From atom to industry

Nuclear Energy in France and in Nordic Countries

"CEA as a RTO supporting Energy Policy and Industrial Development"

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CEA - Alternative Energies and Atomic Energy Commission

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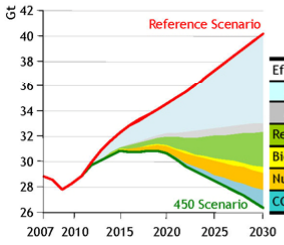
Contents:

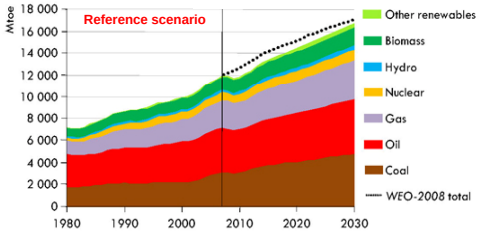
World Energy Outlook

Whatever the energy savings and economy scenarii , the world energy demand is expected to steeply grow…



	Abatement ($Mt CO_2$) 2020	2030	Investment ($2008 billion) 2010-2020	2021-2030
Efficiency	2 517	7 880	1 999	5 586
End-use	*2 284*	*7 145*	*1 933*	*5 551*
Power plants	*233*	*735*	*66*	*35*
Renewables	680	2 741	527	2 260
Biofuels	57	429	27	378
Nuclear	493	1 380	125	491
CCS	102	1 410	56	646

Source IEA : World Energy Outlook 2009



From now to 2050 :

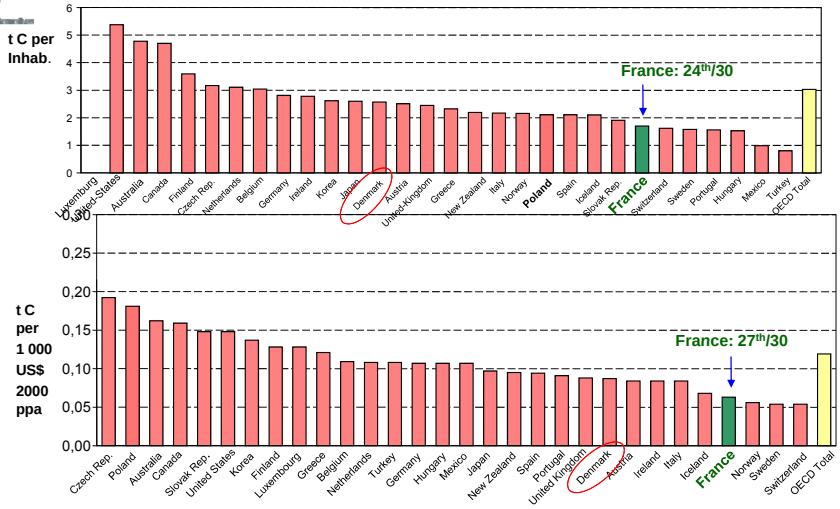
- Energy demand **will** increase (approx. a doubling whatever strong saving policies are implemented)

- Nuclear **will** play a significant role (progressive exhaustion of fossil resources, strengthened environmental requirements) … **alongside increasing contributions** from renewables

Already today, 1.6 billion people have no access to electricity at all !

