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An analysis of energy scenarios to 2050, undertaken at the behest of the French Minister of Industry, Energy and the Digital Economy, offers some answers regarding the future of the French energy mix and the role that nuclear energy should play in a context of climate-related restrictions that will grow increasingly strict over time. This analysis first stresses the key role that energy efficiency must play. In terms of nuclear energy, which is currently a major political issue, our analysis finds that the optimum trajectory for France consists in extending the operating life of existing nuclear power plants as long as the French Nuclear Safety Authority (ASN) allows. This would imply planning a small number of third-generation nuclear reactors (EPR) in order to smooth power generation when the oldest nuclear power plants will be shut down, and laying the foundation for the future by pursuing the development of fourth-generation plants, alongside renewable energies. The study found that no decision should be made yet on the issue of nuclear power's share in the energy mix in 2050, or even in 2030, as this will depend on several factors, including the success of energy management policies, decreasing renewable energy costs, technological breakthroughs, experience feedback of French and foreign EPRs in operation, and natural gas prices. ■

PROPOSALS

1. Make energy conservation and energy efficiency a great national cause; launch a call for proposals, in order to mobilise R&D and innovation in this area, while focusing on the construction and transport sectors.

2. Refrain from any administrative shutdown of a nuclear power plant that has not been decided by the operator at the request of the Nuclear Safety Authority.

3. Refrain from setting, today, an objective for nuclear power's share of the energy mix, whatever the horizon; refrain from compromising the future of this industry, which means maintaining a long-term perspective by continuing to develop fourth-generation reactors. Extending the operating life of existing power plants therefore looks like the best solution (on the strict prerequisite that this is authorised by the Nuclear Safety Authority).

4. Consider an initiative in favour of international standardisation of nuclear safety rules and practices, to make them converge towards a higher level.

5. For each energy policy decision, assess the cost and impact on public finances, the balance of trade, CO_2 emissions and employment (in terms of both number of jobs and qualifications created), in comparison with a different decision, in order to set priorities.

6. Maintain or increase publicly funded research on energy through international cooperation, while placing top priority on joint programmes between public-sector laboratories and innovative companies (large and small) that are able to take on the global market. Special attention should be paid to renewable energies and energy storage.

7. Introduce greater transparency in energy and CO_2 emission prices, with special and separate measures for fuel poverty and energy-intensive industries.

8. Take the initiative of proposing to France's main European partners an in-depth review of EU internal energy market rules. The internal energy market is expected to facilitate the funding of the necessary investments, in particular those related to peak power demand, and to ensure consistency in decision-making.

THE CHALLENGES

On 19 October 2011, the French Minister of Industry, Energy and the Digital Economy asked Jacques Percebois, professor at Université de Montpellier-1, to chair a multi-partisan, open commission, with, as its vice-president, Claude Mandil, former executive director of the International Energy Agency (IEA) and vice-president of the European Commission's "Energy Roadmap 2050" consultation group; the task was to analyse the various energy policy scenarios for France by the year 2050.

The Minister called for an analysis of all energy sources and for a review of four particular options for France's future energy policy: i) extending the operating life of the current nuclear fleet; ii) accelerating the switch to third-generation and perhaps even fourth-generation nuclear power plants; iii) steadily reducing nuclear power's share in the energy mix; and iv) exiting from nuclear generation outright.

This analysis seeks to explain the multi-annual investment plan that the French Parliament will have to debate in 2013 and whose main objective will be to identify the best investments to secure the country's energy supply[1].

(1) "Énergies 2050", rapport, 197 p., February 2012.

THE KEY POINTS

The global and European energy context

Global energy demand is trending sharply upward and could double by 2050, driven by population and economic growth, particularly in emerging economies, especially China and, in the medium term and based on its current demographic trend, India. Emerging economies, particularly the four "BASIC" countries (Brazil, South Africa, India and China), as well as Middle Eastern countries, will "make" the energy markets and the energy prices to a far greater extent than OECD countries, and these parameters will therefore become increasingly exogenous to France's own policies. Fossil fuels, led by oil, currently account for 80% of energy supplies. This global dependence on fossil fuels raises the issue of sustainability in terms of both environmental impact and raw material supplies. While global fossil fuel supplies look abundant enough to cover future needs, they are increasingly difficult to access. Exploiting them requires massive investments in infrastructure, while the geopolitical context is, by nature, uncertain. Meanwhile, climate-related constraint is likely to emerge earlier than geological ones.

The dynamics are different in Europe, in part because population and economic growth are weaker. Europe's energy consumption has been relatively stable since the first two oil crisis. However, the share of fossil fuels in Europe's energy mix is very close to the mean global share and raises the same questions of sustainability. But in addition, Europe is highly dependent on the rest of the world, as it is a very large net importer of energy. One way the European Union is seeking to meet these challenges is its "Climate and Energy Package" which sets binding targets for 2020. Looking beyond 2020, the European Commission has produced a report, "Energy Roadmap 2050", to assess the various scenarios that are compatible with the target of cutting CO_2 emissions four-fold by 2050 (called "factor 4"). *Energy Roadmap 2050* has found that meeting this target will require massive investments in all energy sectors. Nevertheless, there are great uncertainties over costs, acceptability and the required means, particularly the technologies that would make it possible. The International Energy Agency's *Energy Technology Perspectives 2010* report stresses the importance of energy efficiency on a global scale, as this could account for about 40% of the 2050 emissions reduction target.

Two countries studied for this report have undertaken forecasts on this scale: Germany and the United Kingdom. Germany has made an exit from nuclear power a priority in reaction to the Fukushima accident. Its "Energiekonzept 2050" plan, which preceded the Fukushima events, already assumed a halving in energy demand by 2050 (made possible in part by Germany's shrinking population) and substantial use of renewable energies. The complete exit from nuclear power that has been decided since then will be offset in the short term by an increased use of fossil fuels (coal and gas mainly), imports, and the European power grid, while pushing climate-related objectives into the background. In the longer term, by apparently ruling out one of the technologies possibly leading to the "factor 4", Germany energy mix will be made less flexible. Challenges that Germany must meet in the coming years include stabilising the German (and European) power grid, which is currently subject to sharp fluctuations, as well as resolving the problem of low financial returns on new gas-fired power plants that are meant to provide back-up power[2] only on limited durations, building massively power lines (more than 4300 km of new high-voltage lines), and controlling the costs of renewable energy subsidies. Meanwhile, the United Kingdom is developing an approach based on a broad portfolio of low-carbon technologies that includes renewable energies, nuclear power and carbon capture and storage (CCS), with a view to technological neutrality and an economic optimum. It is focusing particularly on offshore wind power and wants to build 19 GW of electricity generating capacities, probably either gas-fired or nuclear, to replace older coal-fired plants. After several decades of deregulation, the United Kingdom has begun returning to regulations that promote the development of the most competitive decarbonised energies, in order to meet its greenhouse gas emissions target and to cope with the challenge of a massive replacement over a period of 10 to 15 years of its ageing fleet of power plants.

