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Techno-Economic Analysis of the Decarbonisation of Power Mix in Europe -France in Particular- by 2050

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1. Introduction

本日は、このような素晴らしいシンポジウムにお招き頂き有難うございます。
秋元先生をはじめとして、ＲＩＴＥの皆様に感謝いたします。

Research Institute of Innovative Technology for the Earth

Thank you very much for inviting me to this wonderful Symposium.
I would like to express my gratitude to Professor Akimoto and the entire RITE team.

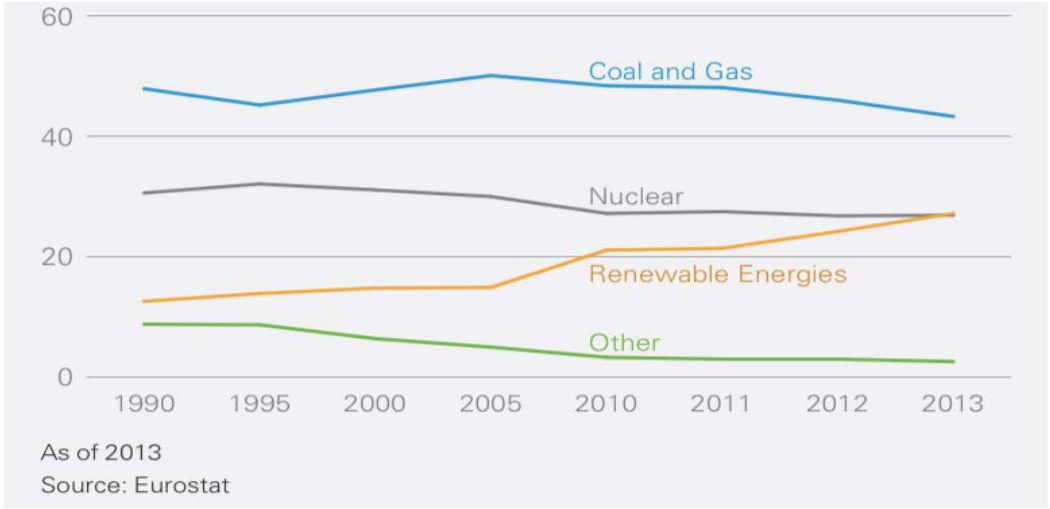
1. Introduction

- My work, team, and collaborations at Paris Saclay

1. Introduction

- *What would I like to share with you in this talk?*
  - What do **electrical investments by 2050** depend on?
  - The cases of **Europe** and **France**, facing **liberalisation** and **climatic goals**.

Shares electricity generations in the European Union (EU) (in %)



1. Introduction

- *What are the results of liberalisation on electrical markets in Europe?*
  - **Heterogeneous** and **wide-ranging** from one country to another.
  - **Less innovations** than expected, compared to telecoms or aerial transport.

- In my presentation:
  The **parallels and paradoxes** between the objectives of **liberalisation** and the agenda of **climatic policy** of Europe.

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3. The French case
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2. The European Context

- *Is the energy-climate plan a good thing or a bad thing for growth and employment?*
  - **Back in time: in 2009**, Europe was working on its energy-climate programme, 2012-2020 period.
  - **Auctioning of carbon quotas** for more than 40% of the emitters of GHG.
- The **assessment** was conducted using the macroeconometric model with endogenous growth known as **NEMESIS**:
  - **3 scenarios: S1, S2 and S3**, are compared to the baseline scenario called **'Kyoto Forever'** (the Protocol of 1998).
  - Results draw an integrated vision of the energy future of the EU.

