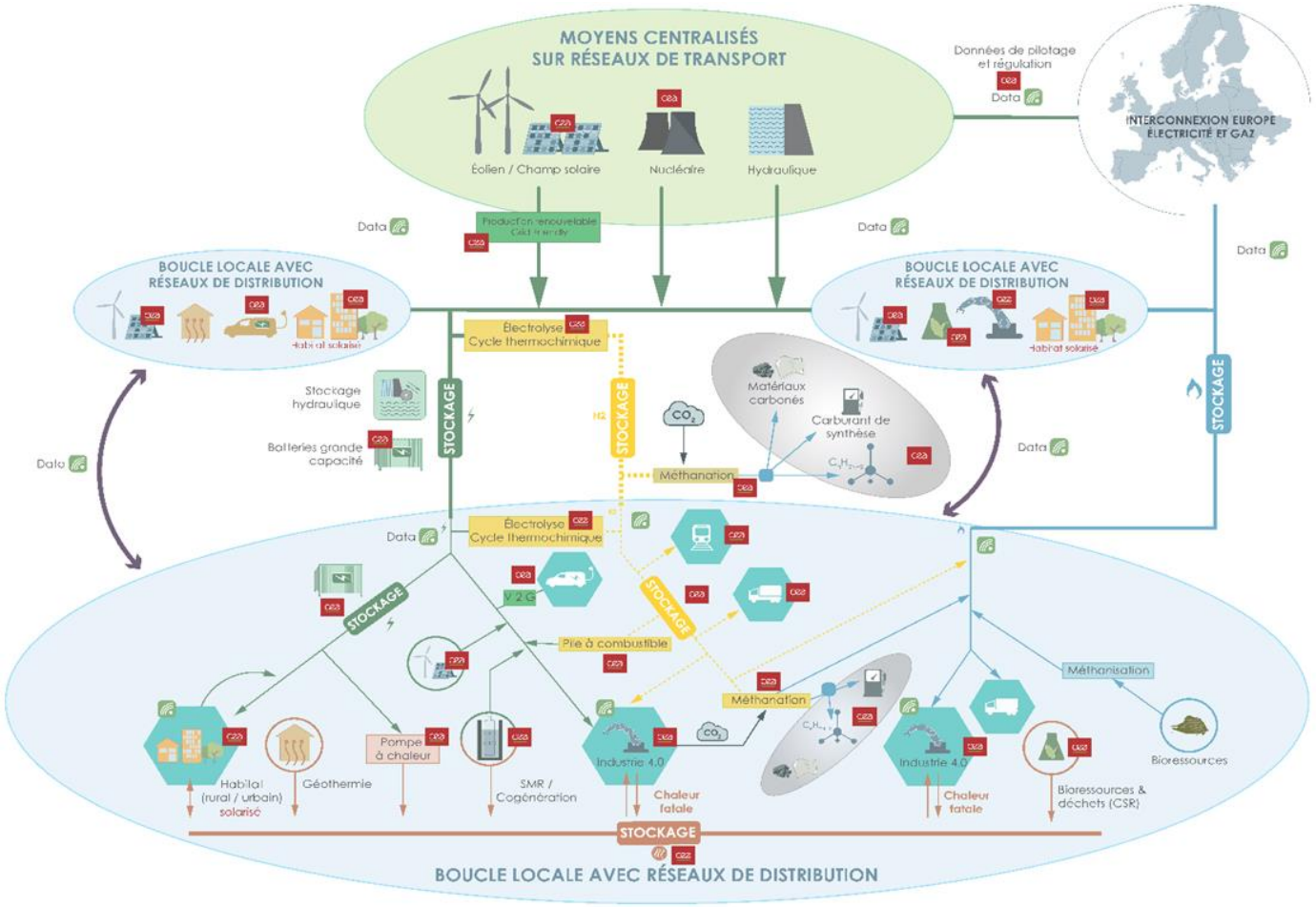
Research Institute for Nuclear Systems for Low-Carbon Energy Production

June 2023

1. The Energy Division at CEA.

A integrated view of energy

Net zero emissions target by 2050



Multi-vector
Electricity, heat, gas / hydrogen

Multi-scale & multi-agent
From local-territorial clusters to continental scale

Smart grids
Digitalisation & instrumentation, demand management

Circular economy
Primary and secondary resources, carbon (CO2)

Implementation requires :

- Technological innovation
- Convergence of nuclear and renewable energy
- Economic models and regulation
- Societal ownership

The Energy Division missions

A low carbon energy production

Nuclear energy

Supporting industry in the development of technologies :

- Generation II and III reactors
- Generation IV reactors
- Small modular reactors
- Fuel cycle
- Defence

Renewable energy / energy carriers

- Solar energy
- Hydrogen and Li-ion batteries

Connected systems

- For example SMR for hydrogen or heat production.