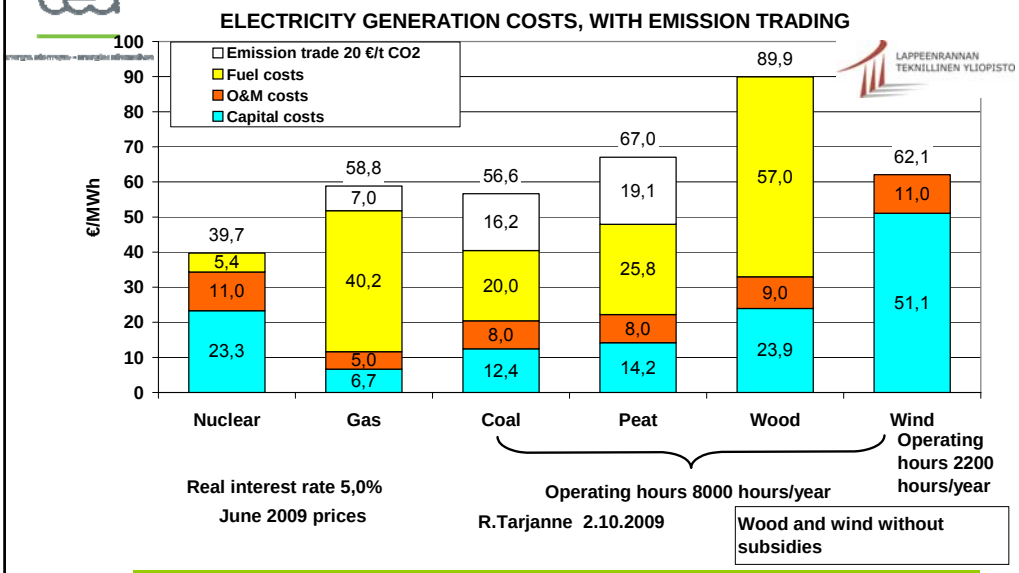
World Energy Outlook

CO_2 emissions in 2005 per inhabitant and relating to GDP



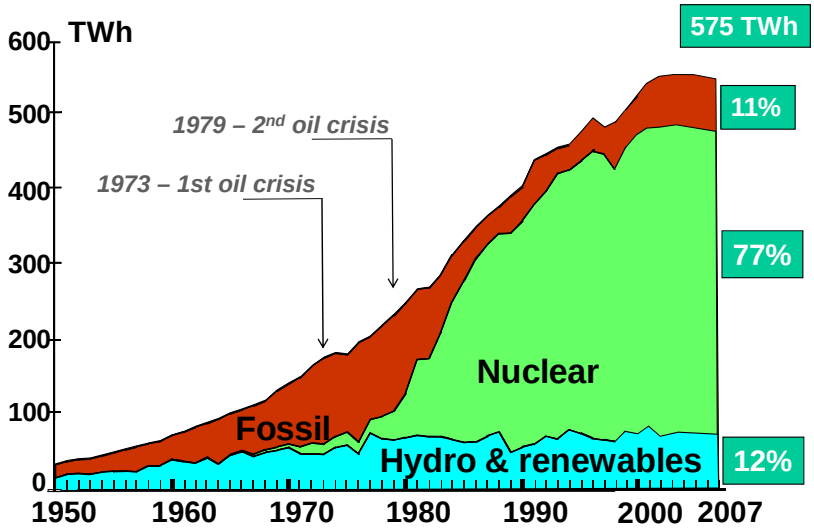
Source : IEA/OECD 2005

World Energy Outlook – Electricity generation costs

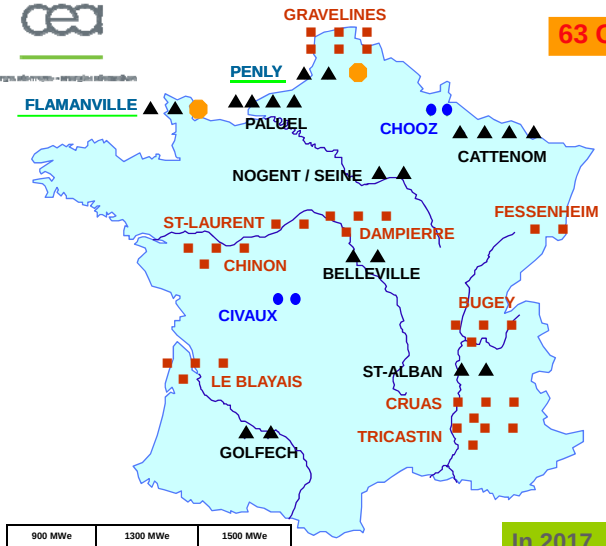


Nuclear Energy in France

Electricity production in France since 1950 and share of nuclear



Nuclear Energy in France



63 GWe installed, 58 PWR units

- **19** sites ; **1** single technology
- A nuclear production fleet:
  - Recent : average age **= 23 y**
  - Mature : **> 1250** cumulated reactor-years
- Under construction : 2 EPR
- One shut down in 2009: Phenix

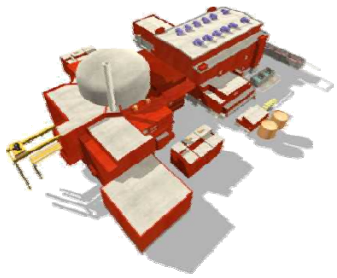
In 2017, 60 units and 66 GWe installed

Nuclear Energy: AREVA Reactors

The EPR™ Reactor

AREVA

1 650 MWe PWR



EPR™ by AREVA

The Path to Greatest Certainty

- Generation III+ PWR
  - 4-Loop
  - 4 590 MWth
  - SG pressure 77bar at 100% power
  - 4x100% redundancy of active safeguard systems
  - Backup in case of total loss of safety function
- High power output (1 650 MWe)
- Evolutionary design (Konvoi/N4)
- Low global power generation costs
- Outstanding safety level
- Maximized benefit from size effect
- Minimal environmental impact