2. The European Context

Table 1: Macroeconomic results for Europe EU-27 in 2020 in **S1: no recycling of auctioning revenues**

Main Macroeconomic Results	
GDP	-0.65
Final consumption	-0.60
Firms' investment	-2.18
Energy consumption	-7.68
Extra-EU Exports	-0.86
Extra-EU Imports	-1.09
Private R&D	1.33
Employment	-0.17

Table 2: Macroeconomic results for Europe EU27 in 2020 in **S2: reduction of labor costs**

Main Macroeconomic Results	
GDP	0.11
Final consumption	0.68
Firms' investment	-1.39
Energy consumption	-7.15
Extra-EU Exports	-0.04
Extra-EU Imports	-0.80
Private R&D	0.17
Employment	1.43

Table 3: Macroeconomic results for Europe EU27 in 2020 in **S3: reduction of labor costs and increase in R&D subsidies**

Main Macroeconomic Results	
GDP	1.41
Final consumption	1.25
Firms' investment	-1.80
Energy consumption	-8.46
Extra-EU Exports	3.34
Extra-EU Imports	-3.10
Private R&D	25.90
Employment	1.07

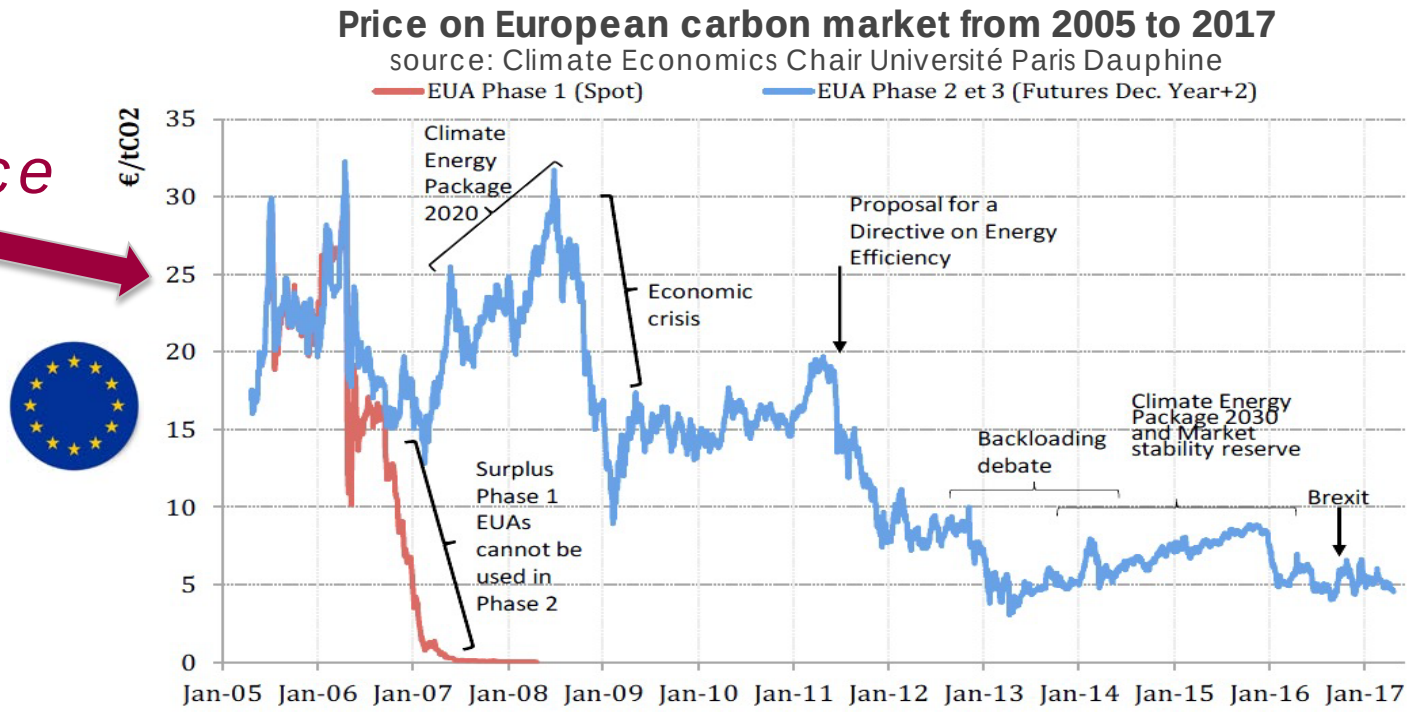
The main **results**:

- A weak cost in terms of **GDP** loss… which may be negative depending on how revenues from carbon allowances are spent by governments.
- **Employment** could be stimulated if the spending of auctions revenues reduce the cost of labour.
- GDP and innovations in renewables highly stimulated by **R&D subsidies**.
- An **opportunity** for the countries whose GDP is below the EU average and are carbon intensive.

