Nuclear Power in France
Beyond the Myth

By

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In 2006-2007 he was part of a consultant consortium that assessed nuclear decommissioning and waste management funding issues on behalf of the European Commission. In 2005 he has been appointed as nuclear security specialist to advise the UK Committee on Radioactive Waste Management (CoRWM).

Mycle Schneider has given evidence and held briefings at Parliaments in Australia, Belgium, France, Germany, Japan, South Korea, Switzerland, UK and at the European Parliament. He has lectured extensively on four continents including at Carlton University, Ottawa (Canada), Tsinghua University (China), Freie Universität, Berlin (Germany) and Ritsumeikan University, Kyoto (Japan).

Between 1998 and 2003 he has been an advisor to the French Environment Minister's Office and to the Belgian Minister for Energy and Sustainable Development.

Mycle Schneider has provided information and consulting services to a large variety of clients including the International Atomic Energy Agency (IAEA), Greenpeace International, the International Physicians for the Prevention of Nuclear War (IPPNW), UNESCO, Worldwide Fund for Nature (WWF), the European Commission, the European Parliament's General Directorate for Research, the Oxford Research Group, the French National Scientific Research Council (CNRS), the French Institute for Radiation Protection and Nuclear Safety (IRSN).

In 1997 he was honoured with the Right Livelihood Award ("Alternative Nobel Prize") together with Jinzaburo Takagi for their work on plutonium issues (http://rightlivelihood.org/recip.htm).

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Introduction

Not long ago, "French Fries" were renamed "Freedom Fries" in the United States, as part of an intense anti-French campaign following the French government's refusal to join the Iraq war. But the rage against France now seems forgotten. Not only are "French Fries" politically correct again, but France has become a role model in the U.S. and beyond, the nuclear power model. "It's time to look to the French," New York Times columnist Roger Cohen wrote. "They've got their heads in the right place, with nuclear power enjoying a 70 percent approval rating." Similarly, former Republican presidential candidate John McCain has wondered, "If France can produce 80 percent of its electricity with nuclear power, why can't we?"

The current Sarkozy-Fillon Government, acting presidency of the European Union's Council of Ministers, has chosen to massively promote nuclear power even to newcomer countries like Algeria, Jordan, Libya, Morocco, Tunisia, and United Arab Emirates. As President Sarkozy put it in a speech in Marrakech: "We have it in France, why shouldn't they have it in Morocco?"[1] The French president travels the world as salesman for the glittering nuclear industry, from the Middle East to China, from Brazil to India. On 29 September 2008, even before the U.S. Congress had given the green light for the U.S.-India nuclear deal, France signed a similar cooperation agreement with India.

The international credit crunch will not make it easier for nuclear planners to implement their projects. Finance is rare and will be more expensive. On 19-20 November 2008 the participants to the 1978 Arrangement on Guidelines for Officially Supported Export Credits met in Paris under the auspices of the OECD. The main goal was to extend the granted payback period for nuclear credits from 15 years to up to 30 years. The key expected sources of funding of export credit agencies are Japan and France. The two countries plus the U.S. recently agreed to fund a study within the World Bank to reassess the cost-competitiveness of nuclear power. The move is a further step to increase pressure on multilateral development banks that generally have an outspoken or implicit ban on nuclear financing. For example, the World Bank has not financed nuclear projects for a number of decades, while the Asian Development Bank has never provided funding for nuclear.

The state utility Electricité de France (EDF) has amplified its own international strategy with the recent takeover of British Energy, investment in the U.S. utility Constellation and the creation of the Guangdong Taishan Nuclear Power Joint Venture Company with the purpose of building and operating two European Pressurized Water Reactors, in which EDF will hold a 30 percent interest for 50 years.

The general message is clear: in France nuclear power works, in 2007 providing 77% of the electricity in the country and 47% of all nuclear electricity in the EU. “The requests by countries that wish to profit from that clean and cheap source of energy are legitimate”, claims French Foreign Minister Bernard Kouchner.[2] But does it really work that well and is it all that clean and cheap in France?

France is amongst the top economic powers in the world and it has considerable political influence on the international level. The country has the seventh largest Gross Domestic Product (GDP, in 2006), the eighth largest primary energy consumption (in 2007) and by far the most foreign tourists' visits worldwide. With over 63 million inhabitants, France has the second largest population in the EU behind Germany.

