Nuclear Power: an Irreplaceable Option for Sustainable Development

Philippe Pradel

French Atomic Energy Commission (CEA)
Low carbon energy scenario for 2050

Energy demand will increase (approx. double if no strong energy management / saving policy is implemented)

Nuclear will play a major role along side renewables (including hydro), fossil with carbon sequestration (still under development).

Today, nearly 2 billion people without electricity
Climate change & sustainable nuclear energy

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<th></th>
<th>World</th>
<th>EU</th>
<th>France</th>
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<tbody>
<tr>
<td>Electric power in the final energy consumption mix</td>
<td>16%</td>
<td>20%</td>
<td>23%</td>
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<tr>
<td>Nuclear electricity / total electric power output</td>
<td>15%</td>
<td>30.5%</td>
<td>78.5%</td>
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- **1st low carbon track**: Electricity,
- **2nd low carbon track**: transportation,
- **3rd low carbon track**: residential and tertiary sector
2008 Vision: nuclear part in the energetic mix

- Installed Nuclear GWe: 371 GWe
- Expected Plants Shut downs: 270 GWe
- Life Time Extention and Power Uprate: 150 GWe
- NEW BUILD MARKET: 480 GWe

Around 300 PWR 1500 MWe by 2030

And 1000 PWR 1500 MWe by 2050?

A target for nuclear contribution in the energy mix by 2050:
30% such as in European Union

Around 2500 PWR 1500 MWe
Gen III on the tracks with safety improved EPR

- A 1600 MWe reactor, lifetime 60 years
- A mature concept, based on current PWRs’ experience
- Significant improvements in safety and economy

- Flamanville (France) / EdF by 2012
- Olkiluoto (Finland) / TVO by 2012
- Taishan1&2 (China) / CGNPC by 2013 & 2014
Gen III on the tracks with today envisaged EPR around the world

- **USA**: 4 EPR with Constellation Energy Group, operated by 2016
- **France**: a second EPR with EdF under project (Penly)(2017)
- **United Kingdom**: 4 EPR with British Energy, operated by 2017
- **Italy**: Intent to restart a nuclear program
- **South Africa**: Eskom interested by EPR
- **India**: 2 up to 6 EPR
- **USA: Calvert Cliffs (USA)**

Development, investment & operation of more than 10 EPRs by 2020, Potential Countries: United Arab Emirates, Jordan, Vietnam …
EPR Safety Objectives

- Enhanced defense in depth to reduce by a factor ten the number of significant incidents and global frequency of fusion core meltdown,

- Significant reduction of release and consequences in any situation (including fusion core meltdown),

- Improved resistance of the reactor containment to external impact and majored seism
Towards a high safety level with the rising multinational safety initiatives

- An International Nuclear Safety Harmonization, but:
  - Liabilities in regard to safety remain a national obligation, which cannot be assigned to supra-national authorities,
  - Technologies are not the only one safety parameter, « Safety Culture » and an appropriate institutional framework are also necessary

- A long-standing Coopération (>50 years) between:
  - Institutional actors (IAEA ...),
  - Safety Authorities Cooperation (INRA, WENRA...),
  - And Operators (WANO ...).

- The 2 driving forces behind harmonization:
  - MDEP (Multinational Design Evaluation Prog.) Initiative to assess the new reactors the safety authorities
  - European Construction

- Present International Safety Initiative such as MDEP to be fostered
2008 Vision: world spent fuel amount

**LWR Once-through**

**LWR + Fast Neutrons**
(conversion factor = 0.5)

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<thead>
<tr>
<th>Year</th>
<th>Mass NL (kTons)</th>
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<tbody>
<tr>
<td>2000</td>
<td>0</td>
</tr>
<tr>
<td>2020</td>
<td>1000</td>
</tr>
<tr>
<td>2040</td>
<td>2000</td>
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<td>2060</td>
<td>3000</td>
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<tr>
<td>2080</td>
<td>4000</td>
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<td>2100</td>
<td>5000</td>
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<tr>
<td>2030</td>
<td>10 000 t</td>
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<tr>
<td>2050</td>
<td>20 000 t</td>
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By 2050, around 400 EPR spent fuel pits, + 2 pits / year

700 000 t by 2050,
Closong the fuel cycle, towards sustainability ... 