Construction: Finland, France & China

Licensing engaged in the USA & UK

Nuclear Energy: AREVA Reactors

EPR™ the best from French and German technology

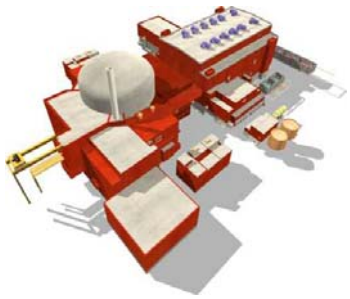
KONVOI ~1 300 MWe

- Emsland ('88)
- Isar 2 ('88)
- Neckar 2 ('89)

- Chooz 1&2 ('99)
- Civaux 1&2 ('00)

N4 ~1 500 MWe

EPR™ by AREVA



Nuclear Energy: AREVA Reactors

AREVA is the only player with a new generation reactor range

AREVA's reactor range

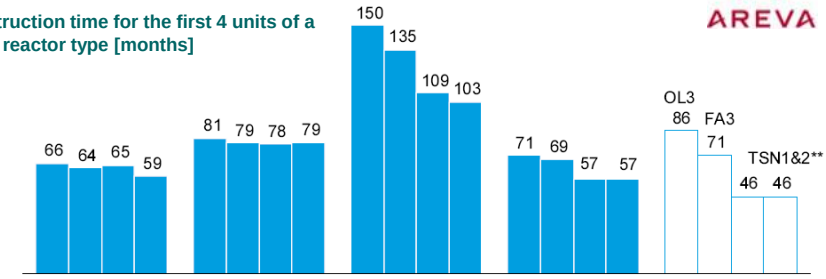


BWR 1250 MWe	PWR 1100 MWe	PWR 1650 MWe
KERENA by AREVA	ATMEA (Developed in partnership with MHI)	EPR by AREVA
Medium Power Output		High Power Output
Boiling Water Reactor	Pressurized Water Reactors	
Basic design completion: 2011	Market launch: 2010	Deployed

Nuclear Energy: AREVA Reactors

How experience improves construction times

Construction time for the first 4 units of a given reactor type [months]

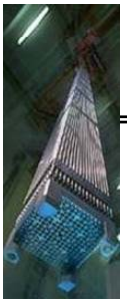


	GEN 2 900 MWe	GEN 2 1300 MWe	GEN 2 - N4 1500 MWe	Export 1000 MWe (Chine)	GEN 3+ - EPR
Moyenne (# de mois)	63,5	79,3	124,3	63,5	62,3

* Sur la base des 4 premières unités des séries de réacteurs
** Source CGNPC

Nuclear Energy in France - Waste management

Offer safe and economically viable technical solutions for managing nuclear waste



Separation

Enhanced Separation

Transmutation

- Save fissile materials
- Reduce toxicity
- Reduce thermal load

- Reduce volume
- Improve package performance

Conditioning

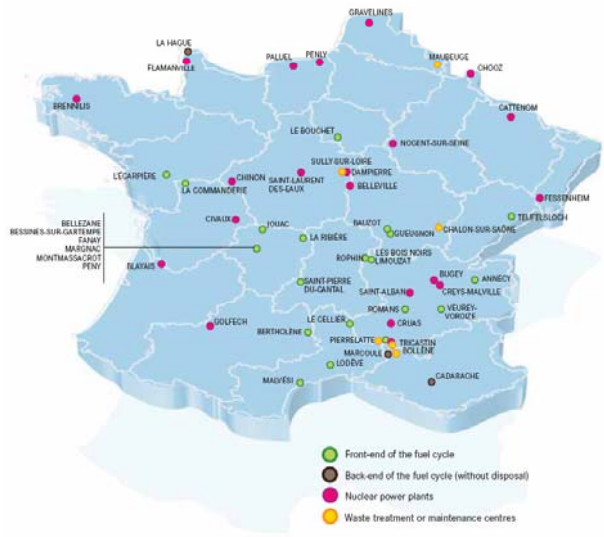
Interim storage

In France
Act of June 28th, 2006

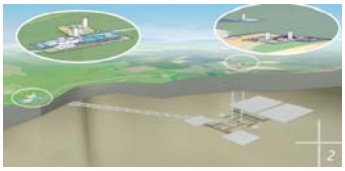
ANDRA

Final Storage

Nuclear Energy in France - Waste management



View of Andra's Bure site, where the Agency is studying a suitable clay-rock formation for implementing the future repository for HL and IL-LL waste at a depth of 500 m in clay.



