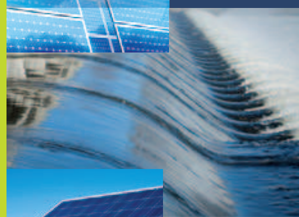
Electricity 2030

THE CHOICES FOR FRANCE?



Study by UFE with assistance from Estin&Co

Union Française de l'Électricité

Erratum

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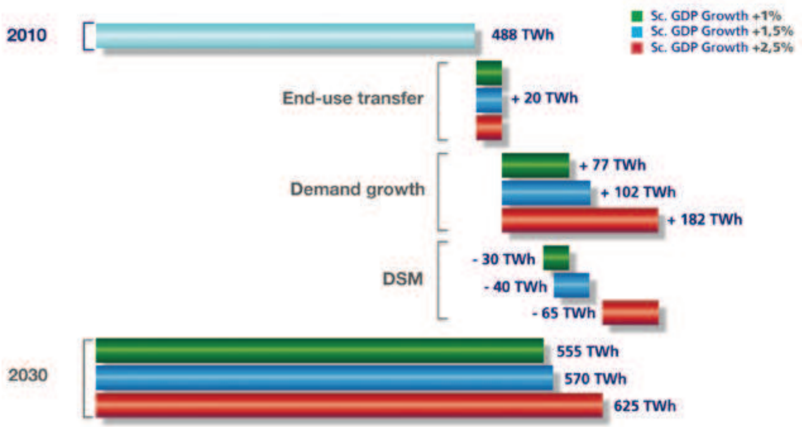
Summary of growth in demand for energy:

ENERGY DEMAND DEVELOPMENT SCENARIOS



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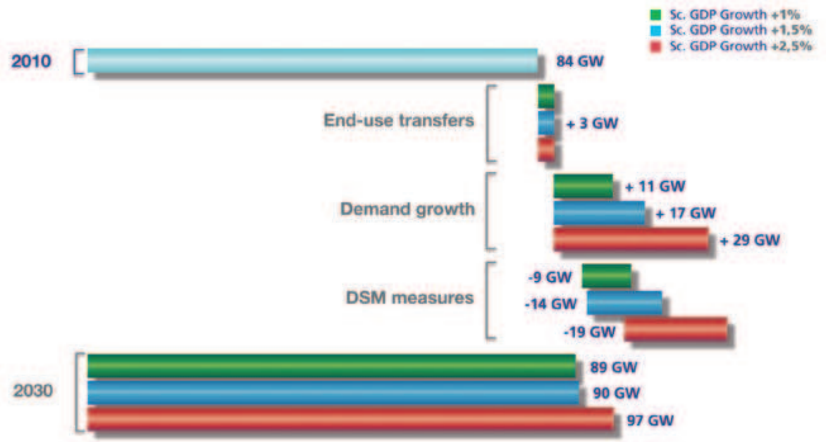
Summary of growth in electric loads:



SCENARIOS FOR GROWTH IN PEAK LOADS (the 60 most heavily loaded hours – under normal climate conditions)

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30 KEY POINTS FOR 2030

To enlighten the debate on future energy policy, UFE has carried out a study of three generation scenarios, looking ahead to 2030: a «70% nuclear» generation scenario (under which the lifetime of the existing nuclear fleet is extended from 40 to 60 years and renewables are developed in line with the Grenelle plan); a «50% nuclear» generation scenario (under which the share of nuclear technology in the energy mix is reduced to 50%); and finally a «20% nuclear generation» scenario (under which all existing nuclear facilities are shut down upon reaching the end of a 40 year working lifetime). A cross-analysis was carried out between these generation scenarios and a range of scenarios for possible future developments in electricity consumption, incorporating various hypothetical projections for demand side management. The results of the study provide a clearer picture of the possible «policy» choices, based on climate, social, economic and financial criteria, each of which requires weighting against the others in a consistent manner. The following key points raised by the study summarize the main considerations that future governments will need to take into account.

Electric mix: nuclear, renewables and fossil fuels?

1. All of the scenarios looked at by UFE assume significant development in renewable energy sources, either equal to or above the Grenelle targets. Consequently, even under the «70% nuclear» scenario, installed renewable capacity exceeds installed nuclear capacity.
2. However, under the scenarios which assume a reduction in nuclear energy production (i.e. the «50% nuclear» and «20% nuclear» scenarios), renewables are insufficient to fully replace nuclear generation by 2030 – and so an expansion in fossil-fuel generation will be necessary. Under the «20% nuclear» scenario, the fossil-fuel fleet will consist of 66 fossil-fuel generation units (gas and coal-fired), compared with around twenty today.
3. Between the «70% nuclear» and «20% nuclear» scenarios, the share of generation accounted for by renewables rises from 24% to 40%, whereas that of fossil-fuel plants rises from 7% to 40%. The greater the reduction in the nuclear fleet, the higher the share of fossil fuels in the energy mix.

Electric mix and the environment

4. By 2030, it will be impossible to abandon nuclear technology, even partially, without increasing CO_2 emissions from electricity generation. Under the «50% nuclear» scenario, France is less likely to be able to honour its European commitments than under the «70% nuclear» scenario.
5. Under the «20% nuclear» scenario, France's overall emissions rise by 20%, and CO_2 emissions from electricity generation are three-times higher than current levels.

Electric mix and DSM

6. Current public policies aimed at promoting DSM measures are insufficient to satisfy the Grenelle environmental targets, without sufficient financial incentives for property owners to invest in improving the energy performance of their buildings.
7. Moreover, demand side management efforts are not enough to offset even a partial reduction in nuclear generation (the «50% nuclear» scenario) by 2030.

Electric mix and consumer prices

8. Higher electricity prices are unavoidable, even under the «70% nuclear» scenario, given the insufficient tariff levels and the weight of future investment (generation, infrastructures, smart grids, etc.).
9. Electricity price rises are likely to be even higher if nuclear generation is scaled back significantly. For businesses and households alike, the study estimates that there would be an increase of around €40/MWh between the «70% nuclear generation» scenario and the «20% nuclear generation», and a €20/MWh increase under the «50% nuclear generation» scenario. As a guide, €40/MWh is the state-regulated price (ARENH) for access to nuclear-generated electricity introduced under the NOME law reorganizing the electricity market, passed on July 1st 2011.
10. Electricity prices are much more sensitive to fluctuations in fossil fuel prices (gas and coal) under the «20% nuclear» scenario than under the «70% nuclear» scenario.

The power system and renewables

11. Given the specific features of renewable energy sources and in particular the intermittent nature of their output, the expansion of installed renewable capacity assumes that changes will be made to the power system and the way it is managed, which is presently highly centralized.
12. With this in mind, it is absolutely essential for control of the power system to be developed with the introduction of new technologies (smart grids).
13. It is important to maintain the profitability of thermal power plants, which are vital to the security of the power system. This will require suitable changes in the way the electricity markets are organized.
14. Electricity storage in all its forms (hot water tanks, pumped storage facilities, etc.) must be not just maintained, but significantly expanded. Very substantial R&D efforts will be required on the various forms of storage between now and 2030, so these solutions can be rolled out on a mass scale by 2050.

European interconnectors

15. Development of the interconnectors between France and other European states is critical under all scenarios, albeit for different reasons. However, despite the efforts of the NETSO, this development has been virtually stagnant for over 20 years, as a result of local opposition.

Developing the electric mix and social acceptability

16. The social acceptability of installations to be built (nuclear plants, CCGTs, CCS facilities, renewable facilities, transmission lines, etc.) is a critical point for the future, especially if France reduces its reliance on nuclear power. Current public policies in this area are inadequate.

Electric mix and end uses

17. The gradual move from fuel-oil to more efficient electric end-uses (heat pumps, electric transport) is crucial under the «70% nuclear» and «50% nuclear» scenarios, to ensure a lower carbon mix.
18. Under the «20% nuclear» scenario, there are no such transfers from fossil-fuels to electricity because they lead to a negative carbon balance (increased CO_2 emissions in connection with an increased thermal back-up in the generation mix).
19. By 2030, under the «70% nuclear» and «50% nuclear» scenarios, France will necessarily have a downstream end-use mix balanced between efficient electricity and gas. A good balance in the rational use of these two types of energy will be critically important.
20. Relatively inefficient end-uses for electricity must be replaced by efficient electric solutions.
21. Significant R&D efforts are needed to develop future electric solutions, with the emphasis on reducing the costs of energy efficiency and DSM measures.

Developing the electric mix and financing investments

22. Under all the scenarios, substantial investment in the electricity sector is needed: between €320m and €430m over the period 2010 / 2030. The latter amount does not represent the total cost to the French economy of abandoning nuclear energy, which includes prices rises for end customers (points 8 and 9) and the deterioration in the balance of payments (point 26).
23. For deregulated operators working in the competitive environment (generation / retail) who look to the markets for financing, levels of return on investment are crucially important, especially in fossil fuel facilities which currently carry a high risk. It is therefore vital to have proper visibility and stability in public energy policies, together with a suitable market architecture.
24. For the regulated operators (DSO, TSO), financing will also be a problem, as the markets will need to understand and sign up to the new electricity system that will be put in place.

Electric mix and the balance of payments

25. Under the «70% nuclear» scenario, France has a 100 TWh export surplus in its exchanges with the rest of Europe, while the balance of payments is balanced (income from electricity exports covers all expenditure on fuels).
26. Under the «20% nuclear» scenario, the balance of payments deteriorates by €10bn per year.

Beyond 2030… open choices?

27. In economic terms, the decision on whether or how fast to withdraw from nuclear power is largely dependent on the issue of «stranded costs» for the French economy. However, the question of the structure of the French energy mix beyond 2030 remains open. Choosing to maximize the use of the existing nuclear fleet does not in any way pre-empt the choices that will eventually have to be made when the current fleet reaches the end of its lifetime.
28. On the contrary, technological advances and potentially lower costs for the different generation technologies should allow more open choices by 2030. CCS is a very good example of this.
29. One of the questions for the future also concerns the development of competitive national industries.
30. Decisions taken today cannot anticipate future developments, and adopting overly radical new policy directions could prove to be economically inefficient. For this reason, in view of the economic uncertainties and technological unknowns, but also possible shifts in public opinion, the issue of energy policy decisions needs to remain flexible and open to gradual change.

