FRENCH OFFER IN NUCLEAR EDUCATION AND TRAINING

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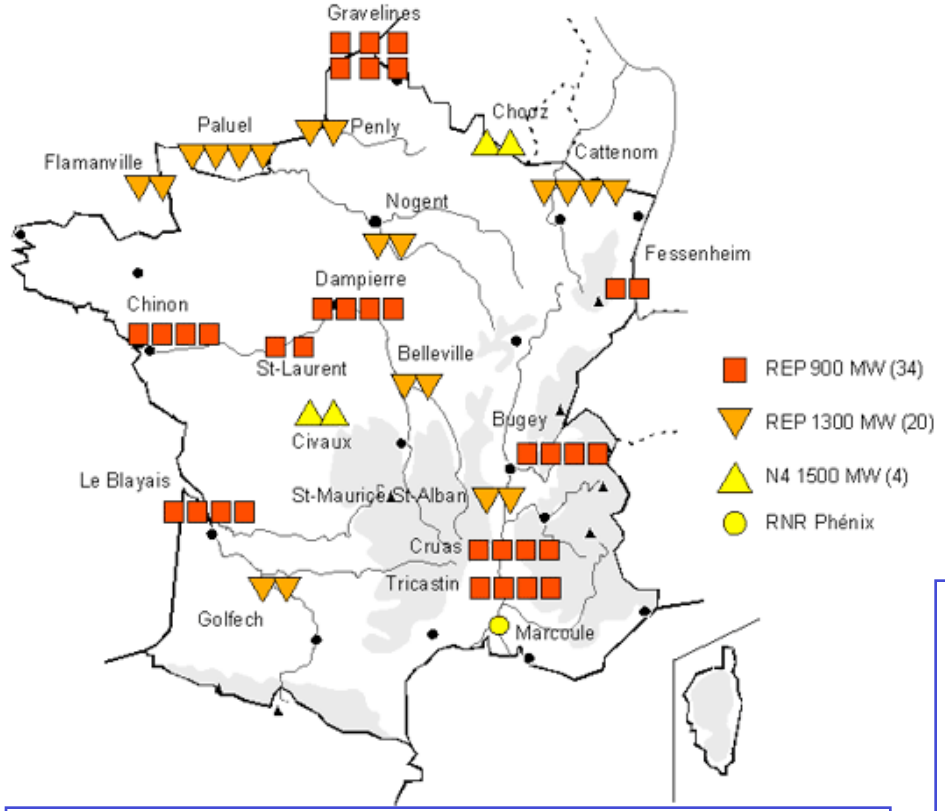
(Commissariat à l'Energie Atomique et aux Energies Alternatives)

Nuclear Power Plants in France



419 nuclear TWh in 2007, 78% of total
Hydro 12%
Fossil 10%

58 PWR units on 19 sites
highly standardized fleet
Net installed capacity : 63 GWe

Feedback on safety and cost effectiveness

- Energy independence increase
  26 % in 1973, 50 % in 2007
- Environment preservation
  In comparison to gas-fired power plant, the French electronuclear park allows to avoid the discharge of 130 millions tons of CO_2 per year, i.e the equivalent of CO_2 emissions of the transport sector in France.