Nuclear Energy : Political involvement – March 2010

Safety : must be the **n°1** priority

Compliance with international treaties and non-proliferation commitments : an absolute necessity

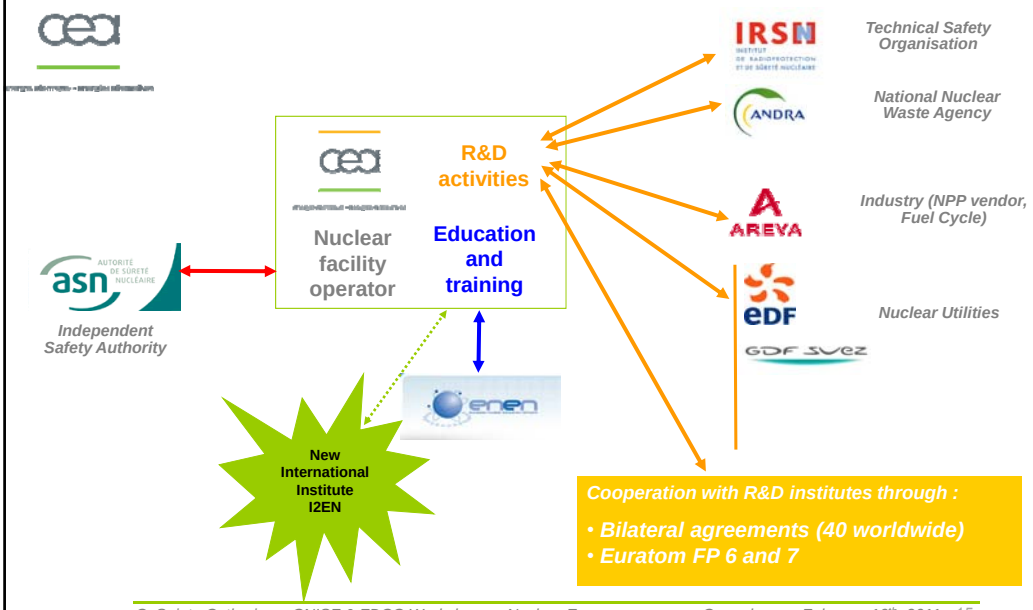
Financing :
« the World Bank, the EBRD and the other development banks should make a firm commitment to finance […] nuclear energy »

Transparency :
« There can be no development of civil nuclear energy without a commitment to transparency » ; " the states have a key role to play"

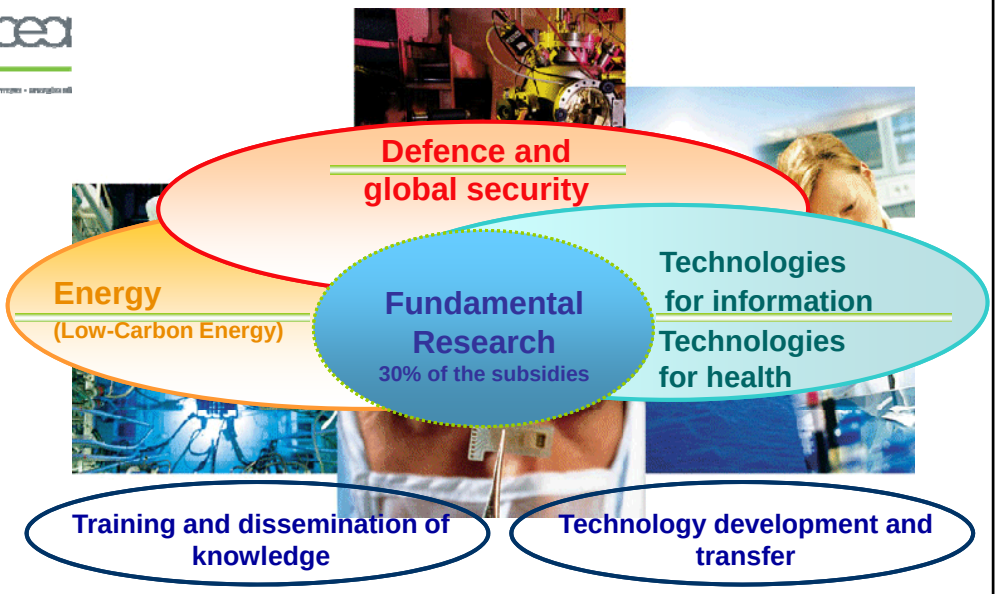
Education & training : a priority. An international network of centres of excellence on nuclear energy should be set up. **President Sarkozy has announced the creation of an international institute devoted to nuclear training and education (Saclay-France)**

afni Agence France Nucléaire International **is dedicated to support newcomers for their development of nuclear energy**

