OECD/NEA
WORKSHOP ON INNOVATIONS IN WATER-COOLED REACTOR TECHNOLOGIES

SESSION II-2
RESEARCH ORGANISATION PERSPECTIVES

Main results and lessons of the 10 years innovation research program dedicated to LWR

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Global picture

**Nuclear Power Plant** connected to the grids:

- **Mainly LWR**: 211 PWR & 76 BWR in OECD countries + 53 VVER*
- **Global distribution**: North America (102 LWR out of 121 NPP), West Europe (118 LWR out of 133 NPP), Asia (67 LWR out of 71 NPP)
- **France**: 1 manufacturer, 1 utility, exclusively PWR (58) + EPR under construction

**Increasing nuclear power capacity** with over 60 reactors under construction in 13 countries

**Plant life extension program** + future **renewed nuclear reactor fleet** notably in U.S or in France (coordinated with GEN IV technologies deployment) taking into account constraints in terms of safety requirement, investment cost, construction time, manufacturing capacities, etc.

**New realities in the energy global market** and evolving **political context**:

- **Global level**: rising global demand for energy, competitiveness (energy cost), financial crisis, Fukushima, security of supply issues, public acceptance
- **EU level**: EC Energy Roadmap 2050, 2030 Framework for Climate & Energy
- **National levels**: e.g. France “Loi sur la transition énergétique”

**Research and Innovation** for cost competitive, high performance, safe and clean technologies
Research perspective

- **Objective of the session**: Discussion on long term developments that could lead to innovations for future advanced water-cooled reactors and their fuel cycle.

**Innovation in LWR** vs **breakthrough vs incremental** part of a seamless innovation chain.

- **Technological breakthrough** may bring **significant economic/safety benefits** by reconsidering parts of (or all) the components of a reactor concept.

- For LWR, significant progress might be expected: e.g. innovative temperature-resistant metal fuel or ceramic cladding, a new tight-lattice fuel assembly to optimise uranium resources, modification of the operating point for reactor design simplifications.
RESEARCH AND INNOVATION IN LWR

Illustration with the past CEA Programmes

- **CEA Innovation Programme**: > 10 years of Research and Innovation programs to develop innovative solutions for existing and future LWRs

- **Overall objectives**: Cost reduction, increased safety, high performance core & fuel

- **Various technical fields covered**:
  - **Core and fuel**: high conversion PWR, innovative fuel (e.g. composite CERCER/CERMET, annular fuel pellet), innovative cladding (e.g. coating, SiC/SiC, burnable poisons), etc.
  - **Materials**: new alloys for vessel internal structure, coating (e.g. valve, control rod ratchet mechanism), component manufacturing based on densification of metal power, etc.
  - **Innovative systems**: passive safety systems (e.g. Secondary Condensing System), severe accident management facilities (e.g. innovative containment, core catcher) and other innovative safety systems (e.g. steam injector)
  - **Reactor design**: simplification (e.g. boron-free PWR, low pressure PWR), breakthrough (e.g. SCOR) etc.
  - **Technical economical studies**: qualitative comparison between concepts and systems

- **Supported by methodologies, tools/code development and experimental programs**
Examples – Innovative safety systems

Rational

- **Many systems for various functions** (e.g. reactivity control, residual power removal, corium recovery system) usually **complex and/or expensive**

  ➔ technological breakthrough to bring **economic/safety benefits**

Examples

- **Secondary Condensing System:**
  - Passive residual heat removal system in natural circulation connected to the steam generator
  - Promising results notably in terms of safety improvement (e.g. steam generator tube rupture)

- **Steam Injector:**
  - Replace/complement safety pump injection (passive system)
  - Possible applications into the primary or secondary with steam sources coming from pressurizer, steam generator
  - Example: provide the steam generator with water when the normal supply fails
Examples – Innovative reactor design (1/2)

Rational: simplification of standard PWR design (Ref. 900 MWe French PWR)

Examples:

- Soluble boron-free PWR
  - simplification of plant operation/management (deboration) and improved safety (reactivity accident through heterogeneous boron dilution) + regulation / legislation and acceptability aspects
  - feasibility studies of the reactivity control only through control rods and burnable poisons while maintaining performances and safety criteria – different levels of boron removal
  - encouraging results: with an adequate assembly design, core reactivity adjusted with burnable poisons + an optimised control rod system for core shutdown
  - to be considered: residual penalties of the burnable poison + redundancy of control means + complex load following

- Low pressure PWR
  - cost reduction for components (e.g. vessel, steam generator), possible high burn up and safety systems simplification
  - study of an adequate operating point by reducing the pressure
  - complete file covering: core (neutronic and thermal hydraulic), fuel, thermal hydraulic systems, technical economic evaluation

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OECD/NEA - Workshop on Innovations in water-cooled reactor technologies – 11&12/02/2015
Session II-2 - Research organisation perspectives
Examples – Innovative reactor design (2/2)

**Rational:** Propose new conceptual designs integrating several innovative systems to analyse the performance of these systems and evaluate their interactions and the overall coherence.

**Example:** SCOR - Simple CCompact Reactor

Evolving basis to evaluate innovative systems, new core design or new strategy

- First version: 600 MWe (threshold effects)
- Then: variation until 1000 MWe (to evaluate the feasibility & possible economic benefits)
- Lately: SMR Version 200 / 150 MWe
Innovative Safety systems

Integrated passive residual heat removal systems

High Ø vessel

Large annular space

2000 MWth SG manufacturing?

2000 MWth SG as the reactor vessel head

2000 MWth SG vessel manufacturing

P ~ 88 bar

Low pressure PWR

Integrated pumps

Submerged coil-type motor

Soluble boron-free PWR

Soluble boron-free PWR

Low core power density

Low power

High Ø vessel

IVR

Integrated control rods

Integrated pressurizer

Integrated pumps

Steam generator

Integrated concept

Threshold effects

SG - Reactor vessel head

SG - Reactor vessel head

Innovative concept

Steam Generator 2000 MWth

Integrated concept

RESEARCH AND INNOVATION IN LWR
Lessons learned from this significant innovation program (> 10 years)

- Many attractive innovative solutions studied
- But lack of industrial applications
  - need for a reinforced industrial involvement (from the very beginning of the studies to define specifications)

Innovation depends on the political context and industrial priorities, such as:

- Economics? e.g. Nuclear vs Shale gas, RES
- Safety? Increased safety demand: e.g. post Fukushima, LTO extension
- Energy mix? e.g. system integration, reactor flexibility, cogeneration
- Optimisation of uranium resources? e.g. Gen III and Gen IV strategies

THANK YOU FOR YOUR ATTENTION