These decisions will be dependent on long term industrial policy, an area in which UFE is keen to be a partner for policymakers.

THE ENERGY CHOICES FACING FRANCE IN QUESTION

France, leading Europe in the fight against climate change

France already has a low carbon electricity supply...

Thanks to the energy policy it has followed since the 1970s, France is already the European leader in the fight against climate change. This was confirmed by a UFE study published in 2008[1], but which was not sufficiently taken into account in the conclusions of the Grenelle environmental plan.

Two figures illustrate this observation:

- France's CO2 emissions from electricity generation are around 70 to 80 g per kWh, compared with the European average of 350 g of CO_2 per kWh.
- To produce one unit of GDP, France emits half as much CO2 as Germany.

This is of course attributable to two major choices:

- The development of a powerful fleet of hydro-electric and nuclear plants;
- The development of efficient end-uses of electricity by consumers, both in industry and in the tertiary and residential sectors, although some types of electric heating do not fit the criteria for «efficient end-uses».

These choices have reduced the use of fossil fuels, especially fuel-oil, and met the dual aim of boosting France's energy independence whilst lowering its sensitivity to fluctuations in international energy prices.

...and the Grenelle plan will improve it further

Under the Grenelle environmental plan and the multiannual investment programme (known as the 'PPI') for 2009, France set out its electricity policy for the period leading up to 2020. In particular, it has:

- Placed greater emphasis on developing embedded renewables, with an ambitious target of 25 GW for installed wind capacity; 5.4 GW for solar (PV); 2.3 GW for biomass; and 3 GW for peak hydro-electricity by 2020 ;
- Officially ordered the decommissioning of old fossil fuel plants due to be closed in line with European rules on atmospheric pollution[2];
- Commissioned two EPRs, at Flamanville and Penly;
- Sought to redouble its demand side management (DSM) efforts.

With this energy policy, France is ahead of the targets set by Europe in its low carbon roadmap for 2050[3].

Fukushima has raised new political questions

The Japanese earthquake and tsunami of March 2011 and the resulting nuclear disaster at Fukushima have led some countries, and a part of public opinion in France, to reconsider the place of nuclear power in the energy mix. Research into new technologies, with promising economic and environmental implications, have also come under question.

Throwing light on the potential policy choices

Electricity, a specific form of energy

Electricity, in all its aspects, is dependent on long term choices. Investing in generation takes at least five years, and often more than ten years. Developing transmission lines and interconnectors often takes more than eight to ten years. Adapting end-uses of electricity (in homes, industry, etc.) and developing efficient demand side management systems often takes more than a decade, and even longer for the mass markets.

1 Climate challenge, new electrical challenges: the role of electricity in the fight against climate change.

2 Oil or coal-fired power plants.

3 For the electricity industry, the 2050 roadmap includes a target of a 54 to 68% reduction in greenhouse gas emissions.

Electricity is a system. History shows that the choices between the different components - generation, grids, building and plant equipment – need to be consistent: electricity generation, transmission and consumption form an integrated system. That is why UFE has looked at the total investments needed to implement the various scenarios, in terms of generation, storage, grids and energy efficiency. Since electricity cannot be stored, the power system forms a single entity and its components – both upstream and downstream - remain inextricably linked.

The design of the power system: a political choice

As in all countries, the design of the power system is obviously a political choice, since with electricity - unlike gas or oil - the State holds most of the cards. Nowhere is this clearer than in French electricity policy since the 1970s.

So as the time for major energy policy choices draws closer, UFE has taken upon itself to examine the possible paths.

Three generation scenarios

To study the options open to policymakers, UFE has selected three contrasting generation scenarios, that together are deemed a representative typology of the possible choices:

- *The first scenario is* ***«70% nuclear» generation:*** it assumes that the decisions taken in the 2009 PPI and the Grenelle environmental plan will be followed through.
- *The second scenario is* ***«50% nuclear» generation:*** the share of electricity demand covered by nuclear generation is assumed to fall to 50% by 2030.
- *The third scenario is* ***«20% nuclear» generation:*** all France's nuclear units are assumed to be systematically shut down after reaching 40 years of active service.

Under these three generation scenarios,

- the development of renewables replaces a part of the drawdown in nuclear generation;
- the additional energy needed to satisfy demand is provided by thermal power plants;
- the back-up needed to offset the intermittent output of renewable sources is provided by thermal plants and by hydro-electric capacities, particularly pumped storage facilities.

Three demand scenarios

Three scenarios modelling demand, both in terms of loads (power) and in terms of energy, have been studied. They combine:

- The impact of economic growth, with French GDP growth scenarios of 1%, 1.5% and 2.5%
- The impact of energy efficiency, with two hypotheses: full implementation of the Grenelle measures (100%), and partial implementation (50%). This latter hypothesis was included because UFE takes the view that, given the economic reality of energy efficiency and particularly the very long leadtime for measures to produce results (over thirty years in some cases), current public policies are economically unsuited and therefore relatively ineffective.

Developing a multi-criteria analysis to identify choices

The primary purpose of this study is to provide a greater insight into possible energy policy options. UFE has therefore developed a multi-criteria analysis:

- The fight against climate change, based on CO_2 emissions;
- The economic competitiveness of France (investment financing, competitive advantage of electricity in price terms);
- The purchasing power of households, through trends in «average» household bills;
- France's energy independence;
- France's balance of payments;

Depending on their degree of sensitivity, each of the criteria can be weighted differently. For this reason, UFE does not recommend any particular scenario.

GROWTH IN ELECTRICITY DEMAND IN THE PERIOD UP TO 2030

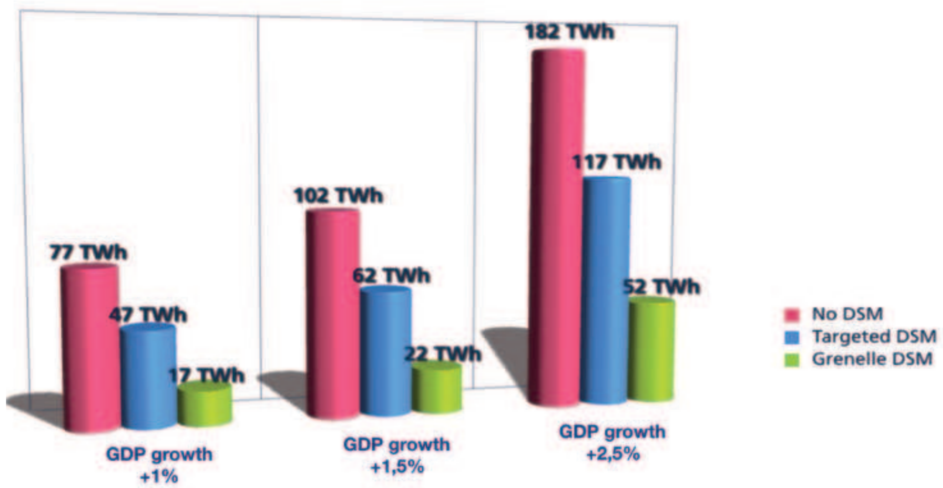
Electricity demand growth has been estimated, in terms of both energy and power.

Growth in demand for energy

The impact of economic growth

The study looks at three growth scenarios in which French GDP growth is assumed to be 1%, 1.5% and 2.5% respectively. Annual GDP growth of 1.5% can be considered representative, as a minimum, of a degree of re-industrialization in France, with an outlook that firmly rules out any prospect of recession. Thus 1.5% annual growth rate was adopted as the «Median» baseline scenario. In the below graph, red columns are consistent with the french consumption natural growth (all other parameters being equal). Green columns are consistent with 100% of the Grenelle Energy Efficiency Scheme. Blue columns are consistent with targeted measures implementing 50% of the Grenelle Efficiency Scheme.

GROWTH IN DEMAND AND DSM EXCLUDING END-USE TRANSFERS, PERIOD 2010 – 2030



The impact of energy efficiency on energy demand

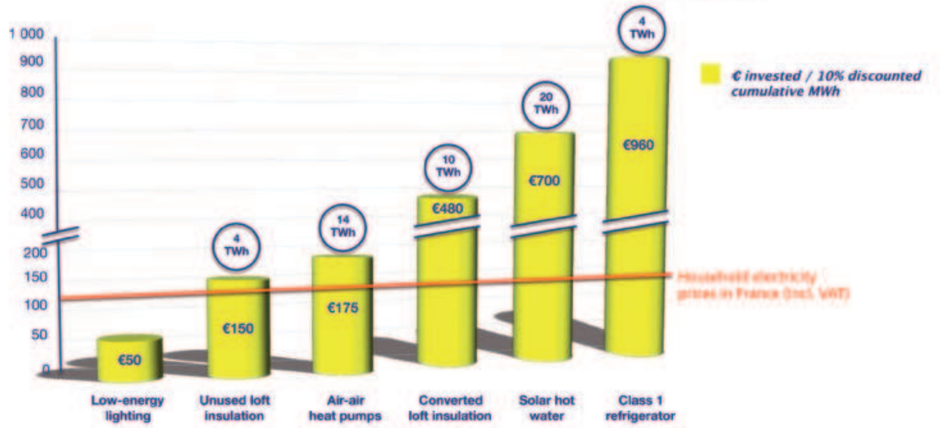
The DSM measures proposed under the Grenelle environmental plan would allow savings of 12% in electricity consumption by 2030, i.e. 70 to 80 TWh.