2. The European Context

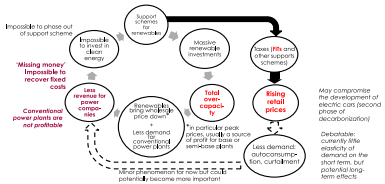
- *What was the price of a quota of carbon on the European market?*
  - The model calculated the optimal price over **60 €/t.CO2** in 2020…
  - This compared to **5€** in today's European carbon market!

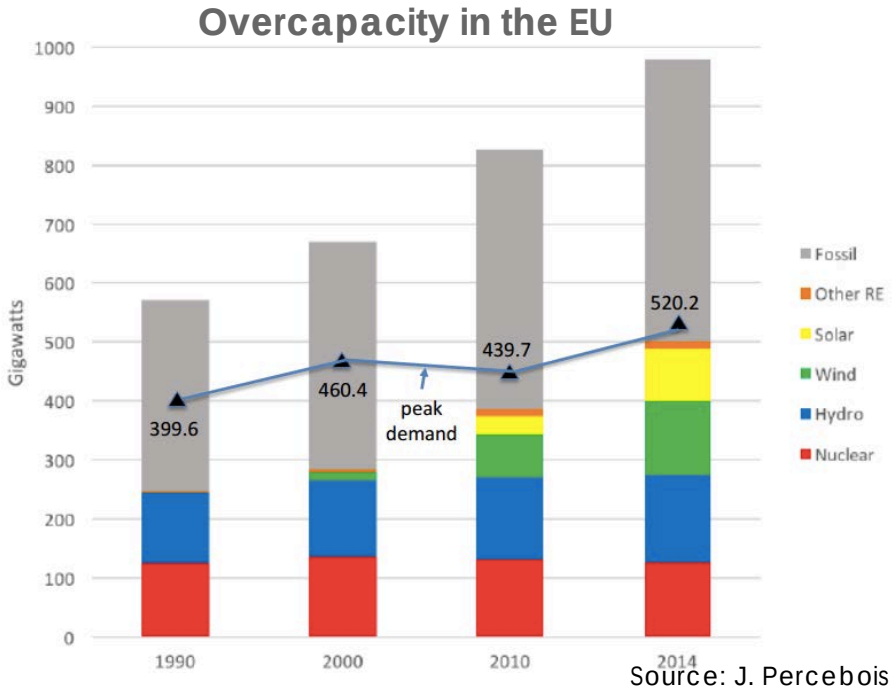
- *Why this price gap?*



2. The European Context

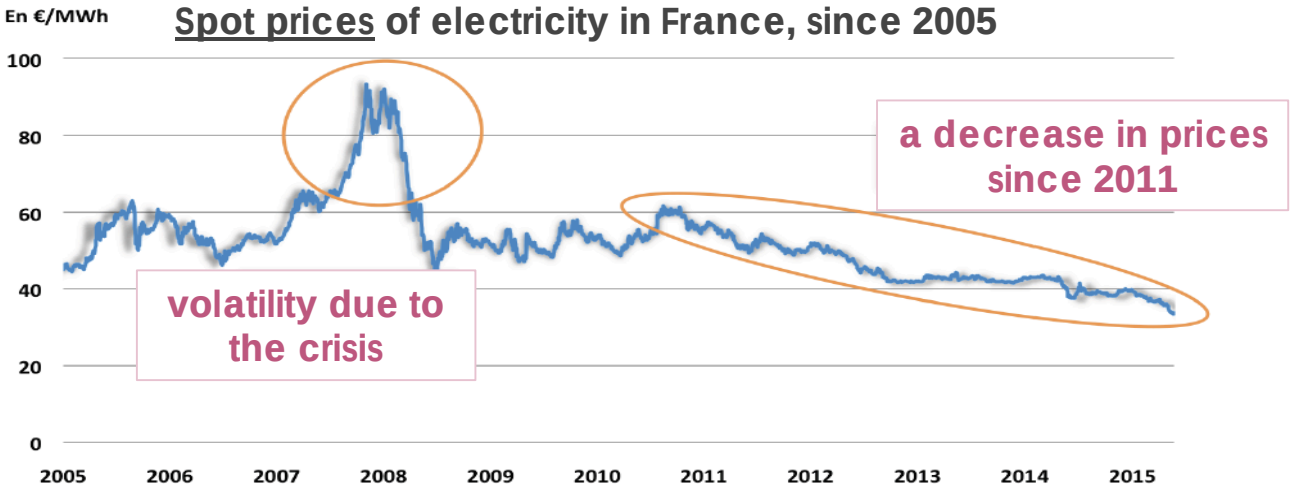
- Liberalisation causes **substantial problems when combined** with the energy-climate package :
  - **a rise in the price for Households due to new taxes**, these necessary to subsidy renewables - wind and solar (FiT).
  - **a critical missing money problem for the Utilities**, due to spot prices negative trend (near-zero marginal costs of the renewables), and overcapacity.

