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Nuclear energy

The use of Water For cooling

France Nuclear Power Plants

EDF owns 58 units (+2 with EPR..)

On 19 sites

14 on the seashore

10 with heatsink in open circuit on river

30 with closed circuit on river

4 cooled with open circuit on an estuary

Nuclear Energy in France

A prominent contribution to energy sustainability

- 77 % of electricity production in France
- CO2 free and clean resource
- long term energy independence
- within an energy mix to adapt to electricity market needs, and development of renewables

An efficient production tool, without CO2 release

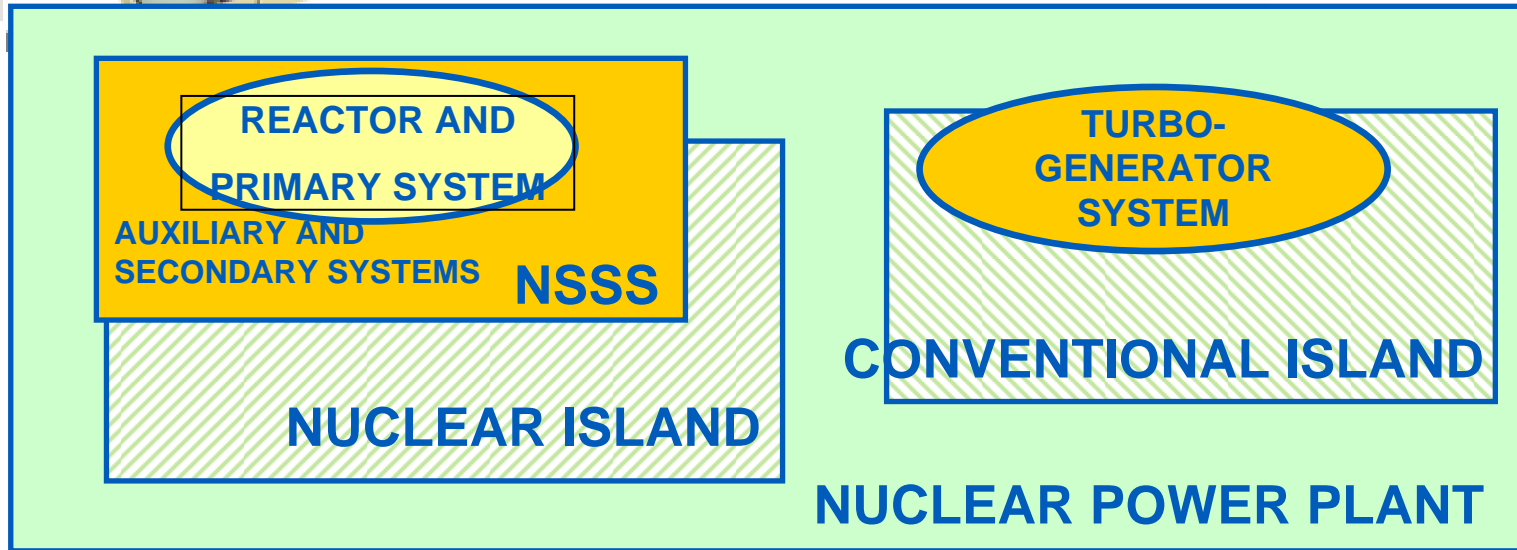
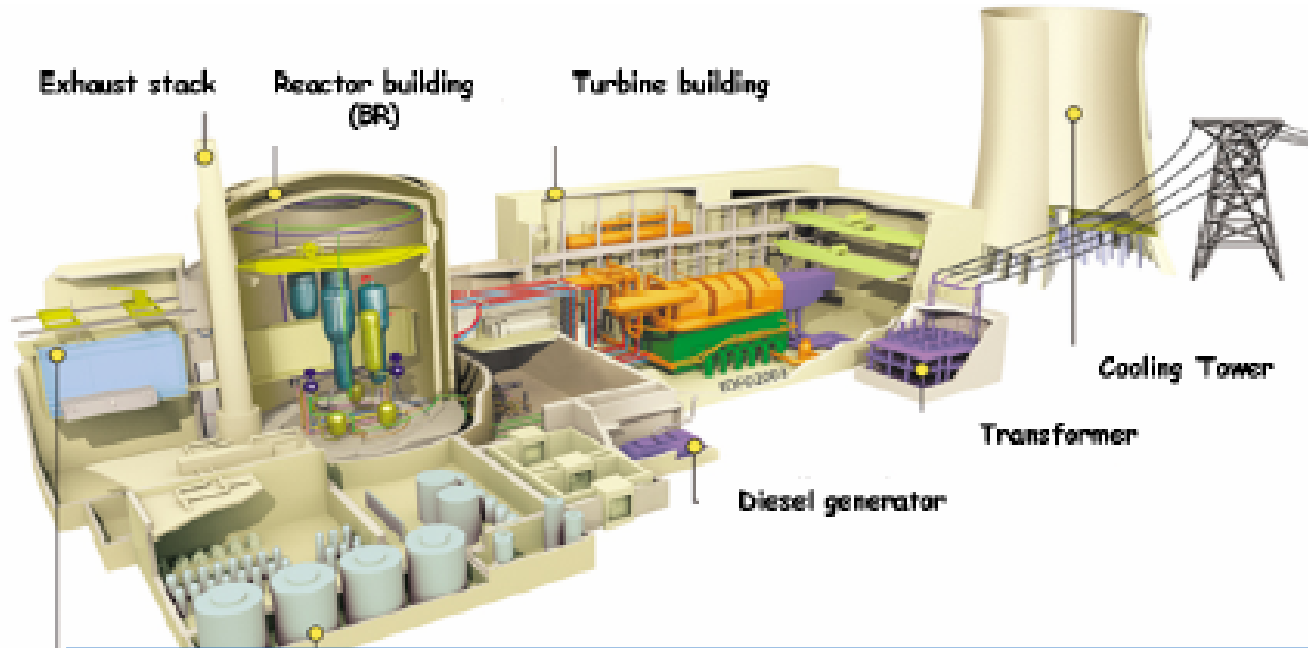
Electricity production (EDF) in 2008: 478,3 TWh, of which 417 TWh nuclear