Closing the carbon cycle

- Converting CO2 into a useful energy source.

Toward an integrated low CO_2 Energy System: Priority topics for R&D at CEA

- PWR (GII – GIII)
- Digital reactor
- SMR & coupled concepts
- SFR-Na (GIV)
- MSR (GIV)
- Fuel for enhanced safety and flexibility & 'Digital' Fuel

Production

Decarbonized production (nuclear, renewable energy)

Resources

Circular economy **&** advanced **materials**

Carbon circular economy

System

Tools for **Flexibility & storage** multi-energy vectors

Smart Grids & demand **management**

Energy **Conversion** (efficiency, sobriety)

Energy mix

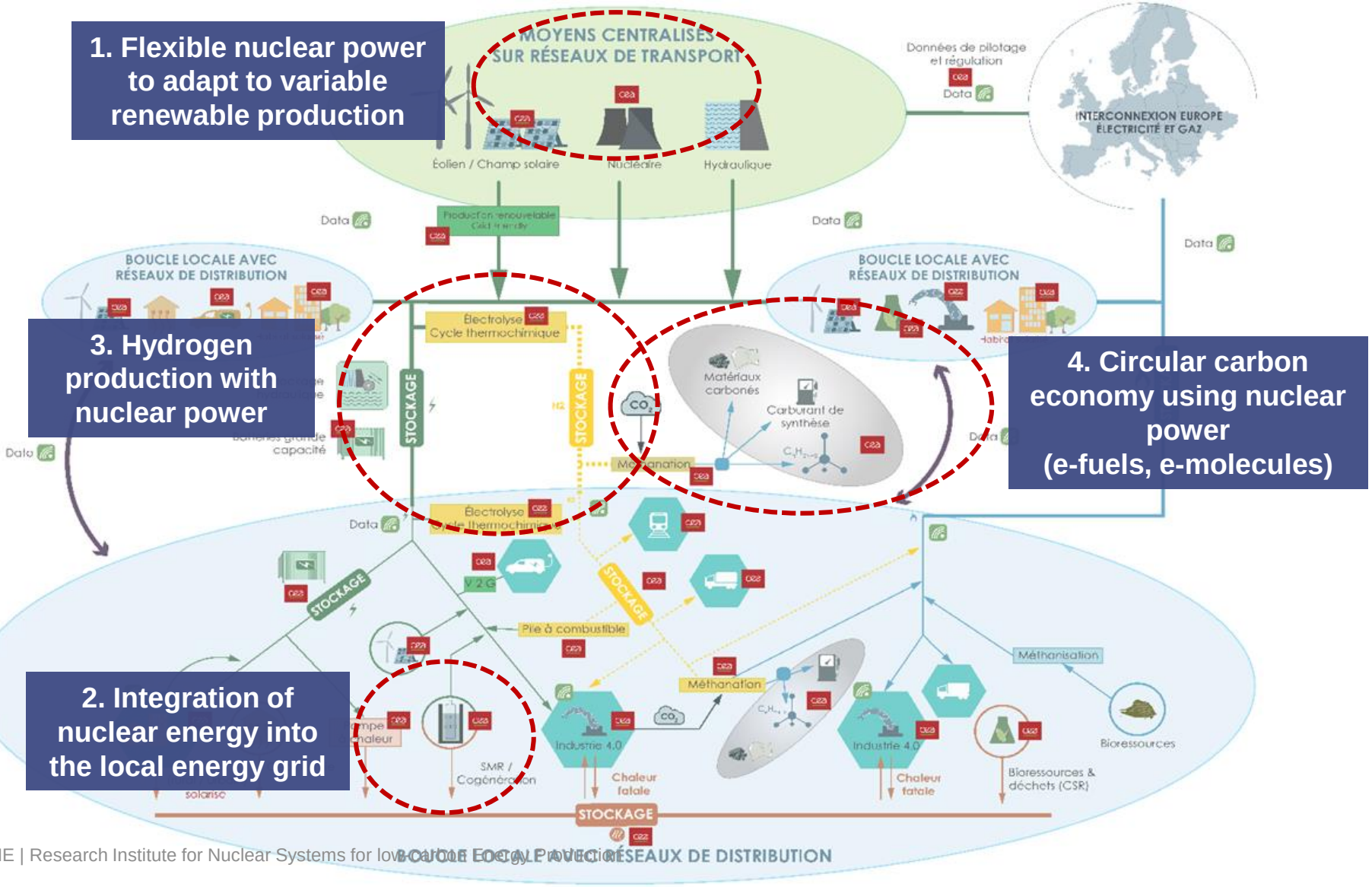
Energy **Scenarios** & **tech-eco** models

