Nuclear Power in France

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French Embassy in Tokyo

Seminar on WNE and Overseas Nuclear Industry
February 9, 2016

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RÉPUBLIQUE FRANÇAISE
AMBASSADE DE FRANCE
AU JAPON

AGENDA

- Energy Context and Key Trends
- Nuclear Power Development
- Today's Fleet and Actors
- Energy Policy
- Safety Regulation
- Waste Management
- The Fuel Cycle
- Dismantling Experience
- Fast Neutron Reactors
- Other R&D Activities

Energy Context and Key Trends

Pressure on the economical model of energy providers in Europe

- Low electricity demand in Europe and low fuel prices leading to low electricity market prices (33 €/MWh in 2014 – source : EEX)[1]
- Subsidies of European Union to the development of Renewables
- Overcapacities in Europe over the next 10 years (except in the UK)
- After 2030, massive need for renewal in Europe

Policies promoting low-carbon energies and energy independence in Europe

- Towards a mix of Renewables, Nuclear, Energy Efficiency, and gas as complement
- Market model adapted to the UK political vision
- Market model to conceive and carry out in France

Strong growth in Emerging Countries

- Strong growth of demand in Emerging Countries, linked to population increase, which benefits non European energy operators in the international world competition
- Nevertheless, an opportunity to export our technics, our standards, and our associated services

Key Trends for Tomorrow's Energy

In tomorrow's world :

- **Growth will be « electrical »**
- **Customers will be actors**
- **Energy will be low-carbon**

Growth will be “electrical”

- **A general trend in Europe as well as in emerging countries:**
  - **Even though, on the sort term, in Europe, the economic crisis is much longer than anticipated, leading to stagnating electricity and gas demand, economic and financial situations difficult for industries**
  - **On the long term, the need for clean electricity will continue to grow**
    - **In emerging countries : due to population increase and economic growth**

      Electricity consumption grew by 3 % per year in China and by 4 % in Africa

    - **In developed countries : new uses of electricity**

      Electrical mobility, connected houses, smart cities

→ **As a result, there is a very strong need for electricity, which will contribute to growth, industrialisation and job creation**

Customers will be actors - Electricity will be Local and Global

Local

- **Individuals, firms/industries, local authorities will want to benefit from new technologies to act on their own consumption, and even produce their own electricity**
- **The development of connected objects, of the digital age, progress in energy storage and drop in the production price of decentralised sources of energies will open new horizons**

→ Proximity, sustainable cities and smart electric systems

Global

- **Gas, coal and oil prices are determined on the world scene**
- **Industrial dimension**

  For e.g. : China's role in the growth of new nuclear and photovoltaic

→ Need to be a player in the regions where tomorrow's technologies are being deployed : nuclear, hydraulic and other renewables, thermal, smart grids, sustainable cities… all while factoring in geopolitical dimensions

→ The local players in emerging countries : our competitors but also our partners

Tomorrow's energy will be low-carbon

- Faced with the need and the urgency to act against climate change, our societies are looking for new energy models
- Tomorrow's energy mix will be different from today's
- The targets for reducing CO2 emissions and increasing energy efficiency are high : in France, less than 40 % CO2 emission in 2030 as compared to 1990 and a 27% increase of energy efficiency
- That was the aim of the Climate Conference, the COP 21, held in Paris in November/December 2015

→ At stake : master and promote new energy technologies

→ In this context, two sources of energy appear as very suitable to meet today's challenges: Nuclear and Renewables

Developments and innovations

- Nuclear, with significant needs in the world, mainly in emerging countries : first, in countries which have already acquired the technology, and above all, from 2030 onwards, in acceding countries

- Indeed, if, today, ¾ of Nuclear power plants are within the OECD, more than ¾ **of the nuclear power plants under construction are outside the OECD and more than half in China**

- Three main priority areas **: safety, financing and control over investment costs** *(essential for a technology where investment represents 2/3 of the kWh cost)*

- Renewable Energies, with a large potential in regions with a high growth rate, and with lots of wind and sun; therefore, here too, in emerging/developing countries

Nuclear Power Worldwide – IAEA 2015 projections

35th Edition of IAEA's

"Energy, Electricity and Nuclear Power Estimates for the Period up to 2050"

Nuclear power's global expansion projected to continue in the coming decades—albeit at a slowing pace—amid challenges including low fossil fuel prices, a sluggish world economy and the legacy of Japan's Fukushima Daiichi accident

Several factors :

- Volatility of fossil fuel prices,
- Nuclear power's role in greenhouse gas reduction,
- Energy supply security,
- Population growth and demand for electricity in the developing world

Latest projections : slower growth in nuclear power, in keeping with the trend since the 2011 Fukushima Daiichi accident. World's nuclear power generating capacity projected to expand by between 2.4% (low-case projection) and 68% (high case projection) by 2030, compared with the previous estimate of between 7.7% and 88% from last year.

Uncertainty related to energy policy, license renewals, shutdowns and future constructions accounts for the wide range.

Nuclear Power Worldwide – IAEA 2015 projections

Factors Weighing on Growth Prospects of nuclear power, leading to temporary delays in NPP deployment:

- Low prices for natural gas,
- Subsidized renewable energy sources,
- Global financial crisis, which presents hurdles for capital-intensive projects,
- Heightened safety requirements as a result of stress tests introduced in the wake of the Fukushima accident.
- Likely future retirement of many of the world's 438 nuclear reactors currently in operation, more than half of which are over 30 years old.

Nuclear Power Worldwide – IAEA 2015 projections

Regional Breakdown:

-Policies and developments in the more than 30 countries considering or planning their first NPP also play a role in the projections.

-IAEA's recently updated guidance documents "*Milestones in the Development of a National Infrastructure for Nuclear Power"* which forms the basis for its assistance to these "newcomer" countries

-Middle East: United Arab Emirats, building its first NPPs

-South Asia: India, driving the expansion and constructing 6 NPPs

→in that region, capacity growth projected at 25.9 GW(e) by 2030 in the low case scenario from the current 6.9 GW(e), rising to 43.8 GW(e) in the high case scenario

-Growth also projected in Eastern Europe: Russia (9, reactors under construction), Belarus (building its first reactors).