The challenges facing the French energy mix and the uncertainties involved

While France's energy dependence has shrunk considerably since 1973, due mainly to its construction of a fleet of nuclear power plants, its energy mix still depends closely on fossil fuels, which cover 70% of final energy consumption. Its resulting energy bill reached €46.2 billion in 2010, the equivalent of its trade deficit (€51.4 billion). With more than €60 billion spent as of October 2011 over a rolling year, the bill will be even heavier in 2011, due to higher oil prices. In this context, France's electricity generation infrastructure gives it the advantage of carbon-free electricity that is inexpensive and whose export reduces the country's deficit. In the last 20 years, France has been a net electricity exporter (in average with a surplus equal to €2.3 billion annually in current euros). Nuclear power generation also saved it €20 billion in 2011, based on a rough estimate.

The future energy mix will depend on many uncertainties: 1) the real but slow progress in international climate negotiations, which are casting doubt on governments' determination to effectively reduce their greenhouse gas emissions and do not provide sufficient visibility to economic agents on the future of carbon constraints; 2) hydrocarbon prices, which are uncertain and volatile; 3) the European internal market, which is enhancing the security of its member-states' supplies, but whose architecture must be improved in order to help building electricity generating capacities that can take over from intermittent energies when they do not work, the so-called "back-up" capacities. At certain times and despite their geographical diversity, the electricity output of all Europe's wind farms represents only about 5% of the total installed capacity; and 4) the refining industry is shifting increasingly to Asia, which raises the challenge of keeping less-efficient refineries in operation.

France's energy situation faces three challenges: to diversify forms of energy, to enhance energy efficiency, and to provide manœuvring room. For the first two challenges, the *Grenelle de l'environnement* initiative, including the recent national round table on energy efficiency, has adopted an ambitious roadmap to 2020, which will be extended beyond this date, in particular in close links with the European discussions. For the third challenge, France differs from its neighbours in that its electricity is generated mostly by a nuclear fleet that was built in only a little more than a decade. Hence, around the 2020s, several dozen reactors will reach their 40th anniversary. Even so, the fleet is still relatively young and with additional investments - important but nothing like what would require new equipments -, its operating life could be extended, subject to ongoing discussions between EDF and the Nuclear Safety Authority (ASN) and the ASN's ultimate decision. France is much better off in this area than the United Kingdom, which will have to replace its fleet massively in the short or medium term. The main technologies in the mix look predictable out to 2030 but are uncertain

(2) "Back-up" installations step into the void left by intermittent energies when they do not produce (replacement by fossil fuels).

beyond that date. So 2030 is shaping up as a watershed year. On the one hand, no premature bets should be placed on any technologies for 2030, while options should be kept open beyond 2030. This will be easier to do if the current nuclear fleet's operating life is extended.

Infrastructures planned under the next multi-annual investment plan *(PPI)* for electricity generation are subject to the approval of local residents. Public opinion is currently favourable to renewable energies and less favourable to nuclear power in the aftermath of the Fukushima disaster, but is still energy price-sensitive. Given the opposition expressed to most infrastructure projects, regardless of the energy, public consultation and debate are crucial. This is especially the case for grids, which will require significant investments. Power grids will require €135 to 155 billion in funding by 2030 to develop new transmission lines, reinforce distribution grids and introduce smart grids.

Hence, an appropriate energy mix for France, within the European Union, must be technologically feasible, guarantee secure supplies in a weaker European context, reduce France's greenhouse gas emissions, and promote its competitiveness. It must therefore be designed under an industrial policy that makes it possible to master the technological choices of the future. And, lastly, given the main uncertainties that we will face, it must remain flexible and not close the door too early on technological options.

An analysis of the French energy mix by 2050, based on an examination of various models

We examined various energy scenarios for France. Most of them (except for NégaWatt and Négatep) limit the scope of their study to the electricity sector, from now till 2030. Some scenarios have been devised by NGOs or associations (NégaWatt, Global Chance, Négatep), others by sector players (Enerdata/DGEC, RTE, French Electricity Union, AREVA and the French Atomic Energy Commission (CEA)). NégaWatt and Global Chance target a total exit from nuclear power, and they have imagined radical changes in our lifestyles (denser urban areas, changes in diets, etc.). To reduce CO_2 emissions, Négatep proposes an increased use of decarbonised electricity in all areas. Others scenarios take into account various options, in particular differentiated by nuclear power's share in the total energy mix (complete exit, 50% or 70% in 2030 energy output, or an accelerated switch to EPR).

Looking to 2030, there are few differences between the scenarios in terms of electricity demand except in the case of Négawatt and Global Chance, which are especially ambitious in their assumptions on energy demand management. A review of these scenarios in regard to energy demand highlights three core points: i) the crucial role of energy demand management and energy conservation (in the sense of reducing demand), essential for any energy mix chosen; ii) the existence of an important potential of energy savings, but which in some cases are hard to tap and are generally poorly documented; and iii) the cost-effectiveness of energy efficiency initiatives.

The scenarios offer a wide range for the electricity mix, but are based on extremely contrasted methodologies and assumptions, in particular on balancing supply and demand, operating times of production units, the electricity balance of trade, and the necessary trajectories for achieving the mix presented for 2030. So the overall results must be compared carefully.

Under most scenarios, exiting from nuclear power requires heavy investments, which are already high due mainly to the French 2050 emissions reduction target. This will obviously result in higher electricity generation costs in the total electricity bill, as well as in terms of CO_2 emissions, barring a massive switch to decarbonised energies. This could be mitigated by a very sharp cut in energy consumption, but this would not reverse the trend. In terms of acceptability, each solution stresses societal constraints, which are real but vary widely from one scenario to another: 1) accepting nuclear power in line with the multi-annual investment plan; 2) expanding grids aggressively and setting up new infrastructure under scenarios based intensely on renewable energies; 3) making radical changes to society under the extreme scenarios of NégaWatt or Global Chance. Lastly, regarding the employment issue, estimating net job creations within the energy sector is not enough studied by the scenarios so that we could draw precise conclusions.

Our main conclusions

The scenarios we examined include a wide range of energy systems based on models that are, in some cases, extremely developed. Even so, in most of the scenarios there is room for improvement in energy demand, as this parameter is decisive for changes in the energy system, as was acknowledged by the recent national round table on energy efficiency. In designing the next multi-annual investment plans, it seems useful to have a fuller set of modelling (designed in part for the French system) so that we could estimate the cost-effectiveness and energy efficiency of the various measures and, hence, to assess the real energy savings' potential. Such tools could also be used to better decide between energy savings measures and a decarbonisation of the production side.