total capacity 93 GW: Nuclear 63,13 GW (65%), hydro 20 GW (21%), fossil 13,2 GW (15%)

Total energy 417,6 **TWh** nuclear (87,3%), 44,8 hydro (9,4%), 15,8 fossil (3,3%)

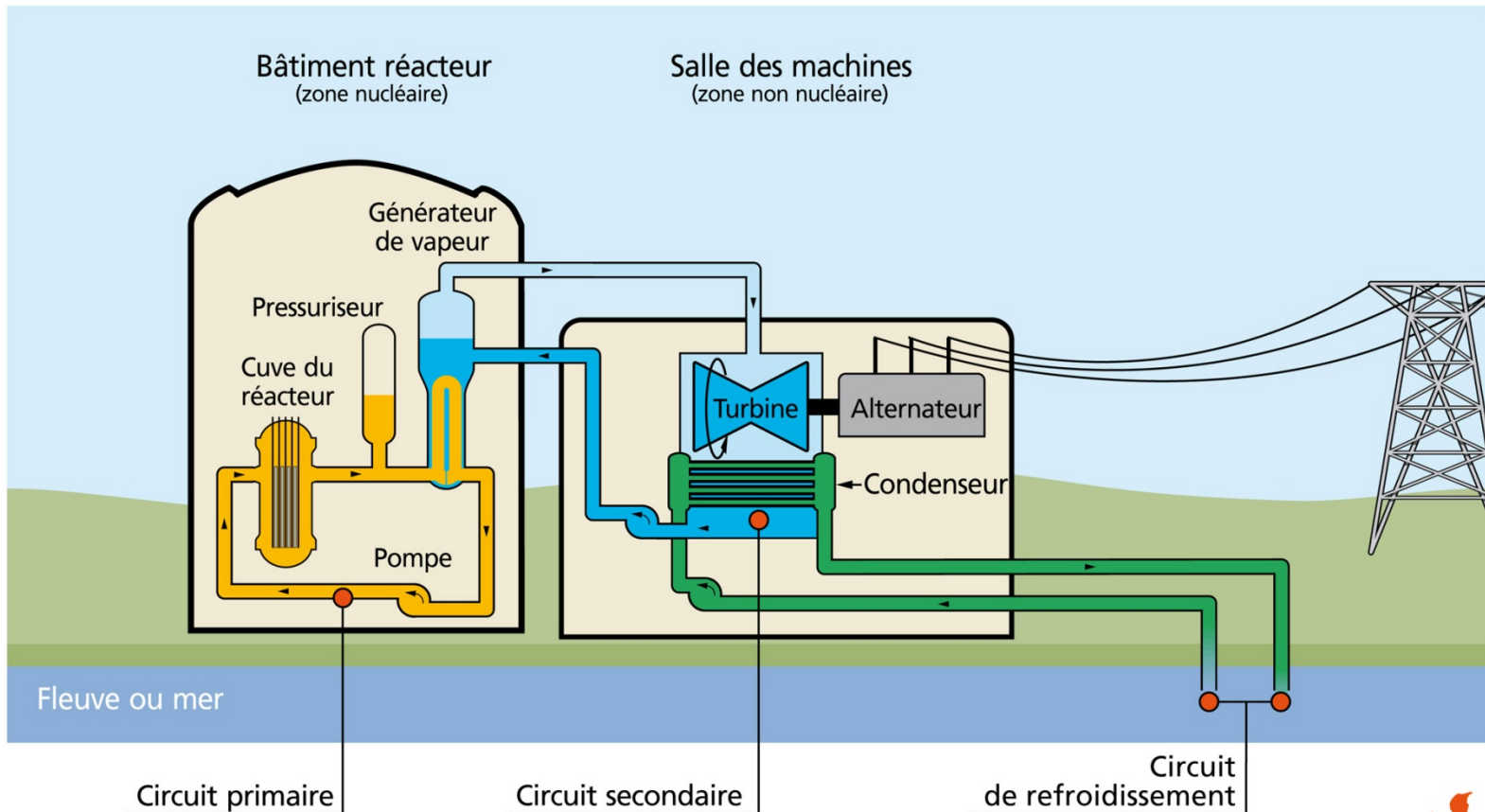
- a highly competitive production mix, mainly nuclear
- 95% independant from fossil fuel
- a clean energy mix: small CO2 releases
- EDF in France » 40 g/kWh , Europe » 400 g/kWh

NUCLEAR POWER PLANT: general scheme



Nuclear Plant Cooling Scheme

in open circuit
(without cooling tower)