French energy policy has considerable international influence in particular through a constant strong representation at the Directorate General of Transport and Energy (DG TREN) of the European Commission[3] and through other organisations like the International Energy Agency (IEA) of the

[1] 24 October 2008, Franco-Moroccan Economic Summit in Marrakech.
[2] *Les Echos*, 29 April 2008.
[3] Including the DG himself.

OECD. The IEA has increased remarkably its pro-nuclear stance since the term of Claude Mandil as Executive Director (2003-2007) began. Mandil is a member of the Corps des Mines, a French State elite of engineers that has designed, pushed through and implemented the nuclear program in France, with its members holding key positions in ministries, industry and State agencies (see main text).

Industry and utility representatives, diplomats and civil servants have been highly successful in depicting the nuclear program as a great achievement, leading to a great level of energy and oil independence and carbon free power.

With nuclear power gaining increasing acceptance in the European Union and elsewhere, it is worthwhile to have a closer look at the "French model". To understand the overall impact of the French nuclear energy strategy, it is necessary to look beyond the number of kilowatt hours produced. Many of the impacts are system effects that are not obvious at first sight.

Historical Aspects

In 1946 the French Government nationalized "the production, the transport, the distribution, the import and the export" of electricity and natural gas and created Electricité de France (EDF) and Gaz de France (GDF) as state energy monopolies.[4] The legislation stipulated that 1% of the companies' turnover go to the "Central Fund for Social Activities" (CCAS)[5], a fund to be managed by a board composed of representatives from the different trade unions according to the previous union election outcome. Since the CGT, close to the French communist party, won the absolute majority of votes every single time from the start, CGT was in a position to manage a huge budget, about €450 million in 2006, in principle on a large number of social and associated issues (vacation facilities, restaurants, child care centers…). The CCAS employs over 5,600 people. It has been suspected for a long time to of constituting a convenient and abundant source of subsidies for the French communist party. In a 2006 confidential report the French Court of Auditors accused the Fund of "total lack of transparency on resources and employment (…) and insufficient internal control".[6]

However, more importantly, the arrangement constituted a long-term guarantee for "social peace". The extraordinary advantages for EDF employees funded by the CCAS were and are complemented by preferential power tariffs. No surprise that EDF has been hit significantly less by strikes than many other French companies (including public ones) and that only on rare occasions have union activities led to power cuts.

In addition to the average preferential electricity tariff for each EDF employee, during the project planning and construction phases, EDF practiced lower tariffs in the vicinity of nuclear power plant sites. The practice has been declared illegal on the grounds that it violates the principle of equal treatment. However, the court case, initiated by consumer and environmental protection organizations, took over five years, time enough for the construction sites to get into an advanced stage. Incitement to acceptance had done the job prior to the method being declared illegal because it was obviously violating the equality principle.

The relationship between trade unions and nuclear sector has been instrumental to the implementation of the various phases of the nuclear program. While EDF was "pacified" by the historical "social fund" deal, the history of the Atomic Energy Commission (CEA) was slightly different. After what was later termed the "reactor line war" (la guèrre des filières) the CEA remained responsible for the implementation of the nuclear fuel chain. Nevertheless, the CEA had lost the "war" at the beginning of the 1970s. Its own gas-graphite reactor line was abandoned in favor of the Westinghouse Pressurized Water Reactor (PWR). By 1972, nine gas-graphite reactors had been started up, of which eight were producing power. At least four of them were used to generate plutonium for the French nuclear weapons program. The last one was shut down in 1994. But in the same year the last unit of the CEA natural uranium reactor line started up, the EURODIF consortium was created with the intention to

[4] Law n° 46-628 dated 8 April 1946 on the nationalization of electricity and gas

[5] Caisse centrale des activités sociales des industries électriques et gazières or CCAS

[6] Le Figaro, 4 January 2007

provide low enriched uranium to a group of participating countries for their light water reactors[7]. And in 1974 the first large-scale 16-unit nuclear power program was launched exclusively on the basis of a Westinghouse PWR license held by Framatome until 1982. At that point, 50 of the now 58 operating units were already in operation or under construction.