It was also difficult to quantitatively assess the consequences of renewable electricity sources on transport and distribution grids and in particular whether any threshold effects exist. However, the 2020 renewable energy targets are perfectly feasible and these renewable units could be integrated into the existing grids with a reasonable investment. Many scenarios' carbon value assumptions are also poorly documented.

Despite these limitations and the uncertainties of the exercise, some robust conclusions can be drawn from the examination of these scenarios. First of all, for any option, cutting CO_2 emissions four-fold will require important investments. A distinction should be made between the 2010 - 2030 timeframe and the 2030 - 2050 timeframe. The first is relatively set in terms of the technologies to be used, while the second presents far more uncertainties but also opportunities for which we must be prepared. The grid impact can be decisive in assessing the various scenarios: those that most disrupt the current structure are also those that are the least feasible; contrary to the conventional wisdom, this is not a matter of going from "producing nationally to consume nationally" to "producing locally to consume locally" but, rather, "producing locally to consume globally" (due to the intermittence of renewable energies and the distance between production units and consumption location), and even "producing globally to consume globally" with offshore mega-wind farms in the North and solar power plants in the South. Beyond 2020, scenarios that are based mostly on renewable energies could have a major impact on grids. Setting the right balance is crucial to go significantly beyond France's current targets.

In terms of industrial policy and research and development (R&D), the challenges of "green growth" should be addressed with ambition and clearly. France cannot be on every step of the value chain of all energies; it will have to be realistic, basing itself on the comparative advantages of its industry, R&D, etc. An analysis of the value chain has found that creating jobs that cannot be offshored depends on each type of energy and on our industrial history. A Malthusian zero-sum approach consisting in offsetting jobs rather than adding new ones should be avoided. We must keep a clear head on the probability that some industrial activities will be offshored to emerging economies, because of a better access to capital, labour, and because of their capacity to mobilise mass production.

Regarding R&D in particular, one priority is decarbonised vehicles, storage technologies, and more generally, regarding renewable energies, technologies that are not yet mature but for which exist already acquired experienced and future technologically disruptive patents that can create value, regardless of their importance for the strictly French market (CCS or photovoltaics, for example).

We examined in detail the four major options that the Minister asked to be assessed (accelerating the switch to third- or even fourth-generation nuclear power, extending the operating life of plants, gradually reducing nuclear power, and exiting from nuclear generation outright). Our analysis shows clearly that limiting operating life to 40 years would have an impact on some or all of the major constants in French energy policy, i.e., secure supplies, environmental protection (notably *vis-à-vis* climate change) and economic competitiveness.

While acknowledging the limits to this exercise, we have put forth some quantitative elements, whose findings depend on assumptions of relative prices or technological investments, parameters that are hard to predict. Even so, these estimates indicate that, for any assumptions' set, the average cost of one megawatt-hour of electricity in 2030 will be lower if the operating life of nuclear power plants have been extended. The relative cost per megawatt-hour of the other options is closely correlated to the assumptions, and additional research would be necessary to determine it more precisely. All in all, for about 60 reactors, on top of the loss of value due to the "non-extension" of reactors potentially able to operate for another 10 to 20 years, a second effect would come from the fact that closed nuclear reactors would be replaced by plants that would be far more expensive to operate, regardless of their type. The order of magnitude of this loss of economic value would be about €100 billion or more. Even so, this is especially a medium-term impact, as the cost of renewable energies is likely to fall until they mature (except for the cost of inputs such as concrete, steel, raw materials, etc., which, incidentally, all forms of energy are subject to). Regarding electricity generated from fossil fuels, which is more expensive than that generated from the existing nuclear power plants but as competitive as new nuclear power plants, the main impact will be on CO_2 emissions and will therefore depend on the estimated cost of emissions.

The average cost per megawatt-hour and, hence, electricity prices, will be decisive for the economic impacts of the electricity mix. Higher electricity prices affect households' purchasing power, companies' competitiveness, and France's balance of trade, while they also contribute to lower electricity demand. Hence, a 20% reduction in nuclear power's share by 2030 could raise electricity prices by 20% to 30% (depending on the category of consumer) compared to the prices that would result from keeping nuclear power's share at current levels, which itself would require a major increase in investments and, hence, an increase of costs. This analysis also shows that if nuclear power's share was reduced by 20%, the full cost of generating electricity would be more than 50% higher by 2030 than if the operating life of existing plants were extended.

Despite differences between the economic models, they all agree that shifts in the electricity mix will result in a variation of only a few thousands or tens of thousands of jobs within the electricity generation sector. Obviously, these changes would have to come with suitable training or retraining policies. In contrast, the models suggest that the price effect prevails and will considerably impact the national economy, The options of reducing nuclear power's share could result in 100,000 to 200,000 job losses compared to a scenario where nuclear's share is maintained.

THE FOUR OPTIONS

"Energies 2050" Commission's objective was to assess France's various possible options up to 2050. To do so, four options for shifting electricity supply were reviewed:

1 ▸ accelerating the switch to third-generation nuclear power;

2 ▸ extending the operating life of the current nuclear fleet;

3 ▸ gradually reducing nuclear power;

4 ▸ exiting from nuclear generation outright.

These four options were analysed on the basis of criteria such as electricity costs, investment needs, CO_2 emissions, jobs' impact, GDP, and their impact on France's balance of trade and on secure supplies.

In the four options, cost is central to the analysis. Full production costs were assessed, including investment/operating, maintenance and fuel costs, but not the cost of demand management, grid-management costs, and back-up costs incurred under each of these four options.

The assumption made on operating times of GCC (gas-fired combined cycle) plants is decisive for estimating the full cost of production. Under various options, GCC plants that replace nuclear power plants have been assumed to operate on a continuous basis (7000 h/year), with the GCC plants backing up intermittent energies operating at 2500 h/year. This is a simplifying assumption. Ideally, their operating times should be calculated for each option.

Keep in mind also the high opportunity cost of shutting down, after 40 years, a nuclear reactor that has been deemed safe to operate for up to 60 years. As an illustration, the net discounted cost (to 2012) of shutting the Fessenheim plant down, after 40 years instead of 60 years, is about €1 billion (or €2 billion in 2020 NPV when shutting it down after 40 years).

Keep in mind also that, under all the options, investments in electrical grids will be massive, between €135 and €155 billion, depending on renewable energies' share in the electricity mix, three quarters of which will be for the distribution grid.