However, based on measures currently implemented, there are grounds for questioning whether these targets can be met or exceeded in scenarios where nuclear generation is scaled back. To this end, UFE has carried out a special study[4] on energy efficiency and DSM for all energy types (electricity, gas, fuel-oil). This is based on:

- An assessment of the «merit order» (economic ranking) of DSM measures, estimated in euros to be invested per cumulative discounted MWh[5] saved
- An assessment of the potential (TWh, €) theoretically profitable measures on the target
- A calculation of the difference between this theoretical potential and the target fixed by the Grenelle plan, updated to reflect the impact of the economic crisis.

As an example, the graph below shows the merit order of certain energy efficiency measures related to electricity.

ELECTRICITY AND THEORICAL POTENCIAL ENERGY SAVINGS



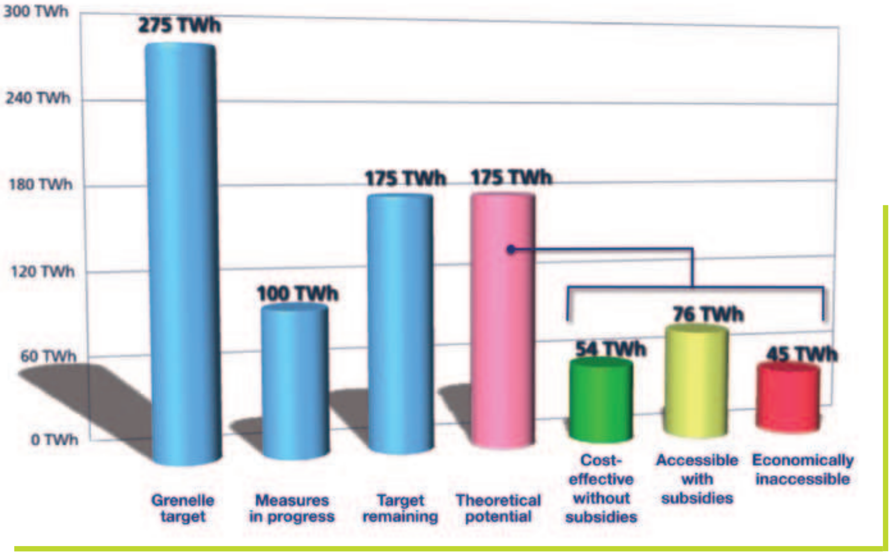
4 To be published after this one

5 10% discounted cumulative MWh

For its «Median» baseline (growth of 1.5%) and «High» growth of 2.5%) scenarios, UFE therefore only included the measures most likely to be implemented under current public policies, i.e. those with a turnaround time shorter than 15 years (building loft insulation, move to low energy lighting, heat pumps, industrial engine upgrades). This assumes that 50% of the targets set by the Grenelle plan will be achieved, for a total of 40 TWh (targeted DSM). For its «Low» scenario (growth of 1%), UFE assumed that 100% of the DSM targets set by the Grenelle plan will be achieved, for a total of 75 TWh.

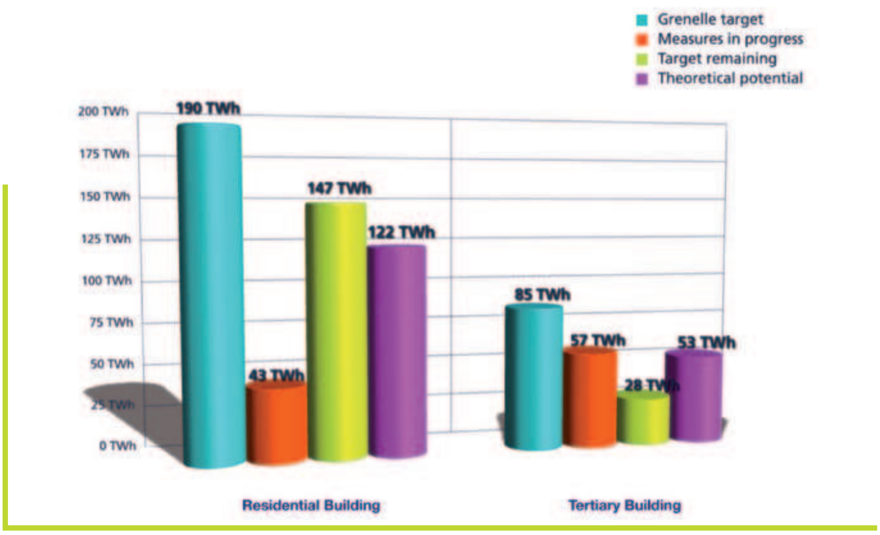
More generally, regarding one of the key planks of the Grenelle plan - buildings (residential and tertiary), where the energy efficiency target is 275 TWh and concerns all energy types (electricity, gas, fuel-oil) - the study concludes that beyond 100 TWh, under measures currently in effect, the additional 175 TWh of savings by 2020 can only be achieved through energy efficiency measures distinguished in three categories:

- measures that are «cost-effective without assistance», i.e. which offer a sufficient intrinsic return as to be undertaken without state subsidies and which generate just 54 TWh of energy savings. They represent private investment of some €24bn;
- measures that are «accessible with assistance», i.e. which offer a satisfactory return, provided private investment (estimated at €60bn by 2020) is augmented by public subsidies of €70bn, allowing 76 TWh of savings;
- measures that are considered to be «economically inaccessible», which generate 46 TWh of savings but which fail to provide a sufficient return unless the private investment of €38bn is augmented by state incentives totalling €408bn.



COMPARISON OF THEORETICAL POTENTIAL ENERGY SAVINGS / GRENELLE BUILDING PLAN 2020

As things currently stand, public policies to incentivize DSM measures and energy efficiency suffer from a number of major drawbacks:



COMPARISON OF THEORETICAL POTENTIAL ENERGY SAVINGS / GRENELLE BUILDING PLAN 2020 Breakdown Residential / Tertiary

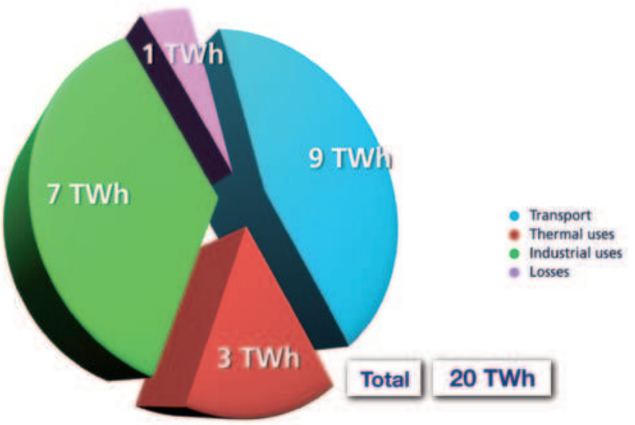
GROWTH IN ELECTRICITY DEMAND IN THE PERIOD UP TO 2030

- The Grenelle targets have been poorly defined. They are unfeasible in the residential sector, and underestimated in the tertiary sector.
- Tax credits are targeted at one-off measures (replacing windows, for example) which are often relatively ineffective in terms of energy efficiency: it is vital for public policies to be brought into line with the energy efficiency merit order.
- Given the size of the incentives required to promote energy efficiency (€70bn for building insulation alone by 2020 as part of cost-effective measures with subsidies), there is no scope for placing such a burden on the State finances and adding to local or national public debt.
- Measures such as energy efficiency certificates (called CEEs in France), which are costly and cumbersome for suppliers to manage, may «trigger» energy efficiency actions that are financially cost-effective for economic actors. They cannot under any circumstances compensate for the lack of return generated by other measures.
- A new system is needed, one that does not place a burden on the public finances, but which creates genuine economic solidarity between citizens.

So there is a wide gap between the desire for energy efficiency, the economic reality and public policy choices. Consequently, UFE believes that the energy efficiency efforts laid down in the Grenelle plan are unrealistic, given current public policies.

The impact of shifts in end-use technology to electricity on demand

End-use transfers are summarized in the table below, and estimated at 20 TWh. UFE based its study on realistic hypotheses, including the development of heat pumps and electric transport, both public and private.



ADDITIONAL DEMAND TRANSFERRED BY 2030

To maximize the environmental impact, the development of renewables needs to be combined with a large-scale move from fossil fuel-based end uses (notably fuel-oil) to electricity. The same principle applied during the expansion of nuclear power in the 1970s and 1980s. End-use transfers from fossil fuels to electricity should therefore be taken into account in the demand scenarios, as long as their resulting carbon footprint is generally positive for France. For this reason, under the «20% nuclear» scenario, it was deemed inappropriate to include them, since they present a negative carbon impact (i.e. CO_2 emissions after the transfer are higher than before, due to the generating fleet being more reliant on fossil fuel technologies).

As UFE emphasized in its previous study in 2008, these transfers from fossil fuel end-uses to more efficient electricity-based uses, must be combined with a policy aimed at correcting current inefficient uses of electricity, such as certain types of electric heating in poorly insulated homes.

It should be noted that by 2030, gas (also with efficient end-uses) will remain an essential source of energy in France, both upstream for combined cycle gas plants (CCGs), and downstream for heating buildings. The hypotheses on sharing of end-uses between gas and electricity can be found in the appendix to the study.

Finally, it is worth noting the efforts needed in favour of new energy technologies, especially in the electricity field. UFE has sought to rank key technologies in order of importance, and to ensure that public policies provide backing for the development of the most efficient and most promising technologies, but without placing an undue burden on the public finances. This analysis is based on three simple criteria: employment, compliance with the European «3x20» targets[6] and France's international competitiveness.