By the middle of the 1970s, the trade union CFDT, close to the Socialist Party, had gained considerable influence within the CEA. The CFDT was very critical about the plutonium program and the health and safety conditions at the La Hague reprocessing plant. In 1976 COGEMA was established as a 100% subsidiary, under private law, of the public CEA with the clear strategic orientation to build up over time a powerful nuclear fuel group that would master everything from uranium mining to plutonium fuels, civil and military. The "private" company COGEMA had been given the industrial uranium fuel and reprocessing facilities. The change broke up the powerful position of the La Hague section of the CFDT, which had led a successful strike there the same year. Union leaders left the site to stay within the public CEA in order to protect their status. In 1981 the newly elected President François Mitterrand entrusted top CFDT leaders and engineers from the CEA and EDF with the development of the French Energy Efficiency Agency (AFME). The deal was basically that they would get full government support on the condition that they not intervene on nuclear issues anymore… The only existing nuclear expertise federated on the national level was decapitated. In the following years the CFDT lost most of its credibility in the sector. After EDF, CEA and COGEMA were "cleared" of potentially costly trade union impact.

Decision Making

Until 1991 France did not have *any* specific nuclear legislation and the 1991 law was limited to the question of research and development on high-level radioactive waste. It was only in 2006 with the "Law relative to transparency and security in nuclear matters"[8] that specific legislation was introduced. There has never been a vote in parliament on the launch of the nuclear power program. A "great energy debate" promised by François Mitterrand prior to his election in 1981 never materialized. It took until 1989 to finally discuss national energy policy in the National Assembly: the discussion lasted three hours and was followed by 24 members[9]. The "energy debates" organized in various French cities in 2004 and after, like the events organized by the "National Public Debate Commission" did not influence the decision-making in any way. Major decisions like the construction of a first Generation III European Pressurized water Reactor (EPR) at Flamanville were taken *before* a parliamentary debate even took place. Greenpeace accused the government of demoting the members of parliament to individuals "elected for nothing" (Elus Pour Rien or EPR).

This is no coincidence. The elected representatives always had and have a very minor influence on the development, orientation, design and implementation of energy and nuclear policy in France. The issue is entirely under control of the elite technocrats of the state Corps des Mines[10]. Officially, the governing body of the Corps des Mines, the General Mining Council and is presided over by the Minister of Industry. However, ministers change, the "corpsards" remain. Therefore the most powerful position in reality is the vice-president of the Council, who, as all its other members is a member of the Corps des Mines. It is remarkable to what extent the Corps has managed to lockup all of the key positions linked to the nuclear issue. The nuclear advisors to the President of the Republic, the Prime Minister, the Ministers for Economy, Industry, Environment and Research, the CEOs of the CEA, AREVA, Framatome and the safety authorities, all have historically been members of the Corps des Mines.[11] If there is an "Energy Mission" to advise on policy, it is headed by the Corps des Mines.

[7] including Iran that holds until today 10% of EURODIF via SOFIDIF (40% Iran, 60% AREVA) that is a 25% shareholder of EURODIF

[8] Law n°2006-686 dated 13 June 2006 relative to transparency and security in nuclear matters

[9] The author counted them at the time.

[10] The Corps des Mines is fed historically by the top dozen graduates of the military Ecole Polytechnique plus, more recently top graduates from other elite engineering schools. In total, the annual admissions to the Corps des Mines is 20 or less. The cumulated number of living engineers of the Corps des Mines is approximately 700.

[11] Exceptions confirm the rule: The current energy advisor to President Sarkozy is not from the Corps des Mines but from the Corps des Inspecteurs des Finances.

This state organized elite clan has made it possible to push through long-term policy orientations like the nuclear program, entirely outside election concerns. The mechanism provides a huge advantage for long term planning and the implementation of large infrastructure projects. It constitutes also a significant disadvantage for democratic decision-making, which is entirely cut off. And it is a serious handicap for any significant policy adaptation or reorientation.

Georges Vendryes, who represented France at the IAEA's Board of Governors for 23 years and who is considered as the "father of Superphénix" (the fast breeder reactor at Creys-Malville) summed up the French exception this way:

> "Since forty years the big decisions concerning the development of the French nuclear program are taken by a very restricted group of personalities that occupy key positions in the government or in the top administration of EDF, CEA and the few companies involved in the program. The approach remains unchanged in spite of the change of ministers thanks to the permanence of these personalities that occupy the same position generally for some ten years."[12]

Access to Information

Access to information on the nuclear sector in France has been restricted since the launch of the industry in 1946. Trust in the information provided by state and industry were entirely demolished in the aftermath of the Chernobyl accident. On 6 May 1986, one week after the disaster, the Ministry of Agriculture issued a press statement declaring that "the French territory, due to the distance, has been totally exempted from radioactive fallout after the accident at the Chernobyl plant". While vegetables were destroyed systematically on the other side of the borders with Germany and Italy, the French government did not take any precautionary measure except for the destruction of a single load of spinach. The head of the radiation protection agency SCPRI[13] declared in a telex "to be distributed to medical doctors and the public", that one would have to imagine "levels 10,000 or 100,000 times higher" in order to justify precautionary measures.