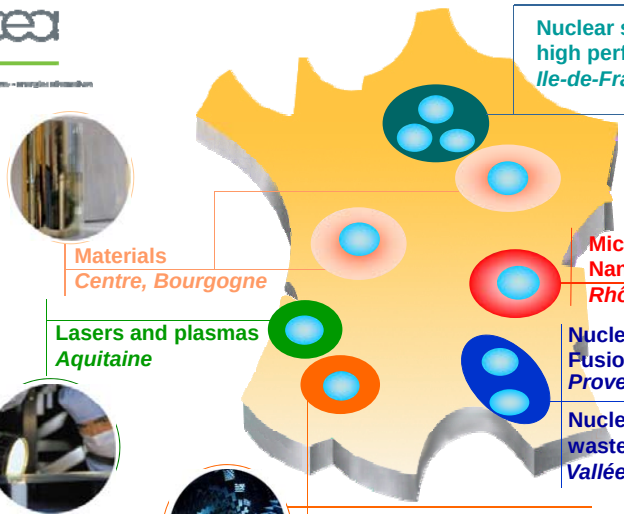
CEA as RTO & other nuclear actors in France



CEA R&D strategy



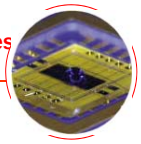
CEA - 10 Research Centres in France



Nuclear sciences, software technologies, high performance computing, biomedicine
Ile-de-France

Materials
Centre, Bourgogne

Micro/Nanotechnologies
Nanobiotechnologies
Rhône-Alpes



Lasers and plasmas
Aquitaine

Nuclear :
Fusion, fission
Provence

Nuclear fuel cycle and waste management
Vallée du Rhône

Vulnerability assessment
Detonics
Midi-Pyrénées

- 15 718 employees
- 3.9 billion € budget

Energy Policy for the near future : How to manage supply and demand?

CO_2 free ENERGY

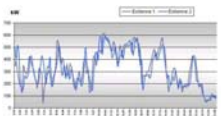
NUCLEAR

RENEWABLES

Hydraulic, Bioenergy
Solar energy
Wind…

+ Smart Grids

How to store available electricity ?



Type of storage

Applications

Direct

Batteries

Clean vehicles

Indirect

H_2

Fuel cells

Biofuels

Photovoltaic Energy : from silicon material to device

"Solar Mobility"

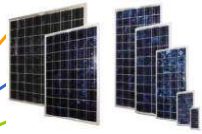
Smart Grids & Intelligent electric devices

Photovoltaic Devices

Modules and device Certification

INES INSTITUT NATIONAL DE L'ENERGIE SOLAIRE

Solar Modules



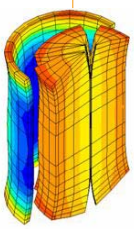
Solar Cells

Silicon new refining methods

INES is located in Chambery, Alps

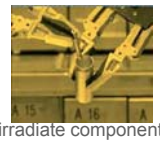
CEA R&D in support to the nuclear industry

- **Respond to the R&D needs of the nuclear industry**
  - Extension of the lifetime of reactors (58 reactors in operation in France)
  - Improve reactor availability and safety
- **Contribute to the construction of the European research area**
  - Launch of the construction phase of the JHR
  - Development of new modelling simulation tools



CEA has a wide range of unique hot cells facility :

- Ramp testing in Osiris reactor for fuel optimisation and cladding development



- Metallographic observation both on structural metallic irradiate components and on nuclear fuel

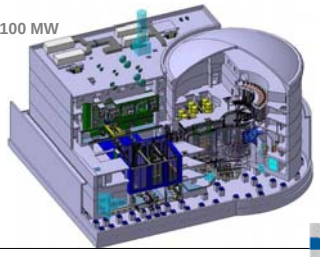
CEA Nuclear : JHR – Jules Horowitz Experimental Reactor

➢ International partnership

➡ EU, Belgium, Czech Republic, Spain, Finland, India, Japan, Sweden …

JHR is a high performance MTR under construction in Cadarache

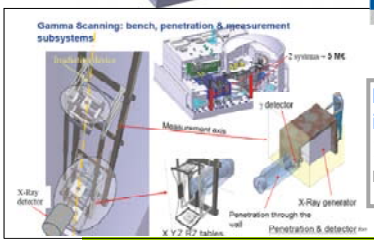
JHR power : 100 MW



➢ A high performance and flexible reactor

- ✓High level neutronic flux
- ✓Address Gen II, III and IV materials testing needs
- ✓Able to produce radioisotopes

- ➢ Sept. 2007 – Building permit
- ➢ July 2009 – First concrete
- ➢ 2015 – Planned Operation



Finnish participation via VTT in-kind contribution (2%)

➢γ-scanning bench in reactor pool and in hot cell

CEA Education – Nuclear Engineering

I2EN
International Institute for Nuclear Energy

- The French offer of training on nuclear energy open to foreign students
- A partnership between ministries, educational institutions, research organizations and industry

Including :

