuel
  - ????? Mt/a

# An example on hydrogen consumption

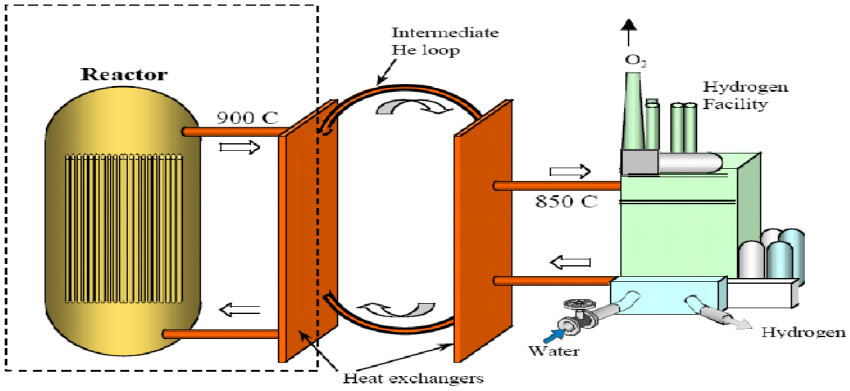
- 2005 US consumption: 13 million tons $H_2$/yr
  - 95% produced by steam reforming of natural gas (8% of US natural gas use)
  - Releases 80 million tons $CO_2$/yr
- *Replacing present US transportation fuels* (gasoline, diesel, jet fuel) with hydrogen would require a 17-fold increase in hydrogen prod. i.e:
  - Would consume >100% of natural gas supply, or
  - Would require ~500 of 1000-MWe power plants to provide energy for water splitting

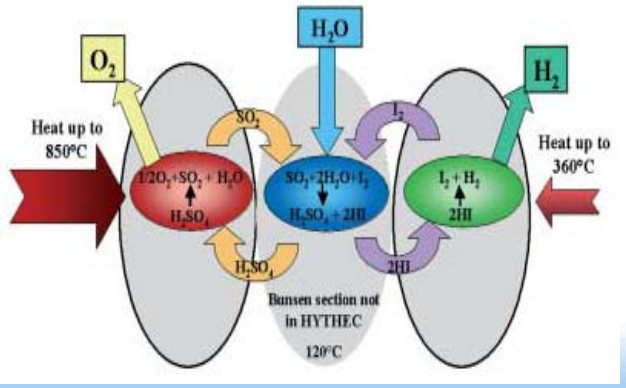
# Hydrogen production using nuclear power

- Current nuclear reactors:
  - ✓ low-temperature electrolysis,
    efficiency ~ 75% ;
  - ✓ Off-peak power or intermittent



- Future nuclear reactors:
  - ✓ high-temperature electrolysis,
    efficiency ~ 95%;
  - ✓ Thermo chemical splitting,
    efficiency ~ 95%:
    - Sulfur- Iodine cycle.
    - Sulfur-Bromine hybrid cycle



# Conventional Vs High-Temperature Electrolysis

| | Conventional | High-Temperature |
|---|---|---|
| Feed | Water – liquid phase | Steam |
| Temperature | <100ºC | ~850ºC |
| Electrolyte | Alkaline or Proton Exchange Membrane (PEM) | Oxygen ion conducting ceramic or proton-conducting ceramic |
| Overall efficiency | ~ 27% (integrated with current generation reactors) | ~50% (integrated with future generation high-temp reactors)<br>>33% (integrated with ACR-1000 and electrical resistance heating) |

# *Electrolysis is promising*

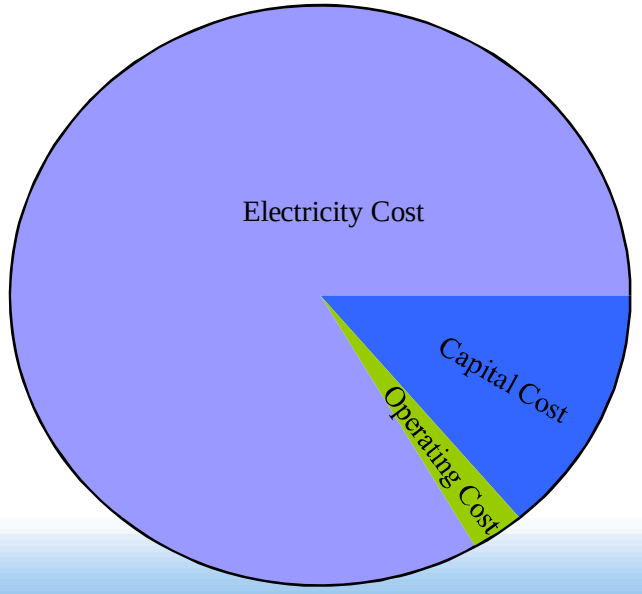
Short-Term Option

- Off-peak power from existing Nuclear power plants.
- Ideal for remote and decentralized $H_2$ production

