NUCLEAR RENAISSANCE
Status and Perspectives

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The Drivers for Renaissance

• Increasing energy needs.
  – Mainly from developing countries.
  – It will continue at least for the two or three next decades.
  – Some delay due to the crisis.

• Energy source availability and costs.
  – Strong increase of oil and gas costs
  – Fossil resource are not indefinite
  – Non conventional sources can help temporarily
  – Renewable have there own limitations

• Climate change risks
  – Since the Kyoto Conference it is a growing concern
  – Energy saving is a necessity but not sufficient
  – All carbon-free sources should be favored.
Nuclear Energy: One of the Solutions

• The cheapest way of producing large amount of carbon-free electricity.
• New industrial designs taking benefit of a rather long experience and integrating lessons of past accidents (Generation III reactors).
• International cooperation for the development of future systems making a better use of natural uranium resource and therefore suppressing any availability concern (Generation IV systems).
Generation IV International Forum

Fourth Generation Nuclear Systems for a Sustainable Energy Development

Argentina

U.S.A.

United Kingdom

Brazil

Canada

China

E.U.

France

Japan

Switzerland

South Korea

South Africa

Russia
Experienced Countries and Newcomers

• **New projects in all the experienced countries (30) except Germany:**
  – Strong development programs in China, Russia, India,
  – On-going programs in Europe, Japan, Korea,
  – Many plans but not yet final decisions in the US.

• **Newcomers: more than 40 countries showing interest in a future use of nuclear energy:**
  – United Arab Emirates, the first to build the necessary infrastructure and to order four reactors;
  – A few others ready to start;
  – Most of them still in the process of feasibility studies;
  – Foreseeable delays due to revolution in some countries
Experienced Countries and Newcomers

Source AIEA

Operating

Considering
Earthquake and Tsunami in Japan
The Fukushima Daiichi NPP
FUKUSHIMA DAIICHI
A First Generation BWR
The FUKUSHIMA Accident

• Japan submitted to a natural disaster, the biggest earthquake experienced in the country followed by a large tsunami without historical equivalent at least for many centuries.

• Among the consequences of this event, a nuclear accident due to the loss of all electrical sources in reactors which have been successfully shutdown but which still needed cooling.

• Part of the buildings have been destroyed by hydrogen explosions, leading to radioactive release in the atmosphere. The fallout contaminated the site and some surrounding areas which have been evacuated on time.

• A large amount of water coming from the tsunami and from emergency cooling measures is contaminated.
Aerial view after explosions
Huge Damages due to Hydrogen Explosions
Radioactive Release in the Air

Fig. 2 Spatial Dose Rate at the front gate of Fukushima#1 NPS
The Present Situation

• It will take months to restore normal cooling systems for the reactors and the spent fuel pools and to build a new cover above the reactor buildings.

• The radioactive release are now very low but there is some urgency to treat the contaminated water and to clean the contaminated soils.

• The health consequences for the population should be very limited, if any, but more than 80,000 people have been evacuated (in addition to the 300,000 homeless after the tsunami).

• Some workers were slightly injured or received rather important radiation dose but not exceeding the limits which are internationally admitted for such situations (29 workers have dose between 100 and 250 mSv).
After FUKUSHIMA

• Even if the circumstances were quite exceptional, there are many lessons to be drawn from the accident, concerning both the operation of existing plants and the construction of new ones.

• Most of the countries have already decided to submit their power plants to a thorough review of safety measures to face severe accidents and to better take into account low probability natural risks. For instance, Europe is organizing a ‘stressed tests’ review of all its operating reactors.

• But, the drivers for a nuclear renaissance are still there and only a few countries are considering to abandon their nuclear plans.
Generation III Reactors

• Most of the existing nuclear power plants have been built in the 70s and 80s. After TMI and Tchernobyl, the nuclear industry has started the preparation of new designs taking benefit of the technology experience but with improved safety features, mainly:
  – A reduction of severe accident probability,
  – Mitigation devices to limit the consequences of such an accident.

• The FUKUSHIMA accident confirms the relevance of the Generation III objectives and most of the new plants under construction or planned around the world are Generation III designs.