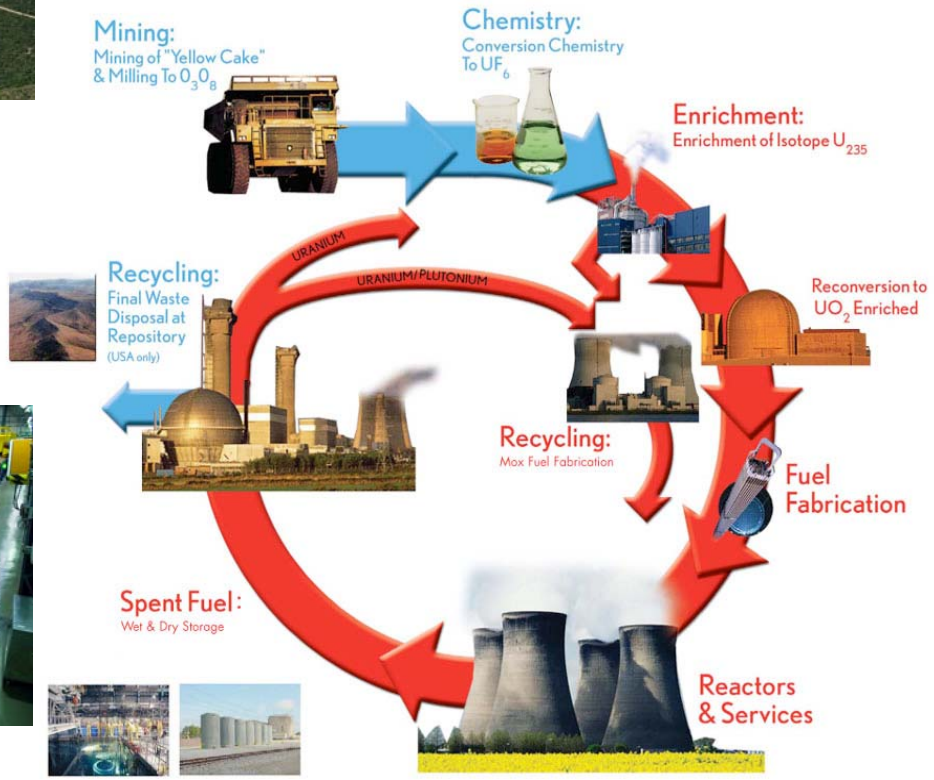
Generation III: European Pressurized Reactor (EPR)

Designed and developed by AREVA

- increased safety
- enhanced economic competitiveness
- scaled up to an electrical power output of 1650 MWe
- Bring burn up to 65 GWd/t using 5% enriched uranium oxide or MOX

