In short

Nuclear Power: the Great Illusion

Promises, setbacks and threats

At a time when France is setting itself up as the political and industrial leader of a supposed European and worldwide 'renaissance' in nuclear power, *Global Chance* shows how this plan is a largely illusory response to the challenges of development and the environment. The present dossier, published to coincide with France's European Union presidency, approaches the issue from two complementary angles.

Nuclear "solution": short of power to meet energy and climate challenges

The first part of the dossier considers in overall terms the extent to which nuclear power is really capable of making a decisive contribution, within the necessary timescale, to the objectives of energy security and combating climate change. While these preoccupations are not new, they are looming ever larger as risks in the short term, to which an answer must be found within the next 20 years. It is against this timescale that the nuclear industry's capacity for revival – after a long period of stagnation of which French people are generally unaware – should be measured and compared with other solutions.

Left behind as an energy source at the global level

Nuclear power was responsible for 15% of the electricity produced worldwide in 2006, contributing 6% of primary energy production but only 2.4% of final energy consumption (ie the share of consumers' energy needs that it met). Its contribution was twice as large within the 27-member European Union (EU), at 29.5%, 13% and 5% respectively.

The nuclear industry's relative stagnation, set against a considerable increase in electricity production, has seen its contribution to global and European electricity output fall regularly since 1995, and more rapidly since the beginning of the present century. Between 2000 and 2006, 18 times as much gas-fired, 13 times as much coal-fired, 5 times as much hydroelectric and even 3 times as much wind-powered electricity generating capacity entered service worldwide than nuclear capacity.

The level of greenhouse gas (GHG) emission reductions brought about by nuclear power depends on what power sources it is assumed to replace: its associated reductions represented 3.6% of global emissions and 10% of EU emissions in 2006, and 20% of French emissions in 2005, on the assumption that it replaced a generation mix identical to that of the overall electricity generation fleet. However, if it is assumed to have replaced a fleet of combined cycle gas plants, these savings fall to 2%, 7% and 15% respectively – and even less if renewable energy is added to the equation. Nuclear power's effective contribution to GHG emissions reduction per unit of energy generated has been falling steadily since the 1990s.

From the energy security standpoint, while nuclear power can take the place of coal- or gas-fired electricity generation, it has only a very marginal effect upon oil consumption, which is dominated by transport. Conversely, by reason of its extremely centralised production and the particular risks that it presents, nuclear power increases energy vulnerability.

In its present state, the nuclear industry is not in a position to make a major contribution to improving energy security or to combating climate change over the coming decades. SUNBURN, the highly proactive scenario postulated by *Global Chance* in 2005 which involves multiplying by 50 the number of reactors to be constructed between 2005 and 2030, would result in a mere 2.9% drop in global GHG emissions and a 5% cumulative saving in fossil fuel resources by 2030, by comparison with the International Energy Agency's (IEA's) business-as-usual scenario. In any case, such a successful growth of nuclear energy, quite apart from the security, proliferation and waste management risks that it would engender, appears more and more unlikely in view of recent developments.

The marginal nature of nuclear power's contribution, even in the most proactive scenarios, emphasises in contrast the considerable potential of other solutions. The IEA suggests a proactive scenario for

reducing worldwide GHG emissions by 2050 which includes, among other proposals, a development of nuclear output from 2,800 TWh a year today to 6,000 TWh in 2030 and 9,000 TWh in 2050. At this level, nuclear power would cut by 3.5% GHG emissions in 2050. This only represents 6% of total emission reductions in the scenario, far behind the total contribution in the same scenario of energy savings (54%) and even that of renewable energy (21%).

France, showcase for the limitations of nuclear power

Although marginal in global terms, nuclear power is nevertheless presented by its promoters as an effective tool for countries or regions that are ready to take full advantage of it. France, which has long relied on nuclear power to an extent unmatched elsewhere, offers the perfect example by which to measure the reality of this contribution.

France's energy balance and GHG emission figures and projections give a full picture of the limitations of nuclear power. Despite a contribution unparalleled worldwide, with 79% of France's electricity output in 2007, nuclear power represents just 14% to 16% of final energy consumption, far behind oil products (49%) and gas (21%). France's energy independence is much closer to 20% than to the 50% artificially calculated in official statistics.