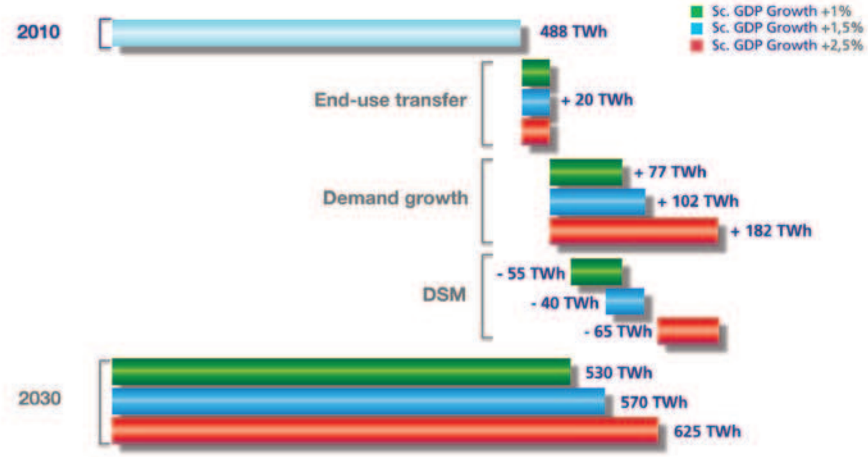
6 In its climate energy package, the EU set three targets for 2020, based on 1990 levels: a 20% reduction in greenhouse gas emissions, a 20% increase in the proportion of demand covered by renewables, and a 20% reduction in energy consumption

It proposes to rank technologies (see appendix) in three categories:

- Category 1: **promising technologies that are already present in the market,** and that concern priority energy sources in the energy efficiency merit order mentioned above. These do not require any particular subsidies. If they are not thought to be developing sufficiently rapidly, then standards or regulations may be used to speed up the process (as with low energy lighting).
- Category 2: **promising technologies available in niche markets, at high costs,** and which require state subsidies in order to expand. In this case, there is a need not just for subsidies to help these technologies overcome the temporarily higher costs, but also for genuine structuring incentives to encourage productivity.
- Category 3: **Technologies with long term promise (> 10 yrs),** for which research efforts need to be intensified and supported.

Summary of growth in demand for energy:

ENERGY DEMAND DEVELOPMENT SCENARIOS



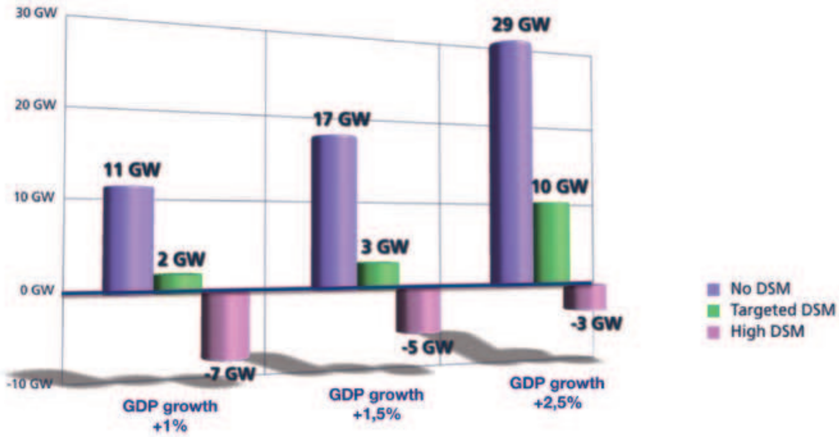
The reference point is the year 2010, when demand adjusted for climate contingencies was 488 TWh[7]. Projecting forward to 2030, there are two additional factors to be taken into consideration for total demand: first, end-use transfer from fossil fuel to efficient electric and the impact of economic growth; and second, the impact of DSM measures.

Electric load growth

Power or loads are an essential parameter for the power system, as electrical energy cannot be stored[8]. However, for the last ten years, peak loads have been rising twice as fast as electricity demand. «Natural» load growth[9] could be considerable if no load management measures are taken, as shown by the graph below.

GROWTH IN PEAK LOADS, PERIOD 2010-2030

(the 60 most heavily loaded hours – under normal climate conditions)



7 Source: RTE (values recorded for 2010 and climate-adjusted - 8 See UFE»s 2008 study, «Climate challenge, new electric challenges: the role of electricity in the fight against climate change» - 9 Excluding political incentives for load management

GROWTH IN ELECTRICITY DEMAND IN THE PERIOD UP TO 2030

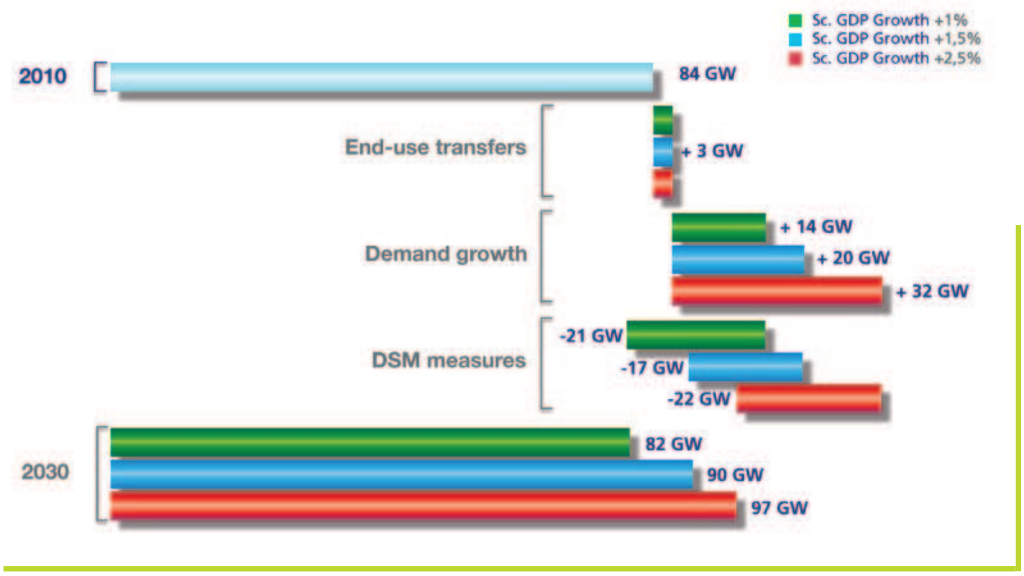
To evaluate load management efforts looking ahead to 2030, UFE has looked at the impact of economically efficient DSM measures, especially at peak times[10]. The impact of DSM can be strengthened by the introduction of a dynamic tariff system that gives consumers incentives to manage their energy use based on prices and periods. A further general boost can be provided by the development of smart systems[11].

With normal climate contingencies, and taking the 60 hours of the year with the heaviest loads, it is therefore possible to envisage peak loads stabilizing around the 87 GW mark under the «Median» baseline scenario (annual GDP growth of 1.5%), with a targeted DSM and disregarding end-use transfers.

However, it must be noted that the generating fleet would need to be of a sufficient size to withstand extreme demand peaks and exceptional climatic conditions. So a sufficient safety margin would be required in the form of capacities over and above 87 GW.

These figures underline the importance of load management measures. More incentivizing public policies could bring about an even greater reduction in peak loads.

Summary of growth in electric loads:



SCENARIOS FOR GROWTH IN PEAK LOADS

(the 60 most heavily loaded hours – under normal climate conditions)

10 DSM measures identified as economically efficient are have a positive effect on load management: this is true of the move to low energy lighting

11 Development of Linky meters combined with the rollout of efficient smart grids.

GENERATION AND NETWORK SCENARIOS FOR 2030

Three generation scenarios

To study the options open to policymakers, UFE has modelled three generation scenarios, that provide a representative typology of the possible choices:

- *The first scenario is a* ***«70% nuclear» generation scenario,*** under which the decisions laid down by the 2009 PPI multiannual investment programme and the Grenelle environmental plan are followed through. This scenario assumes that the lifetime of the existing nuclear fleet is extended and two EPRs are commissioned, the 2020 renewables targets are met and the development of renewables remains virtually stable until 2030.
- *The second scenario is a* ***«50% nuclear» generation scenario,*** under which the share of nuclear output in the total energy generated to cover demand is reduced to 50%. The development of renewables by 2030 is assumed to be higher than under the «70% nuclear» scenario. The additional energy needed to satisfy demand and the back-up to compensate the intermittent nature of renewable generation is provided by thermal power plants.
- *The third scenario is a* ***«20% nuclear» generation scenario:*** all nuclear units are assumed to be shut down after reaching 40 years of active service. The development of renewables is assumed to be pushed to the maximum level judged possible by the experts, with accordingly high levels of intermittent generation. The additional energy needed to satisfy demand and the back-up to compensate the intermittent nature of renewable generation is provided by thermal power plants.

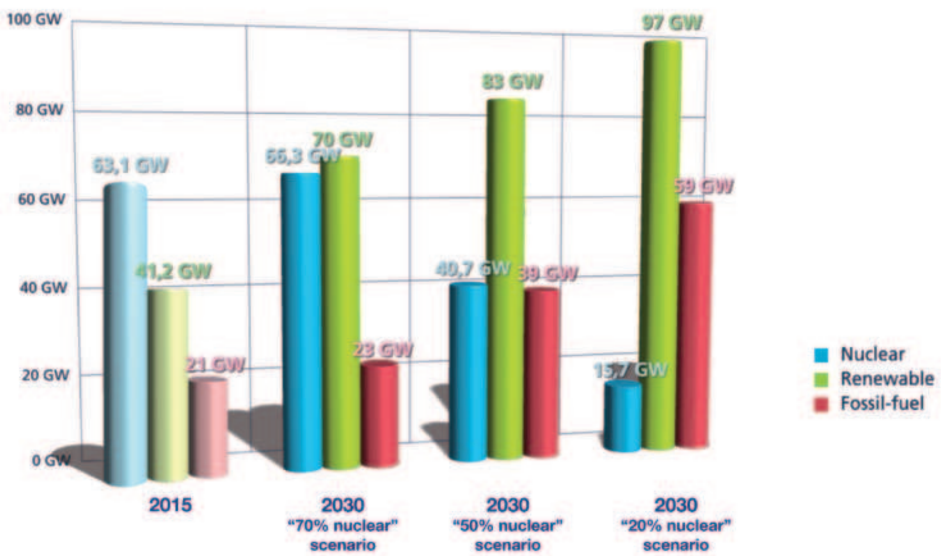
UFE understands «20% nuclear» generation to equate to the «withdrawal from historic nuclear power» referred to in the NOME law reorganizing the electricity markets, i.e. the shutdown of a nuclear plant whose active lifetime has been extended, subject to approval from the nuclear safety authorities. This withdrawal could therefore be described as accelerated, and for France could imply a «stranded cost» in the economic sense of the term.

