GenIII/III+ Nuclear Reactors
RESEARCH NEEDS AND CHALLENGES

FISA 2009, Prague
Contents

• What are the GenIII features
  – Evolutionary development and improvements
  – Commercial GenIII power plant features
  – OL3 / EPR features

• Needs and challenges for R&D
  – Areas of research for GenIII nuclear reactors
  – EU FP6 and 7 projects GenIII/III+
  – New challenges and needs for R&D and resources
EARLY PROTOTYPES

- Magnox (1956)
- Shippingport (1957)
- Dresden (1959)
- RBMK (1963)
- FBR (1963)
- HTR (1966)

COMMERCIAL POWER REACTORS

LWR: PWR and BWR
CANDU, AGR

NEW GENERATION LWR-PLANTS + HTR

Economically more competitive evolution types
- High efficiency
- Long life time
- Passive safety

Generation I

- 50 MW

Generation II

- 500 MW

Generation III

- 1 300 MW

Generation III+

- 1 600 MW

Generation IV

- (200) - 1 600 MW

VVER-1000, ABWR
EPR
SWR-1000, AP-1000
ESBWR-1500

GENERATION IV

- Very competitive
- New application, such as process heat
- Enhanced/inherent safety features
- Reduced waste generation
- Improved proliferation resistance

In Finland:

- Commissioning of present 4 units (Lovisa & Olkiluoto)
- Olkiluoto3 commissioned
- Decommissioning of present plants after 50-60 years lifetime


2009-06-22
GENIII/III+

Heikinheimo Liisa
GenIII/III+ nuclear reactor features

• A GenIII reactor incorporates evolutionary improvements in design developed during the lifetime of the GenII reactor designs:
  – improved fuel technology
  – superior thermal efficiency
  – passive safety systems and
  – standardized design for reduced maintenance and capital costs.

• Development will result in a longer operational life, 50 to 60 years compared to Gen II reactors with 20 to 30 years (today extended +20 yrs to meet the needs before GenIII).

• The first Gen III reactors were built in Japan, several others have been approved for construction.

• In Europe in Finland and France plant construction is ongoing (Olkiluoto and Flamanville).
GenIII/III+ nuclear reactor features

- **Advanced Pressurized Water Reactors, 600 – 1 600 MWe:**
  - AP 600, AP 1000, APR1400, APWR+, EPR

- **Advanced Boiling Water Reactors, 1 250 – 1 550 MWe:**
  - ABWR II, ESBWR, HC-BWR, SWR-1000

- **The market prospects:**
  - A large industrial offer: USA NRC 28 + China, India, South Korea 85 + Europe 2 + XX = 110 new reactors by 2020.
  - The nuclear power capacity could grow from 400 GWe to 1000 - 1500 GWe by 2050.
  - Most of the new NPP will be Gen III systems.

IAEA energy technology roadmaps, Paris 08
http://www.eia.doe.gov/cneaf/nuclear/page/analysis/nucenviss2.html
GenIII/III+ nuclear reactor features

EPR at Olkiluoto plant
May 2009
GenIII/III+ nuclear reactor features

Main EPR Safety Features

- Double containment with ventilation and filtration
- Melt core cooling area
- Containment heat dispersion system
- Four redundant safety systems
- Water reserves inside the containment
## OL3 REACTOR MAIN DATA

<table>
<thead>
<tr>
<th>Property</th>
<th>value</th>
<th>Property</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal output</td>
<td>4300 MW</td>
<td>Number of fuel assemblies</td>
<td>241</td>
</tr>
<tr>
<td>Net electric output</td>
<td>Approx. 1 600 MW</td>
<td>Amount of uranium in reactor</td>
<td>128 tons</td>
</tr>
<tr>
<td>Operating pressure</td>
<td>155 bar</td>
<td>Number of control rods</td>
<td>89</td>
</tr>
<tr>
<td>Main steam temperature</td>
<td>290°C</td>
<td>Containment height</td>
<td>63 m</td>
</tr>
<tr>
<td>Pressure vessel height</td>
<td>13 m</td>
<td>Containment diameter</td>
<td>57 m</td>
</tr>
<tr>
<td>Reactor core height</td>
<td>4,2 m</td>
<td>Containment wall thickness</td>
<td>2 m</td>
</tr>
</tbody>
</table>
GenIII/III+ features and needs => R&D challenges