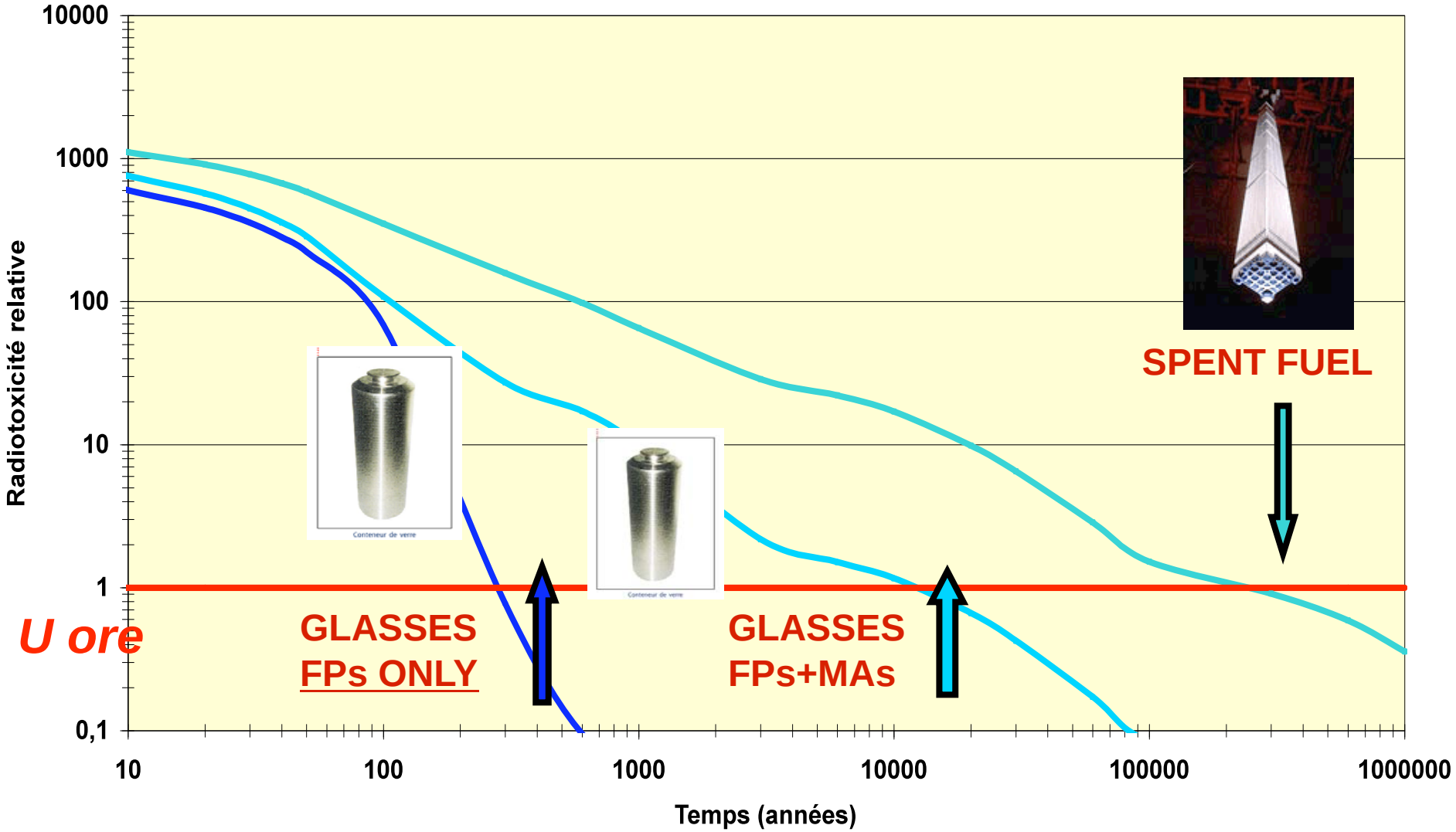
Flamanville

Closing the fuel cycle
a 25 years old industrial experience



- **20 000 t_{HM} spent fuel reprocessed**
- **1200 t_{HM} MOX fuel recycled**
- **1100 t_{HM} /yr of spent fuel discharged from PWRs**
- **Up to 1 600 t_{HM} /yr of spent fuel reprocessed (domestic + foreign)**

Final waste toxicity



Safety characteristics of Generation III reactors

- Enhanced reliability to reduce the number of significant incidents
  - Improvement of the reliability of the systems
  - Ability to tackle with possible human errors

- The facility is robust enough to prevent evolution to severe accident
  - The probability of core melting reduced to less than 10^{-5} per year and per reactor (to be compared to 10^{-4} for the existing reactors)

- If an accident occurs: the facility is designed to limit its consequences :
  - no emergency evacuation beyond the proximity of the plant
  - no permanent rehousing of people
  - no long-term restriction in the food consumption

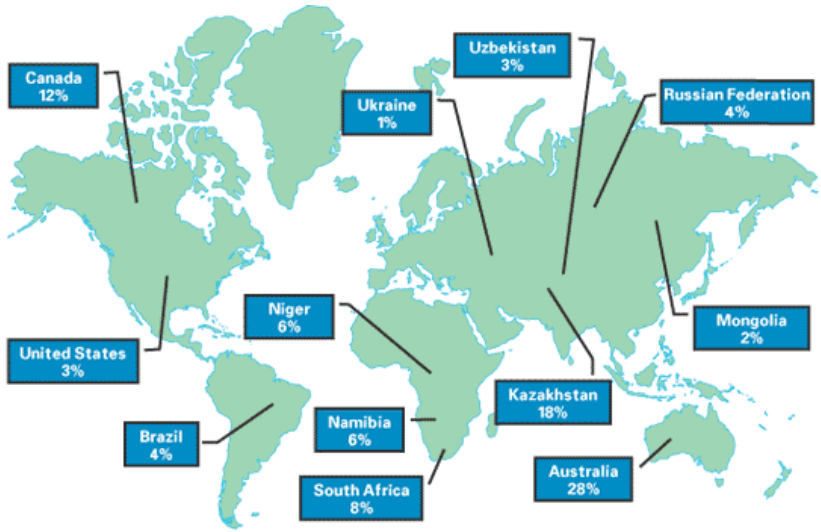
- Satisfactory protection against external hazards (airplane crash, explosion, earthquake…)