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Nuclear Power Worldwide – IAEA 2015 projections

- **Far East:** biggest expansion expected, especially in China and the Republic of Korea, which are building 24 and 4 reactors respectively.

→ In the low case, capacity growth projected at 131.8 GW(e) by 2030 from the current 87.1 GW(e) (low case scenario), and, in the high case scenario to 219 GW(e)

- **Western Europe:** by contrast, seeing as experiencing the biggest decline. Apart from the UK, Germany's phase out, no other plans in France or anywhere else…

→ Low projections estimate a decrease in capacity to 62.7 GW(e) by 2030 from the current 113.7 GW(e). The high projections estimate a decline to 112 GW(e).

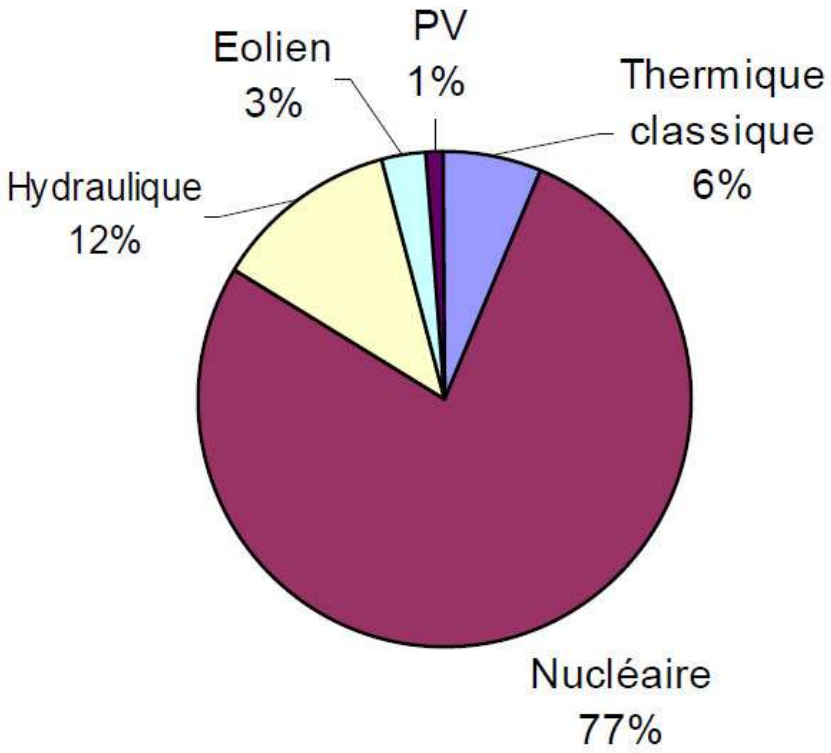
- **North America:** also seen a fall in its nuclear capacity

→ In the low case scenario to 92 GW(e) by 2030 from the current 112.1 GW(e). The high projections, however, estimate an increase to 139.7 GW(e).

Nuclear Power in France

NUCLEAR POWER DEVELOPMENT

Electricity production by sources



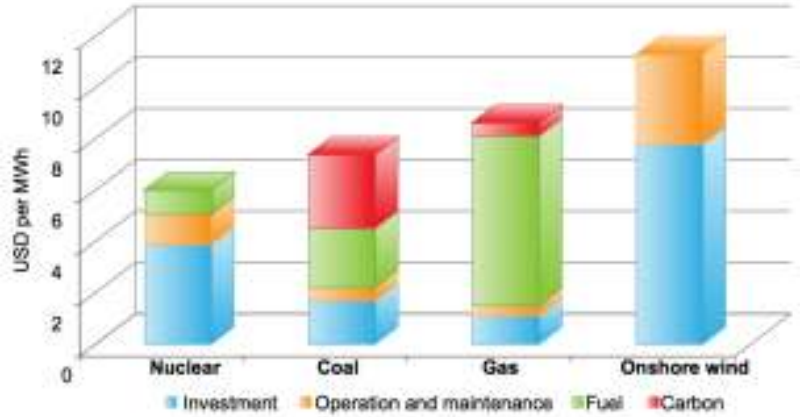
Electricity Production : 564 TWh in 2014

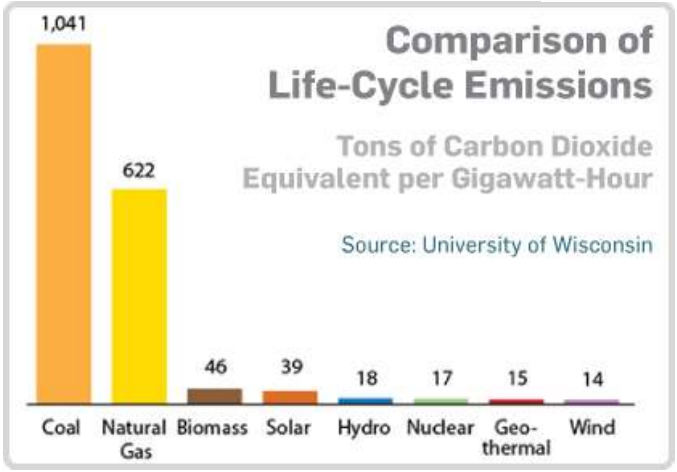
Why Nuclear Power?