200 $m^3/h$

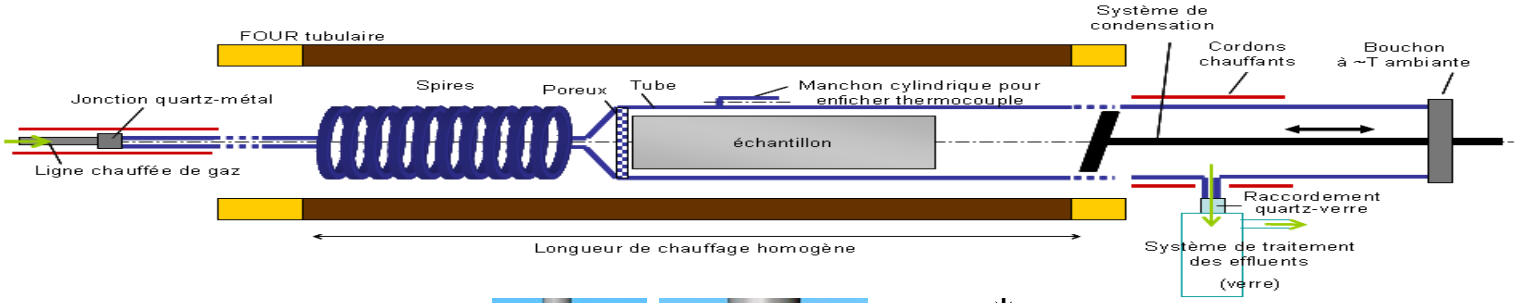
*For low temp Electrolysis:*

- Electricity costs dominate total hydrogen cost (80- 90% of cost)

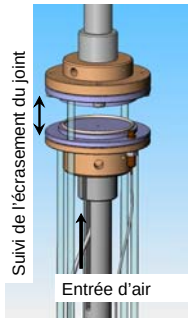


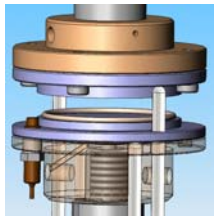
# Breakthrough on HTSE (France, Canada, US)