Nuclear Future: A need for substantial R&D

- Fast Breeder Reactors:
  - core studies for a better void coefficient
  - for a better breeding factor without blankets
  - from oxides to carbides (higher density, higher th. cond.) or metals
- Recycling of Minor actinides
  - Homogeneous incorporation of MA in fuel
  - Heterogeneous recycling
- Waste management
  - Ageing of glasses
  - Transport of radioelements in clay
- Material Sciences
  - Fuel materials, cladding and structure materials
  - Irradiation effects: stabilité, defects, fracture,deformation,
  - Temperature effects, corrosion, ..
- The growing role of numerical simulation
  - Multi-scale modeling: electronic structure, dislocation dynamics, averaging, contiuun mechanics

attractive features of nuclear energy

- An almost domestic energy
  - Uranium is distributed over the Worl
  - Uranium supply is not an issue of energy security as oil or gas can be



- An economical cost which is predictable
  - When a power plant is built : a predictability of cost for the next 60 years.
  - The cost of uranium is only about 5% of the KWh cost. Even if prices increase it won't change dramatically the price of a KWh

- Nuclear produces no CO_2

Impediments to nuclear

- Social sustainibility is hindered by:
  - Risks of weapon proliferation and terrorism : access to fissile nuclear material (^{235}U or ^{239}Pu)
  - Storage of radioactive waste over 100000 years or more :Wastes have the potential to leak, threaten water supplies and human health
  - Safety of nuclear plants: Chernobyl disaster
- Need to address these issues rationally, rigorously, internationally
- Reduce the risks to such a low level so that advantages of nuclear largely balance these risks

New Challenges

France has a massive agenda

- Operation and maintenance of the existing fleet
- Renewal of the fleet
- R&D for increasing the sustainability of nuclear energy (4th generation)
- Decommission of closed plants
- Management of nuclear materials and radioactive wastes
- Openness to the international demands

Present situation

- French nuclear actors have to deal with competences renewal
  - for domestic needs
  - for French contribution to nuclear development worldwide
  - Need of hiring and training thousands of people every year both in France and in partners /customers countries.

New workforce needs

- Estimation of needs at a Master degree level:
  - to about 1200 engineers per year for at least the next ten years,
  - the main employers being EDF, AREVA, GDF-Suez, and supply chain.
  - about 100 engineers and PhD's per year during the coming years in main agencies for R&D in nuclear technologies, safety, waste management, such as CEA, IRSN (TSO) , or ANDRA
  - around 200 foreign students
  - Total of about 1500 Master level graduates every year.
- Technicians with a typical bachelor degree: about 1000 per year.
- In addition: possible partnership in setting up training capabilities abroad

Present capacities of nuclear education and training

- About 300 graduated students per year in 2006 or before

- setting up new curricula

- At the end of 2008, various curricula contributed to:
- about 600 graduated at Master level in nuclear engineering or related
- about 100 graduated at PhD level
- about 450 specialised technicians

- December 2009 : 886 students enrolled in nuclear related masters and a potential of 1250 enrolments

- It is worth noting that most of the employees in the major companies are trained “on the job” through internal processes.

CFEN

French Council for Education and training in Nuclear energy

CFEN was created by the Minister of High Education and Research in 2008

- CFEN aims to assess the adequacy between the education offer, the students population in different curricula and the industrial/research needs.

- It advises the Office of High Education on opening new academic curricula in the nuclear domain. It gives a label.

- CFEN pays attention to provide students with a clear presentation of various educational trainings and degrees and possible professional careers in nuclear.

- CFEN coordinates the international recruitment of students. Point of contact of AFNI

- CFEN promotes international curricula such as the new International Master of Science in Nuclear Energy starting in Paris 2009.