Environment

Economics

Energy Security

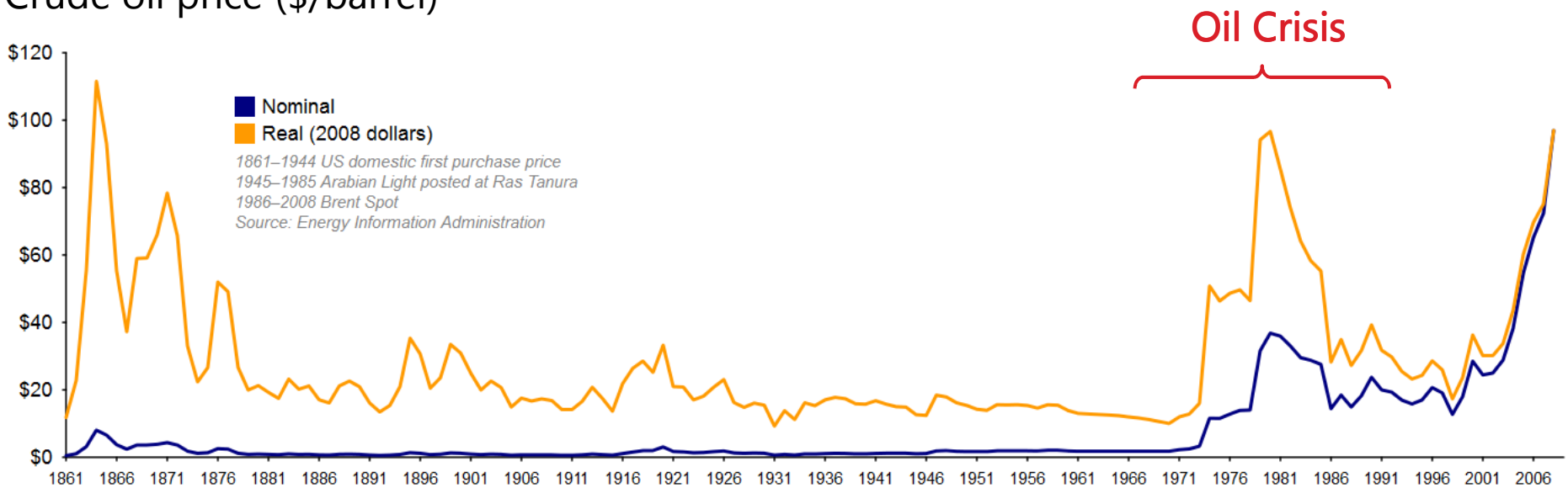




Reduced dependence on import of fossil fuels
High energetic density

France's Answer to Oil Shock: Nuclear Power

Crude oil price ($/barrel)

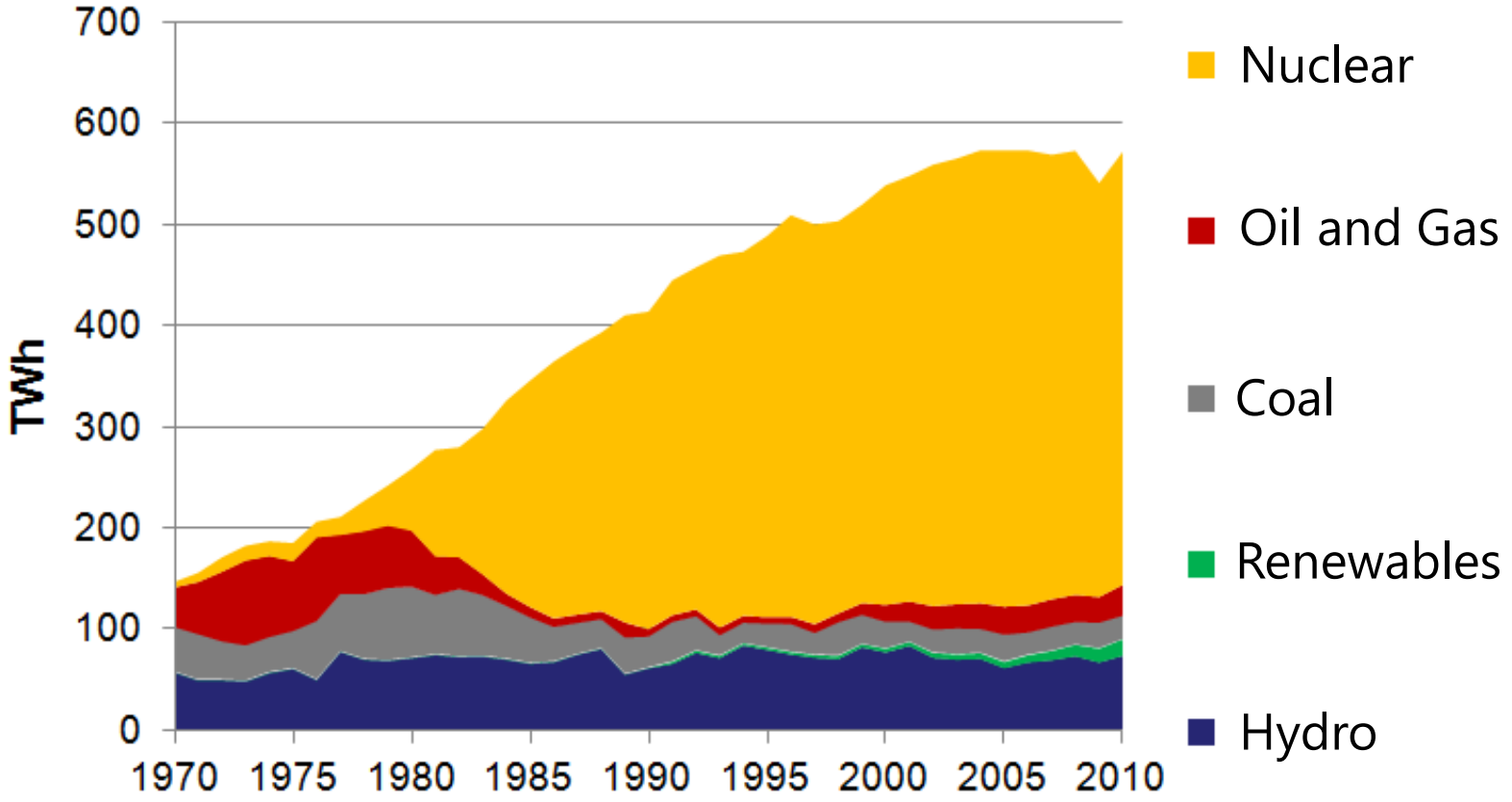


- Nuclear energy experience
- Few natural resources
- Need to minimize import

→ NUCLEAR POWER

→ Massive deployment **after 1973 oil crisis**
(Standardized PWR technology)