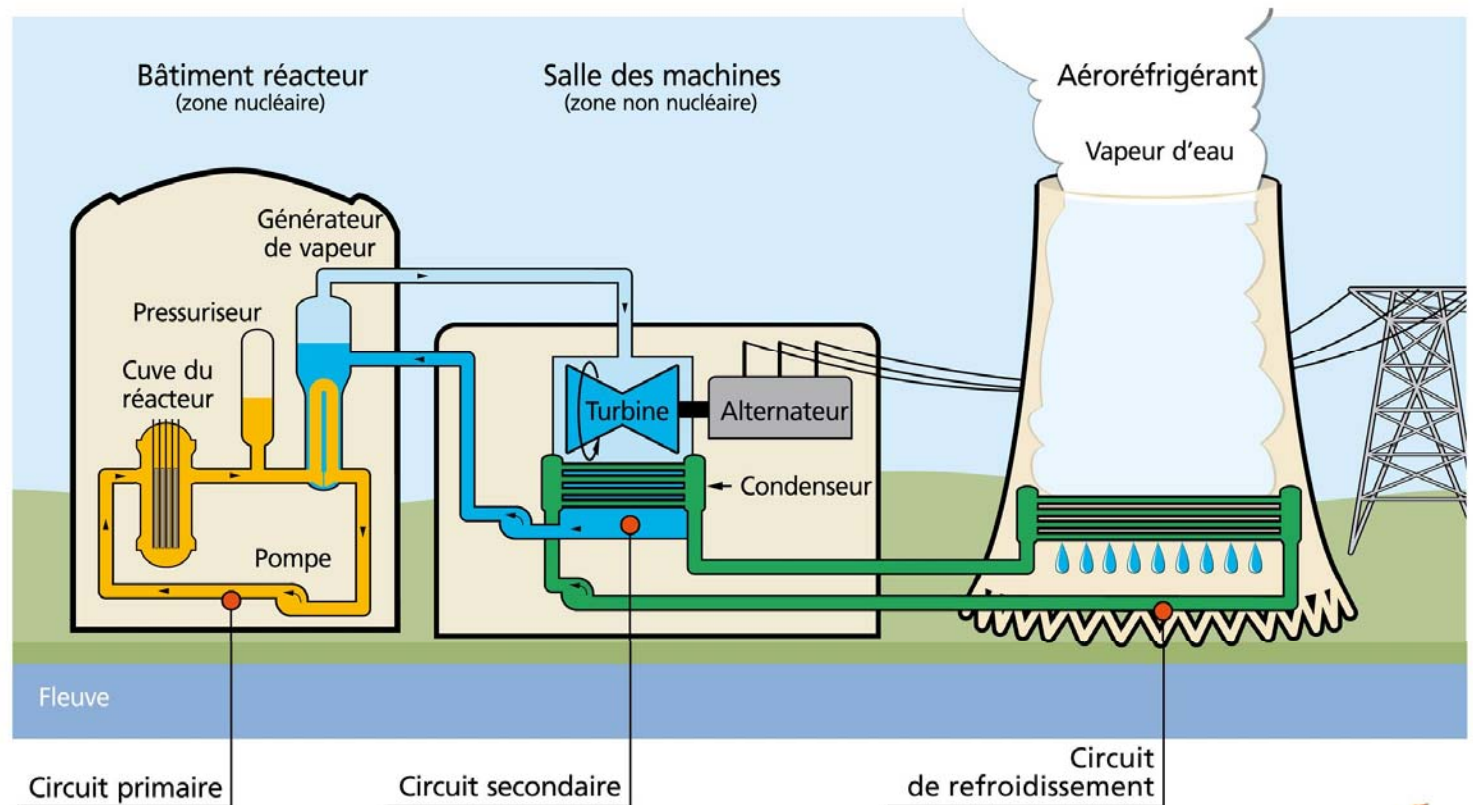


Scheme with cooling tower



LA CENTRALE NUCLÉAIRE

Principe de fonctionnement, avec aéroréfrigérant







The French Nuclear Fleet at a glance

58 units on 19 sites
(4 seaside sites, 1 estuary, 14 riverside)


Connection to the grid :