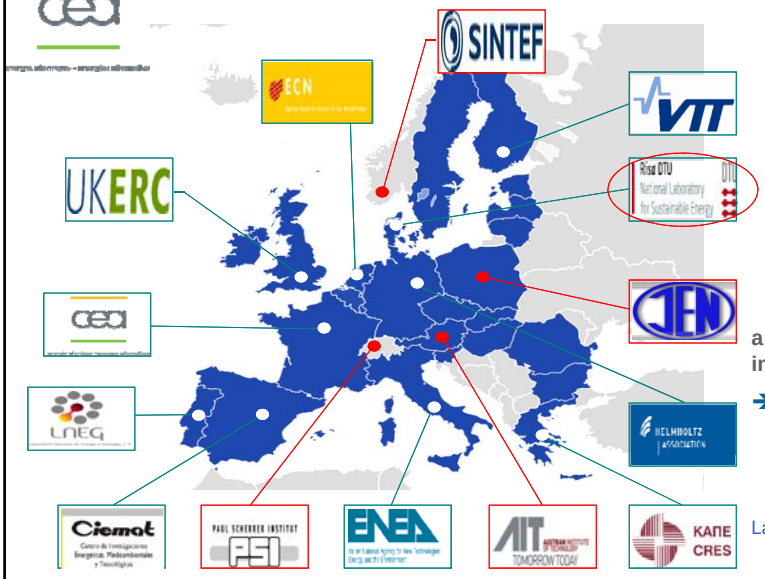
- A network of nuclear S&T curricula in France, with Masters such as “Master of Science in Nuclear Energy”
- A « centre of excellence for a sustainable nuclear energy future »

CEA-INSTN (Institut National des Sciences et Techniques Nucléaires) created in 1956 jointly with the French Ministry of research and higher education:

Operational since 1st of September 2010

IAEA

CEA involvement : European Energy Research Alliance



10 founding members
+ 4 incomers
with support of :

EUA

EUROHORCs

a major contribution to the implementation of SET-Plan

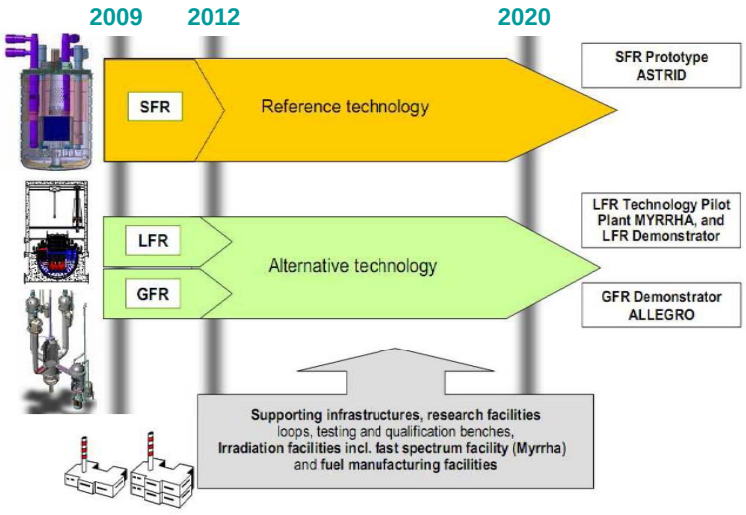
➔ **Joint programming :**
- Wind
- Solar PV
- Smart grids
- Geothermal energy

Launched in Madrid June 4th 2010

SNETP Members (2010)

Involvement of Utilities, RTO and University is high and appreciated

Nuclear : roadmap ESNII *(target 2040 for a GEN 4 Fast Neutron Reactor)*



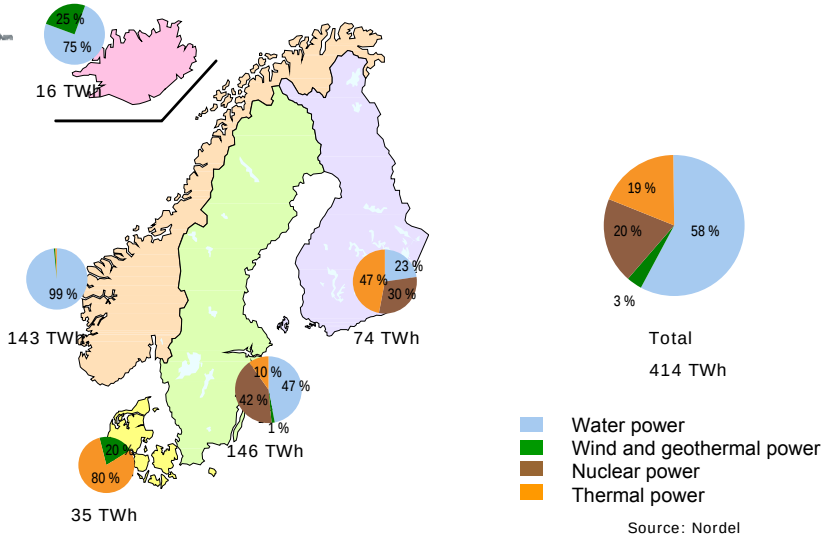
Nuclear Energy in France

Conclusions: *Altogether towards low-carbon energies*

- **Strong involvement** of France and CEA in low carbon energies
- **European & International cooperation** are vital to reach the objectives including at the bi-lateral level
- **High Scientific and Technical education** must be reinforced in particular in Nuclear Engineering
- **Large infrastructures for demonstrators** and prototypes have to be international ones and developed in close cooperation with industry
- **R&D** remains the key to overcome technological breakthrough
- **CEA is a major player in the French national technologic research** fully involved and open to international cooperation