Fast Deployment of Nuclear Power



Nuclear

=

75% of production*

Nuclear + Hydro

=

90% of production*

* 2012, RTE

Nuclear Power in France

TODAY'S FLEET AND ACTORS

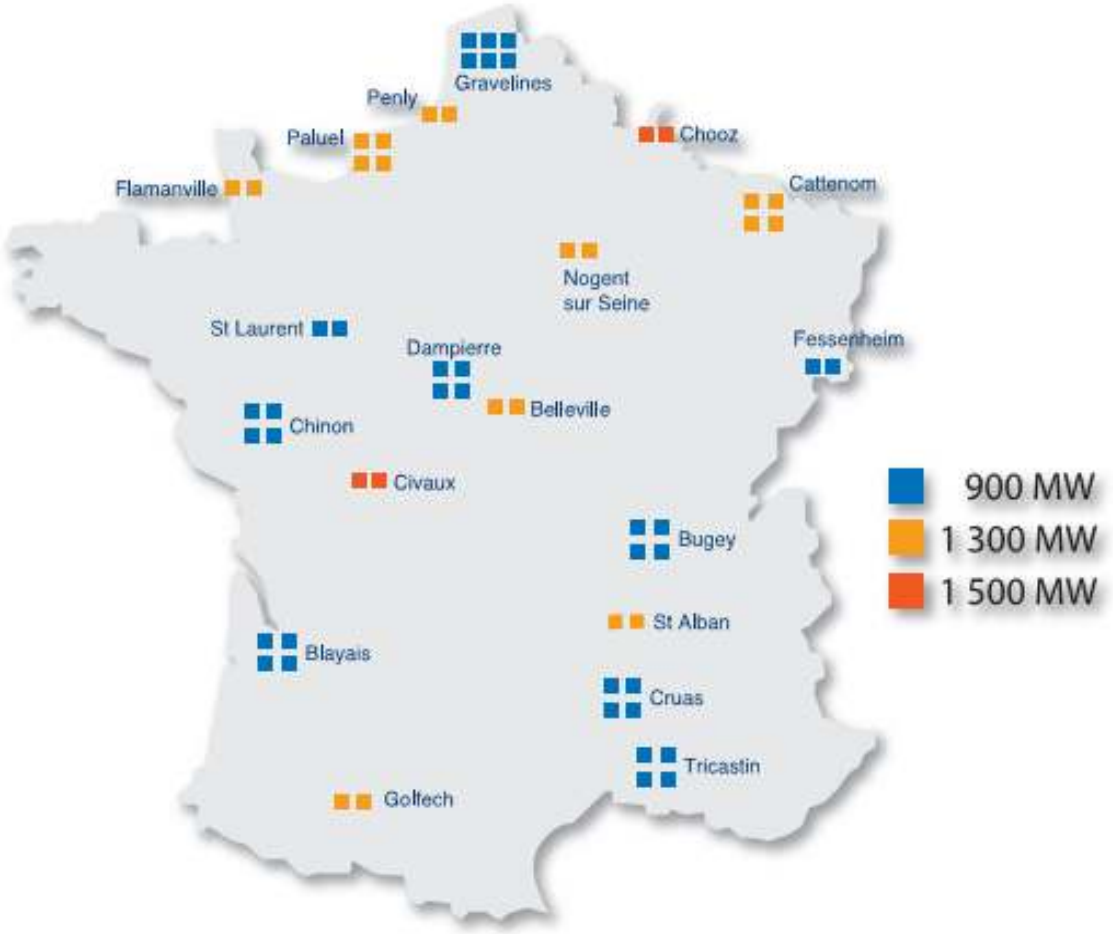
Main Nuclear Actors in France

Nuclear Power Plants Operator	Fuel Cycle + Reactor Design & Maintenance	R&D

Safety Authority	TSO for Safety, Safeguards, Security	Waste Management	Learned Society