Accelerating the switch to third-generation plants

Under this option, existing reactors would be replaced by third-generation (EPR) reactors upon their fourth 10-year inspection ("40 years").

- **Challenges:** this option raises two main challenges: being able to build at least two EPRs annually within 10 years (from 2020 to 2030), which would require starting up an entire production chain. This result seems difficult to achieve by 2020. Moreover, €10 to €12 billion in annual investment would be required for more than 10 years.
- **Electricity generation costs in 2030:** the full cost of electricity production has been estimated at between €60 and €73/MWh in 2030 under the option studied by the Commission calling for accelerating the switch to third-generation plants. However, these figures are to

be treated with caution, as they are closely correlated to assumptions on an EPRs' electricity generation costs (we have assumed a range of €55 to €75/MWh). In reality, the cost would rise as the nuclear fleet is renewed, then level off over a long period, given EPRs' operating life.

- **CO_2:** under this option, the electricity sector's CO_2 emissions are similar to those of extending the operating life of existing plants (20 Mt of CO_2 in 2030).
- **GDP and employment:** this option was not specifically analysed with the macroeconomic model used by this Commission. However, the results from this model for the other options highlight the importance of the energy costs. The opportunity cost could therefore reach €10 billion annually once the fleet had been replaced, which would lead to job losses.
- **Balance of trade:** the impact on electricity generation's balance of trade depends mainly on fossil fuel and uranium costs and electricity export prices. The equilibrium of the balance of trade could be reached.
- **Supply security:** there is no true difference between this option and the option of extending the plants' operating life, nor with the current situation.

Extending the operating life of existing nuclear power plants

Under this option, existing plants would continue to be operated until their sixth 10-year inspection ("60 years"), as long as they meet ASN standards.

- **Challenges:** the scale of the industrial programme necessary for extending the life of existing plants must not be overlooked. In addition, the risk of an ASN-ordered premature reactor closing must be taken into account.
- **Electricity generation costs in 2030:** electricity generation costs in 2030 have been estimated at between €52 and €59/MWh, depending on the assumptions used for the production costs of existing plants (i.e., between €35 and €43/MWh in 2030). However, depending on the technologies available at the time of replacement, and in particular on the lessons learnt, production costs will rise in hard-to-predict proportions. By 2050, most of the current fleet will have been replaced, and electricity generation costs will have shifted accordingly.
- **Investments:** most regeneration investments will be made in the next 15 years, with a cumulative amount of about €55 billion. Massive investments to renew the fleet would begin in 2030, but they could be anticipated, in order to smooth over the transition and to place the priority on safety. These investments will depend on the technology chosen by then to replace the current fleet. Meanwhile, extending plants' operating life gives some potential substitute technologies time to reach technical and economic maturity, with a view to decarbonising the energy mix.
- **CO_2:** CO_2 emissions from the electrical sector in 2030 would be about 25 Mt of CO_2/year.
- **GDP and employment:** keep in mind that employment in the electricity generation sector varies little from one option to another. The decisive factor is electricity cost. Hence, the option of extending the operating life of the current fleet is, from this point of view, the most favourable, as it maximises GDP and employment, all other things being equal (notably in terms of demand).
- **Balance of trade:** the impact on the electricity generation's balance of trade depends in particular on fossil fuel and uranium costs and electricity export prices. The equilibrium of the balance of trade could be reached.
- **Supply security:** identical to the current situation.

Gradual reduction in nuclear power

Under this option, nuclear reactors would be decertified after 40 years and replaced on a "1 for 2" basis by EPRs. The others would be replaced by a mix of renewable energies and fossil-fuel-fired thermal power plants (GCC plants mainly). This option assumes a sustained development of renewable energies (mainly wind power, followed by photovoltaic) and of thermal electricity generation to replace nuclear power.

- **Challenges:** the opportunity costs incurred by early shutdown, renewable energy subsidies, maintaining nuclear skills to manage existing power plants, and limiting CO_2 emissions. This option would also require aggressive development of grid-interconnection capacities with neighbouring countries.
- **Electricity generation costs in 2030:** the full cost of production would range from €69 to €79/MWh, depending on nuclear power and gas price assumptions. The 2030 snapshot hides the changing reality, i.e., costs rise as the current fleet is replaced. In the longer term it depends on trends in the costs of various means of production.

- **CO_2:** CO_2 emissions of the electricity sector in 2030 would rise to more than 30 Mt of CO_2/year (vs. about 20 Mt of CO_2/year if installed nuclear capacity was maintained at current levels).
- **GDP and employment:** compared to a scenario of maintaining nuclear power's share at 70%, GDP would fall by 0.6% in 2030 and about 140,000 jobs would be eliminated (due to the knock-on effects on employment, i.e., lower purchasing power due to higher electricity prices, which is much greater than the effect on jobs in electricity generation sector).
- **Balance of trade:** gradually reducing nuclear power's share would mean shrinking electricity export capacity and increasing fossil fuel imports. This could lead to a deficit in the electricity generation's balance of trade of as much as €8 billion annually.
- **Supply security:** supplies would be more diversified than under a scenario of extending the operating life of nuclear power plants. On the other hand, fossil fuels imports would increase.

Exit from nuclear generation outright

Under this option, nuclear power plants would be decertified after 40 years and mostly replaced either by renewable energies or by fossil-fuel installations.

- **Challenges:** the challenges are identical to those of gradual reduction, but on a tighter timeframe, which would also require heavier investments, a disruption in the transport/distribution grid and foregoing, at least initially, new uses of electricity such as electric vehicles.
- **Electricity generation costs in 2030:** the full cost of production would range from €92 to 102/MWh, with heavy use of renewable energies, and from €80 to €89/MWh with heavier use of fossil fuels. The usual precautions described above apply especially to these scenarios, as this would involve a major disruption to grids, as well as, for the options involving heavy use of renewable energies, developing a large number of substitute resources.
- **CO_2:** depending on the extent of back-up, CO_2 emissions from the electricity sector in 2030 would rise to about 45 Mt of CO_2/year with aggressive development of renewable energies, or to about 120 Mt of CO_2/year if the focus was on fossil-fuel technologies.
- **GDP and employment:** compared to a scenario of maintaining nuclear power's share at 70%, 200,000 jobs would be lost (figure given as an order of magnitude) and GDP would shrink by 0.9% by 2030 under a "20% nuclear" scenario like that the one of the French Electricity Union (UFE), due to the knock-on effects on employment, i.e., lower purchasing power due to higher electricity prices, which is much greater than the effect on jobs in electricity generation sector.

Production costs of replacements of the original nuclear power plants could be twice as high, on average. Hence, opportunity cost could reach €20 billion annually once the fleet has been replaced. In all, the cost of an outright exit from nuclear power could be about €100 billion in 2010-2030 on an NPV basis (loss of GDP).