## On cells and interconnects

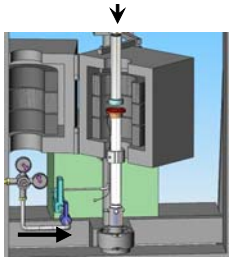



## on seals and leaks management systems

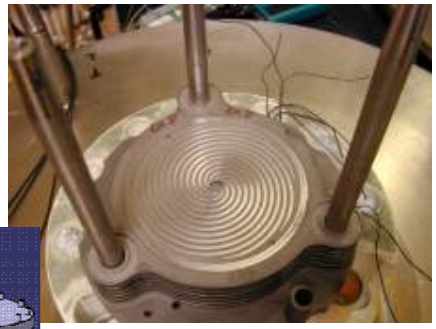


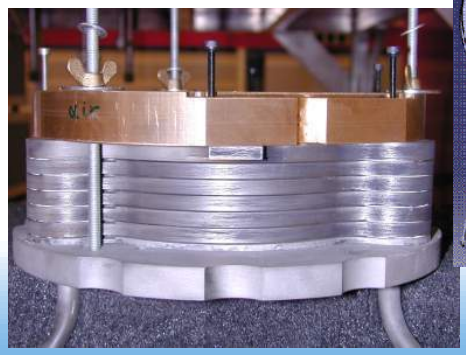
Détails tringlerie

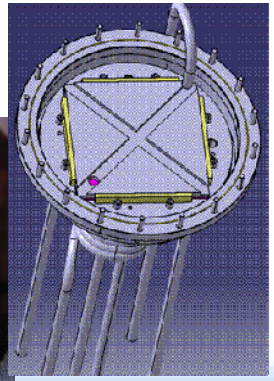


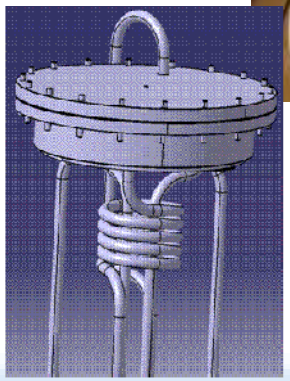
Pression et débit



## Progress on Designs and tests on stacks





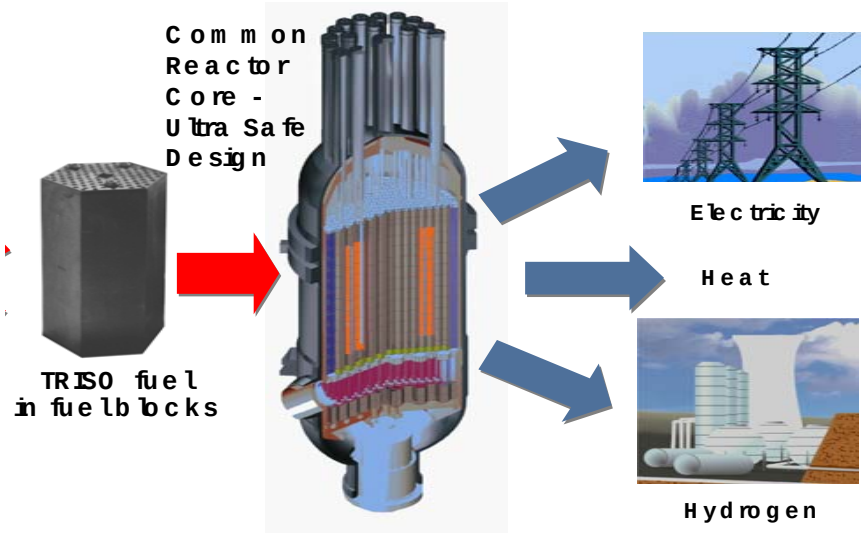


# Insight of IAEA Member States

- Increasing interest in electrolysis
  - Low temperature has potential – economics?
  - High temperature is 10 to 20 years away
    - Major effort in China, US, Canada, India?
- Chemical processes of interest, but…
  - Which reactors ??
  - Which processes??
- Economics???

# Global status on high temp reactors

- South Africa suspends PBMR effort
- China developing HTR – start up imminent
- India looking at molten salt option
- France VHTR was a breeder option
- Japan has operated HTR at 950 C and interested in S_I process
- Rep. of Korea is interested in thermo chemical process
- Canada in HTSE
- USA proceeding on NGNP (next generation nuclear plants)

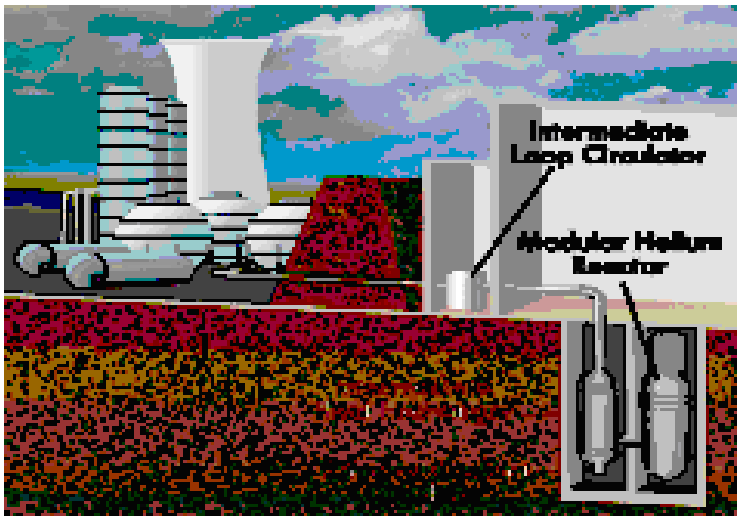


# Technical R&D Challenges for Nuclear Hydrogen

- Reactor designs and materials.
- Develop chemical processes that operate efficiently and reliably.
- Demonstrate production and large-scale storage of hydrogen.
- Overcome barriers to economic hydrogen generation.