Today's Nuclear Fleet

One operator EDF



19 stations

58 PWRs

+ 1 under construction

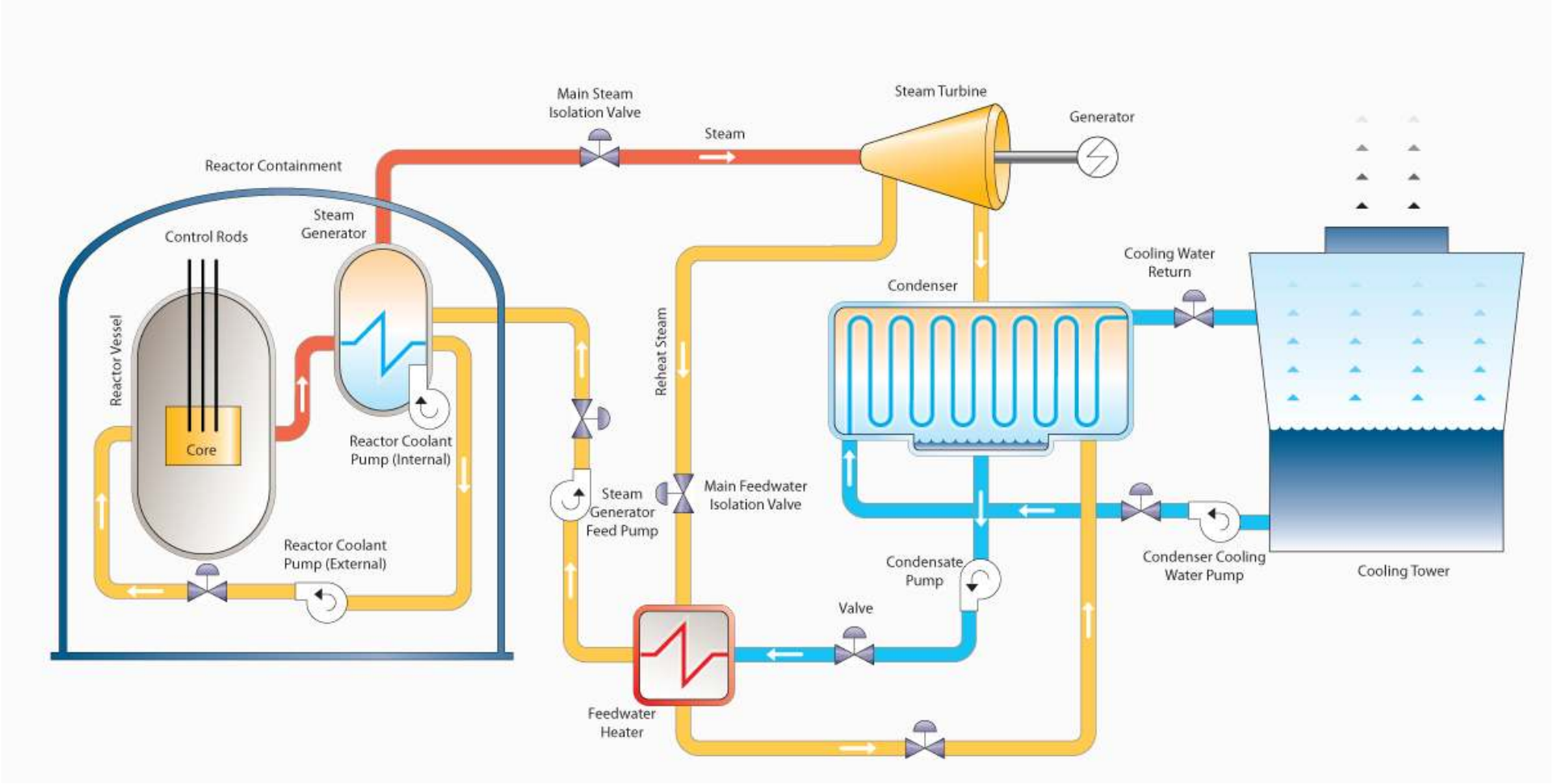
63 GWe

406 TWh/year*

* 2012, EDF

Technology: Pressurized Water Reactors

All 58 operating commercial reactors are PWRs



A Standardized Fleet

Class	Reactor	MWe net, each
900 MWe	Blayais 1-4	910
	Bugey 2-3	910
	Bugey 4-5	880
	Chinon B 1-4	905
	Cruas 1-4	915
	Dampierre 1-4	890
	Fessenheim 1-2	880
	Gravelines B 1-4	910
	Gravelines C 5-6	910
	Saint-Laurent B 1-2	915
	Tricastin 1-4	915
1300 MWe	Belleville 1 & 2	1310
	Cattenom 1-4	1300
	Flamanville 1-2	1330
	Golfech 1-2	1310
	Nogent s/Seine 1-2	1310
	Paluel 1-4	1330
	Penly 1-2	1330
	Saint-Alban 1-2	1335
N4 - 1450 MWe	Chooz B 1-2	1500
	Civaux 1-2	1495
	Total (58)	63,130

- **3 generations, 6 series** of reactors:

- 3 series of **900 MWe**
  CP0, CP1, CP2

- 2 series of **1,300 MW**
  P4 and P'4

34 reactors

- 1 series of **1,450 MWe**
  N4

20 reactors

+ 1 EPR under construction

4 reactors

63 GWe

76 months average construction time

40-50 €/Mwh

2000 reactor-years' OEF

World's highest level of standardization

Benefits of Standardization

- Simplified authorization processes:

- Series-based authorizations by the Nuclear Safety Authority (ASN)

- Within a series, few differences:
  - Heat sink
  - Connections to power grid
  - Foundations
  - ...

} Reactor-specific authorizations

- Savings:

- Less man-hours/reactor after 1st reactor
- Lower building costs
- Long-term planning for subcontractors

⇨ Investments reduced by 30-40%

Current and Future Upgrades – New Build

- 1,300 MWe: uprate 20 reactors by 7% starting 2015 → + 15 TWh/yr
- 1,650 MW-EPR under construction (Flamanville 3)
- Several aging reactors → Life extension to 60 years? (40+10+10)
- Progressive renewal → Rate?

EdF's « Grand Carénage » Program

The « Grand Carénage »: EdF's industrial program, aimed at renovating and enhancing the safety of its existing nuclear fleet, and, if the conditions are met, extend its lifetime.

Investment estimate: 55 billion € over 2014-2025, which will comprise :

- Recurring investments to maintain the nuclear fleet at its current level ;
- Additional investments to allow for the extension, beyond 40 years, of the fleet lifetime.