The three generation scenarios in terms of installed capacity

Overview

In terms of installed capacity, the generating fleets under each scenario look like this:

GENERATION SCENARIOS – INSTALLED CAPACITY



GENERATION AND NETWORK SCENARIOS FOR 2030

The scaling back of installed nuclear capacity, between the «70% nuclear» and «20% nuclear» scenarios, is accompanied by:

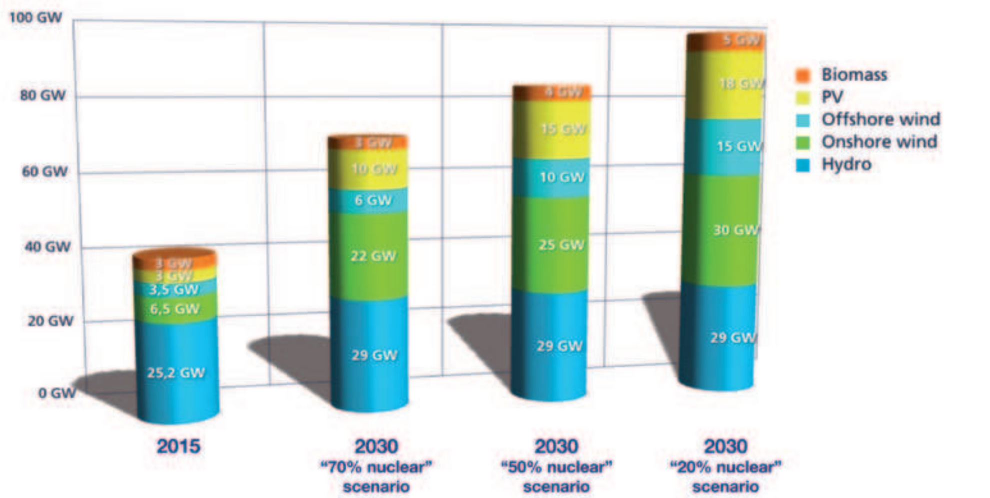
- an expansion in renewables, becoming more significant the more nuclear facilities are decommissioned;
- an expansion of fossil fuel plants, becoming more significant the more nuclear facilities are decommissioned and the greater the installed renewable capacity, in order to guarantee the supply/demand balance and provide back-up for intermittent renewable generation.

	Projection for 2015	70% nuclear generation	50% nuclear generation	20% nuclear generation
NUCLEAR	63,1	66,3(1)	40,7	15,7
RENEWABLES				
Hydro	25,2	29,0	29,0	29,0
Onshore wind	6,5	22,0 } 28,0	25,0 } 35,0	30,0 } 45,0
Offshore wind	3,5	6,0	10,0	15,0
Photovoltaic	3,0	10,0	15,0	18,0
Biomass(2)	3,0	3,0(2)	4,0(2)	5,0(2)
FOSSIL FUELS				
Embedded thermal(3)	4,0	4,0	4,0	4,0
Coal Of which potential CCS	4,1 (0,0)	3,0 (0,0)	5,0 (0,0)	8,0 (3,0)
CCGTs	5,9	9,0	17,0	32,0
Fuel-oil and Combustion Turbines	7,0	7,0	13,0	15,0

(1) Construction of two EPRs (Flamanville, Penly) in addition to the 2010 fleet (63.1 GWh) - (2) including 1 GW of industrial blocks - (3) CHP

The development of renewables

This may be judged in terms of installed capacity.



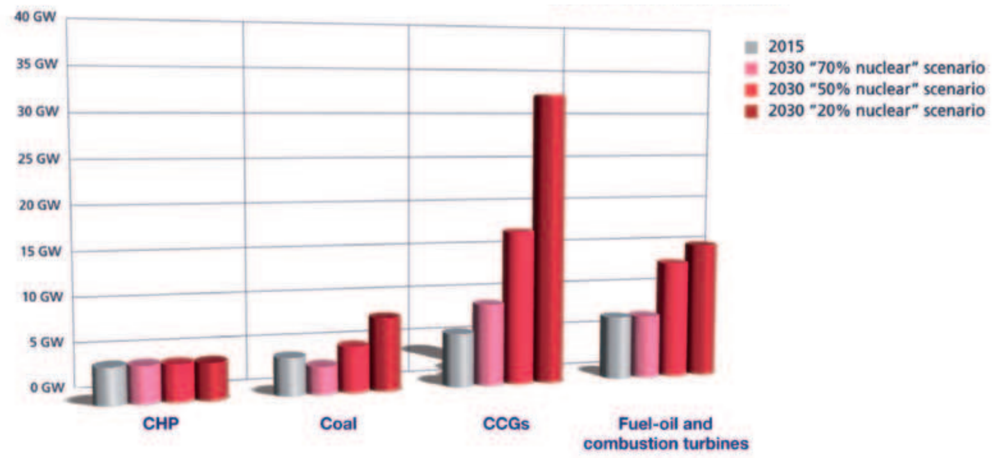
RENEWABLES: INSTALLED CAPACITY

The issue of local and geographical acceptability would need to be explored further in the case of large numbers of new installations generating energy from renewable sources (solar and wind).

Furthermore, power system security becomes an increasingly important area for concern as installed renewable capacity rises: the issue of intermittence is an extremely important one, and needs to be dealt with appropriately to guarantee the secure operation of the power system.

The development of conventional thermal generation

FOSSIL FUELS: INSTALLED CAPACITY



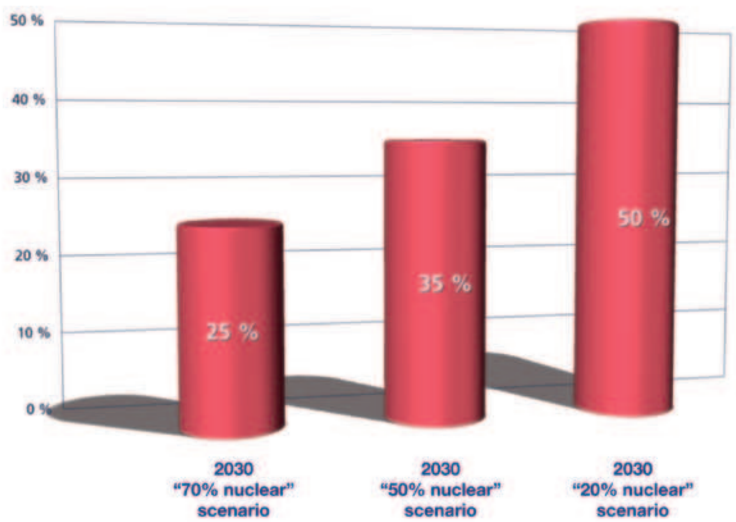
The use of CCGT, combustion turbines and, to a lesser extent, coal-fired units, is necessary to ensure:

- The generation/consumption balance: looking ahead to 2030, renewables alone cannot possibly compensate for the loss of nuclear power under the «50% nuclear» and «20% nuclear» scenarios;
- Back-up for renewables, to cover intermittence (wind, solar, etc.). Conventional thermal generation will need to be developed to guarantee France's security of supply (a criterion for the multiannual investment plan and the NOME law), with moderate use of imports, against a backdrop of rising uncertainty in Europe: all of the countries that have announced plans to reduce their reliance on nuclear generation intend to resort to imports to a greater or lesser extent (e.g. 10% in the case of Germany).

As regards coal, its continued presence in the energy mix is explained by its wide use around the world and the advantages for France of having a diversified supply source. It is theoretically developed with carbon capture and storage (CCS). However, many experts have expressed doubts that this technology will be developed on a mass scale by 2030.

It should also be noted that the development of CCGT units under the «20% nuclear» scenario, with around fifty units (32 GW installed), will raise social acceptability issues on three levels:

- the construction of plants at new sites;
- the construction of new gas infrastructures (storage, networks, etc.)[12];
- the construction of electricity transmission and distribution lines.



FOSSIL FUELS UTILIZATION RATE

12 Investments for the new infrastructures mentioned have not been studied at this stage.

GENERATION AND NETWORK SCENARIOS FOR 2030

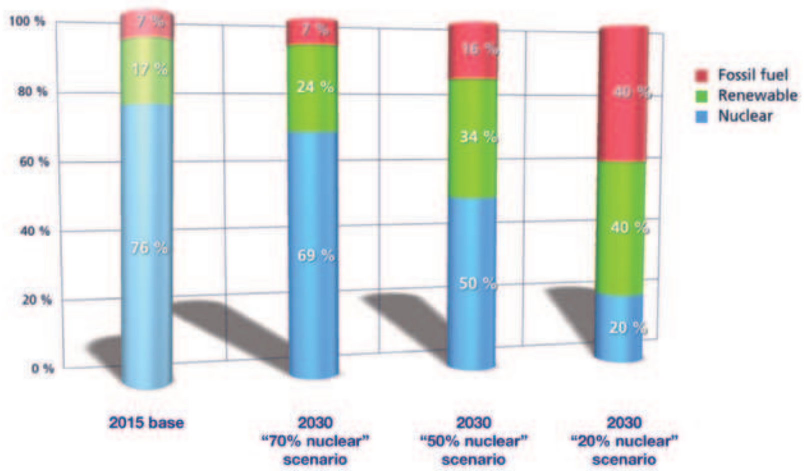
Finally, it is important to note that the low use of thermal generation in 2030, particularly under the «70% nuclear scenario, will pose a problem as regards the profitability of this type of generating facility, which is nonetheless essential to the balance of the power system, particularly for offsetting the intermittent nature of renewable output. The problem cannot fully be resolved under current market organization models (for energy, capacity).

This shows that a power system comprising a high proportion of embedded renewables cannot be designed and operated in the same way as a centralized generation system. The power system's design and operation will have to be revised, both in terms of generation and grid structures.