- 1st Unit (Fessenheim 1) : April 1977
- 58th Unit (Civaux 2) : December 1999

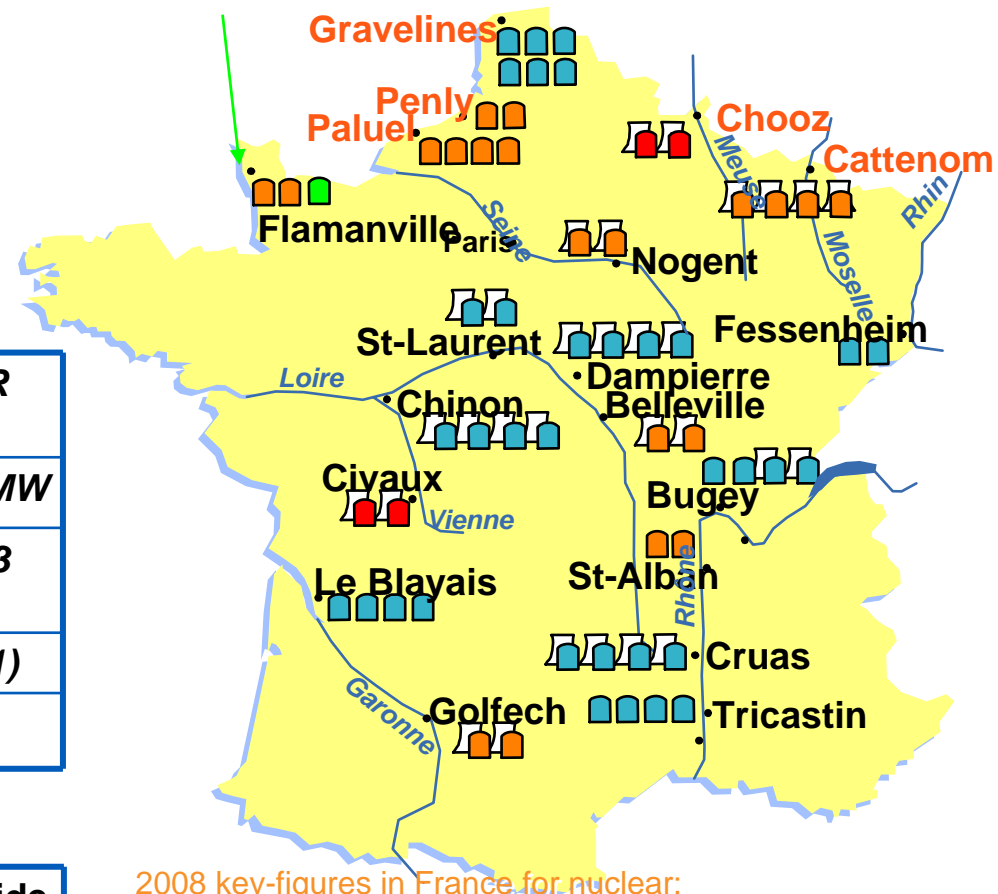
A standardized fleet for NI and CI:

Type	CP0 CP1-2	P4 P'4	N4	EPR
Power	900 MW	1300 MW	1500 MW	1650 MW
Ref Plant	Tricastin Cruas	Paluel Cattenom	Chooz	FA 3
Number	34	20	4	1 (+1)
				

With adaptations to the site for heat sink:

Site	seaside	estuary	riverside	riverside
Heat sink type	Open loop	Open loop	Open loop	Closed loop
Number	14	4	10	16
				

EPR site



2008 key-figures in France for nuclear:



GWe
installed capacity



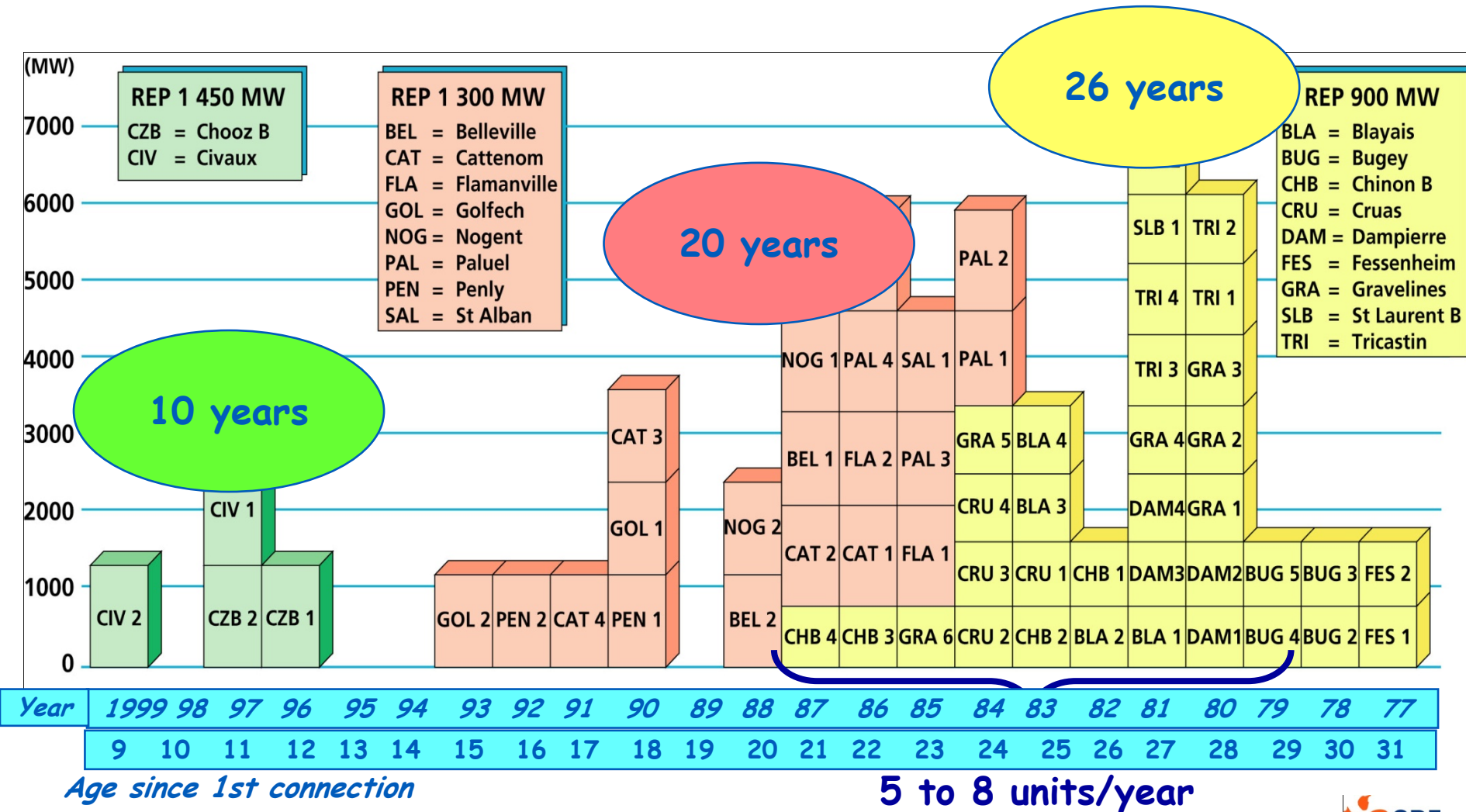
TWh
produced



of
electricity
produced

History & Age of Series (01.01.09)

3 different series: 900 MWe (34 units), 1300 MWe (20 units), 1500 MWe (4 units)
 average age 24 years - 1400 reactor-years of Operation



Example of seaside site with open loop circuit: **Paluel**

Paluel – 4 units P4 – 1300MW



General case of seaside sites: Flamanville, Paluel, Penly

Gravelines particular case (seaside site):

Gravelines - 6 units CP1 – 900MW



Open loop with parallel intake and outfall

Le Blayais Example of estuary site with open loop circuit:

Blayais – 4 units CP1 – 900MW



Fessenheim Example of river site with open loop circuit:

Fessenheim – 2 units CPO – 900MW

Need river with high flow rate (also case of ...St Alban, Tricastin) on the Rhone River

Nogent Example of river site with closed loop circuit:

Nogent – 2 units P'4 – 1300MW



Cattenom particular case:

2 water sources:

Moselle river (3/4 km far away from the plants)

Mirgenbach lake (artificial lake created especially for safety needs)