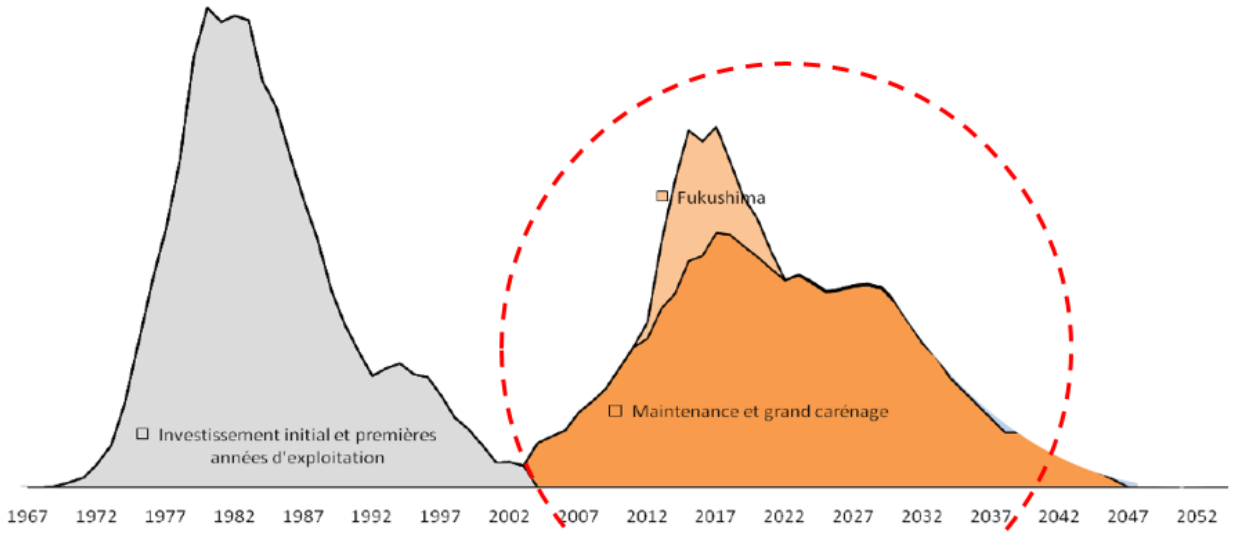
The « Grand Carénage »: task of wide magnitude, due to 3 reasons :

- **Life cycle** : French fleet built over a short period of time (~15 years). Renewal of large components thus to be performed over a concentrated period of time (~10 years), that is 25~35 years after start of operation.

- **Significant safety improvements, following the Fukushima accident.** To be implemented in a very tight schedule, and under stringent regulations: For e.g., the diesel backups have to be operational by 2018. In addition to these improvements, need to account for the important « safety step » required for lifetime extension beyond 40 years.

- **Need to make up for a period of low investments in the early years of 2000,** which led to numerous flaws, causing the halt of several NPPs between 2000 and 2010.

Le Grand Carénage (EdF)*



Source : EDF - CIPN, 3ième rendez-vous business du nucléaire civil en PACA, « Les grands chantiers du nucléaire civil : le grand carénage du parc nucléaire de production d'EDF », 14/01/2014

Répartition des prévisions d'investissements du programme Grand Carénage (en milliards d'€)	
Projet Post-Fukushima	10
Amélioration de la sureté des réacteurs (mise à niveau de la maintenance exceptionnelle lors des VP et VD)	20
Remplacement des gros composants (ex : générateurs de vapeur)	15
Autres projets patrimoniaux (environnement, risque incendie, risque grand chaud-grand froid)	10
TOTAL	**55**

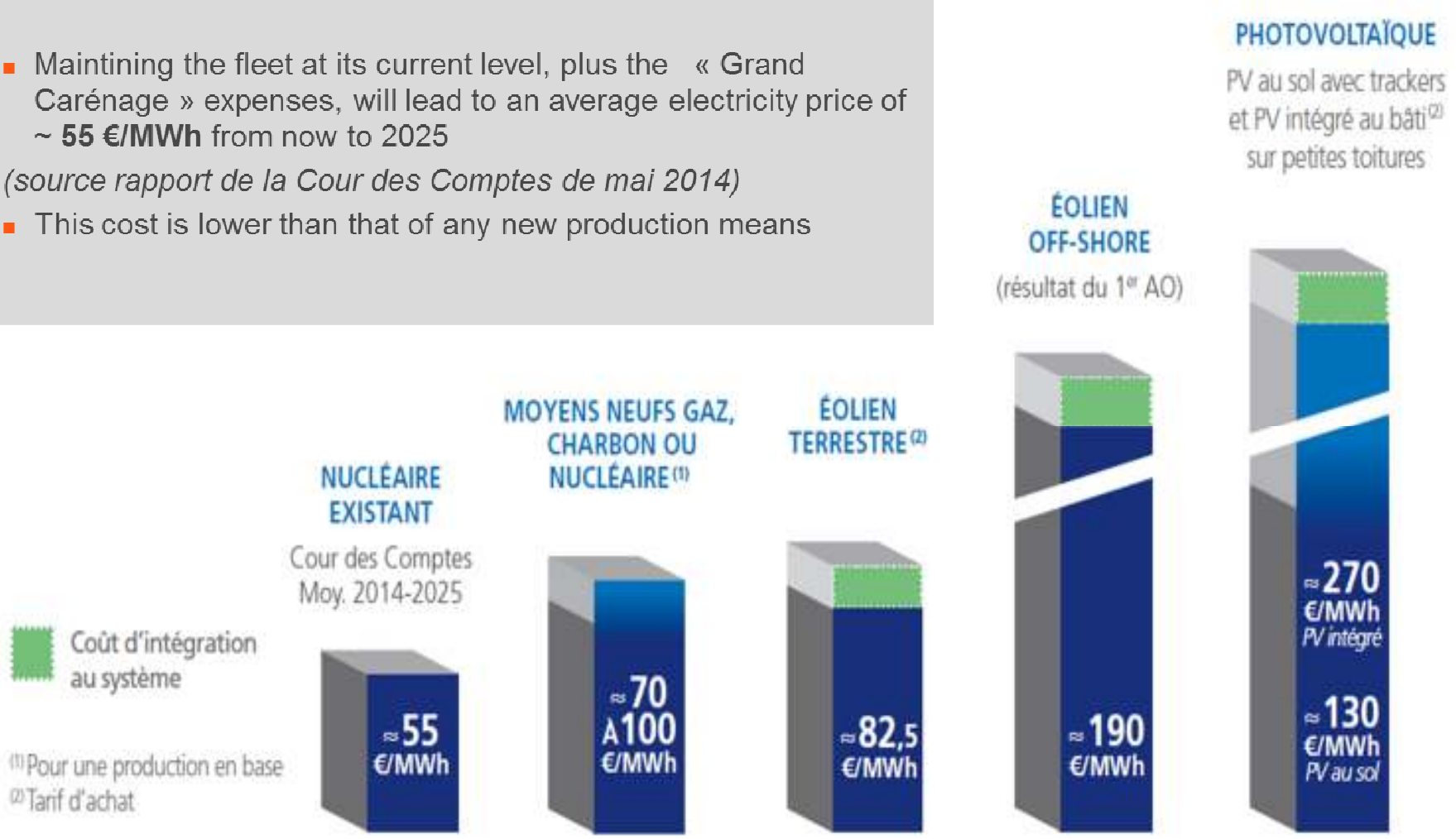
Source : L'Usine Nouvelle, « Nucléaire : le détail des 55 milliards du grand carénage d'EDF », 21 février 2014