CFEN

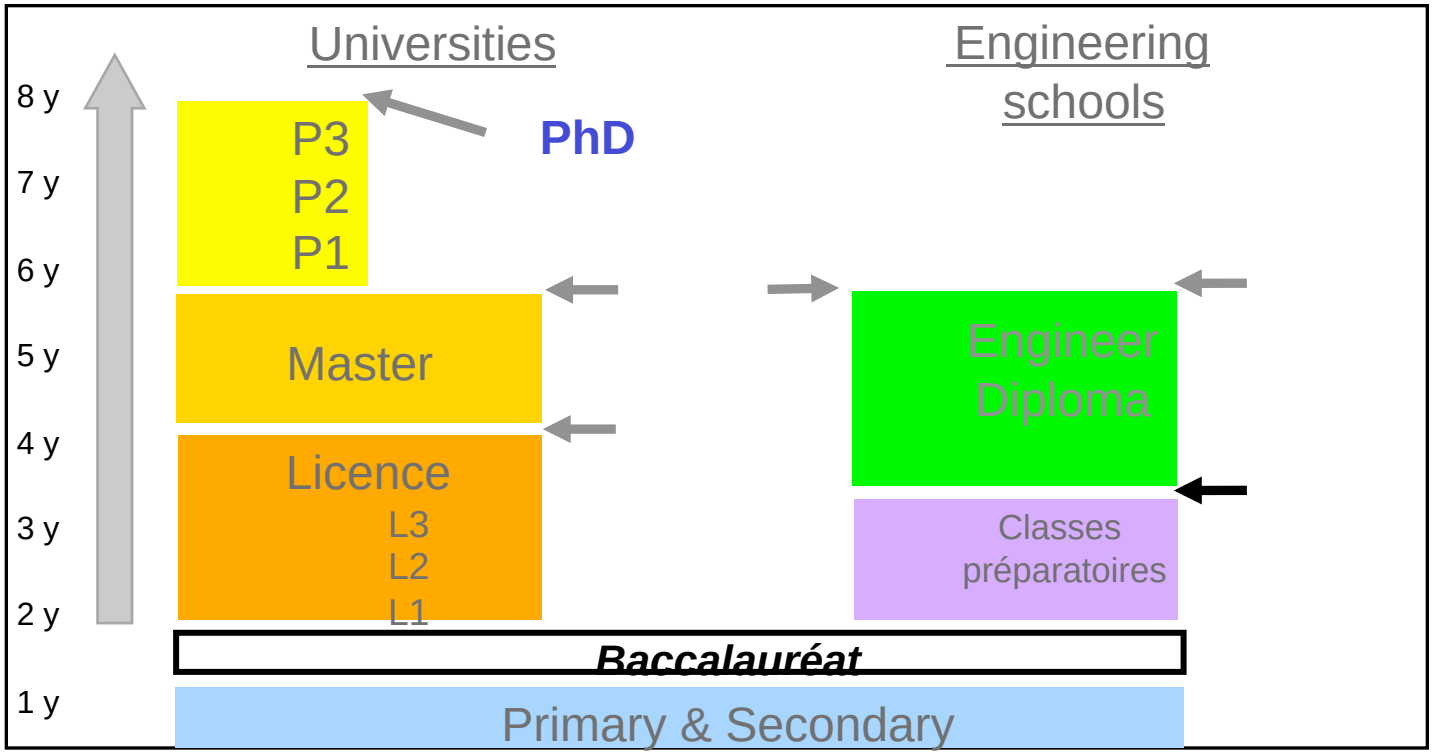
Chaired by the High Commissioner for Atomic Energy (Catherine Cesarsky)

Members are:

- representatives of governmental authorities in Education, Research and Industry,
- representatives of academic institutions (universities and engineering schools),
- representatives of the main industrials actors (AREVA, EDF, GDF-SUEZ, sub-contractors),
- representatives of main nuclear R&D institutions (CEA, IRSN, ANDRA)
- Secretary (C. G.)

French educational system

- Engineers are usually trained in special schools rather than at universities.
- Currently, around 25 000 students graduate at a Master Level per year in the French Engineering Schools. The engineering graduates from Universities need to be added to this figure, but they remain a small fraction.