- Solar Photovoltaics
- Hydrogen & Energy Storage
- Energy management & Networks
- Carbon Circular Economy
- Energy conversion & Hybrid – Coupled Systems

A integrated view of energy

How does nuclear energy contribute to an integrated vision?

1. Flexible nuclear power to adapt to variable renewable production



3. Hydrogen production with nuclear power

4. Circular carbon economy using nuclear power (e-fuels, e-molecules)

2. Integration of nuclear energy into the local energy grid

Energy Division

A strategic division for R&D in the energy field.

R&D activities are structured as follow within the Energy Division :

- The Energy Programmes Division (EPD) with a transversal role for all energy R&D.

- 4 research institutes :
  - **IRESNE :** Nuclear Systems for Low-Carbon Energy Production
  - **ISAS :** Simulation and applied sciences
  - **ISEC** : Circular economy in the energy field
  - **I-TESE :** Techno-economy

- The Energy Division is also responsible for decontamination and decommissioning programmes, as well as engineering and construction projects.

- The Energy Division manages R&D programmes that are also carried out by institutes in other CEA operational Division :
  - Technological Research Division institutes (in particular LITEN and LIST)
  - Fondamental Research Division institutes (in particular Institute For Magnetic Fusion Research).

2. IRESNE R&D for nuclear innovations.

Positioning of the Institute

R&D within the Energy Division

Study of nuclear systems for low carbon energy production integrated into an energy system.

Expertise and innovation for nuclear systems :

- Fuels
- Reactors
- Systems and Technologies

Applications for a low carbon mix :

- Complementarities of nuclear and renewable energies
- Energy vectors, storage, coupling and cogeneration

Transversal R&D actions within IRESNE :

- Instrumentation and measurement
- Development of the multiphysics and multiscale approaches
- Innovation in nuclear systems
- Experimental platform for energy systems

IRESNE

Core activities

R&D activities at IRESNE

Design & Innovation

From component and system design to reactor design :

- 4th generation reactors - closing the fuel cycle (with SFR feedback)
- Innovative modular reactors: Small Modular Reactors (water) - Advanced Modular Reactors (sodium, molten salt reactors MSR)
- Energy conversion systems, other energy carriers
- Development of innovative fuels, components and instrumentation

With the support of all engineering sciences: Neutronics, solid and fluid mechanics, thermohydraulics, material sciences, magnetohydrodynamics, robotics, system dynamics, process engineering, ... and the use of technical-economic approaches.

R&D activities at IRESNE

Experimentation & Instrumentation

A unique set of experimental facilities:

- Nuclear research reactors (CABRI, future JHR)
- Contribution to JHR project and preparing dedicated experiments
- Nuclear fuel study laboratories (LECA-STAR, Labo UO2)
- Experimental platforms and test loops (POSEIDON, PLINIUS, PAPIRUS, etc.)
- Analysis, nuclear measurement and instrumentation laboratories (MADERE, LMN, LARC, etc.)
- Design laboratories (innovative technologies (LCIT), Fission chamber manufacturing workshop, etc.)
- On-site nuclear measurements (EMECC, etc.)