Nuclear Energy in Nordic Countries

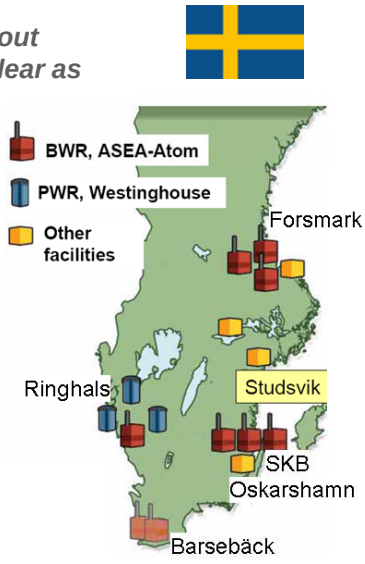
Electricity production in Nordic Countries in 2008 (Nordel)



Nuclear Energy in Sweden

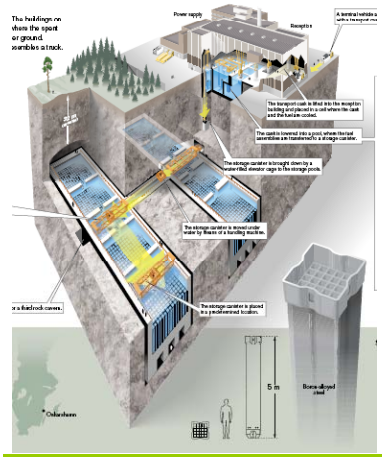
1980 – Referendum for a nuclear phase out
2010 – New energy policy including nuclear as low carbon energy

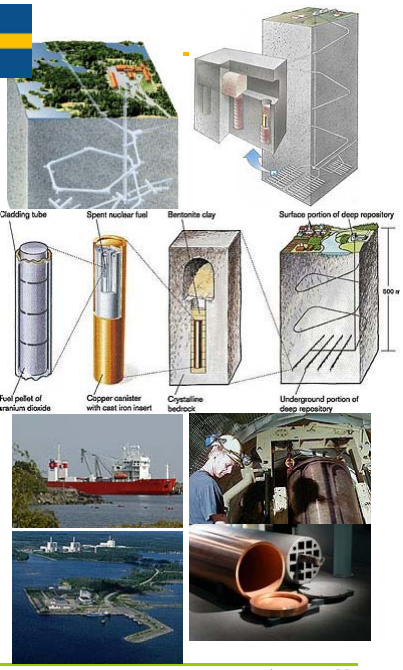
Site (Type)	Operator (%)	Date conn. (Lifetime)	Electric Power (MWe)
Forsmark (3 BWR)	FKA (Vattenfall 66%, Fortum 22%, E.ON 8,5%)	1980 & 1985	3157
Oskarshamn (3 BWR)	OKG (E.ON 54,5%, Fortum 43%)	1971 & 1985,	2215
Ringhals (3 PWR & 1 BWR)	Ringhals NP (Vattenfall 70,4%, E.ON 29,6%)	1974-1982	3662
Barsebäck (2 BWR)	Barsebäck (E.ON & Vattenfall)	Arrêtés 1975-1999 1977-2005	-



Nuclear Energy in Sweden

Sweden has developed a very strong system for nuclear spent fuels with SKB company.



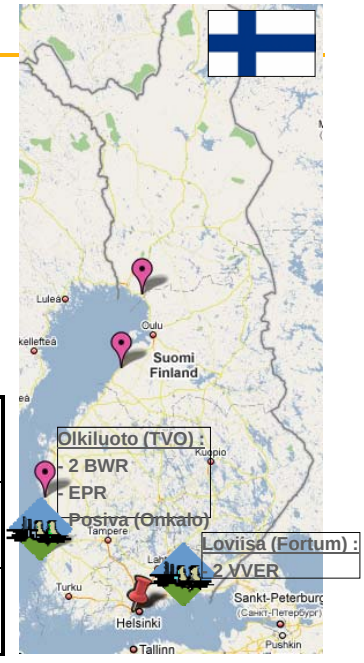


Nuclear Energy in Finland

Finland has 4 nuclear reactors under operation and a 5th one under construction.

