

Past, present and future trends of French nuclear

François Lévêque,
Professor of economics at Mines ParisTech
and Romain Bizet,
PhD Candidate at Mines ParisTech

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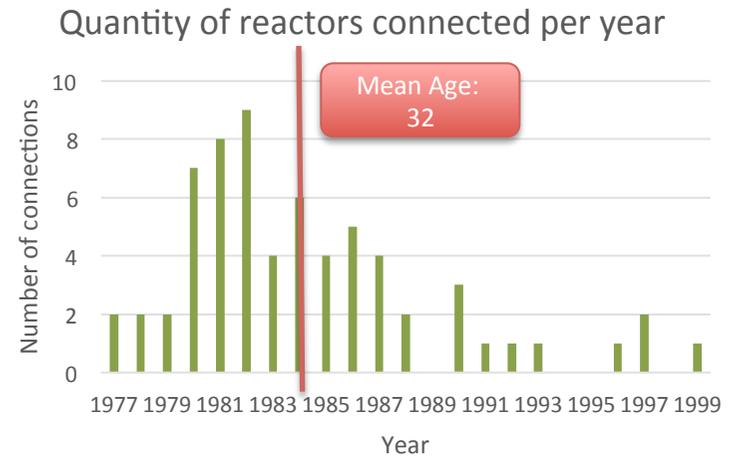
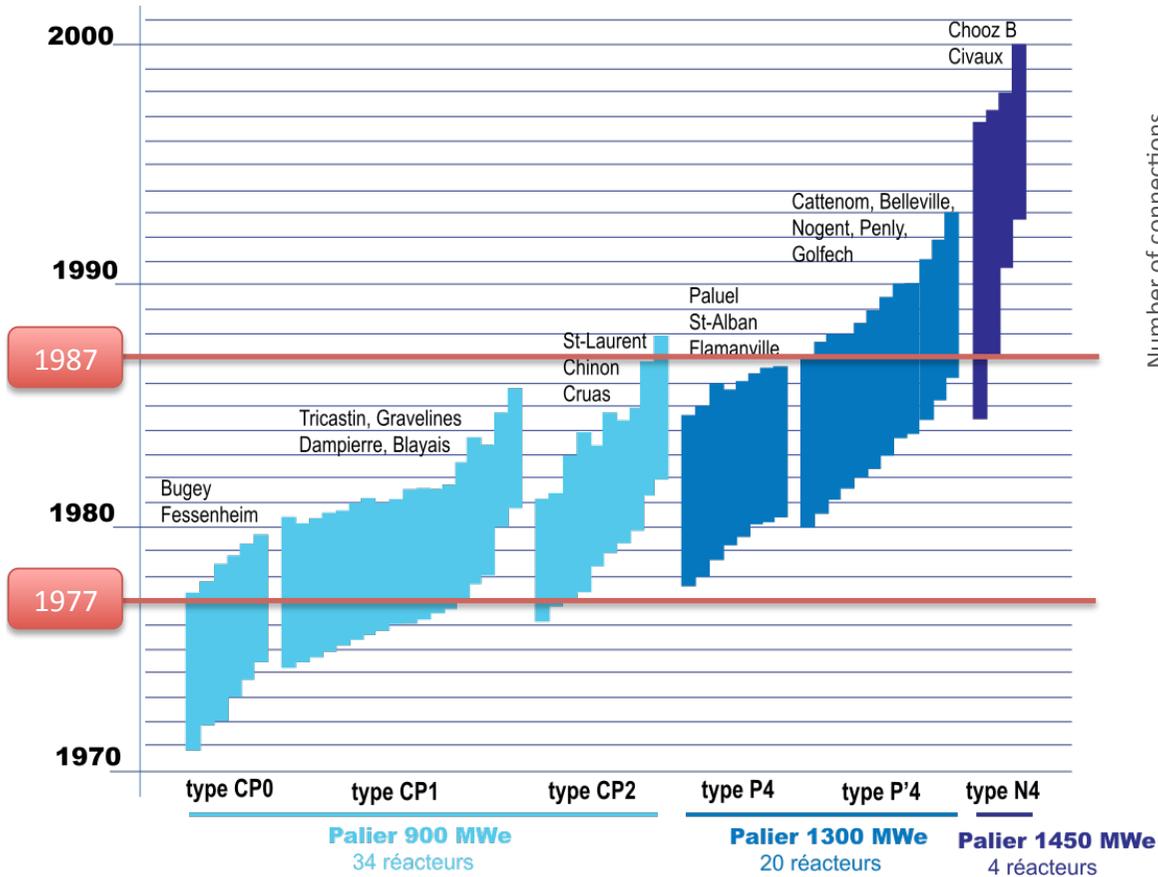
Disclaimer