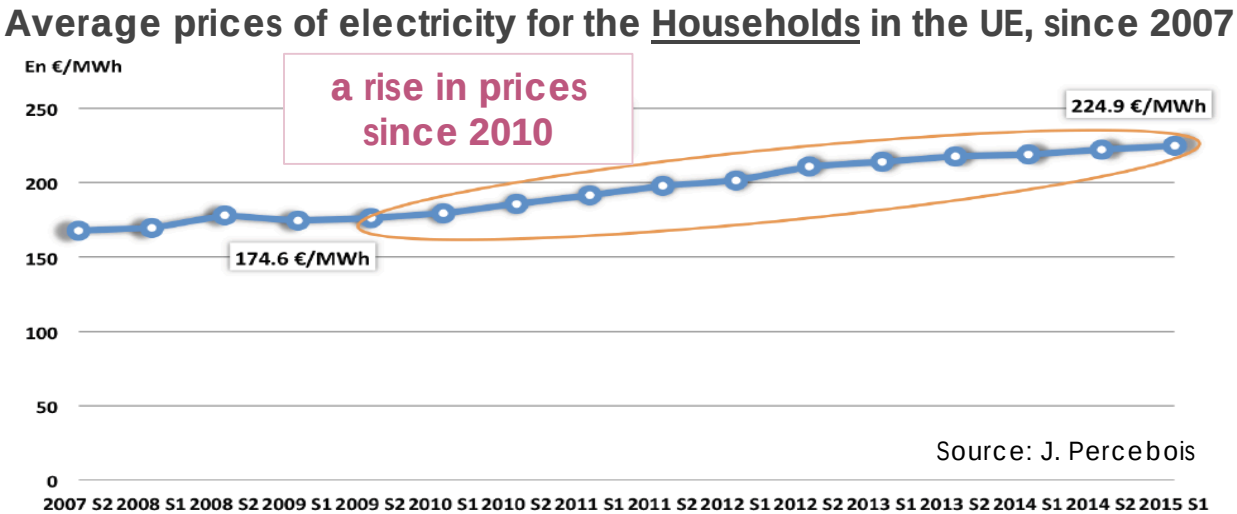




Source: J. Percebois

2. The European Context

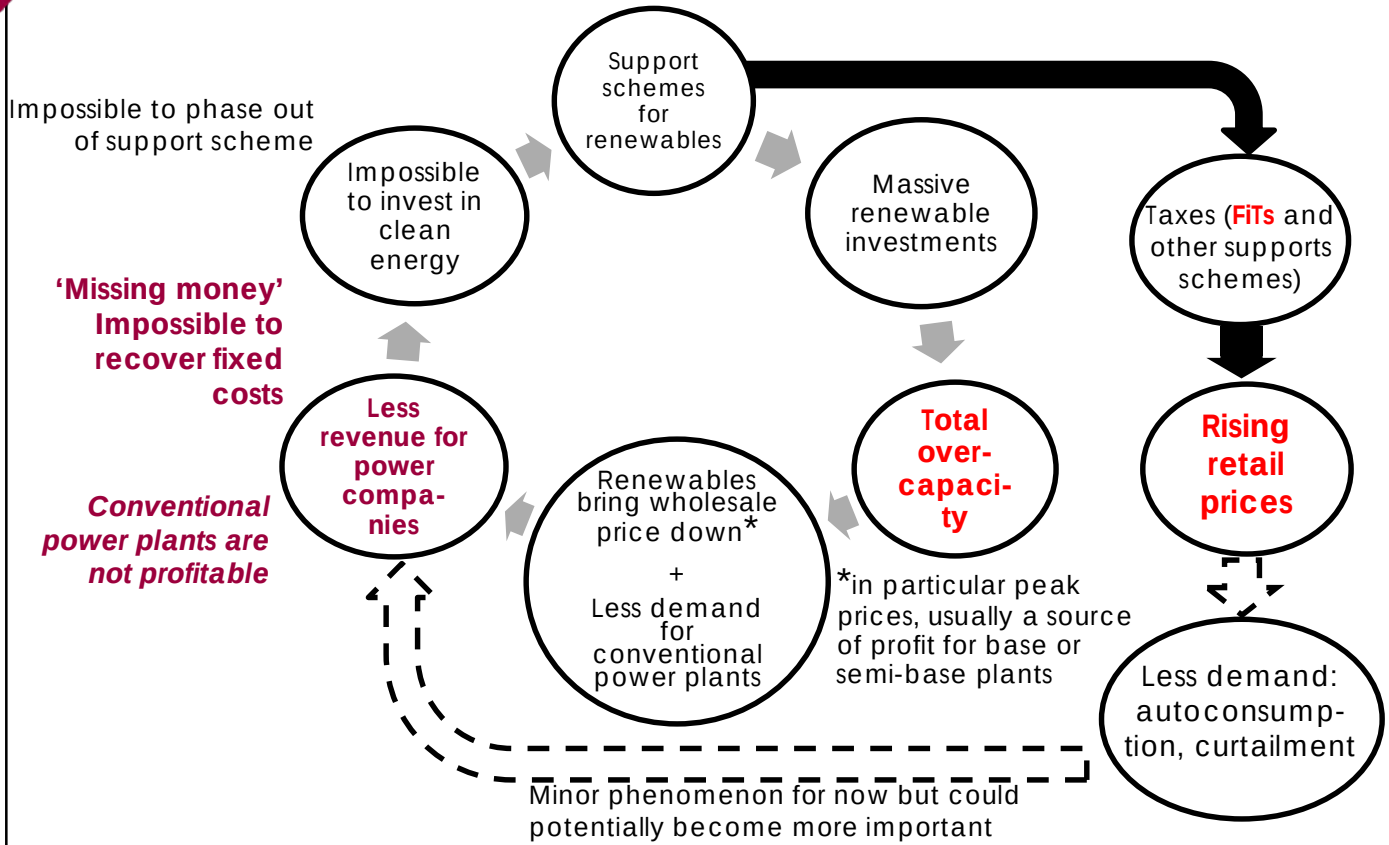




Source: J. Percebois

2. The European Context

The combined effect of renewable support and liberalisation

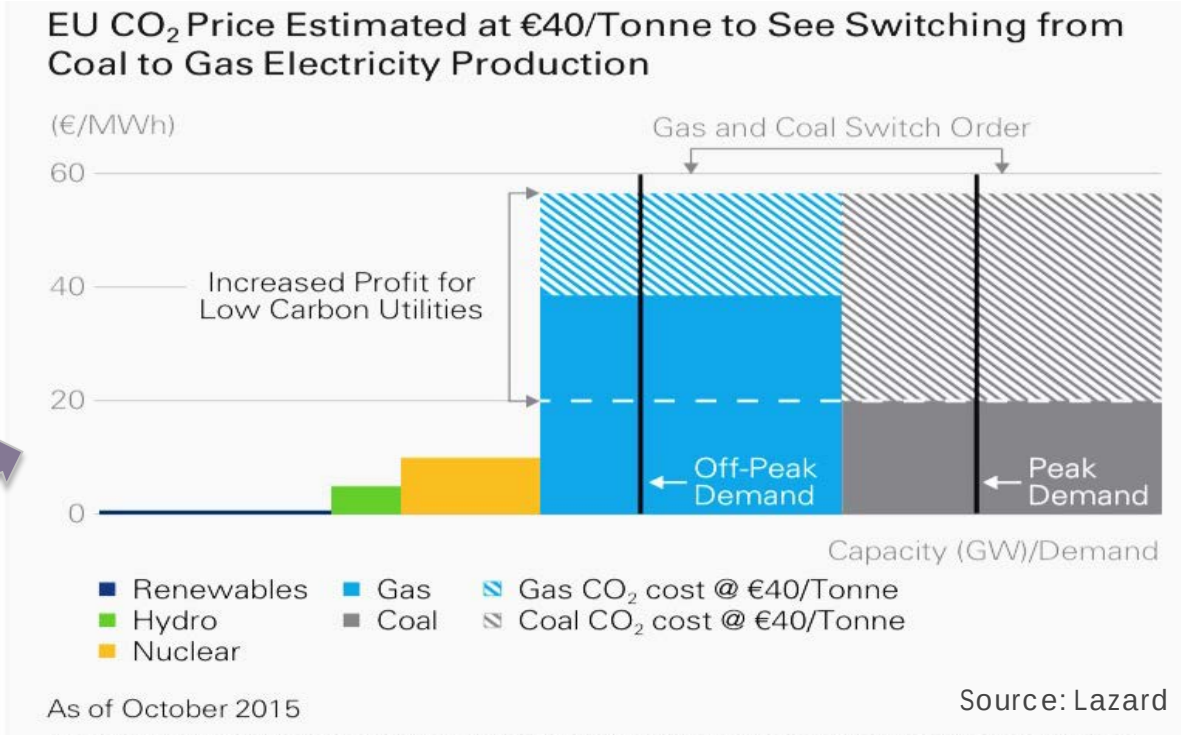


Source: **Shoai Tehrani, Da Costa, Akimoto, Nakagami** (2016). Are Deregulated Electricity Market and Climate Policy