# Non-technical Challenges

- Public Opinion




- Need for Large and Long-term investment

- Safety of Coupling between Nuclear plant and Chemical plant

# Current/future IAEA activities on nuclear hydrogen

- Documents and reports
  - *Status of Hydrogen Production using nuclear energy (**under publication, 500 pages**)*
  - *Advances in Nuclear Power Process Heat Applications (**under publication, 326 pages**)*
  - *Use of NPP for cogeneration (incl. Hydrogen) (**under preparation**)*

- Economic evaluation of nuclear hydrogen
  - *Development of HEEP computer model*
  - *HEEP Benchmarking and validation: a Coordinated Research Programme (CRP)* ***starting in 2012***

- Training Workshops and conferences
  - *Technical meeting on non-electric applications, Czech Rep. 3-6 Oct, 2011*

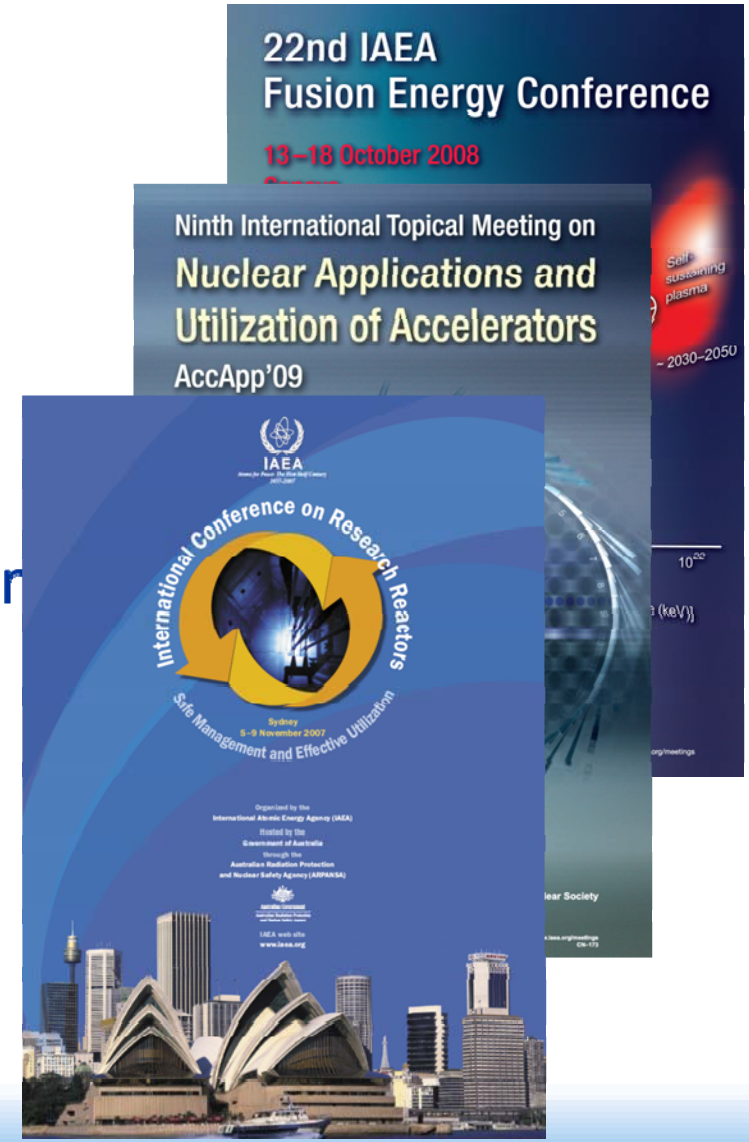
# Physics section profile

The PS supports the IAEA Member States regarding utilization of:

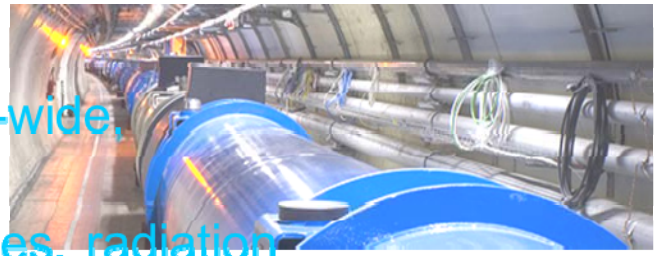
- Accelerators
- Research reactors
- Cross-cutting material research
- Controlled fusion
- Nuclear instrumentation

PS implements P&B activities based on MS demand. Organisation of Int. conferences, Technical and expert meetings, CRP, Networks, DBs, Technical Cooperation, etc.