France consumes more oil per head of population than the European average, and more than Germany, the UK and Italy. On the other hand, its per capita GHG emissions are lower. But it appears incapable of reining in their upward trend, even though its long-term objective is to reduce them by three-quarters. This situation is connected to the weakness of policies on energy efficiency and support for new energy sources, under the influence of the priority accorded to nuclear power.

Thus the example of France shows the fatal gap between, on the one hand, the substitution of nuclear power for other energy sources and, on the other, a fundamental reform of the energy system – and raises the question of how compatible these approaches are. Analysis of official and alternative scenarios shows that pursuing its present policy would not enable France to comply either with European commitments at the 2020 timeline or with its own commitments for 2050.

Controlling energy demand, and to a lesser extent developing renewable energy, are more crucial than pursuing the nuclear programme as means to achieve France's objectives of energy security and long-term emission reductions. In fact, the development of nuclear power actually encourages the system to evolve in various ways that are opposed to these goals – like the large scale use of electric heating.

Empty promises: behind France's nuclear dream

In the minds of many national leaders and on the international stage, the French nuclear industry nevertheless embodies an effective, safe and proven response to present-day energy problems. The second part of this dossier questions this myth, which underpins plans for a revival of the nuclear industry. After a brief résumé of the programme which France has implemented, it reconsiders that programme's performance and, point by point, confronts the official narrative with the facts.

Industrial policy

The French nuclear programme's image is first and foremost that of **a highly successful industry**, but this is **a sham**. The development of nuclear power in France has been marked by a succession of technological blind alleys, planning errors and all kinds of difficulties, which are generally noted and corrected without any public discussion. The need to preserve the image of control can in itself be a sufficient reason for refusing to acknowledge mistakes: it is on this ground that a 1989 EDF report concluded that it was necessary to go ahead with the reprocessing and reuse of MOX even though the whole initial justification for this, connected to the introduction of breeder reactors, had disappeared.

The French nuclear industry has frequently gambled on the wrong technologies. Prior to the failure of the breeder reactors, the French Atomic Energy Commission (Commissariat à l'Énergie Atomique – CEA) had supported the development of a fleet of natural uranium-graphite-gas (UNGG) reactors; but EDF ultimately established its programme with American pressurised water reactor (PWR) technology, building the first 50 of its current 58 reactors under American licence. Again, France rejected centrifuging as a method of enriching uranium, instead choosing gas diffusion in the present

Eurodif plant and then conducting research and development on laser technology, before Areva finally bought the centrifuging technology of its main competitor Urenco to replace Eurodif.

France has also persistently failed to bring new equipment up to the performance standards envisaged, including those for factors which are crucial to its economic justification. The official projected investment costs, for example, have consistently been lower than the actual costs subsequently acknowledged, which have never fallen as promised. Construction times and load factors have lagged badly behind the projected figures.

Even the size of the reactor fleet, far in excess of the required capacity, is based on hugely erroneous estimates: France's electricity consumption in 2000 was oversestimated by a factor of 1.75 when the programme was launched, while the development of the global nuclear fleet was overestimated by a factor of 10! Export projections have also proved erroneous, with only nine reactors exported (before the EPR), whereas exports were supposed to match the number of plants built in France.

The EPR reactor project, by aiming to replace the fleet with this vaguely 'evolutionary' line of reactors, continues in the footsteps of past decisions. Above all it reflects the need to maintain capability, the loss of which, in terms both of human resources and of industrial capacity, is a major challenge for the French nuclear industry. The problems encountered with the first stages of the two EPR reactor construction sites in France and Finland exemplify this difficulty.

Safety

The development of the French nuclear industry is not without danger. The lack of major accidents conceals, from the viewpoint of safety, **an evolution laden with risks**. The French nuclear programme's proponents initially claimed that a major accident was impossible, before gradually conceding that it was merely unlikely. The lessons of Three Mile Island (based on the same technology as the French PWRs) in 1979 and Chernobyl in 1986 could be incorporated only very belatedly and incompletely into a fleet three-quarters of whose units (42 out of 58) had been ordered before 1980 and completed before 1987. Even the most recent reactors have been essentially designed before 1984 – to the point that the authorities have acknowledged since 1995 that as new reactors they would no longer meet evolving safety demands.