- **Balance of trade:** an exit from nuclear power would lead to a reduction in electricity export capacity and greater fossil fuel imports. If massive use is made of renewable energies, electricity generation's trade deficit could be as high as €10 billion annually, and as high as €20 or 30 billion annually if massive use is made of fossil fuels.
- **Supply security:** if massive use is made of fossil fuels, France's dependence on them would rise. Conversely, a focus on intermittent renewable energies would raise the issue of electricity security, barring an electricity storage solution.

COMPARING THE FOUR OPTIONS

- **Challenges:**
  - the option of accelerating the switch to the third generation requires meeting two main challenges: being able to build at least two EPRs annually within 10 years (from 2020 to 2030), which would require starting up an entire production chain. This looks like a hard pace to reach by 2020. Moreover, €10 to €12 billion in annual investment would be required for more than 10 years.
  - under the option of extending the operating life of the existing nuclear fleet, the scale of the industrial programme necessary must not be overlooked. In addition, the risk of an ASN-ordered premature reactor closing must be taken into account.
  - the option of gradually reducing nuclear power incurs opportunity costs from early shutdown, renewable

energy subsidies, maintaining nuclear skills to manage existing power plants, and limiting CO_2 emissions. This option would also require aggressive expansion of grid-interconnection capacities with neighbouring countries.

- in addition to the above constraints, the nuclear exit option would involve a tighter timetable, which would also require heavier investments, a disruption in the transport/distribution grid and foregoing, at least initially, new uses of electricity such as electric vehicles.

- **Electricity generation costs in 2030:**
  - under the option of accelerating the switch to third-generation power plants, the full cost of electricity production has been estimated at between €60 and €73/MWh in 2030;
  - under the option of extending the operating life of the original nuclear fleet, electricity generation costs in 2030 have been estimated at between €52 and €59/MWh;
  - the full cost of production under the option of gradually reducing nuclear power has been estimated between €69 and €79/MWh;
  - under the nuclear exit option, the full cost of production has been estimated at between €92 and €102/MWh with massive use of renewable energies, and at between €80 and €89/MWh with a focus on fossil fuels.

The 2030 snapshot hides the changing reality, i.e., costs rise as the current fleet is replaced, as all substitute production means are more costly. Hence, they rise earlier under options in which the current fleet is rapidly decertified. They rise at the end of the reference period under the option of extending operating life, but, depending on what technologies are available at the time of renewal and their costs, production costs will trend upward in hard-to-predict proportions.

- **Investments:** by 2050, regardless of the option, the vast majority of the original nuclear power plants will have been replaced. Hence, assumptions on cumulative investments out to 2050 include in all cases the replacement of the current fleet. However, the timing differs appreciably between extending the operating life of the current fleet and the other options, where investments increase intensely over the years 2020-2030. Meanwhile, the option of extending operating life makes it possible to benefit from any lessons learnt and, hence, to possibly reduce investment costs for certain technologies between now and 2040.

- **CO_2:** under the options of extending the operating life of the current fleet or accelerating the switch to third-generation plants, CO_2 emissions from the electricity sector would be about 25Mt of CO_2 in 2030.

A partial or total exit from nuclear power would result in greater emissions, even if most nuclear plants were replaced by renewable energies, due to the need for back-up fossil-fuel power generation. Depending on the degree of back-up, emissions would exceed 30 Mt of CO_2/year in 2030 under a partial exit, 45 Mt of CO_2/year under a total exit with aggressive development of renewable energies, and almost 120 Mt of CO_2/year under a total exit if the focus was out on fossil-fuel technologies.

- **GDP and employment:** keep in mind that employment in the electricity generation sector varies little from one option to another. The decisive factor is electricity cost. Hence, the option of extending the operating life of the current fleet is, from this point of view, the most favourable, as it maximises GDP and employment, all other things being equal (notably in terms of demand).

No macroeconomic model was done on accelerating the switch to the third generation. However, an EPR's production costs are at least 50% higher than those of the existing fleet. The opportunity cost could therefore reach €10 billion annually once the fleet was replaced, which would mean a loss of jobs, based on the above argument.

A partial exit from nuclear power could mean a 0.6% decline in GDP in 2030 compared with the option of extending operating life, and 0.9% compared to an outright exit. In both cases, the cost of building infrastructure to replace original nuclear power plants can average twice as much. Hence, the opportunity cost could reach €20 billion annually once the fleet has been replaced. All in all, an outright exit from nuclear power could cost a net present value of about €100 billion from 2010 to 2030 (loss of GDP).

Analysis of the four options						
Options / criteria		**Full cost of electricity generation in 2030**	**C02 emissions in 2030**	**GDP and jobs in 2030**	**Balance of trade**	**Supply security**
1. Accelerating the switch to third-generation plants		€60 to €73/MWh	- 25 Mt of C02/year			=
2. Extending the operating lives of the current fleet		€52 to €59/MWh	- 25 Mt of C02/year	=	=	=
3. - Gradual reduction in nuclear power		€69 to €79/MWh	between 30 and 50 Mt of C02/year	-	-	Diversified sources but fossil fuel imports increase
4. Outright exit from nuclear power	Substitution by renewable energies	€92 to €102/MWh	- 45 Mt of C02/year depending on the back-up	-	-	Possible energy security problems
	Substitution by fossil fuels	€80 to €89/MWh	-120 Mt of C02/ year depending on the back-up	--	--	Fossil fuel imports increase

According to the estimates of the NEMESIS[3] model, about 140,000 jobs would be eliminated by a partial exit from nuclear power and 200,000 by an outright exit.

- **Balance of trade:** under the options of extending the operating life of existing plants and accelerating the switch to third-generation plants, there is little impact on the balance of trade. This depends mainly on fossil fuel and uranium costs and electricity export prices.

This option could lead to a deficit in the electricity generation's balance of trade of as much as €8 billion annually.

An outright exit from nuclear power would lead to a 0.1% increase in imports and a 0.65% reduction in exports, hence a sharp worsening in France's balance of trade. It would reduce the ability to export electricity and increase fossil fuel imports. The electricity generation deficit in the balance of trade could be as high as €10 billion annually for options focusing on renewable energies, and up to €20-30 billion annually when fossil fuels are used massively.

- **Supply security:** the options of extending the operating life of the current fleet and accelerating the switch to third-generation plants would have no impact on the security of France's energy supplies.

A partial or total exit from nuclear power would make it possible to diversify electricity supply sources. However, under every option, fossil fuel imports rise, particularly under the outright exit option with heavy use of fossil fuels. Massive use of intermittent renewable energies would raise the issue of energy security, barring an electricity storage solution.