The « Grand Carénage »: the most competitive solution

- Maintining the fleet at its current level, plus the « Grand Carénage » expenses, will lead to an average electricity price of ~ **55 €/MWh** from now to 2025

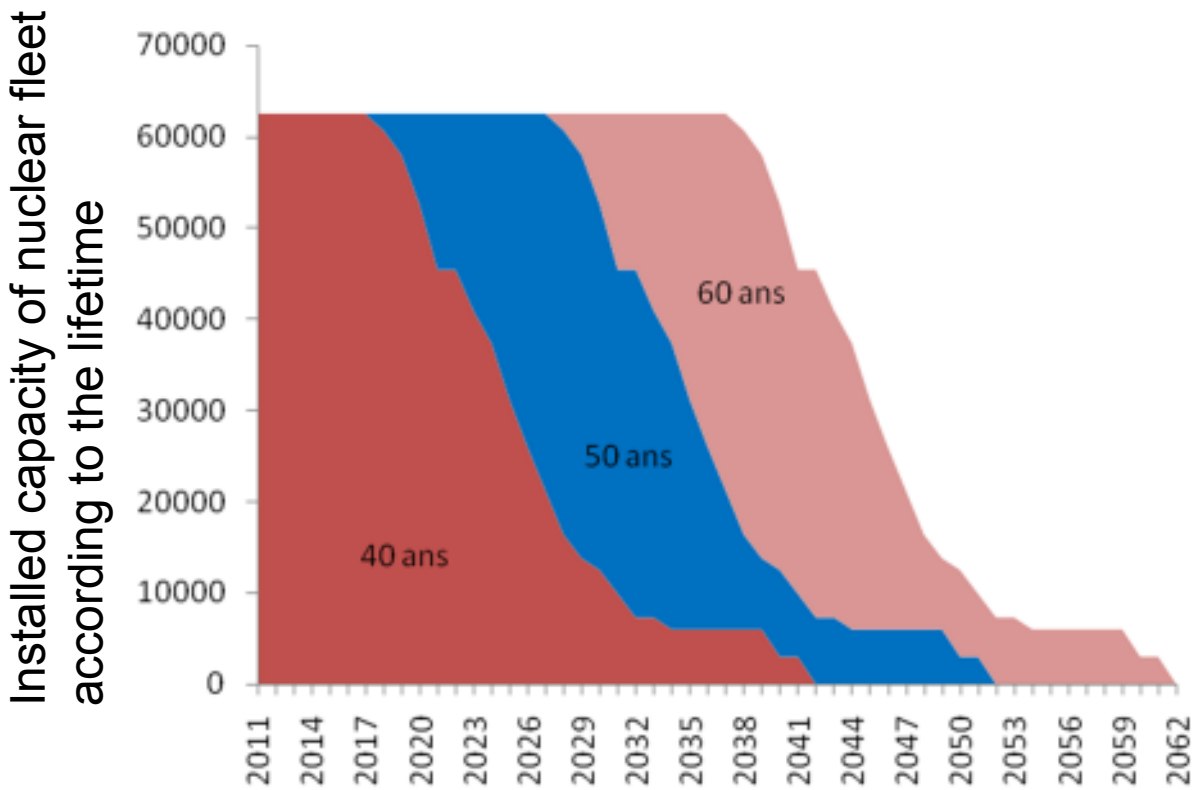
(source rapport de la Cour des Comptes de mai 2014)

- This cost is lower than that of any new production means



The « Grand Carénage »… And what after?

The « Cliff Effect », if all reactors are shutdown around the same age



Need to allow for 60 years of operation, in order to spread out the shutdown of NPPs, between 50 years for the oldest ones, and 60 years for the youngest ones

The Closed Fuel Cycle

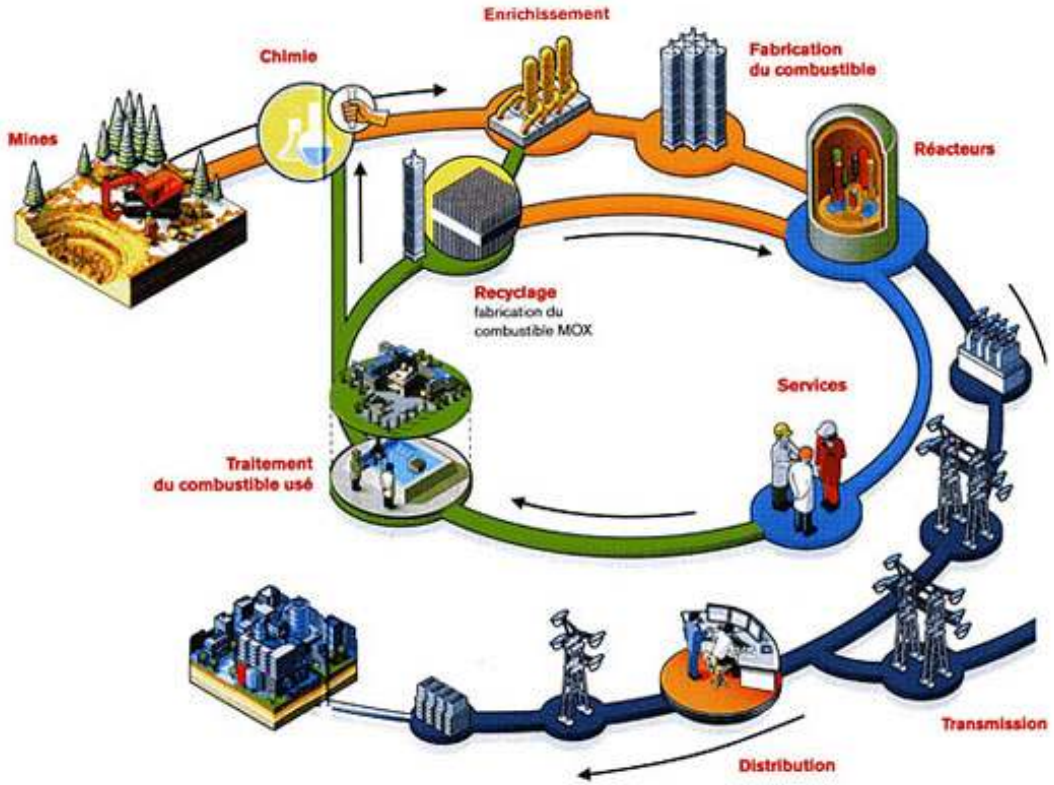
A major feature of the French nuclear policy