Cattenom – 4 units P'4 – 1300MW

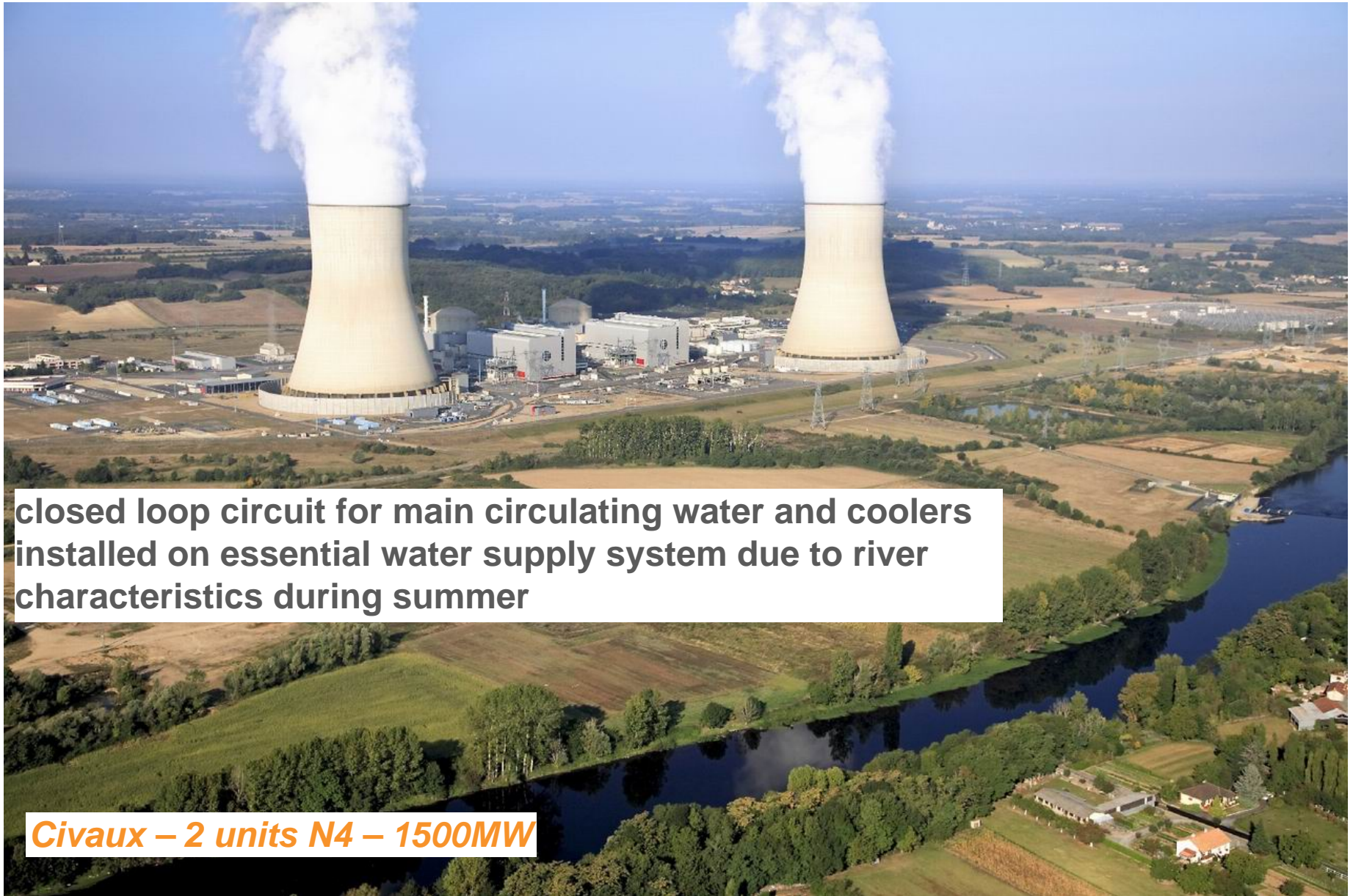
Bugey particular case (river site):

2 open loop and 2 closed loop circuits, a mixed heat sink due to river capacity limit



Bugey – 4 units CP0 – 900MW

Civaux particular case (river site):



closed loop circuit for main circulating water and coolers installed on essential water supply system due to river characteristics during summer