- A research programme on nuclear power economics at Mines ParisTech
 - details and publications:
<http://www.cerna.mines-paristech.fr/fr/recherche/economics-nuclear>
 - financially supported by EDF
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1. The current state of the French nuclear fleet

- A mature fleet...
 - built during the late 1970s and early 1980s
 - 32 years old on average
- ... built at a reasonable cost...
 - Standardization (PWR, Westinghouse licence)
 - A single supplier (Franco Américaine de l'Atome) and a single buyer and architect engineer (Electricité de France)
 - Smooth and steady safety regulation
- ... and without subsidies
 - paid by French consumers, not by French taxpayers (unlike fundamental nuclear R&D)

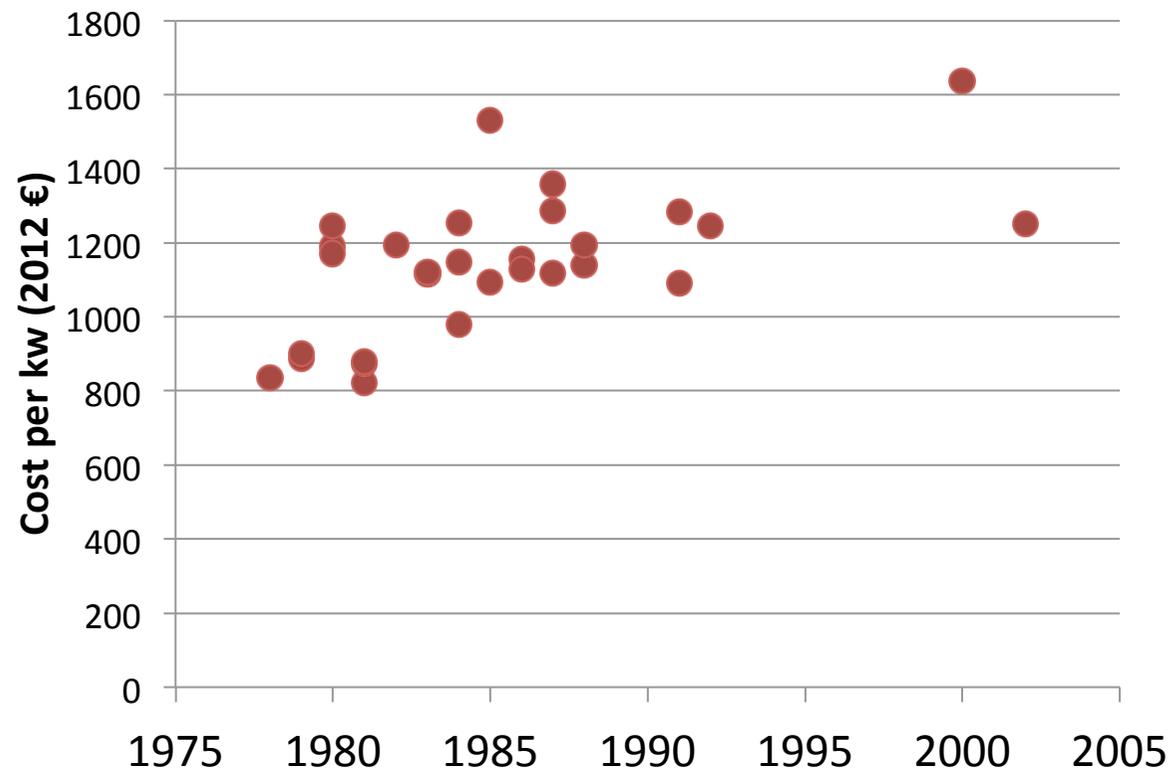
Construction of the existing fleet



Over two thirds of the French fleet was connected to the grid between 1977 and 1987