- First step: Pu recycling in LWRs, Conditionning of waste

  Continuous progress has been made in the processing of spent fuel, recycling of nuclear material and conditioning of waste

- Next step: Recycling of minor actinides to reduce thermal load and radio-toxicity of waste is the object of on-going research

  - Recycles 96% of spent fuel materials
  - Saves 30% of natural resources
  - Costs less than 6% of the kWh total cost
  - Reduces by 5 the amount of wastes
  - Reduces by 10 the waste radiotoxicity

  Adapted technologies allow a safe conditioning of wastes to guarantee their long term confinement and stability, for dozens of thousands of years
Closing the Fuel cycle... and an industrial reality

More than 25 years of unequalled experience in France:

- Until now: ~ 20 000 Mt\(_{\text{HM}}\) spent fuel reprocessed and more than 1200 Mt\(_{\text{HM}}\) MOX fuel recycled
- 1100 Mt\(_{\text{HM}}\) /yr of spent fuel discharged from the French PWRs
- Up to 1 700 Mt\(_{\text{HM}}\) /yr of spent fuel reprocessed (domestic + foreign)

Ultimate Waste Disposal
Mines
Chemistry
Enrichment
Fuel Fabric.
Recycling: MOX Fuel fabrication
Reactors & Services
Spent Fuel Reprocessing

La Hague
Rokkasho-Mura
Nuclear Plants for new comers: reactor + Fuel services + Education & training

➢ To address the expectations of customers interested in developing nuclear energy production plants (power range, design for site flexibility and various grid conditions...),

➢ Combining reliable and proven nuclear technologies, including fuel cycle facilities (glass canister storage...)

➢ Answering non proliferation criteria,

➢ Setting an ambitious training offer

**RR21 Characteristics:**
Power range 10 MW,
Pool type reactor
Inherently safe fuel (no fuel melting),
Spend Fuel recovered for treatment and recycling,
Easy handling,
Easy experimental work

A specific research and training reactor
Nuclear renaissance in the world

End of 2007
439 reactors in operation
372 Gwe installed
33 reactors under construction

North & South America
Europe
Russia
Asia

123
160
46
111

Nb of reactors
Nuclear renaissance in the world

North & South America  Europe  Russia  Asia

Nb of reactors

~4000 tHM spent fuel

Used nuclear fuel 2007 inventory: 170,000 tons
Estimate in 2030: 400,000 tons!
(Source: AREVA Group)
Nuclear renaissance in the world

North & South America: 123 reactors
Europe: 160 reactors
Russia: 46 reactors
Asia: 111 reactors

⇒ Drastic waste reduction with only few recycling plants

(Source: AREVA Group)
1. The stockpiling in indefinite interim storage is not a responsible management of the fuel back-end, in the perspective of a wide nuclear renaissance,

2. Spent fuel recycling shall be carried out vitrified waste sended back to countries of origin, to be safely and economically stored, waiting for final disposal: for a safer, a more secure and a more proliferation resistant spent fuel management

3. A global service offer for spent fuel reprocessing and recycling shall be set up with the appropriate international framework, i.e; the IAEA umbrella

4. Supply of recycling plants based on best available proven technologies:
   - by current La Hague / Rokkasho and future facilities
   - operated by major players
   - Distribution of the recycling facilities on a regional basis with respect of commercial contracts

Commitments and international obligations with regard to safety, security and non-proliferation standards, shall be strictly observed.
Bridging Technologies from the Renaissance to Sustainability

Adapted initiatives taking into account the best available technologies, towards the emerging economies

to enlarge the access to the nuclear energy in terms of

- electricity production without green gas emission (up to 40-50% in 2050),
- natural resources conservation,
- waste minimisation,
- potential for new applications (hydrogen, desalination, heat…)

IAEA 2009  October 27-30. 2009  Vienna
Sustainability: Development of Fast Neutrons Systems with closed fuel cycles

- R & D (2000)
- Prototypes (2015 – 2030)
- Industrial deployment (by 2040)

R&D sharing in GEN IV Forum

International harmonization of prototypes

In a bi or trilatéral framework Example (USA-Japan-France) of the Sodium FBR

INPRO

- Dialogues between technologies suppliers and operators,
- Clarification of user’s needs
Atoms for Prosperity