compatible? Lessons from overseas, from Europe to Japan, proceedings of the USAEE.

2. The European Context

- *What are the policy recommendations to direct investments in the right direction?*

  - ~~*Feed-in-Tariffs*~~
  - *recent tools:*
    - ✓ capacity mechanisms (France)
    - ✓ Feed-in-Premium (UK)
  - *in discussion:*
    - ✓ public tenders
    - ✓ **floor price for carbon of 30-40 €/t.CO2**



2. The European Context

- Next the problem of **intermittence -or variability- of the renewable energies**, wind and solar:
  - The cheapest of back ups, the most flexible as well are the most carbonated: **gas power plants**.
  - Let's see the **French problem with intermittence**.

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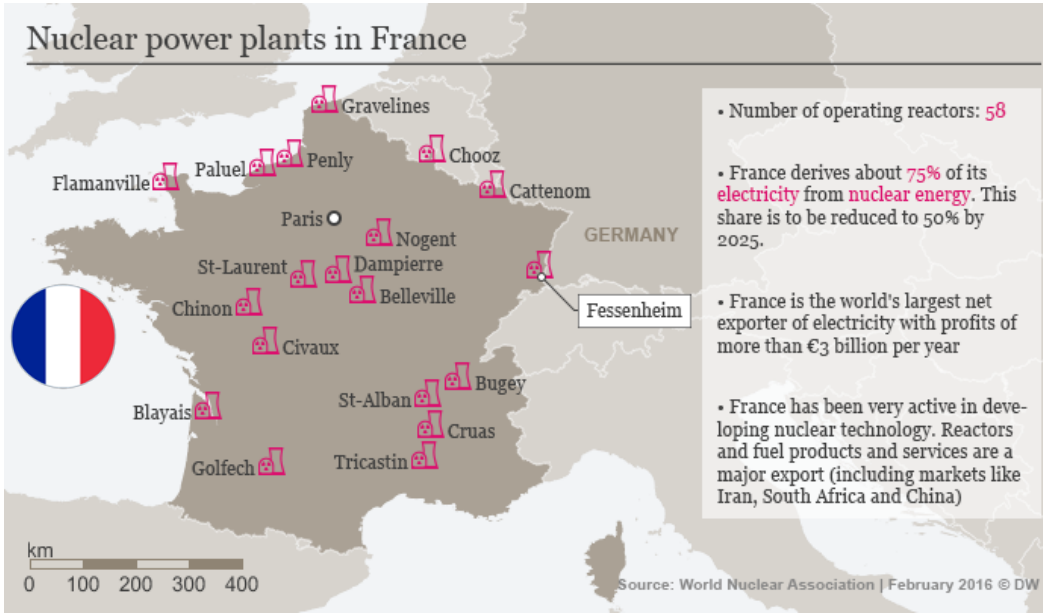
3. The French Case