(Source: IRSN)

Evolution of construction costs



(Source: Report from the French Court of auditors on the costs of the nuclear industry, 2012)

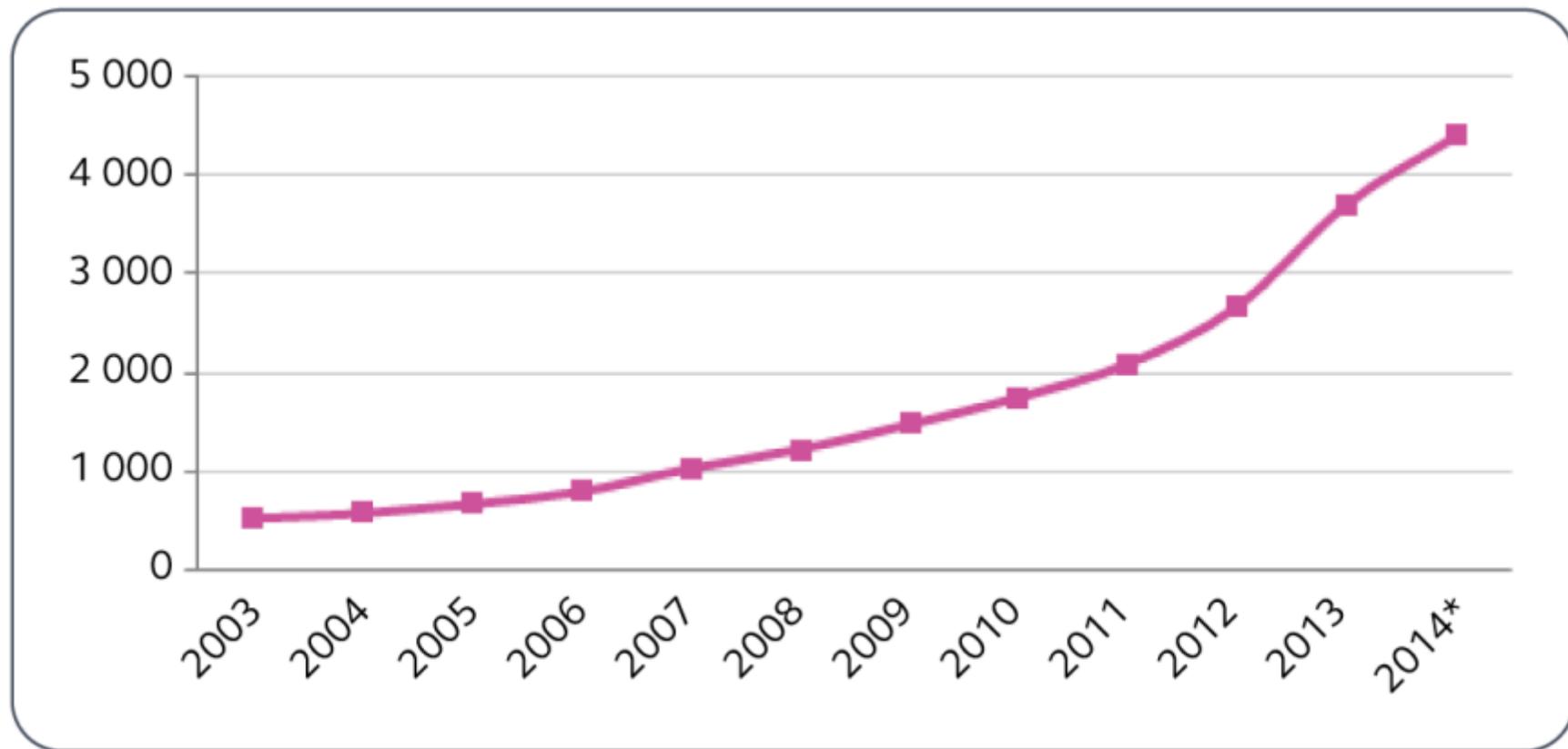
2. The economics of the existing fleet

- In France, **existing NPPs** are cost competitive and will likely remain so, even if costs continue to increase
 - construction costs have been amortized
 - life extension investment is a cheap investment
- The safety regulatory framework is satisficing
 - Independency, transparency and competency of the ASN
- However, the context has changed and EDF needs a new business model
 - Less political emphasis on nuclear power, more on renewables