The statistics testify to a large number of significant incidents at French reactors – around 700 to 800 a year. While the number has tended to rise in recent years, the number and seriousness of incidents classified on the International Nuclear and Radiological Event Scale (INES) has tended to fall, ranging between 50 and 100 classified incidents annually. The main criteria of the INES classification are related to the immediate seriousness of the event more than to its in-depth lessons for safety.

However, analysis of the numerous incidents over the last 20 years throws up many serious alerts covering the whole range of initial accident causes, from design faults or equipment failure to inadequate procedures and human error. In particular it illustrates the limitations of the current probabilistic approach and the worrying proliferation of generic incidents affecting one or more series of EDF's standardised fleet. In addition to these problems, there is the factor of ageing reactors and, increasingly, the burden imposed by the demands of profitability.

The limitations of the approach to safety apply to the EPR, which closely follows the probabilistic approach and introduces new technologies such as the 'core catcher' whose practicability remains theoretical, implying new vulnerabilities. What is more, its concept offers no improvement in terms of the rest of the sector – the upstream and downstream stages of the fuel chain – whose safety levels, although less closely examined, remain open to question.

Security

Analysis of recent developments in terms of security, moreover, reveals **an industry incapable of adapting to the post 9/11 environment**. In the area of protection against malicious acts, the nuclear industry runs up against a fundamental difficulty: the credible threats have evolved so far as to exceed the load levels (mechanical, thermal etc) incorporated, essentially from a safety standpoint, into the design of the installations.

While no public evaluation exists of the consequences of an aeroplane crashing onto a reactor, public discussion has highlighted the important questions to be answered on this subject, and has revealed the

vulnerability of other installations such as the irradiated fuel storage pools at La Hague. Other attack scenarios must also be taken into account. Transports are a weak security link in the nuclear chain, their vulnerability and potential for danger exacerbated by France's opting for reprocessing.

The authorities nevertheless favour the developing of security measures rather than the industry itself adapting – or even a reinforcement of secrecy rather than concrete measures. The fundamental role of secrecy in this doctrine – to the point of absurdity when it is applied to clearly visible elements – prevents the emergence of any democratic debate on this issue.

Furthermore, in terms of proliferation, France conducts itself as though it were a **pyromaniac fireman**. In the past, French technology has helped to develop official or unofficial military nuclear programmes (for example in Israel, Iraq and South Africa). Today, without any debate on the risks of misuse, France is negotiating nuclear cooperation agreements with numerous North African and Middle Eastern countries (from Algeria to the United Arab Emirates by way of Libya), to whom it is offering its EPR reactor. This plan exceeds both these countries' inspection capacity and the capacity of their energy systems.

France is moreover sending a very negative signal to the world by stockpiling the separated plutonium produced by reprocessing – which, as the industry admitted only in 2006, could be used to manufacture a bomb. At the end of 2006 a total of 82.1 tonnes was being stored in France, of which 29.7 tonnes was foreign-owned. EDF's stock of unused plutonium powder at La Hague alone represents 26 tonnes, or over 3,000 times the 'significant quantity' required for a bomb. The operator of the French nuclear fleet is currently the main producer of separated plutonium in the world.

Waste management

Despite the efforts recently made in this area, the figures reveal **the false reasoning** that remains **the backbone of the waste management policy**. The central principle of systematically reusing the 'usable' material (uranium and plutonium) produced by reprocessing, although in reality far from being applied, serves as the basis for a flattering but incomplete balance sheet.

On the one hand, this principle relies on perpetual move: the materials accumulated by the present fleet could never be entirely reused by that fleet; renewal of the fleet with the same technology would only defer the problem. On the other hand, the principle enables part of the problem to be skirted: when the Government compares the inventory of waste to be stored underground at the end of the present fleet's lifespan depending upon whether or not the nuclear fuel is reprocessed, it omits all waste associated with the reuse or storage of the 300 tonnes of plutonium and 30,000 tonnes of uranium to be transferred to a future fleet.