- **Highly specific**:
  1. 82% of local French consumption and 76% of the total demand (with exports) met by the **nuclear fleet**.
  2. The nuclear portion would be reduced to 50% of total electricity production as of 2025 or 2030 (recent discussion), and the renewables portion reaching 40% **in 2030**.
  3. Half the nuclear fleet will be **over 40 years** in 2025.



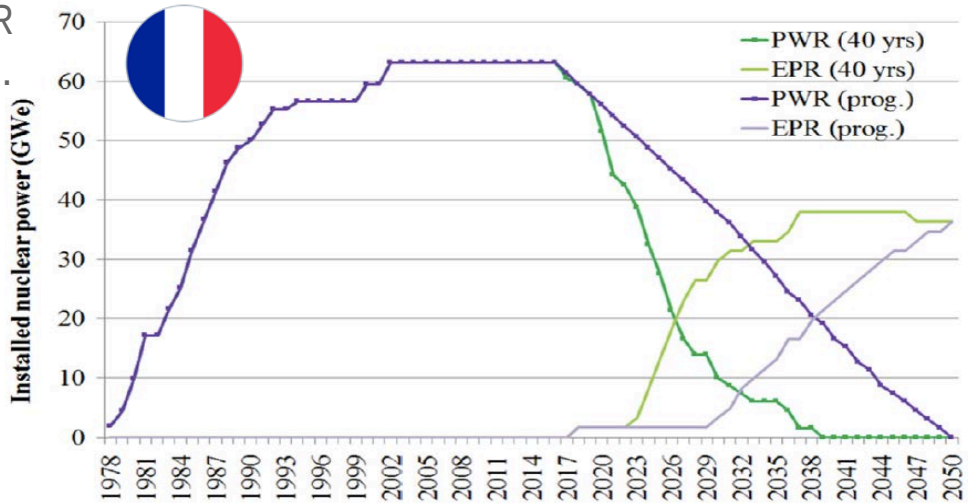
3. The French Case

- *Is the flexibility of nuclear power possible as part of the solution of balancing supply and demand in real time?*
  - The construction of **scenarios by 2050**:
    - The levels of penetration of renewables into the mix.
    - The future constraints of the nuclear fleet.

3. The French Case

- **The Levelized costs of energy for nuclear, in 2 scenarios** of replacement of Pressurised water reactors (PWR) with new Evolutionary power reactors (EPR):

1. **The '40-year' scenario**: with a decommissioning of PWR once they've clocked 40 years.
2. **The 'progressive' scenario**: with a continuous decommissioning of PWR (2 decommissions a year) towards an full EPR fleet in 2050.



PWR and EPR capacity evolution scenarios (for 50% nuclear penetration)

Source: **Cany, Mansilla, Da Costa, et al** (2016). "Nuclear and intermittent renewables: two compatible supply options? The case of the French power mix", Energy Policy 95.

3. The French Case

- The reduction of installations in nuclear capacity could engender an increase of fossils in the mix, with:
  - **up to 25% more emissions in GHG with a share of wind and solar energies of 50% in 2050**.

- To avoid this and to ensure the penetration of renewables, I show that:
  - **the big size of the French fleet of nuclear reactors can allow high flexibility thanks to small variations in each nuclear plant**.

3. The French Case

- *What is the level of response of nuclear flexibility?*
  - If nuclear capacity is maintained at 60GW (current French situation): a mix of **30% of wind and solar already requires considerable flexibility**…
  - … of the order of **a hundred euros** per MWh (for the costs of nuclear flexibility).