The three generation scenarios in terms of energy

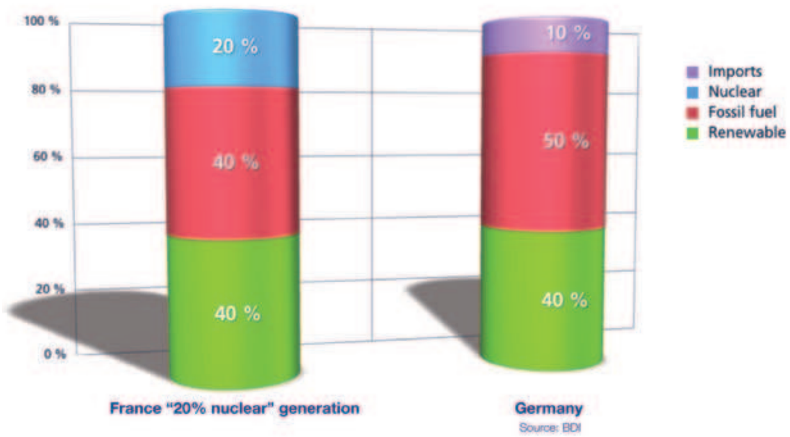
The share of energy produced by each generating technology to satisfy energy demand is shown in the diagram below:

ENERGY GENERATED – BREAKDOWN BY TECHNOLOGY



It is clear from the graph that, despite the expansion of renewables, a significant proportion of the shortfall created by the withdrawal from nuclear energy is made up by conventional thermal generation. This is particularly visible under the «20% nuclear» scenario, due to the relatively short periods of use for both wind and solar facilities. Under the «50% nuclear» scenario, the breakdown between energy sources is relatively well balanced. Under the «20% nuclear» scenario, the proportion of energy obtained from renewables is identical to that obtained from thermal generation.

Under the 20% nuclear» scenario in France and with Germany abandoning nuclear power, the structures of the French and German generating fleets will become increasingly similar by 2030. However, the security of supply to France will be virtually independent of imports, unlike Germany.

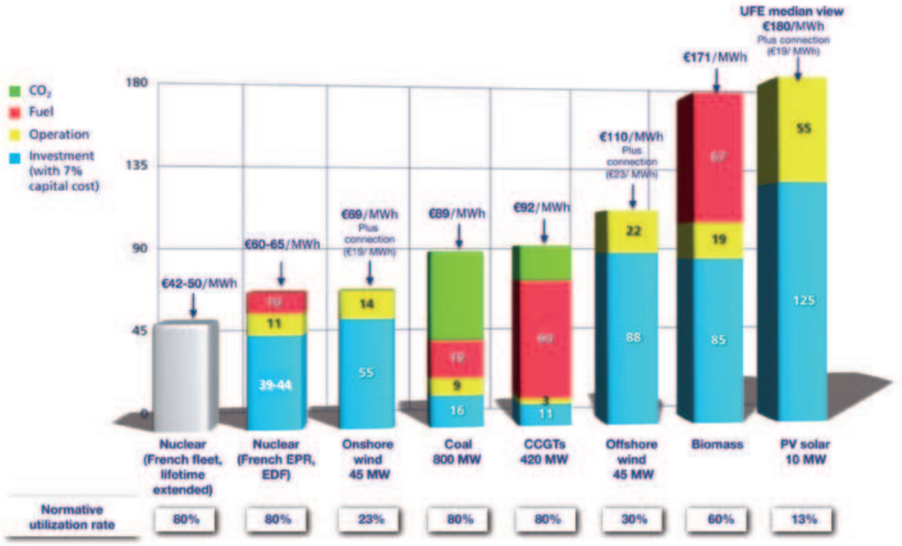


ENERGY GENERATED – COMPARISON FRANCE / GERMANY IN 2030

Development costs for the generation scenarios

In order to determine the impact of the generation scenarios on prices paid by end customers, UFE attached values to each scenario based on the development costs below:

DEVELOPMENT COSTS IN 2030



These development costs are calculated using the following figures:

- Investment costs: costs adopted either by the IEA, or by the DGEC (Directorate General for Energy and Climate).
- Cost of fuels and CO2: 2030 values in constant euros (based on 2010)
- The capital cost adopted is that for the sector, i.e. 7%[13].

- CO_2 at € 50 / t
- Uranium at $14 / pound
- Gas at $14 / MBtu (€34 / MWh)
- Oil at $150 / barel
- Coal $ 100 / t

For solar power, a range from €120 to €240/MWh was tested for sensitivity. It is difficult to attribute a single price to solar power, given the differences in developing technologies (integration of thin layer solar panels in roofs) or installation types (solar farms or individual installations), for example.

For nuclear power, the potential impact of Fukushima has not been taken into account at this stage. However, a range has been adopted, both for existing facilities (costs of extending active lifetime and maintenance - €42 to €50/MWh) and for new nuclear installations (change in construction costs - €60 to €65/MWh).

Interconnectors

Looking ahead to 2030, according to RTE[14], there are plans to increase interconnection capacities to between 20 and 22 GW.

Interconnection capacities 2010-2030

Total 2010	14-15 GW
RTE planned	3-4 GW
Total 2020	17-18 GW
Hypothesis 2020-2030	3-4 GW
Total 2030	20-22 GW

Under all these scenarios studied, interconnectors will have to be developed for two reasons:

- to carry exports from France to neighbouring countries (under the «70% nuclear» scenario in which France is a net exporter of energy)
- to improve the security of supply at peak times by taking advantage of generation smoothing[15] with neighbouring countries.

13 Weighted average cost of capital, nominal after tax, of 7%

14 2011 Generation Adequacy Report – baseline scenario

15 Smoothing: demand peaks do occur at different times in different countries

GENERATION AND NETWORK SCENARIOS FOR 2030

Given the uncertainties surrounding electric mixes in Europe, UFE chose to assume generating fleet sizes for each scenario that would enable France to guarantee its own security of supply under normal climatic conditions.

The development of interconnectors, compared with the situation in 2010, represents an investment of 10bn, which under some scenarios could be financed through electricity exports.

It should be noted that the expansion of interconnection capacities will also come up against acceptability issues.

Grid development

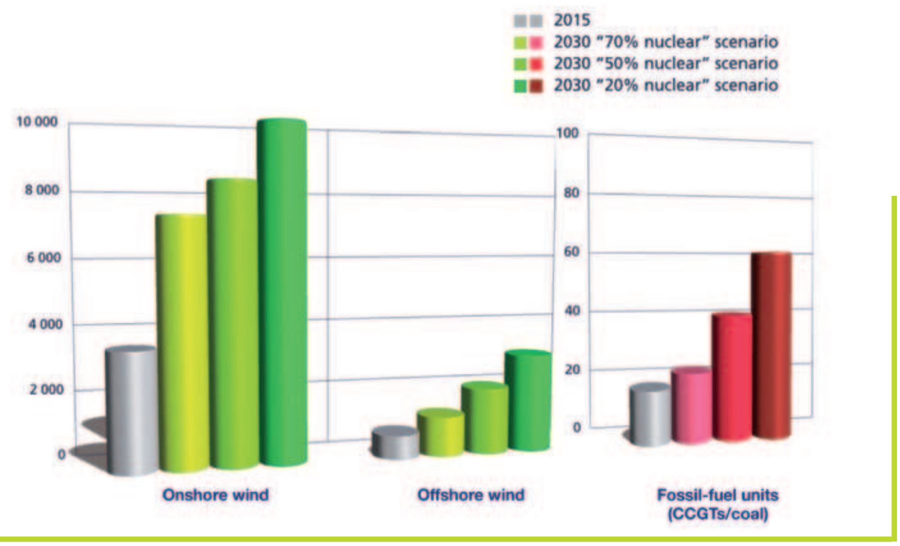
For the distribution grids, the study took into account investments in three areas:

- Upgrading network quality;
- Reinforcing networks to cope with the expansion of electric end-uses (electric vehicles, heat pumps, etc.) and the development of embedded generation (renewables);
- Modernizing networks with the development of «smart meters» and «smart grids».

For the transmission grids and interconnectors, the study took into account the need to adapt or reinforce transmission networks under the various scenarios. For example, it is uncertain whether, under the «20% nuclear» scenario, transmission lines connected to nuclear power plants could be re-used, at least partially.

Social acceptability of installations

The graph below shows the total number of wind turbines and thermal generation units that will make up the generating fleets under each scenario.



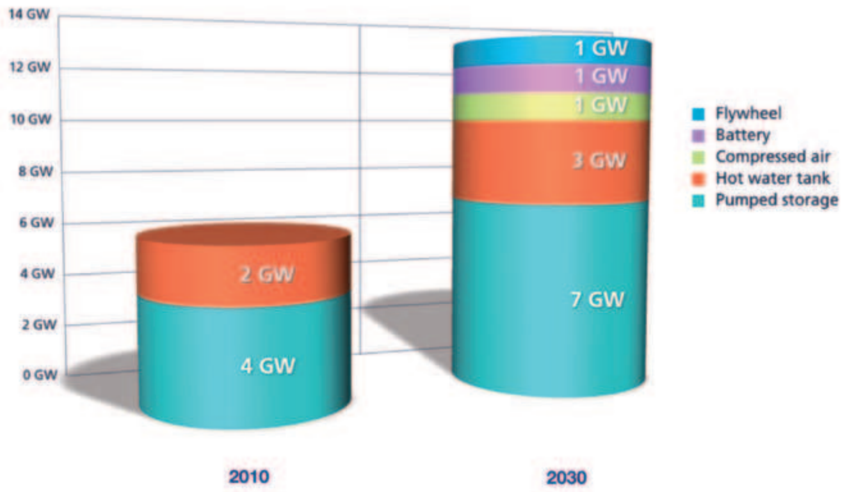
NUMBER OF WIND AND FOSSIL FUEL GENERATING UNITS

This highlights a central issue: the compatibility of public policies governing the siting of these installations, and their priority importance in terms of transforming and securing the power system. Some interconnectors, for example, have been the subject of ongoing debate for over twenty years.