In reality airborne radioactivity from the Chernobyl accident had triggered the alarm systems on many nuclear sites in France. The reaction was to modify the set-point accordingly rather than to inform the public. An extensive environmental measuring campaign (over 3,000 samples) carried out by the independent laboratory CRIIRAD – that started up in the aftermath of Chernobyl – and published in 2002 revealed current cesium contamination levels of up to 50,000 Bq/m2. In 1999 a small group of people that had contracted thyroid cancer started an association that developed by 2002 into a group complaint by over 400 people with thyroid sicknesses. They accused the government of misleading statements and lack of precautionary measures. The case is still under active instruction.

On 13 June 2006 the French Nuclear Transparency and Safety Act was passed. This is the first more comprehensive piece of legislation on the nuclear industry. Until then, the sector had been legally managed by a 1963 truncated act and specific regulations. The new law stipulates in section 2: "Every person shall be entitled, on the conditions laid down by the present act and its implementing decrees, to be informed about the risks related to nuclear activities and their impact on the health and safety of persons and on the environment, and on the release of effluents from installations".

It is seen as a major change that "while the government remains responsible for informing the public about the risks related to nuclear activities and their impact all operators and persons in charge of transport now have obligations to disclose information too, which considerably broadens the range of enterprises concerned".[14]

However, the author's experience since the passing of the Transparency and Safety Act illustrates that much needs to be done yet, in particular when it comes to cost figures. For example, none of the three

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[12] IAEA Bulletin, Autumn 1986

[13] Pierre Pellerin, who had been at the head of the SCPRI, since its creation in 1956, 30 years previously. Pellerin was indicted in 2006 for aggravated deceit.

[14] Marc Léger and Laetitia Grammatico, "Nuclear Transparency and Safety Act: What Changes for French Nuclear Law?", Nuclear Law Bulletin, OECD-NEA, 2007

main nuclear operators EDF, CEA and AREVA answered a questionnaire on decommissioning and waste management funds, developed in the framework of an official study on behalf of the European Commission.

On the other hand, a more constructive attitude has been adopted by the Nuclear Safety Authority (ASN) and its technical back-up, the Institute for Radiation Protection and Nuclear Safety (IRSN). For example, even prior to the Nuclear Transparency Act, ASN began publishing all of the letters that are sent to nuclear operators following inspections. On request, it has also released very detailed emissions data and transmitted a database on nuclear events.

Following an incident discovered on 7 July 2008 that involved the spill of uranium into groundwater at a nuclear maintenance facility at Tricastin in the south of France, the Minister of Ecology asked the High Committee for Transparency and Information on Nuclear Security (HCTISN) to elaborate an opinion on the radio-ecological monitoring of all nuclear sites and the management of former nuclear waste storage facilities. The minister requested that particular attention be given to the "quality of information", the level of transparency and the modalities allowing better involvement of stakeholders in the process. On 7 November 2008, the HCTISN published its report including 18 recommendations concerning access to information, including "the development of an expert capacity that is diversified and independent of the organisations currently implicated in the evaluation of nuclear dossiers".[15]

Civil – Military Links

Unlike the United States, which has attempted, to a large extent, to separate civil and military uses of nuclear power, France has never divorced the administration of nuclear energy and nuclear weapons, this has remained the underlying rational until today. As the latest French official report on the protection and control of nuclear materials states: "In fact, France is a civil and military nuclear power but does not have two separate [fuel] cycles."[16]

The State owned CEA, created in 1945 with the explicit, though secret, task of developing the French nuclear bomb program, has since implemented the military-civilian nuclear link. Until today, the same number of people, 4,500 each, work under the military applications and civil energy departments. The CEA has a wide area of responsibility in nuclear matters, which includes everything from fundamental research in physics to research and development for radioactive waste management. Its Direction des Applications Militaires (DAM) was responsible for warhead testing at Moruroa. Its former subsidiary COGEMA (Compagnie Générale des Matières Nucléaires), now AREVA NC, is responsible for the production and maintenance of nuclear materials, including plutonium. The CEA built the plutonium production plants at Marcoule and La Hague.