 - Erosion of regulated tariffs and depression of wholesale market price
 - Financial constraints and huge needs in investment

The costs of the existing nuclear fleet

	€/MWh	Source
Fuel (including WM)	5,7	Cour des comptes (2014)
Opex	24,4	Cour des comptes (2014)
Cash cost	32	E. Macron (2016)
Considered costs to set the regulated access tariff to EDF nuclear MWhs	39	Champsaur Commission (2011)
Average cost 2010	49,6	Cour des comptes (2012)
Average cost 2013	59,8	Cour des comptes (2014)

The increase in investment and maintenance costs in M€

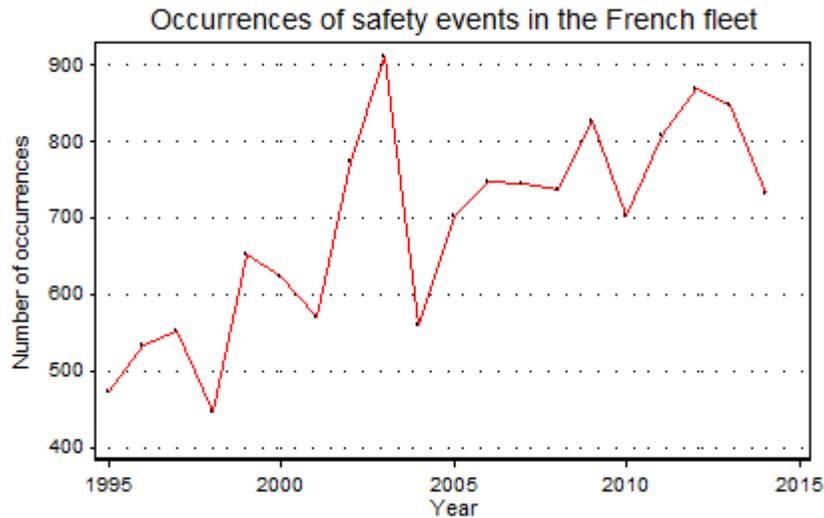


Source: Rapport annuel de la Cour des Comptes, 2016)