Costs of nuclear flexibility

Horizons	Shares of wind and solar	Nuclear in GW (shares in the mix)	Shares of fossils in France	Reduction in charge factor compared to the base case	Costs of the nuclear flexibility (€/MW)
2030	17 - 23%	60 (72% to 65%)	0%	[-9% ; -15%]	[110 ; 150]
		50 (65% to 60%)	3 – 6 %	[-2% ; -6%]	[60 ; 130]
2050	30%	50 (55%)	2%	-11%	100
		40 (45%)	9%	-4%	70
	50%	40 (35%)	1%	-26%	110

Source: **Cany, Mansilla, Da Costa, et al** (2016). "Nuclear and intermittent renewables: two compatible supply options? The case of the French power mix", Energy Policy 95.

3. The French Case

- I show that:
  - **The greatest influence of solar penetration** - compared to that of wind - on the need of flexibility of the nuclear:
    - The benefit of **integrating both renewable sources** by smoothening out the effects of solar.
  - **New incentives** necessary for nuclear power to play a competitive role as **back-up technology**:
    - A carbon tax or other similar incentives for investment could smooth the gap.
    - When compared with gas CCGT, a value as low as **100 €/t.CO2 in 2030** could change the trends.

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4. Conclusion

My conviction in 3 points:

1. **Nevertheless, technology alone will not meet the challenges of climate change.**
   - Technological change isn't happening quickly enough to respond to the dynamics of the climate change.
   - A multi-dimensional response is required.
   - In richer countries, a necessary reduction in electrical demand?

4. Conclusion

My conviction in 3 points:

2. **And the best techno-economic choices will not necessarily be those adopted into society.**
   - The issues of :
     - the diffusion of innovations,
     - the acceptability or social feasibility,
     - political choices...
   - Germany:  *versus*  about the nuclear energy.

4. Conclusion

My conviction in 3 points:

3. **Finally numerous questions remain…**

- **On the supply side:**

  What sort of an electrical mix are we heading for?
  What are the innovations that we have in stock?
  Will there be a Gen IV for nuclear energy?
  How do we finance electrical investments when spot prices plunge?
  What is the future for the Utilities (EDF in France) and other historical producers?
  Are we witnessing a convergence of electrical and digital energies?

4. Conclusion

My conviction in 3 points:

3. **Finally numerous questions remain…**

- **Demand side:**
  What is the level of electricity demand in the future?
  Will the demand response be effective?
  What about the electrification of mobility?
  About electrical self-generation and self-consumption: what are the consequences on centralised electrical systems?
- **And regulation side:**
  What is the role of politics in the context of liberalisation?
  What industrial policies can there be in the field of energy?
  Will we see a rise in carbon prices?
  Will there be tender offers determined by the type of technology?
  Etc.

Some of my related publications

- *The paradoxes of European energy market regulation: an analysis of the electricity mix*, B. Shoai-Tehrani and P. da Costa, *in Towards a Sustainable Economy*, da Costa and Attias (eds.), Springer, 2018 Forthcoming.
- "Socioeconomic potential for deploying large district heating networks using heat from nuclear plants in a French urban area", M. Leurent et al, *Energy Policy*, 2018.
- "Cost-benefit analysis of district heating systems using heat from nuclear thermal plants in Europe", M. Leurent et al, *Energy*, 2018.
- "Adapting the French nuclear fleet to integrate variable renewable energies via the production of hydrogen: towards massive production of low carbon hydrogen?", C. Cany et al, *International J. of Hydrogen Energy* 42(19), 2017.
- "Three investments scenarios for future nuclear reactors in Europe", B. Shoai Tehrani and P. da Costa, *Energy Studies Review* 23(1), 2016.
- "Nuclear and intermittent renewables: two compatible supply options? The case of the French power mix", C. Cany et al, *Energy Policy* 95, 2016.
- *Are reregulated electricity market and climate policy compatible? Lessons from overseas, from Europe to Japan*, B. Shoai Tehrani et al, Y. Nakagami, proceedings of the *USAEE*, 2016.

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