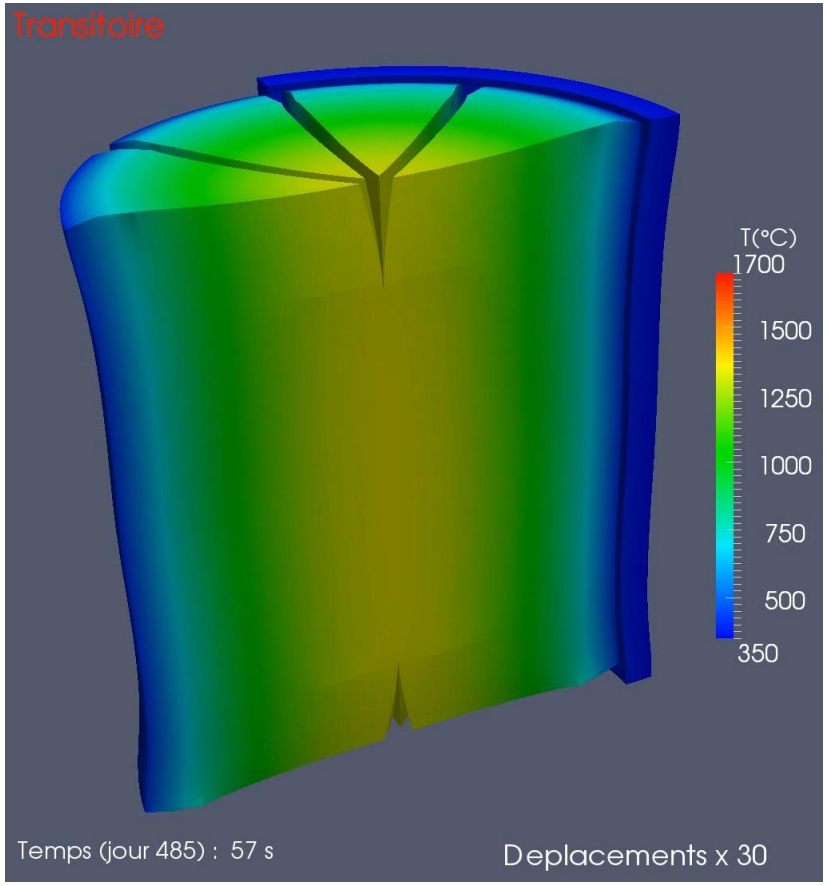
Experimentation is essential for the validation of our calculation codes.

R&D activities at IRESNE

Modeling & Simulation

Development, validation and use of scientific calculation codes.

- **Reactor physics - neutronics** (APOLLO, TRIPOLI ...)
- **Fuel behaviour in nominal, incidental and accidental situations** (PLEIADES ...)
- **Solid and fluid mechanics** (CASTEM, TRIO-CFD, NEPTUNE ... & "commercial software")
- **Reactor operation in nominal, incidental and accidental situations:** severe accidents (CATHARE, SIMMER, PROCOR,...)
- **Calculation of nuclear energy scenarios** (COSI)



R&D activities at IRESNE

FOCUS on SMR and AMR

3 areas for SMR development at the CEA:

1. CEA is part of the **strategic industrial partnership NUWARD™**

- Commercial SMR project for export, aiming at providing a solution to replace thermal power plants (coal or gas).
- The reference unit is a 340 MWe: 2 modules of 170 MWe each.

2. **SMR an AMR for the production of other energy carriers**: heat, hydrogen ... (e.g. by coupling with a high temperature electrolyser).

- SMR as a tool for decarbonising the energy mix at local level
- Studies on cogeneration and hybrid systems for the conversion of energy into heat, hydrogen, electricity, etc.
- Sodium cooled AMR
- MSR fast spectrum AMR

3. IRESNE data.

IRESNE

Resources and collaborations

900 **employees**
(permanent & fixed-term)

650

engineers – researchers
including
150 doctoral students & postdoctoral fellows

250

operating and experimental engineers and technicians and
administrative team

100

block release apprentices

IRESNE

Scientific output

- **300 publications per year,** 100 of which are peer-reviewed
- **160 active patent families** | 20 new patents per year
- **2 "instrumentation" start-ups** in operation
- **3 "nuclear" start-ups** in development

IRESNE

Partnerships

Various partnerships, collaborations and projects.

Industrial

- Partnerships and services with the major French nuclear industries: EDF, FRAMATOME, ORANO, IRSN, ANDRA (with multi-year framework contracts)
- Collaboration agreements and services with other companies and R&D organisations (including SMEs) in France and abroad (Westinghouse, MHI, KEPCO, JAEA, etc.)
- A R&D toward real industrial issues and challenges of the nuclear sector

Academic

- Aix Marseille University: joint laboratories LIMMEX and MISTRAL and joint institute ISFIN
- Schools and Universities of Toulouse, Montpellier, Lyon, Bordeaux, Grenoble, Strasbourg, Nancy,...

Institutional

- Multilateral framework: OECD/NEA, IAEA
- European projects : H2020 and Horizon Europe
- National offices: ANR, PIA, Economic Recovery Plan and regional initiatives.

Thank you

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