**Objective is to promote nuclear science & technology, specifically applied physics and material science related to nuclear energy.**



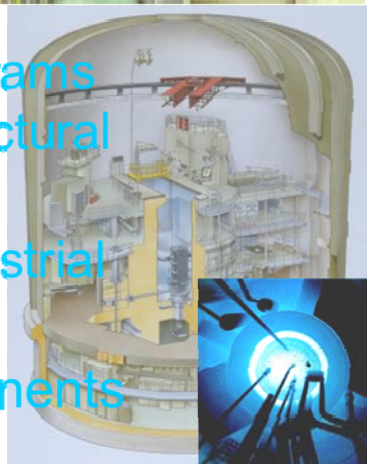
# Accelerators & Research reactors



**Accelerators:**

- In total more than 15.000 accelerators used world-wide, multidisciplinary use, s), CC schema.
- Research & industrial applications, nuclear (isotopes, radiation processing, materials testing) and non-nuclear (biology, geology, archeology, medicine, etc.), primarily energy related, novel materials for hydrogen production, storage and conversion.
  www-naweb.iaea.org/napc/physics/accelerators/database/index.html

**Research reactors:**



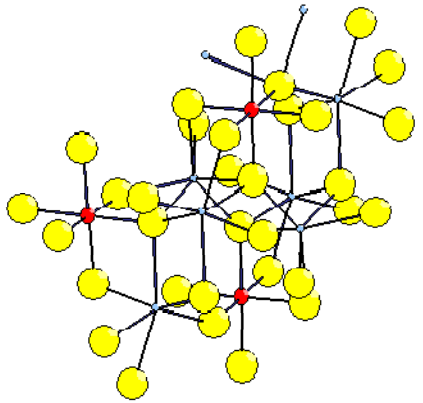
- Today, about 240 are still operating, support of irradiation programs (radio-isotopes for medicine, testing of components), R&D structural materials, nuclear and non-nuclear energy applications)
- Support of basic & applied research (neutron physics and industrial applications), including training activities.
- Operational safety: monitoring and assessment of core components

www-naweb.iaea.org/napc/physics/research_reactors/database/database.html

# Accelerators & Research reactors

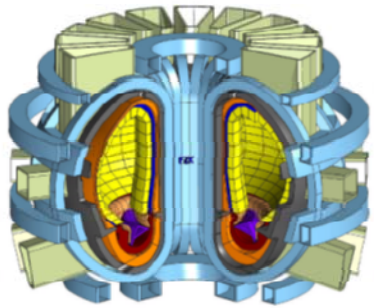
**Material science:**

- Cross cutting activities related to the energy applications, primarily fission and fusion reactor systems.
- Study of various degradation mechanisms and support of ongoing international initiatives.
- Non-nuclear areas: hydrogen energy systems (production, storage & conversion).



**Controlled fusion:**

- Support of national and international initiatives (small and medium size tokomaks).
- Plasma physics and further fusion technology developments (main components and instrumentation), incl. operational safety.
- Memorandum of understanding on cooperation with ITER.
- Biannual fusion conference and IFC meetings



# Recent activities

**IAEA has several ongoing activities which have similar objectives to the IEA-HIA schema, particularly the task;**

- *Integrated system evaluation -Development of Hydrogen Economic Evaluation Programme (HEEP) ,*
- *Hydrogen safety - impact of co-location of hydrogen and nuclear plants,*
- *Role on Nuclear technology in Characterisation and Performance Testing of Materials for Hydrogen Storage and Storage Technologies,*
- *High temperature production of hydrogen - activities in the gas cooled reactor technical working group.*

# Upcoming activities

JRC EUROPEAN COMMISSION Institute for Energy

IAEA International Atomic Energy Agency
*Atoms for Peace*

**Development of new structural materials for advanced fission and fusion reactors**

**In cooperation with**

FUSION FOR ENERGY

***16 – 20 April 2012***

**Hosted by JRC Ispra (Italy)**

IAEA International Atomic Energy Agency
*Atoms for Peace*

TECHNICAL MEETING
ON
**MATERIALS AND CHEMISTRY FOR SUPERCRITICAL WATER COOLED REACTORS**

hosted by

**INSTITUTE FOR ENERGY**
**JOINT RESEARCH CENTRE OF THE EUROPEAN COMMISSION**

Petten, the Netherlands
July 18-22, 2011

**KEY DEADLINES**
**ABSTRACT: 15 April 2011**
**FULL PAPER: 12 June 2011**


http://www.iaea.org/NuclearPower/Technology/Meetings/2011-July-18-22-TM.html
http://www-pub.iaea.org/MTCD/Meetings/Announcements.asp?ConfID=41429