Far from reducing the volume of waste by a factor of four or even ten as the industry claims, reprocessing complicates waste management from both a qualitative and a quantitative standpoint, by increasing the number of categories. Comparisons between storage volumes and disposal footprints, once corrected for a set of systematic bias identified in the official evaluations, show no clear advantage in favour of reprocessing. Conversely, the complexity that it entails goes hand in hand with increased risk.

France today has no industrial solution for all its long-term radioactive wastes, which are the subject of research according to their degree of radioactivity. Large quantities of waste and 'usable' material of different categories are accumulating in conditioning and storage conditions which are in many cases inadequate. In the area of dismantlement, too, reality contrasts with the industry's pretended expertise: dismantlement sites have all witnessed serious technical difficulties – sometimes unanticipated – and soaring associated costs.

Economics

The French nuclear industry's good reputation also relies on **the manipulation of economic reality**. A comparison between France's economic development over the last 40 years and that of comparable countries that have made different energy choices reveals no competitive advantage that can be attributed to nuclear power. On the contrary, it seems incapable of protecting the balance of payments. Indeed, in 2006-07 France's energy bill saw levels of deficit comparable to those of the first and second oil crises, before the present nuclear fleet came into service.

Nuclear power's contribution is not zero: in 2007 it is estimated to have 'saved' gas imports worth up to €10.7 billion. But demand for hydrocarbons has not fallen, and the energy bill reached €44.8 billion in 2007, leading to a balance of payments deficit of €39.2 billion. Conversely, the supposed financial benefits attributed to massive exports of electricity (actually a way of disposing of the French nuclear fleet's excess capacity) have never exceeded €3.5 billion a year and are falling markedly: base-load exports are dropping while peak-rate imports, at much higher tariffs, are increasing.

Electricity price comparisons do not support the French authorities' claim that French prices are the lowest in Europe thanks to nuclear power, even if overall they do appear to be low. Moreover, the comparison is skewed by some important factors. For example, France's high ranking is in part due to the fact that it maintains a dominant regulated market, whose rules as regards the passing on of real costs are set by the state, which is both the regulator and the principal shareholder of EDF. Furthermore, while French households enjoy attractive tariffs, they also, as a result of the policy of promoting electricity, consume on average twice as much electricity per dwelling as the European norm (used for price comparisons).

What is more, it is known that the official reports, with very few exceptions, have systematically underestimated the real costs of nuclear power compared with the alternatives, and continue to do so – sometimes hiding behind commercial confidentiality. When EDF presented its EPR reactor project to the public debate in 2005, it had to justify the fact that its own cost estimate appeared to be 44% higher than the estimate presented by the Government in 2003 in order to include the programme in energy planning legislation. EPR's costs – both those of EDF's French project and those of the plant being built in Finland by Areva – have risen continually since the outset. The most recent estimates in mid-2008 were respectively €3.4 billion (for a reactor announced at €3 billion) and €5 billion (for a reactor sold at €3.3 billion).

Current discussions on the cost of reactors should not draw attention from the **hidden associated costs**. These of course include all the costs associated with the fuel cycle and with decommissioning, which are subject to the same distortion in the official estimates. For example, the assumed costs of reprocessing are set not at the actual level but at half that level, explicitly in order to ensure parity with the cost of the non-reprocessing option. Structural costs, although their extent is hard to establish, must also be taken into account. For example, they include the additional electricity network infrastructure costs associated with the highly centralised nature of nuclear generation, and the costs of inspection and security.

Democracy

Finally, the pursuit of the nuclear programme in France is a **permanently undemocratic choice**. Contrary to the image presented abroad, the French population is no more in favour of nuclear power than the European average – indeed a majority is opposed to the building of new plants. Surveys repeatedly show that the public lacks confidence in the institutional promoters of nuclear power.

This disconnect between public opinion and the thrust of policy, which is dogmatically pro-nuclear, results from an institutional system which sequesters policy from any genuine democratic control. Evaluations are carried out and key decisions taken by the country's technocratic elite, away from any external scrutiny – in particular, a central role is played by the Corps des Mines, a state body of 700 engineers who hold almost all the key posts connected with energy.

While the overall progress in terms of information and public participation in decision-making is exerting a growing pressure, the nuclear industry in France remains a separate fiefdom, where the procedures of evaluation and public debate develop but remain disconnected from the real decision-making processes.