The French civil nuclear program has largely profited from the military program and vice-versa. The 1973 CEA annual report explains the "French approach"*:* "The CEA must, within the framework of a rigid budget and strictly limited possibilities of expansion, adapt the production of military nuclear material to rapidly changing needs by taking advantage of technical progress and civilian programs (which themselves have greatly benefited from military programs) in order to limit the costs".

The following quote stems from a document dated 1964, which introduces defence-planning legislation for the years 1965 to 1970. The chapter on nuclear materials production explains unambiguously:

> "This chapter deals with the investment and operational expenditures connected with the production of nuclear materials for military use. This expenditure relates to: (...)
>
> "- the completion, the start-up and the operation of the plutonium extraction plant at La Hague, since that plutonium, extracted from fuel irradiated in EDF reactors, will be used for military purposes.

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[15] HCTISN, "Avis sur le suivi radioécologique des eaux autour des installations nucléaires et sur la gestion des anciens sites d’entreposage de déchets radioactifs", 7 November 2008

[16] BSNMS, "Rapport sur l'application des dispositions de la loi du 25 juillet 1980 sur la protection et le contrôle des matières nucléaire, Année 2007", HFDN, Ministère de l'Industrie, 2008

"- the costs incurred from the production of military grade plutonium in EDF reactors." [17]

It is only consequent that the original La Hague reprocessing plant was financed in equal shares by the civil and military budgets of the CEA. Civil military cross subsidizing has been a principle throughout the entire French nuclear program.

International Nuclear Safeguards in France

The fact that international nuclear safeguards are in force in France frequently leads to the belief that military and civil nuclear activities are separated in France, since France deals with so many foreign nuclear products of countries that do not want to participate in the French nuclear weapons program and as such have signed bilateral or multilateral agreements with France. This is not so. International nuclear safeguards in France are a delicate compromise between defence needs and peaceful end-use obligations. A part of the nuclear installations in France co-processes civil and military nuclear materials. At the same time public opinion in client countries that calls for a clear cut separation to French nuclear weapons has to be satisfied.

Spent fuel from Australia, Belgium, France, Germany, Italy, Japan, the Netherlands, Spain and Switzerland, has been reprocessed at La Hague. Australia, Switzerland and Japan are not members of the European Union. La Hague facilities are subject to two international safeguards regimes, the EURATOM and IAEA Safeguards. Nevertheless, France is a Nuclear Weapons State and as such is allowed to withdraw French "labelled" material from international Safeguards control as often as it likes, thus freeing it for military use. In fact, the rules are even less stringent than that.

EURATOM safeguards in France

The EURATOM treaty is first of all a treaty meant to facilitate and to structure the development of the nuclear industry in Europe. One of the tasks of EURATOM is *"ensuring, through appropriate control and verifications, that civil nuclear materials are not diverted to uses other than those for which they were intended."* The EURATOM agreements forbid a non nuclear weapon state to develop a nuclear capacity, but accept that nuclear weapon states possess the necessary production and maintenance installations for their nuclear weapons.

The EURATOM Safeguards implementation scheme requires continuous inspection for the duration of the operation of certain facilities. The materials for which EURATOM Safeguards apply are: materials subject to a Community commitment for peaceful use, materials subject to a bilateral agreement between France and another country, and nuclear materials which are *"free for any use"* - i.e. not subject to any constraint. EURATOM Safeguards do not apply to materials for which no attribution has yet been decided, nor to nuclear materials directed towards any military use by France.

IAEA Safeguards in France

Some non-European countries like Japan, Canada, Australia and Sweden (before it joined the European Union) have requested from France that their materials in France be placed under IAEA Safeguards[18]. Nuclear Safeguards are meant to allow detection of any diversion of nuclear materials or installations to any undeclared activity, in particular military uses. This applies in principle to the spent fuel sent to La Hague for reprocessing as well as to uranium and plutonium separated during reprocessing. Can the IAEA guarantee the peaceful end-use of these materials?