CONCLUSIONS

The working group's discussions highlighted some basic facts that must be part of any future energy policy decisions.

1 ▸ There is no such thing as energy without drawbacks, nor an ideal scenario, nor an ideal trajectory for achieving such a scenario if it did exist. Each scenario requires weighing advantages and drawbacks, and the public must be kept fully informed of these advantages and drawbacks. Partial or simplistic analyses, those that offer only advantages while overlooking drawbacks, must be ignored, regardless of where they come from. Some scenarios would clearly require revolutions in individual and social behaviour that are neither credible nor desirable. True, all of us shall have to adapt our behaviour to new constraints, in order to save a form of energy that could be expensive and heavily polluting, but not at the price of going

(3) Laboratoire Érasme of the École centrale de Paris.

it alone, a model that some scenarios call for, which would do nothing but manage shortage in all areas of everyday life.

2 ▶ France is not isolated energetically. It sources world markets; it takes full part in the major undertaking of progress and solidarity that is the European Union; its companies compete on world markets; climate restrictions are global by nature; and the financial crisis is deep and long-lasting. That doesn't mean that an autonomous policy is not possible, but that we cannot act as if the outside world does not exist. Long-term trends in the global energy landscape are described in recent IEA publications and are often very different from what we see as necessary or desirable, including continuing increase in energy demand, in particular electricity, driven by the needs of emerging economies; the long-term prominent role of fossil fuels, coal in particular; oil's continued status as the energy for transport; the spectacular development of production of unconventional sources of hydrocarbons (oil and gas); the growing, but still moderate, role of renewable energies and nuclear power; and the fact that a large swath of humanity is still in an unbearable state of fuel poverty. We cannot deny this context; we must simply deal with it. Regardless of the choices that will be made, massive investments will be necessary, while taking into account the European construction and the opportunities that France has on emerging markets.

PROPOSAL 1

Make energy conservation and energy efficiency a great national cause; launch a call for proposals, in order to mobilise R&D and innovation in this area, while focusing on the construction and transport sectors.

3 ▶ Climate change in particular is creating significant constraints. According to IEA, about 30 billion tonnes (Gt) of greenhouse gas emissions are produced annually from energy generation and use and, even under the ambitious policies decided by many countries, these emissions could exceed 35 Gt in 2035. However to have a reasonable chance to meet the Cancun objective (limiting the long-term increase in the average temperature to 2°C), emissions should not exceed 20 Gt in 2035 and 13 Gt in 2050. This truly requires an immediate and complete shift in trajectory, using all the tools at our disposal. This is true on the supply side. Renewable energies, nuclear power plants and fossil fuels – and, hence the capture and sequestration of carbon dioxide – will be massively used. And it is just as true on the demand side. Indeed, all scenarios stress the importance of energy conservation (reduce consumption of energy-related services) and energy efficiency (reduce the energy consumed by the same service rendered). Granted, Europe, and even less so, France, cannot meet this challenge alone and it would be dangerous for the European economy to try to go for it alone, but, on the other hand, nobody would understand that Europe failed to do its part in this essential fight against climate change. In other words, and without underestimating the importance of the depletion of fossil energy resources, environmental protection is now superseding "peak oil" as a primary concern. The strategy France has adopted with the *Grenelle de l'environnement* reflects well the need to control demand and to diversify supplies by 2020. We now have to take action.

4 ▶ Policies under consideration will involve local governments to an increasing extent and municipalities in particular. This is true for energy efficiency, with its two priority targets being housing and transport. It is also true for the development of decentralised renewable energies, the development of district heating and the setting up of smart grids.

PROPOSAL 2

Refrain from any administrative shutdown of a nuclear power plant that has not been decided by the operator at the request of the Nuclear Safety Authority.

PROPOSAL 3

Refrain from setting, today, an objective for nuclear power's share of the energy mix, whatever the horizon; refrain from compromising the future; and maintain the long-term outlook for this industry by continuing to develop fourth-generation reactors. Extending the operating life of existing power plants therefore looks like the best solution (on the strict prerequisite that this is authorised by the Nuclear Safety Authority).

5 ▶ As a matter of fact, no one can predict what the energy landscape will look like in 2050. Just think back to what we would have written in late 1972 on the energy scenarios for the next 40 years, i.e., up to 2012! Uncertainty prevails in all areas: technological, economic, political, financial and even demographic. Flexibility is therefore essential. As decisive feature of an acceptable scenario is the ability to change it in mid-course to reflect unexpected factors, whatever the long-term scenario is. In the short term, we must make decisions that we can go back on, if necessary, decisions that do not close the door too early on options that could later prove to be essential. This is not the case with a number of the scenarios that we reviewed. Some, of course, ignore the need for conservation and efficiency, but others ignore R&D, CO_2 capture and sequestration, and electricity storage, which we may need in the future. Others recommend shutting down nuclear power plants before such shutdowns are ordered by the Nuclear Safety Authority.

Box

The cost of shutting down a 900 MWe reactor

Shutting down a power plant (nuclear or conventional) that is in operable condition and has been deemed safe by the Nuclear Safety Authority (ASN) means an opportunity cost for its operator and the local community that is worth estimating. Two calculations are proposed below:

- the first estimates the opportunity cost of an immediate shutdown;
- the second estimates the opportunity cost of shutting a plant down in 2020 (i.e., upon the fourth 10-year inspection), compared to extending its operating life to 60 years.

Their purpose is to give some order of magnitude.

a) Cost of immediate shutdown

A nuclear power plant of a capacity of almost 900 MWe produces about 6.3 TWh of electricity annually, based on an 80% production rate. In the short term (i.e., the first few years), the immediate shutdown of a nuclear power plant would force EDF to buy lost output on the market. Assuming a market price of €55/MWh and the operating cost of a nuclear power plant of €25/MWh (as cited by the Champsaur Commission), EDF's annual opportunity cost from a reactor shutdown would be €6.3 x (55 – 25) million, or about €190 million, not counting the investments necessary for extending operating life beyond 40 years and not counting investments for additional safety valuations. According to the information published on 28 November 2011, the ratings agency Standard & Poor's estimated at €400 million annually EDF's losses from a shutdown of the two Fessenheim reactors, which would lead to an immediate downgrade of its rating.

In the longer term, the market price is uncertain. Here it will be assumed that, in the event of an immediate shutdown of a 900 MWe plant, the electricity would be replaced by a gas-fired plant, whose full cost can be estimated at €70/MWh, assuming a gas price of $13/Mbtu. Assuming the plant's operating life was extended to 60 years, we have factored in the beneficial impact of postponing dismantling and the investments that would have to be made upstream and during the fourth 10-year inspection, which the French government auditing office, based on EDF's figures, estimates at almost €950 million per reactor, (hence €55 billion for the entire fleet), including measures that would be taken on the basis of additional safety evaluations. The operating cost we have assumed is that of the "Champsaur Commission". The opportunity cost, in terms of 2012 NPV (discounted at 8%) of an immediate shutdown of the plant, vs. extending its operating life to 2040 can thus be estimated at €3 billion.