Engineering Schools

France has 224 schools of engineering

- To enter an Engineering school:
  - accomplish two years of so-called "classes préparatoires"
  - pass a nationwide selective examination named the "concours“

- Study programs usually last for three years. attuned to the needs of industry

- Most of graduates directly go to the industry as engineers, but some of them to Ph.D. programs, as the title of engineer grants a Master's degree.

- An increasing number of schools offer "Specialized Masters", which represent a one-year program leading to a specialization in a given field.

- The most prestigious engineering schools fall into what is called *Grandes écoles. Grandes écoles* are unique institutions, prestigious and very selective.

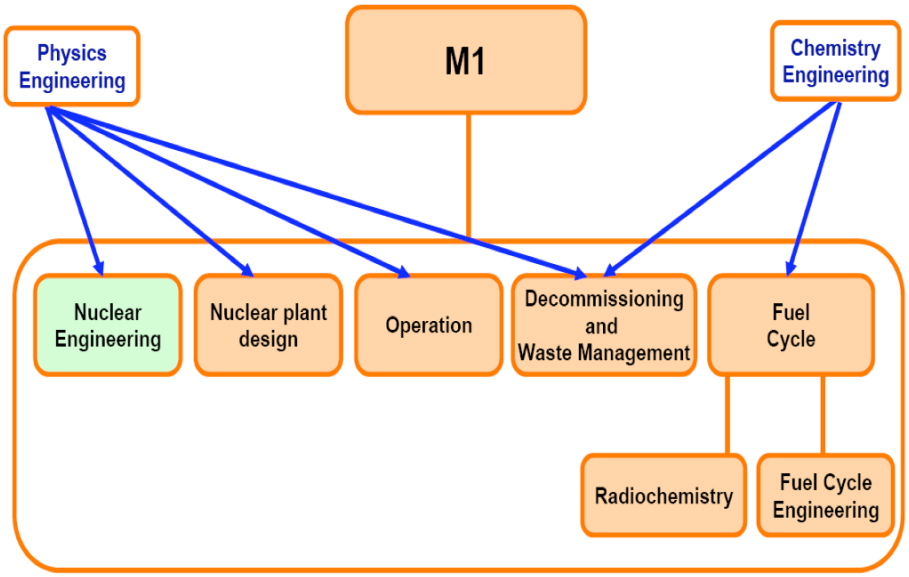
Nuclear education : a broad offer

- Presently more than 20 engineering schools and universities offer nuclear related curricula at a master level.
- These schools and universities are spread all over the country.
- Nuclear-energy industrials and R&D organisations involved in initial education programmes through their experts
- AREVA, EDF, ANDRA have provided grants to endow chairs in various schools
- New efforts to deliver courses in English and to welcome foreign students
  - International Master in Nuclear Energy
  - International Master in Materials Science for Nuclear Engineering

International Master's degree in Nuclear Energy Science

http://www.master-nuclear-energy.fr

- M1 => basic courses (Nucl. Phys., Mat. Sci., Chem. Eng., Elec. Eng., Fluid Mech. & Heat, Economics, Project Mngt, Fr. language& culture.)
- M2: 5 options
- A master's thesis (20 weeks)
- The experimental sessions and training are done on EDF simulators
- Admission : international students with a Bachelor's degree.



Consortium of academic institutions (Uni. Paris-Sud 11, ParisTech, Supélec, École Centrale Paris, INSTN) and industrial establishments (EDF, AREVA, GDF-SUEZ).

Fully taught in English.

The target number of students is about 200/year, half of them being French.

It started September 2009 with 92 students enrolled

Int. Master's in Material Science for Nuclear Engineering

http:/phelma.grenoble-inp.fr

- At Institut National Polytechnique at Grenoble (Grenoble-INP) in close cooperation with EDF and CEA, in partnership with Mc Master University

- A degree suitable both for industry and R&D.

- M2 course is open to French and Foreign students after Physics or Chemistry M1 level, and for engineers in the context of professional training.

- 300 hours course deals with metallurgical and physico-chemical aspects of under irradiation ageing of nuclear fuels and material for reactors.