[17] Exposé des motifs du projet de loi n°1155, déposé le 6 novembre 1964, quoted according to Raymond Tourrain, "Rapport d'information sur l'état de la modernisation des forces nucléaires françaises", Assemblée Nationale, 22 May 1980

[18] BSCMNS, "Rapport sur l'application des dispositions de la loi du 25 juillet 1980 sur la protection et le contrôle des matières nucléaire, Année 1993", HFDN, Ministère de l'Industrie, 1994

According to COGEMA[19] and the IAEA itself[20], the only nuclear installation in France that the IAEA has selected for inspection is the spent fuel storage pools at La Hague. The 13,700 t capacity pools contain the spent fuel from the different client countries awaiting reprocessing. Safeguards of storage pools cannot *measure* the plutonium content of the fuel. The amount of plutonium contained in spent fuel assemblies is *estimated* by calculations based on the characteristics of the fuel. According to the IAEA[21], *"poor accuracy of these calculations"* limits their value as a *"safeguards reference"*. The IAEA does not indicate any figure for error margins. No alternative solution to establish the plutonium content of spent fuel more accurately seems technically possible at the moment. Plutonium and uranium contained in spent fuel can only be measured accurately once the fuel assemblies have been sheared, dissolved, and transferred into an accountability vessel.

The Tripartite EURATOM/IAEA/France Agreement

A tripartite agreement on Safeguards was signed on 20 June 1978 between France, the IAEA and EURATOM. The IAEA was supposed to be able to control nuclear materials from different foreign countries for which France had agreed to conform to IAEA Safeguards, while at the same time not intervening in the French military program. By 1993, 103 facilities in which this foreign material could be processed could also contain nuclear materials for French military uses. The tripartite agreement was meant to diminish IAEA Safeguards costs while facilitating communication between IAEA and EURATOM.

The first article states[22] :

> "(a) France shall accept the application of safeguards, in accordance with the terms of this Agreement, on source or special fissionable material to be designated by France…
>
> "(b) France shall provide the Community and the Agency with a list (herein-after referred to as 'the facilities List') of the facilities or parts thereof which contain the nuclear material referred to in paragraph (a) […]. France shall keep the Facilities List up to date and may at any time make deletions to it. […]"
>
> According to article 14, "if France intends to make any withdrawals of nuclear material from the scope of this Agreement […], it shall give the Community and the Agency advance notice of such withdrawal".

In other words, France is entirely free to use any of its installations for military purposes, and all it has to do is declare it to the IAEA and EURATOM.

A French Industry Ministry report on physical protection and Safeguards of nuclear material[23] describes the scope and the structure of the EURATOM Safeguards in France. The following information concerning the excluded material is particularly illustrative:

> "On the contrary, are excluded from Safeguards materials which are free of use and which are declared by France as affected for its defence needs, as well as eventually those for which the affectation has not yet been decided. In all cases, France always has full control over materials which are free of use and may at any time, by a simple accountancy movement, transfer them from an area under EURATOM Safeguards to an area not under EURATOM Safeguards and reciprocally."

According to the same report, following the 1978 tripartite agreement, France communicated a list of 116 facilities which contain nuclear material *"where community Safeguards are liable to be enforced"*.

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[19] J. Régnier, COGEMA, in his presentation at the Fourth International Conference on Nuclear Fuel Reprocessing and Waste Management, London, UK, 24-28 April 1994 (RECOD '94).
[20] IAEA, 'The Safeguards Implementation Report', various years
[21] Thomas A. Shea, "IAEA Safeguards Implementation at Chemical Reprocessing Plants", IAEA, presentation to RECOD '94.
[22] Official IAEA English translation of the French original.
[23] BSCMNS, "Rapport sur l'application des dispositions de la loi du 25 juillet 1980 sur la protection et le contrôle des matières nucléaire, Année 1993", HFDN, Ministère de l'Industrie, 1994. The quotes have been translated by the authors.

According to the same report, 265 facilities in France contain nuclear material. Therefore, at that point, France did not allow access for EURATOM inspectors to more than half of its facilities which contain nuclear materials. The list of these 149 unsafeguarded facilities is called the *negative* list of facilities.

Furthermore, 30 of the 116 facilities which have been declared to EURATOM "reflect [France's] only nuclear fuel cycle", and "are under a mixed status, since they may contain alternatively or simultaneously material under or not under Safeguards. In this last case, their access is temporarily closed to EURATOM".