Energy storage

The development of technologies for storing electrical energy becomes more important as renewables expand, since they are not necessarily able to generate power at the exact moment it is required. For example, in the case of solar power, the maximum output occurs during the day, whereas the demand peak falls in the evening. Storage, in all its various forms, is the best way of compensating for the intermittent nature of renewable generation.

GROWTH IN STORAGE CAPACITIES



Looking ahead to 2030, it is hard to see current storage capacities more than doubling, given the very high costs of electricity storage other than in pumped storage stations. Nonetheless, efforts in this area are vital for remaining on course after 2030, looking further ahead to 2050 and beyond. For this reason, UFE emphasizes the need not just to preserve existing storage potential, such as hot water tanks and pumped storage stations, but also and in particular the need for massive R&D efforts in this field: the *'Grand Emprunt'* or 'big loan' dedicated to future investments could serve to finance ad hoc programmes on a much larger scale.

The development of 'dynamic' power systems

With the necessary development of renewables, the power system will undergo immense changes to the way it is operated and controlled.

For example, the development of storage combined with maximum renewable generation will require major changes to the way in which the power system is arranged: regionalization, the development of 'dynamic' smart grids, etc.

What are frequently referred to as «smart grids» are in fact often limited solely to networks (transmission and distribution) and will have to be replaced by a new, more all-encompassing approach to «Dynamic Power Systems», whose development is also considered a priority. UFE estimates that their development would require at least €10bn of investment, including €4bn for smart meters (AMR, Linky, etc.).

These new systems will be needed in order to do the following more effectively:

- Manage the intermittence of output from renewable facilities;
- Organize the previously centralized power system on three levels: Europe, France, regions;
- Organize and guide load management and demand response programmes;
- Pilot energy efficiency programmes;
- Encourage consumers to sign up to DSM and load management measures, by introducing incentivizing retail offers.

UFE will make concrete proposals for their development.

COMPARISON OF THE SCENARIOS

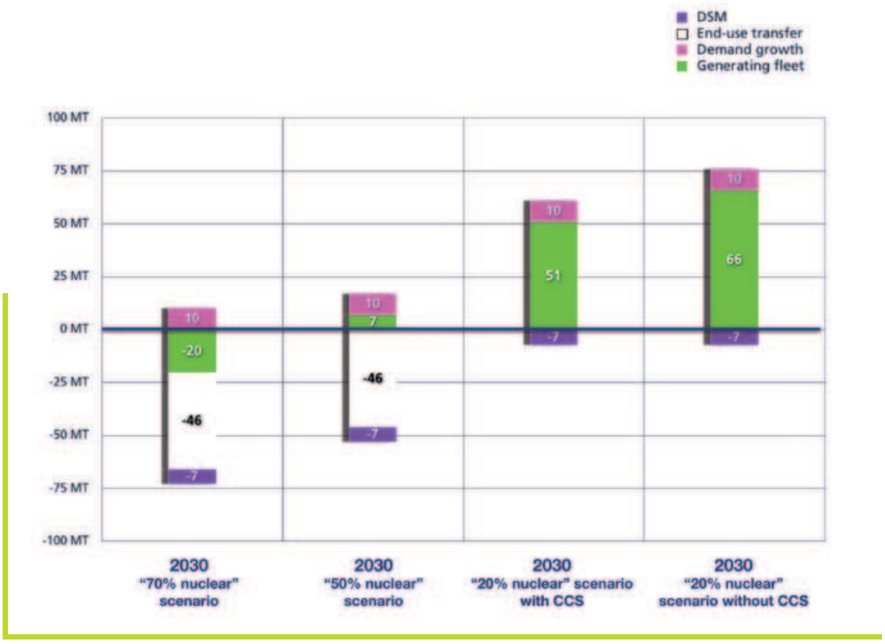
CO_2 impact

CO_2 impacts are summarized in the following three graphs, which show the influence of each electricity scenario on France's emissions (all other things being equal).

CO_2 IMPACT

The graph below shows the development of emissions from electricity generation, identifying each emissions item: generation, DSM, demand growth, and end-user transfers.

CO_2 EMISSIONS, PERIOD 2010-2030



Under the «20% nuclear» scenario, with or without CCS, France's climate change policy is compromised - European commitments are no longer met. Emissions specifically from the electricity sector are multiplied threefold, whereas overall French emissions rise by 27%, all other things being equal. This is explained partly by the significant increase in fos sil fuel power plants to support the expansion of renewables, and partly by the absence of end-use transfers with a positive effect on CO_2 emissions.

Furthermore, to offset the increase in CO_2 emissions due to the scaling back of nuclear power under the «20% nuclear» scenario, it would be necessary to intensify DSM measures by a factor of 15, which would require investments of €1,000bn.

Under the «50% nuclear» scenario, whilst the increased use of fossil fuel plants pushes up emissions from the electric fleet (+10 Mt), on the other hand France's overall CO_2 footprint is improved compared with 2010 (-10%) thanks to end-use transfers.

Finally, for future years, the combination of an expansion in renewables in line with the Grenelle plan and the extension of nuclear power (2009 PPI) is the most efficient in climate terms. This scenario halves CO_2 emissions from the electricity sector and provides an 18% reduction in France's overall CO_2 emissions, both as a result of performance in the sector and end-use transfers.

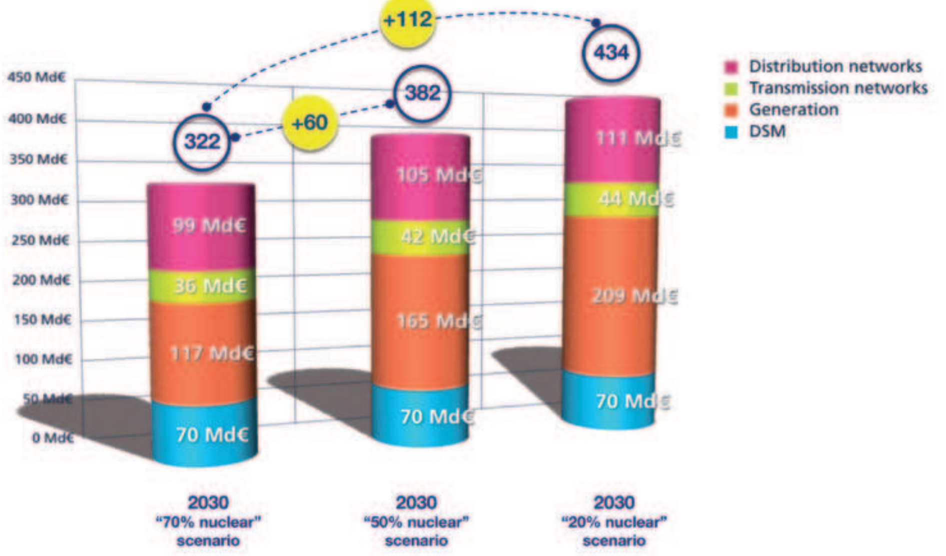
Investments

For each scenario studied, the total investment required over the period 2010-2030 was evaluated on the basis of the extension and development of generating facilities, the transmission and distribution networks, interconnectors, and investments in DSM.

These investments vary from €322bn to €434bn depending on the scenario. The investment cost required under the «70% nuclear» scenario is evaluated at €322bn. The «50% nuclear» scenario entails an additional cost of €60bn. Finally, the difference in investment required between the «70% nuclear» and «20% nuclear» scenario is €112bn.

With these levels of investment, it is essential for actors in the industry to have access to sufficient sources of financing.

INVESTMENT DIFFERENTIALS BETWEEN SCENARIOS



These investments imply new challenges for the sector:

- For deregulated operators working in the competitive environment (generation / retail) who look to the markets for financing, levels of return on investment are crucially important, especially in fossil fuel facilities which currently carry a high risk. It is therefore vital to have proper visibility and stability in public energy policies, together with a suitable market architecture.
- For the regulated operators (DSO, TSO), financing will also be an issue, as the markets will need to understand and sign up to the new electricity system that will be put in place.

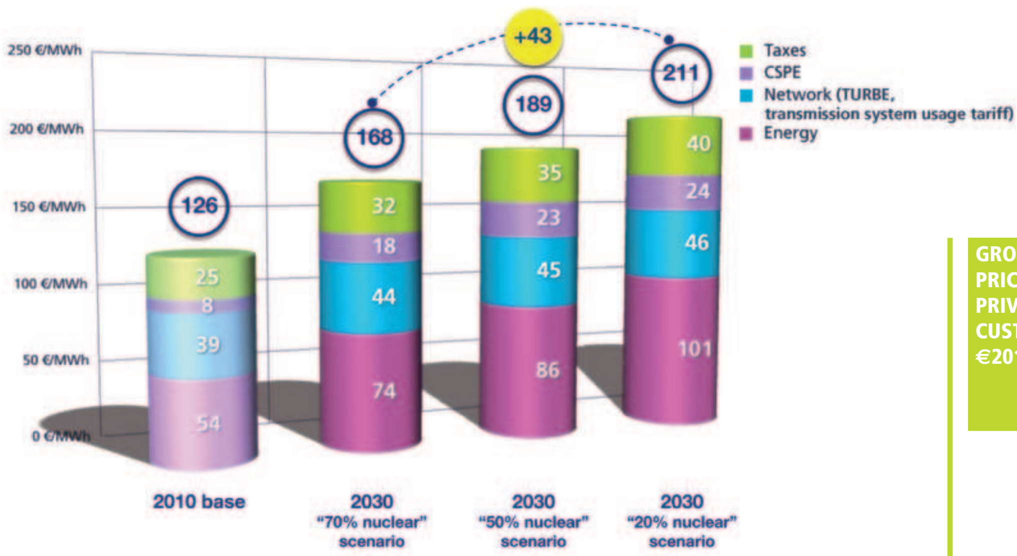
COMPARISON OF THE SCENARIOS

Impact on prices

Prices were calculated in constant euros (base: 2010).