- Optional 'structural materials' course by EDF engineers-on site
- Optional 'nuclear fuel materials' course by CEA engineers on-site

Institut National des Sciences et Techniques Nucléaires
INSTN http://www-instn.cea.fr

- As a part of CEA, INSTN was created in 1956

- provides high level courses in nuclear energy disciplines including training of nuclear physicians, radio-pharmacists and medical physicists

- associated with numerous national and European academic courses

- 114 in-house staff, 1400 lecturers and specialists, 7500 trainees per year (vocational sessions), 600 students per year taking academic courses,

- with many years of experience in international collaboration since the 70's, INSTN is associated with ENEN (European Nuclear Engineering Network)

- it organizes IAEA courses like Regional Post-Graduate Educational course on radiation protection and on the safe use of radiation Sources, basic professional training course on nuclear safety, training needs assessment,

Institut National des Sciences et Techniques Nucléaires
INSTN http://www-instn.cea.fr

- The over 50 years old "Génie Atomique" curriculum has trained a large fraction of the French leading nuclear practitioners.
  - open to students in engineering schools.
  - It provides them with an extra diploma which certifies their qualification in nuclear engineering, operation of reactors, safety management, decommissioning, and waste management.
  - Today "Génie Atomique" curriculum welcomes 100 graduates.
  - Note however that courses are given in French.

training facilities for students

- An experimental reactor ISIS (700kW)
- PWR simulators for normal operation or accidental situations
- 2MeV Van de Graaff accelerator
- Scanning and transmission electron microscopes fitted with an energy dispersive X-ray analyser
- Teaching laboratories for : radiobiology, chemistry, radiochemistry, metallurgy, laser, nuclear measurement
- Data-processing equipment...

INSTN. Continuing education. I

International training seminars are organized within the ENEN framework

- advanced training for experienced professionals. Contact with French industry
  - Nuclear Fuel Cycle
  - Dismantling experience
  - Nuclear Waste Management
- ½ course and conferences, ½ visits of facilities
- Students from ENEN can enroll, with the possibility of getting ECTS.

INSTN. Continuing education. II

Specific seminars for non-nuclear professionnals willing to learn about a specific topic (either basic or applied) :

- Generation IV
- Nuclear safety
- Probabilistic estimate of safety (a 2011 project in collaboration avec TUM
- Criticality and safety (2010 project)
- Neutronics (2009)
- Thermohydraulics for reactors (2009)

INSTN. Continuing education. III

Courses for nuclear professionnals with neither Master nor engineer degree. Typically bachelors

- Course specifically tailored to the audience (12 to16 part.)
- Exemple : 4 weeks divided into 3 courses:
  - Course I : Basic Sciences (2 weeks)
  - Course II : Nuclear Engineering (1 week)
  - Course III : Nuclear reactors (PWR…1 week)
- Pre-requisites are required: *basic nuclear physics, thermal physics, fluid mechnics, metallurgy,.;*

Institute of Radioprotection and Nuclear Safety (IRSN)

- IRSN trains medical staffs and people professionally exposed
  - Practical training for the evaluation for radiological and nuclear risks
  - Radioprotection of staffs exposed in industry
  - Evaluation of worker's exposure to ionizing radiations, dosimetry
  - Sensitisation to radioprotection
- Criticality
- Principles and practices of nuclear safety: safety of PWR
- the trainers are national or/and international experts, contribute to the research, and to the standardization and the legislation of the subject taught.
- about 100 teachers

AREVA

http://www.areva.com

- *AREVA* (*global nuclear industry, fuel cycle, reactor design and construction, related service*) provides all related skills and training solutions to its partners

- A dozen of training centers in France, Germany and USA

- Scientific and technical training, Project management, Facility operations,.;

- 500 courses on offer

- 100 trainers, and thousands of students/year

- E-learning, simulators training, study trips,..

- Courses available to group's partners and stakeholders: gvt authorities, customers and suppliers, electric utilities, fuel cycle operators,.