# Education & training activities

The Abdus Salam
International Centre for Theoretical Physics

*Joint ICTP/IAEA Advanced Workshop on*
*Development of Radiation Resistant Materials*

**20 – 24 April 2009**

**(Miramare – Trieste, Italy)**

The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy, in cooperation with the International Atomic Energy Agency (the IAEA), Vienna, Austria, is organizing the Advanced Workshop on Development of Radiation Resistant Materials, to be held at ICTP, Trieste, from 20 to 24 April 2009.

Within the frame of the INPRO and Generation IV initiatives, the next generations of nuclear power reactors are under assessments and in the R&D process. Almost all new reactor concepts are specified by higher efficiency and better utilization of nuclear fuel with minimization of nuclear waste. For the sustainability of the nuclear option, there is currently a renewed interest worldwide in new reactors and closed fuel cycle research and technology development; however, such an approach means that a new class of structural materials with significantly better radiation resistance will have to be introduced. To achieve the high performance parameters, more focused research and testing of new candidate materials are necessary.

Recent development of new classes of materials with improved microstructural features, such as composite materials (SiC) and Oxide Dispersed Strengthen (ODS) or advanced Ferritic-Martensitic (FM) steels, is quite promising since they have very good radiation resistance properties. In view of the successful and timely

Open to IAEA & UNESCO Member States.

The Abdus Salam
International Centre for Theoretical Physics

*Joint IAEA – ICTP Advanced School on*
*"Development and characterization of materials for hydrogen-based energy systems: Role of nuclear technology"*

*in co-operation with the European Commission*

*13 – 18 June 2011*
*(Miramare - Trieste, Italy)*

The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy, in co-operation with the International Atomic Energy Agency (IAEA), Vienna, Austria, is organizing a Joint ICTP/IAEA Advanced School on *"Development and characterization of materials for hydrogen-based energy systems: Role of nuclear technology"*, to be held at ICTP, Trieste, from 13 to 18 June 2011.

A hydrogen-based source of energy can greatly contribute to more sustainable, and less carbon-dependent global energy consumption because the absence of any emissions at its point of use. To achieve this goal, new technological developments in terms of materials and solutions are needed. In this context, nuclear science and technology play a very important role in the development of new materials and improvement of existing ones and in the characterization of their properties and performance. This school will address an overview of the state-of-the-art in area of hydrogen storage and conversion systems and it will enhance participants' knowledge in the selection and application of relevant nuclear techniques used in the frontier research of such materials. Furthermore, the school will highlight aspects of nuclear hydrogen production and some promising methods and technologies used. Moreover, this school aims to enhance international awareness on new strategies and technological orientations for future clean industrial and energy policy with respect of environment protection.

The scope of the School is education, training and information exchange. Participants will be

IAEA
International Atomic Energy Agency
*in co-operation with the International Atomic Energy Agency*

DIRECTORS:

*A. Zeman*
*(IAEA, Vienna, Austria)*
*I. Khamis*
*(IAEA, Vienna, Austria)*

Further details: www.ictp.it

- Support of international and regional education and trainings
- Cooperation with ICTP and other collaborating centres (ANL, ANSTO, RID, ELETTRA, etc.).

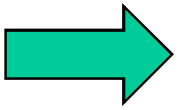
# Conclusion

- Nuclear energy:
  - is suitable for commercial hydrogen production.
  - can provide greenhouse gas-free energy for transportation

**For more information on IAEA activities on Nuclear Hydrogen, please visit:**

http://www.iaea.org/NuclearPower/NEA/

Contact: I.Khamis@iaea.org

To Join IAEA CRPs, please visit: 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Approval Date
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New Technologies for Seawater Desalination Using Nuclear Energy
2009-02-26
D24013
Isolation and Characterization of Genes Involved in Mutagenesis of Crop Plants
2009-02-04
D62008
Development of Generic Irradiation Doses for Quarantine Treatments
2008-12-11
D52036
Development of Radiometric and Allied Analytical Methods to Strengthen National Residue Control Programs for Antibiotic and Anthelmintic Veterinary Drug Residues. (activity 5)
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T13013
Spent Fuel Performance Assessment and Research (SPAR III)
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F12022
Application of Nuclear Methods in Microstructural Characterisation and Performance Testing Of Materials for Hydrogen Fuel Cell and Storage Technologies
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# Coordinated Research Projects