A sensitivity analysis finds that:

- at 25% higher regeneration costs, or €1200 million, net present value (NPV) of the 900 MWe nuclear power plant would be €2.8 billion;
- an actual operating time of 55 years instead of the planned 60 years would lower its value by €2.8 billion;
- if replacement electricity prices were €55/MWh, its NPV would be €1.8 billion.

b) Cost of a shutdown after 40 years instead of 60 years

Based on the same assumptions but comparing the case of a plant shut down in 2020 with one shut down in 2040, opportunity cost, based on 2012 NPV, of an early shutdown would be about €1 billion (or almost €1.8 billion in NPV at the time of the shutdown, in 2020).

A sensitivity analysis finds that:

- at 25% higher regeneration costs, or €1200 million, its NPV would be €0.8 billion;
- an actual operating time of 55 years instead of the planned 60 years would lower its value by €0.8 billion;
- if replacement electricity prices were €55/MWh, its NPV would be €0.5 billion.

PROPOSAL 4

Consider an initiative in favour of international standardisation of nuclear safety rules and practices, to make them converge towards a higher level.

6 ▸ This is an opportunity to mention the decision that the "Commission Energies 2050" made, regarding the nuclear power safety, i.e., it refused to have an autonomous view on this particular topic. Indeed, France possesses a demanding, skilled and independent Nuclear Safety Authority *(Autorité de Sûreté Nucléaire)*. In accordance with the "Nuclear transparency and safety" law of 13 June 2006, ASN reports to the ministers in charge of nuclear safety, its independent findings on safety standards of the installations that it inspects. We therefore consider as safe any nuclear plant that ASN has stated to have an acceptable level of safety. However, it would be a matter of concern if safety standards would not achieve the French ones in every country that relies on nuclear power; we would then see a two-track world emerge, regarding nuclear safety. We will recommend that France take all useful initiatives to keep this from happening, by stepping up global governance in nuclear safety.

7 ▸ The development of wind power and photovoltaics beyond 2020 raises the issue of intermittence, which must not be underestimated when the share of such energy sources in the national electricity mix becomes significant. Special attention must be paid to any prospect for massive storage of energy and managing demand, but while addressing their costs. Energy-transfer pumping stations are useful but of limited scope; therefore as long as other solutions are not available and competitive, gas-fired plants (funding of which will be problematic) will have to operate continuously. Even with the effect of a geographical distribution across Europe, a lack of wind for several consecutive days cannot be ruled out. In any case, investments would have to be ramped up in transport and distribution grids, and procedures for public approval of overhead power lines would have to be simplified. Special attention must also be paid to managing peek power needs and to the consequences of massive development of renewable energies on the volatility of spot market electricity prices, unless electricity storage solutions are found.

PROPOSAL 5

For each energy policy decision, assess the cost and impact on public finances, the balance of trade, CO_2 emissions and employment (in terms of number of jobs and qualifications created), in comparison with a different decision, in order to set priorities.

8 ▸ Notions of cost and funding are particularly important for at least two reasons. The first is that all scenarios agree that energy costs will continue rising for some time to come, due to growing demand, increased scarcity of cheap supplies, higher equipment and raw material costs, safety and environmental protection costs, and the need to finance the consequences of intermittent renewable energies. All these factors point to increasingly high energy prices for the end-users.

Box

Public electricity service costs *(CSPE)* to promote the development of renewable energies

The French Energy Code requires that buyers upon request (EDF or local distributors) purchase from producers of electricity using renewable sources. These contracts provide for the purchase of electricity at a guaranteed rate, which is stated by ministerial order or included in a tender offer, for durations ranging from 10 to 20 years. The law provides that the costs incurred by these obligations be fully compensated (Article L. 121-6), and that electricity market prices serve as a reference in calculating avoided costs.

Every year, prior to 15 October, the Energy Regulatory Commission (CRE) calculates the total amount of costs for the previous year, and its calculation is approved by the French Energy Ministry. It also calculates the provisional costs of the following year and the amount of the contribution to public electricity service (CSPE) applicable to each kilowatt-hour, so that the contributions cover all costs incurred from public service missions (Article L. 121-14). Total costs include, in addition to renewable energies, cogeneration subsidies, equalisation payments and rates for low-income households.

The CRE's deliberations of 13 October 2011 state that:

- Provisional public electricity costs are estimated at €4.3 billion for 2012, or 60% higher than for 2010 (€2.7 billion). This increase is due mainly to very aggressive development of photovoltaic energy, which accounts for 36% of provisional costs for 2012, i.e., €1.5bn (16% from other renewable energies, 28.5% from equalisation payments, 17% from cogeneration contracts, and 2% from subsidies for low-income households).
- The contribution to public electricity service for 2012 (2012 CSPE) should make it possible to finance 2012 provision costs, which include provisional costs for 2012 and adjustments in 2010 costs. These costs are estimated at €5.2 billion. The 2012 CSPE necessary to fund them comes to €13.7/MWh. This amount is equivalent to about 11% of the average monthly bill, including VAT, of a residential customer.
- The supplemental budget for 2011 set the CSPE at €9/MWh until 30 June 2012, then at €10.5/MWh until 31 December 2012. The resulting compensation shortfall for EDF in 2012 is estimated at about €1.3 billion (a sum that will have to be reimbursed to EDF *via* a later increase in the CSPE).

During a hearing before the National Assembly on 24 May 2011, the CRE chairman said that his staff had also devised a tool for forecasting renewable energy costs out to 2020. Based on assumptions of the development trajectory of renewable energies and electricity price trends (the average market price is assumed to be €82/MWh in 2020), the scenario reviewed by the CRE suggests annual renewable energy costs of €6.7 billion in 2020, which is equivalent to €90, VAT included, on the annual bill of a typical customer with a basic rate and €170, VAT included, on the bill of a customer with electrical heating (about 11% of the bill). The CRE itself admits that these projections should be treated cautiously, as they are closely dependent on highly uncertain variables (energy prices, production costs, etc.).

Note: the CSPE has been presented as an illustration, but is one of many ways to subsidise the development of renewable energies (others include tax exemptions and credits, low-interest loans, reduced taxes, etc.). To cite one example, the government auditing office's recent report on the subject reported that, from 2005 to 2010, biofuels received €2.65 billion, mainly from consumers.