For private customers

Prices for private customers, minimum prices based on development costs for each scenario, are shown in the following graph:



GROWTH IN PRICES FOR PRIVATE CUSTOMERS €2010/MWH

Determining factors are:

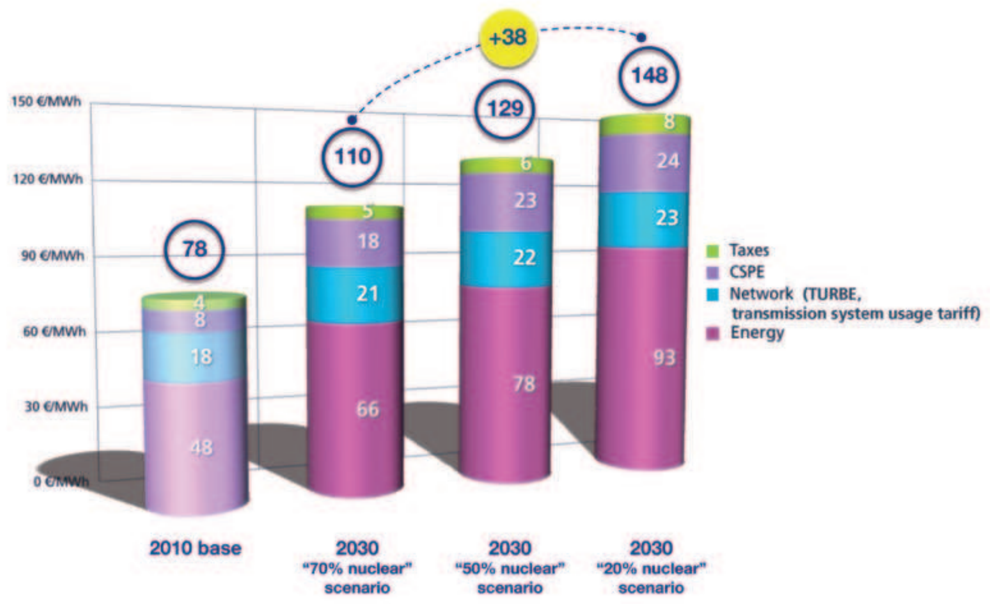
- the energy price, which rises higher the further we move away from the «70% nuclear» scenario,
- the CSPE (public service electricity contribution), which rises due to the development of renewables. Under the «20% nuclear» scenario (and to a lesser extent under the «50% nuclear» scenario), the influence of the cost of developing solar generation may cause the end price paid by customers to vary from -€2/MWh to +€1/MWh.

The price increase between the «70% nuclear» and the situation in 2010, is a reflection of the need to restore order to electricity prices, a process demanded by the industry and begun with the NOME law. The greater the likelihood of a scaling back of nuclear power (i.e. under the «20% nuclear» scenario), the steeper the price rise curve.

For businesses

The effect of moving from one scenario to another is shown by the diagram below. The influence of energy prices and the CSPE is crucial here.

GROWTH IN PRICES FOR BUSINESSES €2010/MWH



Note that the price paid by businesses rises by €40/MWh between the «70% nuclear» scenario and the «20% nuclear» scenario. As a guide, €40/MWh is the state-regulated price (ARENH) for access to nuclear-generated electricity introduced under the NOME law reorganizing the electricity market, passed on July 1st 2011. It is therefore not unreasonable to assume that in the event of a withdrawal from nuclear power, this «advantage» would disappear.

This figure illustrates the relative competitive advantage enjoyed by France in Europe and the world (except in special cases) as a result of the investments made in nuclear power in the 1970s and 1980s.

Price sensitivity to fluctuating global fossil fuel prices

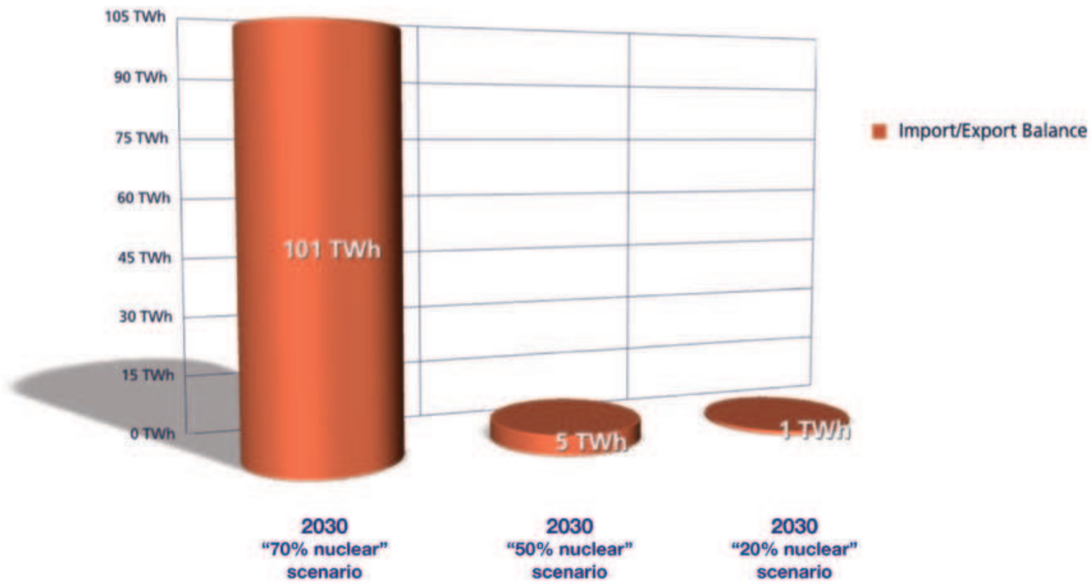
The greater the weight of gas (also applies to coal) in the generation mix, the more sensitive are electricity prices to fluctuations in fossil fuel prices. From being virtually nil under the «70% nuclear» scenario, this sensitivity reaches a volatility amplitude of €10 /MWh under the «20% nuclear» scenario. The volatility of the electricity price is therefore multiplied by 10.

COMPARISON OF THE SCENARIOS

This adversely affects France's competitive advantage over other countries.

The balance of payments

Electricity imports and exports



ELECTRICITY IMPORT/EXPORT BALANCE

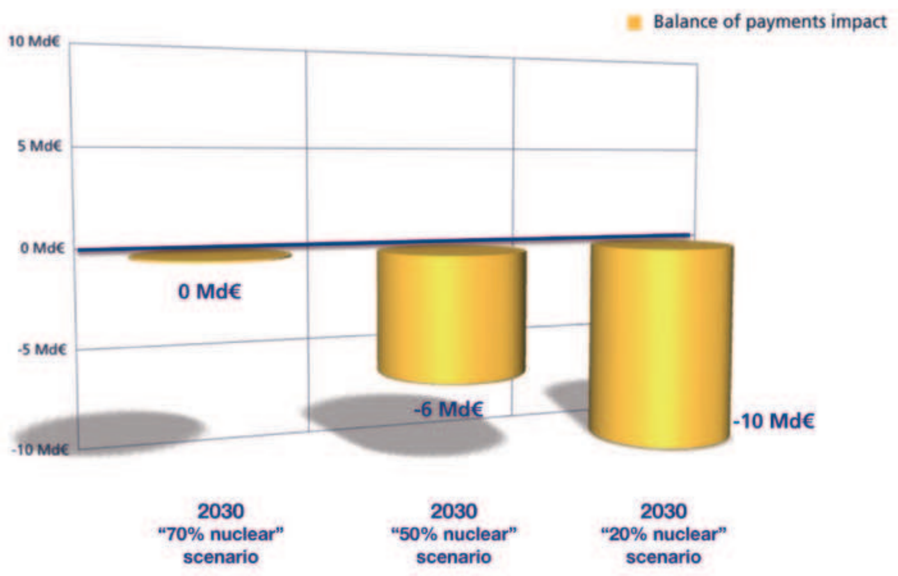
Under the «70% nuclear» scenario, France exports massive quantities of energy. Whilst the import/export balance is low under the «50% nuclear» and «20% nuclear» scenarios, cross-border exchanges will be very substantial indeed, due to the intermittent output of the new generating facilities developed. As a consequence, and this is true of all the scenarios, the development of interconnectors is strategically highly important for securing the power system, and economically justified.

The configurations of the generating fleet are calculated so as to guarantee that France is energy self-sufficient under normal climatic conditions.

The scenarios' influence on the balance of payments in France

This is shown in the diagram below.

IMPACT OF SCENARIOS ON FRENCH BALANCE OF PAYMENTS



The calculations were carried out by evaluating electricity exports on one hand, and on the other hand the purchases of fuels (uranium, coal, gas, etc.) needed to operate the fleet under each scenario. Other commercial flows, such as exchanges of equipment, were not taken into account in these calculations. The costs adopted were those given by the IEA and the French DGEC.

The «50% nuclear» and «20% nuclear» scenarios lead to a significant deterioration in France's energy independence, and therefore its balance of payments.

The impact of the «50% nuclear» and «20% nuclear» scenarios is therefore significant, in terms of reducing the financial resources available to the French power system.

Overall, the greater the extent to which France scales back its reliance on nuclear power, the poorer the country will become, forcing it to find other sources of export income to finance its energy requirements.

In order for renewables and fossil fuels to have a neutral impact on the balance of payments, both of these technologies would have to develop as part of national industries, exporting at least as much as they import.

As regards renewables, if France were able to develop national industries of excellence (as is already the case for hydro-electricity), then the result would be more positive (the «70% nuclear» scenario) or less unfavourable («50% nuclear» or «20% nuclear» scenarios).

GLOSSARY

CO2 : Carbon - DSM : Demand Side Management - NETSO : National Electricity Transmission System Operator - CCGT : Combined Cycle Gas Turbine - CCS : Carbon Capture and Storage - DSO : Distribution System Operator - TSO : Transmission System Operator - GDP : Gross Domestic Product - EPR : European Pressurized Reactor - PPI : Industrial Investments Plan - CEE : Energy Efficiency Certificates