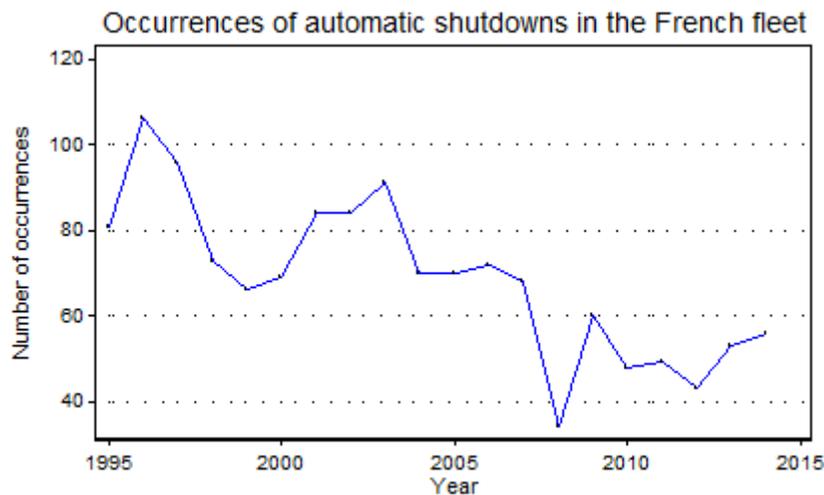
Estimated costs of life extension

- Multiple, but coherent, sources
 - EDF (2014) : €55 billion (1 b€₂₀₁₃/reactor)
 - Capex (2014-2025)
 - Court of Auditors (2016) : €100 billion (1,7 b€₂₀₁₃/reactor)
 - Capex + Opex (2014-2030)
- Remarks
 - Figures include post-Fukushima safety upgrades
 - Equivalent LCOE for 15-year operation (900 MW, 80% load) 1,7 b€₂₀₁₃/reactor = 18 €₂₀₁₃/MWh

The evolution of safety



- Numerous and increasing significant safety events are declared by EDF to the NSA
 - Bad proxy because of an increased transparency and broadened scope of survey



- Automatic shutdowns
 - A better proxy
 - But still a proxy

Source: IRSN. 1 376 Automatic Shutdowns

The French energy transition law

- Focus on renewables, energy efficiency, long-term planning
- Nuclear aspects and their consequences
 - A capacity cap at 63,2 MW:
 - FL3 completion will require to phase-out two existing reactors
 - A 50% share in the electricity mix “*at the 2025 horizon*”:
 - Vague objective with highly uncertain consequences
 - from no changes in case of new political majority in 2017
 - to the shutdown of up to 20 reactors (Cour des Comptes, 2016)
- Early closures under constant safety
 - Incentives for early phase-outs are mostly political
 - They are economically inefficient as the MWh from existing NPPs is cheaper than any other technology and than investments in energy efficiency

Why is a new business model needed?

- Most of EDF output is no longer sold at regulated tariffs but influenced with the wholesale market price
- Financial constraints
 - Broke but greedy main shareholder
 - Small free cash-flow
 - Risk of derating
- How to finance the huge needed investments?



3. Future issues

- EDF faces multiple short-term issues
 - Areva NP acquisition and integration
 - EDF is becoming a manufacturer
 - Engineering a new version of EPR NM
 - Shorter lead times and lower costs
 - Ending FL3
 - Uncertainties on safety tests regarding the steel reactor vessel
 - Signing HPC's FID
 - HPC now versus a new EPR version or nothing?
 - Opportunities of learning-by-doing before new French projects?

Future issues

- EDF also has to address global stakes...
 - life extension
 - new business model
 - cost tightening for new builds
- ... that will depend on multiple factors
 - internal factors
 - human resources management,
 - engineering capabilities...
 - external factors
 - future power prices
 - CO₂ prices
 - stability of French nuclear and energy public policy

Concluding remarks

- The French Nuclear is at a cross road
 - Past success-story vs. « Change or die » future
- Stakes for existing NPPs
 - Ensure safety to benefit from cheap extensions
 - Counteract political forces in favor of early phase outs
- Stakes for new builds
 - Context of present European overcapacity
 - Convince financial markets
 - Overcome the increasing costs curse

Some publications

- *The Economics and Uncertainties of Nuclear Power*. Cambridge University Press, Cambridge. Lévêque, F. (2015).
- Early Decommissioning of nuclear power plants: Is there an economic rationale? *The Electricity Journal*. Bizet, R. and Lévêque, F. (2015).
- Nuclear reactors' construction costs: The role of lead-time, standardization and technological progress. *Energy Policy*, 82:118-130. Berthelemy, M. and Rangel, L. E. (2015).
- How Fukushima Dai-ichi core meltdown changed the probability of nuclear accidents? *Safety Science*, 64:90-98. Escobar Rangel, L. and Lévêque, F. (2014).

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