- High safety/passive safety, design for:
  - Reactor core melting
  - Jet aircrash
  - Extreme weather conditions
  - Securing digital instrumentation and control systems with an analogue system (Finnish requirement)

1. Severe accidents
2. Construction safety
3. Probabilistic safety/risk analysis
4. Automation and control room (development and use of digital automation)
5. R&D support for building and manufacturing industry to meet the requirements
EU SAFETY and SEVERE ACCIDENTS projects in FP6 and FP7

- **SARnet NoE** - Sustainable integration of European Research on Severe Accident Methodology and Management

- **SARNET 2** - > 2009

- **NURESIM** - European Platform for Nuclear Reactor Simulations: Numerical simulation tools for coupled thermal hydraulics and reactor physics problems

- **FP7, NUclear Reactor Integrated Project = NURISP**
  - Application to LWR (Gen-II and Gen-III): PWR, VVER, BWR
  - Links with other European Projects: PERFORM, PRACE
GenIII/III+ features and needs => R&D challenges

- **New reactor designs:**
- Long life time, design for 60 yrs
- High efficiency (EPR about 4% higher than present units)
- High burn up (fuel & water chemistry issues, core design)
- New fuel and cladding types
- High operability requirements
- Improved predictability for maintenance
- Power uprating potential

1. Fuel and reactor physics
2. Thermal hydraulics
3. Structural safety of reactor circuit and
4. Aging management
5. Probabilistic safety/risk analysis
6. Asset management
EU PERFORM60 – Multiscale modelling of irradiation effects and embrittlement for 60 years reactor lifetime (FP7)

- First stage: PERFECT - Prediction of Irradiation Damage Effects on Reactor Components
- Core Partners: AREVA NP GmbH, CEA (SRMP), CNRS (Lille, LMPGM), EDF, NRI, SCK-CEN, SERCO, VTT
- 6 M€ budget from EU
Cleavage fracture model development: FEM simulation

Effect of irradiation on fracture toughness
EU NULIFE - Nuclear plant life prediction
FP6 NoE (Network of Excellence)

- **OBJECTIVE** to create a single organisation structure
  - capable of providing harmonised R&D
  - at European level to all nuclear stakeholders
  - in the area of lifetime evaluation methods for structural components.

- **NULIFE** is a key instrument in implementing LTO (long term operation) related topics.

- Schedule 2006 - 2011 / 5 years
- Total budget over 8 M€
- EC funding 5 M€
- Strong link to SNE TP
- 11 Core contract members and over 30 other members
- VTT coordinator
Past Networking activities

Integration plan

2007

Preparation of business plan

2008

Consolidation of integration plan

2009

Transition plan for permanent entity

2010

Creation of Virtual Institute

2011

Beyond 5 years

NULIFE Institute
• with customer-driven programme

• Permanent management structure
• Long term business plan
• Acknowledged solution provider

• Structure with permanent entity features
• Joint use of facilities
• Investment policy

• Launching of new RTD projects
• Development and application of procedures and best practices

• Business plan, Updated structure
• Links with national programmes
• Approaches to training, knowledge and comm.

• Viable expert groups
• Coherent structure
• Communication methods

Key integration indicators

Major milestones
Challenges for R&D

• **New reactor technologies**
  – Knowledge, data and tools for verification of reactor performance and safety
  – Knowledge, data and tools for verification of new components/manufacturing methods/material grades
  – From design to industrial manufacturing and supply.
Challenges for R&D

• Extended operation requirements
  – Tools and data for reactor performance analysis
  – Aging management:
    • Aging mechanisms of systems, structures and components (understanding for LTO)
    • Multiscale modelling tools
    • Methods for aging monitoring.

– Asset management:
  • Reliable and economic operation and maintenance management for 60 yrs reactor life
Challenges for R&D

• Relevant experimental and modelling tools:
  – Materials testing (active – non active) for aging mechanisms and tools for multiscale modelling
  – Simulating tests (component level) for life management
  – Tests and tools for fuel and cladding performances for reactor operability
  – In-reactor tests and tools for reactor performance.
Challenges for R&D

- **Resources**
  - Training of engineers and scientists
  - Continuous development and verification of codes and models
  - Up to date test reactor facilities and supporting laboratories.
Thank You