In June 2010, the government and Parliament validated the decision for 2 additional nuclear power plants.
TVO and Fennovoima were selected as utilities.
Onkalo site will be operational in 2020.

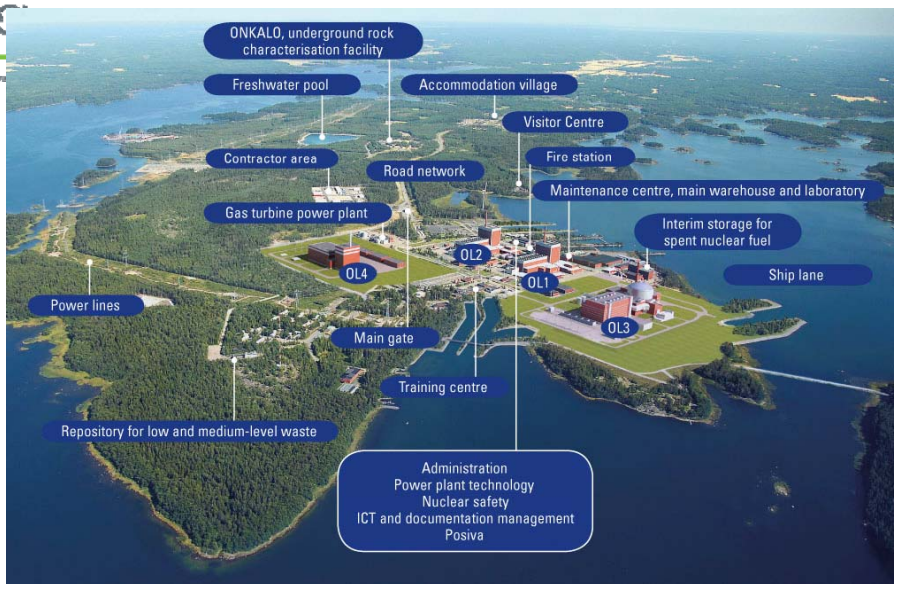
Site (Type)	Operator (%)	Date connexion. (Lifetime)	Electric Power (MWe)
Loviisa (2 VVER)	Fortum (100 %)	1977 & 1980 (-> 2027-30)	976
Olkiluoto (2 BWR & 1 EPR)	TVO (60% PVO, 25% Fortum)	1978 & 1980, 2011 (-> 2038)	1720 & 1600



Nuclear Energy in Finland

Olkiluoto 3

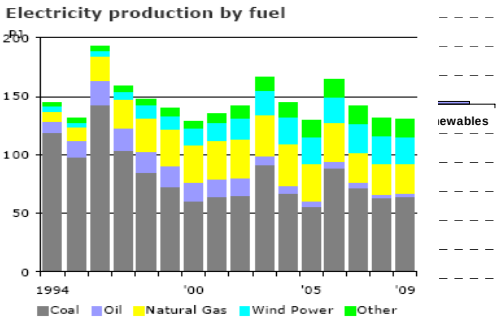
Nuclear Energy in Finland – Olkiluoto (TVO & Posiva)

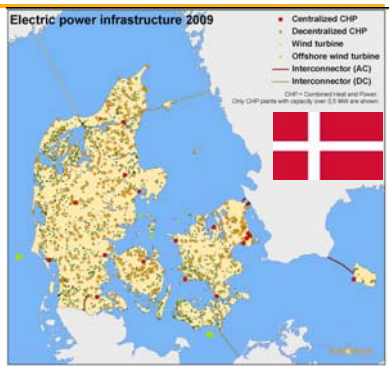


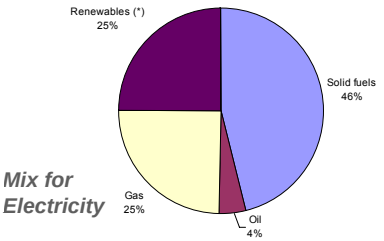
Look at the Danish energy situation

Denmark is the country of the physicist Niels Bohr (Nobel 1922). Institute of Physics and Risø DTU are excellent research centres.

in 1985, the Danish parliament passed a resolution that nuclear power plants would not be built in the country.







Mix for Electricity

Nuclear Energy in France and in Nordic Countries

Conclusions & Discussions:

- France has developed a very strong national industry for nuclear energy with EdF, Areva and now GdF-Suez
- Technological R&D developed within CEA and in international programs is preparing future steps such as SNE-TP and Gen-IV
- Education & Training in nuclear engineering is important
- Within Nordic Countries Finland and Sweden are the main players
  - *Sweden has developed a very strong approach for spent fuel management with SKB*
  - *Finland was audacious enough to order an EPR in end 2003 and now 2 more NPP in June 2010*
- What about Denmark after oil and gas picks?