Civaux – 2 units N4 – 1500MW

Chinon Cooling low towers with fans



Chinon cooling tower with fan



Chinon low cooling towers with fan



TECHNICAL / ECONOMICAL CRITERIA

Land Availability For seawater cooled
One EPR: 40ha, and 30ha for the construction zone
Two EPR: 60ha, and 45 ha for the construction zone
If cooling tower: add 10ha by plant

Water Availability

Heat sink: $60\text{m}^3/\text{s}$ in open circuit, $3\text{m}^3/\text{s}$ with closed circuit

Liquid waste dilution: need an annual average of $30\text{m}^3/\text{s}$

ENVIRONMENT CRITERIA

Water Consumption

Limitation could induce power reduction during low water period (up to shut down !!)

Need hydraulic development to control the flow.

Heatsink

Limitation of the temperature rise

Limitation of temperature impact: less than 1,5°C

For seawater cooled plant: intake / discharge location avoiding recirculation

Flamanville Site in 2006 (seaside with open loop)

Flamanville – 2 units P4 – 1300MW



Flamanville Site in August 2009

Flamanville 3 – 1 unit EPR – 1650MW –under construction



Flamanville Site ...in 2012



Keys for the success of a NPP project

▶ Feasibility study

- Choice of Technology
- Choice of the Site (and adaptation to)
- Economical analysis

▶ Management of the project

- Organizational parameters & choice of industrial model
- Schedule, Cost, Quality

▶ Safety control

- Need of a strong safety authority

▶ Human Resources preparation

- Preparation of Operation
- Safety culture

Project management: EDF as Architect Engineer

- ▶ As an Architect Engineer, EDF's responsibilities involve:
 - Managing the project (quality, schedule, costs, risks, interfaces...)
 - Fronting the French Nuclear Safety Authority (Responsible of the Nuclear License)
 - Deciding how contracts are to be shared out, placing and then managing them
 - Defining technical reference of the plant (general specifications for equipment, for buildings, for the general operation...)
 - Optimizing the ownership cost by including feedback from French nuclear fleet in the design and operation
 - Controlling suppliers' detailed studies and equipment manufacturing quality
 - Controlling on-site construction and commissioning tests

Feasibility study: 4 sets of criteria for NPP siting

- ▶ **Technical / Economical criteria**
viewing to ensure technical ability at a reasonable cost
 - Water availability for cooling and dilution of liquid discharges
 - Lands needs, soil surveys, quarry needs for concrete, earthworks
 - Access to the site for heavy components and connection to the grid

- ▶ **Safety criteria**
express all the requirements needed to NPP, according to laws and regulations
 - Natural external events (seism, flooding, typhoon...)
 - Main induced external events (aircraft crashes, industrial risks)
 - Influence of NPP on the surroundings (radio ecological studies, emergency plan)

- ▶ **Environmental criteria**
viewing to ensure the mastery of impacts , according to laws and regulations
 - Warm water discharges
 - Chemical discharges

- ▶ **Social / Economical criteria**
consequences it has on the social and economical life of the area
 - Public Acceptance
 - Political decision (population inflow, potential impact on tourism..)

EDF and the world nuclear revival

- ▶ China: 2 EPR units under construction
Owner: TSNPC (JV CGNPC 70% - EDF 30%)
First Concrete of unit 1 in October/November 2009
- ▶ UK: 4 units forecasted to be launched by EDF
licensing of EPR model under process managed by EDF & AREVA
- ▶ US: 4 units forecasted to be launched
Unistar Company (JV Constellation 50,1% - EDF 49,9%)
- ▶ Italy: JV with ENEL for feasibility study and project development
- ▶ And of course in France: Flamanville 3 under construction (FCD in December 2007), Penly 3 to be launched
- ▶ Now that India is back on the international nuclear scene, EDF is closely following up the nuclear sector developments, including the evolution of national policies in this field and equipment manufacturing capacities.