- Approach:

- UOX spent fuel processed
- U recycled (4 reactors)
- Pu recycled (22 reactors)

- Benefits:

- U resources savings
- Pu inventory control
- Pu in spent MOX

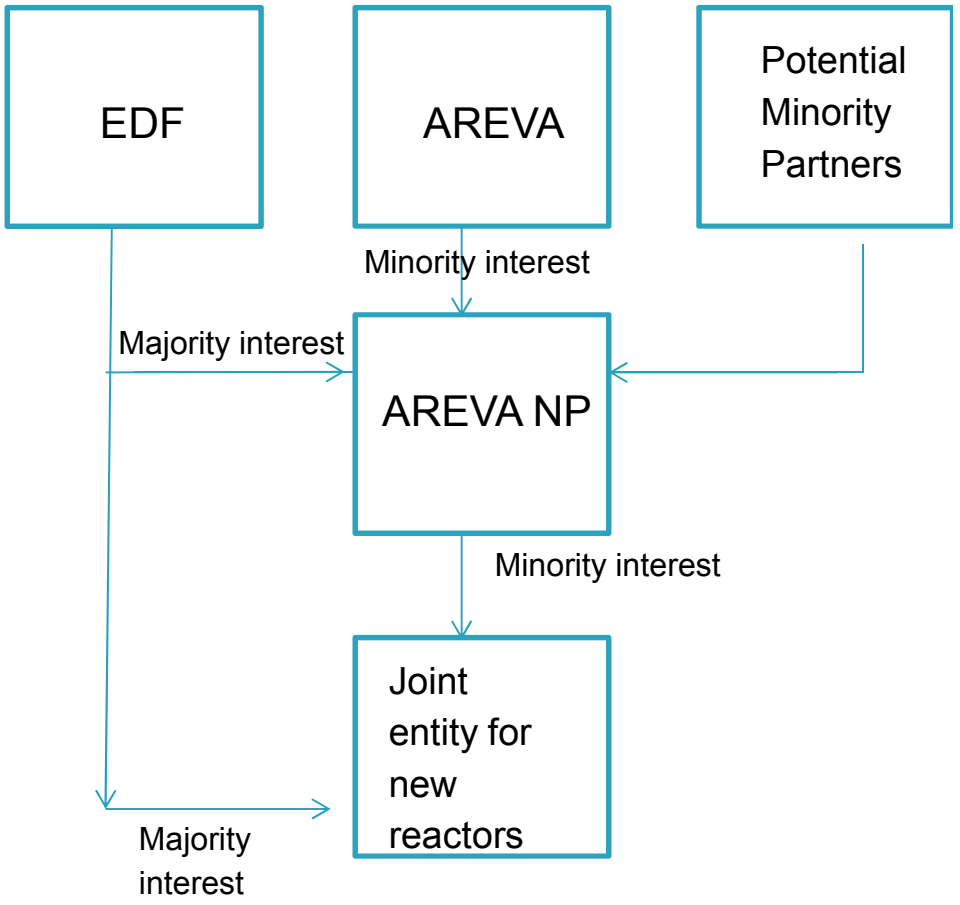


The reorganization of the French nuclear industry*

Announcement in June by French government: transfer of AREVA NP, reactor division of Areva, to EDF.

Among the goals sought: improving Areva's financial situation and strengthening France's nuclear industry.

- EDF will acquire 51% to 75% stake in Areva NP, which is in charge of designs and manufactures of nuclear reactors and provides a range of operation and maintenance services for existing reactors.
- Areva will retain a 25% stake in Areva NP. Areva's strategy is to refocus on the nuclear fuel cycle and continue to produce innovative products for its customers.
- Creation of a new joint-venture company by EDF and Areva NP to spearhead new reactor projects.



Nuclear Power in France

ENERGY POLICY

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RÉPUBLIQUE FRANÇAISE

MINISTÈRE
DE L'ÉCOLOGIE,
DU DÉVELOPPEMENT
DURABLE
ET DE L'ÉNERGIE

Energy transition for green growth act









The Energy Transition Law

- **National energy debate**: January - June 2013

- **Energy transition bill adopted by Parliament in July 2015**

Objectives	
Green-house gas emissions:	-40% by 2030, -75% by 2050 (/1990)
Fossil fuel consumption:	-30% by 2030
Renewables:	23% by 2030, 32% by 2030*
Nuclear:	75% → 50% by 2025**
Total energy consumption:	-50% by 2050 (/2012)

World Nuclear Exhibition 2016

Conclusion

Nuclear = remains the main component of the French Energy mix

However : Major developments in the French energy sector

Potential for more synergies between France and Japan in the nuclear filed

Need to investigate this potential and make the best of it to deepen our bilateral ties.