EDF

htpp://www.edf.fr

- Since its entry into nuclear energy EDF has developed a strong internal vocational education and training organisation to train its personnel, particularly reactor operators

- About 1.5 million hours of training per year, with over 650 different courses. Initial qualification and periodic trainings

- EDF reinforced interaction with Engineering Schools and Universities, both in France and abroad.

- EDF created and placed under the aegis of the Institute of France, a foundation – Fondation Européenne pour les Energies de Demain; the European foundation for tomorrow's energies

- The Foundation funds teaching and research chairs**,** and strikes agreements and specific partnerships with engineering schools and universities. It also supports new talents through the arrangement of funding, grants, study trips or work placements

  http://www.energiesdedemain.com/?lg=gb

doctoral training program

- "International School in Nuclear Engineering" for PhD students also open to researchers in nuclear engineering

This program consists in 10 courses, each of them lasting over one week, and is given on an annual basis. Topics addressed are :

- Reactor Core Physics : Deterministic and Monte Carlo Method
- Materials for Reactor fuels and Structures
- LWR and FR Thermal-Hydraulics, Fuel Design and Safety
- Experimental Validation and Calibration of Numerical Models
- Reactor Multiphysics and Fuel Management
- Bifurcation, Stability and Chaos in Nuclear Systems
- Nuclear fuels for light water reactors and fast reactors
- Fuel Cycle Back-End and Reprocessing
- Reactor dismantling and Waste Management

Teacher's training in Nuclear Engineering

Example: A Polish-French Initiative

A New Poland's Energy Policy : Towards first NPP's in 2020

Need to build up the human ressources.

20 highly motivated faculty members from 6 universities of technology will set up the first curricula of the Polish nuclear energy educational system.

These academicians have expertise in engineering or scientific domains relevant to nuclear technologies

Agence France Nucléaire International

Under the coordination of the French International Nuclear Agency (AFNI) a training offer ensuring dedicated training was made.

▶Cooperation between France and Poland.

▶ Partnership between all French nuclear energy stakeholders.

- **Phase 1. A six weeks nuclear Tour de France**
  - ✓To get well acquainted with a broad nuclear context
  - ✓To visit Technical sites: NPP, fuel cycle, waste
  - ✓To meet and exchange with French education network
  - ✓To learn and exchange about communication and public acceptance

- **Phase 2. twelve weeks intense advanced training**
  - ✓ Fundamental nuclear science
  - ✓Applied courses (safety, radioprotection, NPP's, waste,…
  - ✓Access to experimental facities: ISIS, irradiation and characterization
  - ✓Access to simulators
  - ✓Focus on pedagogical issues

Phase I. Nuclear Introductory « Tour »

Phase 2: Nuclear Engineering Course organised by CEA-INSTN April –July 2010

Fundamental and Applied Courses

- Introductory nuclear physics – 1 week
- Neutron Physics for Light Water Reactors (basics and advanced) – 2 weeks
- Thermal Hydraulics (basics and advanced) – 2 weeks
- Nuclear Materials – 40 hours
- Computer codes – Modelling in Neutronic and Thermal Hydraulics – 1 week

Radiation Protection and Shielding – 1 week

Nuclear Fuel Cycle and Waste management – 1 week

Safety – Criticality - 1 week

Pressurized Water Reactors (PWR) – Description and operation - 1 week

Nuclear reactors systems – 24 hours

Bilateral agreements
Example: Cooperation between Jordan and France

Assistance to a Jordan Center of Excellence for Nuclear Energy and Mega Projects (UJ, JUST, Al Balqa)

- New curricula: Master's programme in Project Management (UJ)
  Master's programme in Nuclear Safety and Regulation (JUST)
  Professional Degree for advanced training of technicians

- Installation of a joint Training and Skills Development Working Group
  - Quality accreditation with international standards and regular reviews
  - Selection and orientation of students and individual academic projects
  - Scholarhips
  - Exchange of faculty members and students
  - Collaborative research projects. PhD under co-supervision
  - Internships in industry for students
  - Access to simulators and facilities for training. E-learning
  - Networking professrs, scientists, and engineers in Jordan and France