Electricity costs include the price of a kilowatt-hour as it leaves the power plant, but also the costs of maintaining and expanding power grids. Moreover, an increase in the CSPE appears inevitable, unless renewable energies and equalisation payments are set aside. This is yet another reason not to make things worse by adding costs to the average KWh that could have been avoided through less expensive energy choices; competitive electricity prices give the French economy an edge and must continue to do so. The second reason is that almost all energy policy choices available to us are extremely capital-intensive. This is true for energy efficiency, in particular the existing housing (the greatest potential for energy savings); it is true for renewable electricity, even more so when factoring in the need for back-up installations to compensate for intermittent wind power and to a lesser extent, photovoltaic power; it is true for new nuclear power plants; it is true for CO_2 capture and sequestration; it is true for electrical and gas interconnections. In all these cases, heavy capital expenditure is required before revenues are generated and before expenditure is mitigated. This is not an original observation, but the current global financial environment has made this a specific source of concern and gives an advantage to the few solutions with low capital intensity, i.e., energy conservation (consume less in energy services), gas-fired combined-cycle plants and the extending of the operating life of existing nuclear power plants as long as the Nuclear Safety Authority deems it possible. While we do not know the exact cost of measures that ASN has ordered EDF to take before it authorises extending the operating life of power plants, including the so-called "post-Fukushima" measures, probably these costs must remain far below €1000 per kW installed, i.e., far below the costs of any alternative solution, whether fossil-fuel or renewable. So economic and financial constraints suggest that priority must be given to the least costly solutions. However, costs must still be estimated; for some of the scenarios we examined, their authors refused to consider the costs of their proposals, an attitude that we find irresponsible.

9 ▸ Regarding this concern about funding, we should emphasize the especially worrisome deficit in France's balance of trade, which is almost equal to the energy deficit. Even though this is a coincidence, it is a disturbing one. More than the notion of energy independence, (which, in any case, is limited by geography and geology and does not ensure security with certainty), this justifies that we focus especially on demand management and on energies whose production generates a strong domestic added value, without overlooking metals and rare earths in the calculation. This involves mainly nuclear power and certain renewable energies (hydropower, biomass, in particular getting greater value out of wood, wind power, and, to a lesser extent, photovoltaic energy), as well as – not to be overlooked – conventional and unconventional hydrocarbon energy, whose reserves, if proven and exploitable in a fully environmentally friendly way, would reduce the trade deficit.

PROPOSAL 6

Maintain or increase publicly funded research on energy through international cooperation, while placing top priority on joint programmes between public-sector laboratories and innovative companies (large and small) that are able to take on the global market. Special attention should be paid to renewable energies and energy storage.

10 ▸ The scale of energy programmes to be launched in the coming years makes it worth examining the industrial impact in terms of job creations, particularly skilled jobs. This is a very appealing area of study indeed, but that must be addressed seriously and without making hasty conclusions or errors in judgement. We see four rules for doing so: i) No industry should be created by considering in priority the domestic market (except, of course, for craftsmen who install and maintain equipment); we should rather consider the global market, while taking into account energy strategies that often vary from one major country to another; to cite one example, France is unlikely to see significant domestic growth in photovoltaic energy or CCS but, as these technologies will probably be developed massively worldwide, it would be absurd to ignore them if French industry can achieve excellence in them (which is indeed the case); ii) There is no point in getting greedy and sacrificing an energy industry of excellent quality: France is the global benchmark in nuclear energy, and it would be irresponsible to walk away from it at a time when China, India, South Korea and Russia are becoming important players; in any case, there will be demand in plant dismantling, which may be an opportunity to call on French know-how; iii) no long-lasting industrial jobs are created from subsidised activities; to do so destroys more jobs than it creates. In other words, competitive industries are created not by maintaining subsidised purchase prices indefinitely, but by using suitable levers to promote innovative projects, backed by R&D and innovation programmes that link public laboratories and industrial groups (large and small ones), with a view to the global market. So having some production done outside of France is not an option to be ruled out; and iv) This new industrial environment should be anticipated by shifting training in the professions concerned.

There are opportunities to be taken or held onto in many fields, including nuclear and photovoltaic energy, offshore wind farms, future-generation biofuels, electricity storage, smart energy management (smart grids in particular), CCS, and energy efficiency in transport and housing and offices. These are the areas that R&D should focus on, *via* public-private partnerships.

PROPOSAL 7

Introduce greater transparency in energy and CO_2 emission prices, with special and separate measures for fuel poverty and energy-intensive industries.

11 ▸ Thanks to its past decisions, France possesses energy at a price that is generally acceptable and that is significantly lower than its neighbours'. But we have already pointed out all the cost factors that will drive prices up in the decades to come. It is important that, except in certain cases, increased

prices be fully passed on to consumers. Prices that are kept artificially low are triply harmful: i) they involve subsidies that destroy jobs and are incompatible with the current state of public finances; ii) they give consumers false price signals, thus discouraging them from saving energy; and iii) they keep operators from generating the cash flow necessary for their investments. Transparency in electricity prices requires, for example, that rates more fully reflect peak demand, and special attention should therefore be paid to better reflecting demand or installing back-up production capacity for peak hours. This price transparency policy is essential, but would create difficulties for two categories of consumers: households in fuel poverty and energy-intensive industries. These two categories must benefit from special instruments, adjusted to their respective situations, but it would be regrettable to deal with all problems, which are of completely different natures, in the same way, i.e., by administrative management of rates. We took note, with interest and a bit of bewilderment, that the German government, acknowledging the energy prices' consequences of its recent nuclear power decisions, seems determined to avoid extra costs for "electricity-intensive" industries *via* a series of measures, including recycling of ETS certificates and special rates for transport. France could use this as a model, as long as it is compatible with EU directives.

PROPOSAL 8

Take the initiative of proposing to France's main European partners an in-depth review of EU internal energy market rules. The internal energy market is expected to facilitate the funding of the necessary investments, in particular those related to peak power demand, and to ensure consistency in decision-making.

12 ▸ The European Single Market has brought some major advantages to member-country's economies. It has enhanced security at a reasonable cost, while leaving room for solidarity, and has allowed the various economic actors to exercise a basic right – the freedom to choose their suppliers. It must therefore be defended from the attacks that it faces. That said, it is no contradiction to say that this market, such as it has been set up, does not make it possible to resolve current problems and must enable member-states and the EU as such to make political decisions on energy mix and to fund the necessary investments. But this is not the case today, for example in decisions on cross-border interconnections, contradictory statements on gas, and the funding of back-up power plants. We can also see that Germany's unilateral decision to exit nuclear power, however legitimate it may have been for a sovereign country, has produced consequences hard to manage for its neighbours and for the EU as a whole. The architecture of the EU domestic market must be profoundly reworked.

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