• Differences among the various models offered by makers are not on the objectives but on practical solutions.
**Generation III : The industrial offer**

<table>
<thead>
<tr>
<th><strong>Generation III reactors identified as</strong></th>
<th>‘Near Term Deployment’ by the Generation IV Forum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Pressurized Water Reactors</strong></td>
<td>AP 600, AP 1000, APR1400, APWR+, EPR</td>
</tr>
<tr>
<td><strong>Advanced Boiling Water Reactors</strong></td>
<td>ABWR II, ESBWR, HC-BWR, SWR-1000</td>
</tr>
<tr>
<td><strong>Advanced Heavy Water Reactors</strong></td>
<td>ACR-700 (Advanced CANDU Reactor 700)</td>
</tr>
<tr>
<td><strong>Small and middle range power integrated Reactors</strong></td>
<td>CAREM, IMR, IRIS, SMART</td>
</tr>
<tr>
<td><strong>High Temperature, Gas Cooled, Modular Reactors</strong></td>
<td>GT-MHR, PBMR</td>
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</tbody>
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Generation III Reactors with Core-catcher

Example: AREVA – EPR

- Double-wall containment with ventilation and filtration system
- Core melt spreading area
- Containment heat removal system
- Inner refueling water storage tank
- Four-train redundancy for main safeguard systems
Generation III Reactors with Internal Vessel Retention

Example: Westinghouse - AP1000
Nothing is perfect

• While taking efficient measures to resist the biggest earthquakes, Japan has underestimated the tsunami risks. Nobody should forget the lesson when studying site implementation of nuclear plants.

• The hydrogen risk in light water reactor accidental situation was identified at the time of TMI. Most of the operating LWRs around the world were then equipped with protection devices, recombiners, natural vents… It was not the case in FUKUSHIMA old BWRs.

• In a more general way, back fitting measures can and should be taken to limit the residual risk in operating reactors of an older design.
Nuclear Safety

- From the beginning safety measures and safety culture are the main concern of nuclear industry.
- The limited consequences of FUKUSHIMA accident are largely due to the safety design of the plant (even if it was far from perfect): automatic shutdown, emergency cooling in the first hours, possibility of injecting sea water in the vessels…
- External events are of utmost importance and besides the Probability Risk Assessments it is necessary to study their consequences in a deterministic way.
Newcomers

• A priority should be given to the establishment of safety organization and education. It is part of the guidelines for infrastructure published by the IAEA (19 actions to be implemented with related milestones).

• Possibility of peer reviews are offered by the IAEA to check at each step the conformity of the infrastructure implementation. As an example, UAE has recently experienced successfully such a peer review.

• Many experienced countries are offering their support to help newcomers in developing a safe and efficient program.
The IAEA Milestones Document

- National Position
- Legal Framework
- Regulatory Framework
- Radiation Protection
- Financing
- Human Resource Development
- Safeguards
- Security and Physical Protection
- Emergency Planning
- Nuclear Fuel Cycle
- Nuclear Waste
- Environmental Protection
- Nuclear Safety
- Sites & Supporting Facilities
- Stakeholder Involvement
- Electrical Grid
- Management
- Industrial Involvement
- Procurement
UAE : The First Newcomer

• Nuclear Power Plant Program decided in 2008
• Company in charge of the program : ENEC
• First order of two reactors : end of 2009
• Model chosen : The Korean APR1400
• Nuclear law adopted in 2009
• No enrichment or reprocessing facility
• Implementation of a Safety Authority : FANR
• An International Advisory Board
• A first IAEA/INIR mission end of 2010
• ENEC asked for a license of construction in Dec 2010
Conclusion

• FUKUSHIMA accident has created a new situation but has not changed the drivers for nuclear renaissance
• All the lessons from this accident should be drawn and immediate actions should be taken in order to restore the public confidence severely damaged in spite of the limited consequences.
• The new design of Generation III reactors is relevant in the light of this accident but site considerations should be reviewed to be sure that natural risks (or other external threats) are correctly taken into account.
• Nothing is perfect but many things can be improved.