CRP: **Advances in Nuclear Process Heat Applications**"

- It is to contribute to the IAEA's efforts to investigate the prospects of using waste heat generated in High Temperature Reactors.
- The objective of the CRP is;
  - To evaluate the potential of all advanced reactor designs in process heat applications.
- The CRP is launched in 2007, expected to be completed in 2009

# Coordinated Research Project

## IAEA CRP on Application of Nuclear Methods in Microstructural Characterisation and Performance Testing Of Materials for Hydrogen Fuel Cell and Storage Technologies

*Activity aims to address the issue related to the hydrogen storage and conversions, specifically form component and structural materials point of view, in order to achieve better performance and durability. project aims to facilitate following issues:*

(1) Availability of improved and harmonised protocols of nuclear methods for testing of hydrogen fuel cell and storage material properties.

(2) Contribution to the R&D programs related to the hydrogen fuel cell and storage materials and promotion of effective and peaceful utilisation of nuclear technology.

(3) Capacity building including strengthened international collaboration and transfer of knowledge, especially between scientists from developed and developing countries.

Project launched 11/2009, 21 contributors (16 members + 5 observers) from 14 MS + EC (ARG, ARM, AUL, CAN, CPR, FRA, HUN, ITA, NOR, NET, RUS, SPA, SWI, UK, UKR).

# Coordinated Research Project (on-going)

IAEA CRP on Accelerator Simulation and Theoretical Modelling of Radiation Effects (jointly NA-NE)

*Deals with several issues related to the proton and ion beam irradiation in order to achieve very high radiation damage, project aims to facilitate following issues:*

(1) Better understanding of radiation effects and mechanisms of material damage and basic physics of accelerator irradiation under specific conditions,

(2) Improvement of knowledge and data for the present and new generation of structural materials,

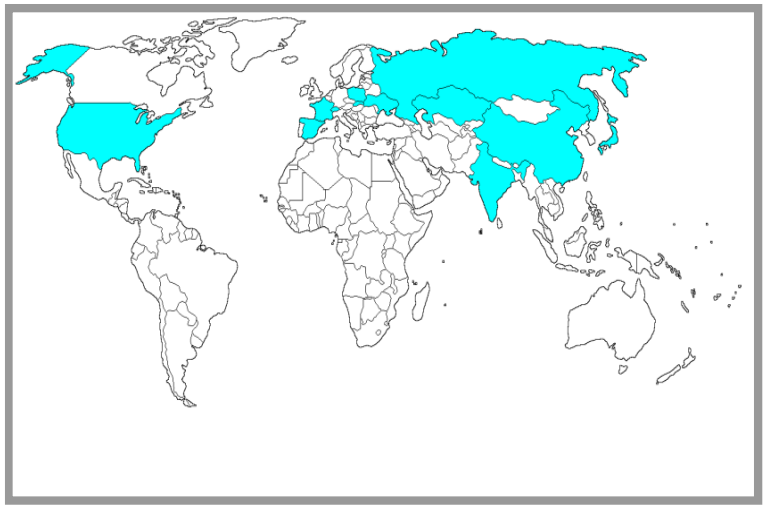
(3) Contribution to developmental of theoretical models for radiation degradation mechanism,

(4) Fostering of advanced and innovative technologies by support of Round Robin testing, collaboration and networking.

# Coordinated Research Project (on-going)

## IAEA CRP on Accelerator Simulation and Theoretical Modelling of Radiation Effects (jointly NA-NE) - FACTS

Extensive theoretical and experimental studies are being carried out among participating laboratories form BEL, CHN, EC, FRA, IND, JAP, KOR, KAZ, POL, RUS, SPA, SVK, UKR, and USA, (18 full members).



- Project launched 01/2009, final reporting RCM November 2011.
- Members have presented recent achievements on experimental testing of various ODS (MA957, PM2000, EUROFER, K3, etc.).
- Irradiation experiments at various temp study of dpa/ dose rate and H/He effect.
- Further improvement of recent theoretical models (incl. experimental validation).


Thank you!