In its latest report[24], the French Government states that it has transmitted a list of 171 facilities where EURATOM Safeguards are "susceptible to be carried out". However, it does not specify anymore the number of facilities that are under civil-military mixed status.

The scope of IAEA Safeguards in France is even more limited the scope of EURATOM Safeguards. According to the French Industry Ministry, the agreement which was concluded was a compromise: France named eight installations - internally called the *"gas meter"* facilities - to be subject to IAEA Safeguards. The identity of these facilities is secret. According to the terms of the agreement, the nuclear materials contained in these facilities shall be at least equivalent to foreign nuclear materials officially subject to Safeguards, in quantity and in quality.[25] According to the International Safeguards Application Division of the French government[26] that follows international Safeguards inspections in France, the IAEA would be allowed to inspect *about* eight installations in which are stored nuclear materials equivalent to the foreign materials. "Eight is a number which varies", but "like everyone, the IAEA has budget problems" and therefore only inspects the La Hague spent fuel storage facility. However, "nothing forbids the IAEA from making inspections in the other installations".

This is confirmed by an IAEA statement: "The IAEA applies limited safeguards at THORP and at the UP2 and UP3 facilities in the UK and France, respectively. The IAEA has not been given the financial resources necessary for full coverage of civil nuclear installations in NPT nuclear weapon states allowed under voluntary safeguards agreements currently in force".[27] According to its International Safeguards Application Division, France sends accountancy reports on foreign safeguarded materials at La Hague to the IAEA. The 1978 agreement therefore allows France to manage according to its civil and military nuclear needs the nuclear materials in the majority of its facilities, even if those materials are in contact with or consist physically of foreign materials under Safeguards.

IAEA and EURATOM Safeguards are controls, which are meant to *verify* that no nuclear material declared for peaceful use has been diverted to a military use or to a use different from the one declared. France, as any other nuclear country, also implements national physical protection measures, to *prevent* any nuclear material from being diverted from the facilities. However, this scheme is not designed to prevent the direct or indirect use of foreign nuclear materials in the French defence programs.

Plutonium Swaps

The plutonium coming out of reprocessing is never identical to in-going plutonium since a certain amount stays in the piping system and in the waste, and plutonium in the piping from earlier campaigns might come out in later campaigns. Theoretically physical tracking of the plutonium of a certain origin would be possible to a fairly high degree of accuracy. But this would mean that the whole piping of the reprocessing plant would have to be cleaned out and rinsed each time before the following batch of fuel of a different client is introduced into the system. This would raise the economic costs of plutonium separation to impracticable levels. Even if this was not done, it would be

[24] BSNMS, "Rapport sur l'application des dispositions de la loi du 25 juillet 1980 sur la protection et le contrôle des matières nucléaire, Année 2007", HFDN, Ministère de l'Industrie, 2008

[25] BSCMNS, "Rapport sur l'application des dispositions de la loi du 25 juillet 1980 sur la protection et le contrôle des matières nucléaire, Année 2005", HFDN, Ministère de l'Industrie, 2006

[26] M. Méramédjian, then assistant director of the International Safeguards Application Division of the French Industry Ministry, personnel communication, 4 August 1995

[27] Thomas A. Shea, op.cit.

possible after each reprocessing campaign to allocate to the customer a given amount of plutonium of the corresponding age and of a certain quality based on the isotopic composition of the plutonium delivered in the spent fuel. Even if "atoms do not carry a flag" this procedure would allow for at least a share of the physical identity of the plutonium to be allocated to the original owner. And, it would allow for the tracking of this material from then on.

In practice, however, the plutonium in store does not have a label, which identifies its origin or the client to whom it is allocated. The plutonium is identified only according to its *quality*. The plutonium is allocated on paper to each customer according to an unknown set of parameters, without regard to the actual *physical origin* of the material. One quantity of plutonium can be replaced by another one. Therefore not only is there always a certain mixing of plutonium of different origins during the reprocessing process, but also under current practice there is the *conscious* exchange (swapping) of plutonium of a given origin/allocation for plutonium from another origin/allocation.

Plutonium swaps can have different purposes. Plutonium separated through reprocessing spent fuel can have very different isotopic compositions, which vary notably with the burn-up rate of the spent fuel, the delay before reprocessing and the storage time after reprocessing. A higher burn-up rate increases the radiotoxicity of the plutonium and diminishes the fissile plutonium content of the resulting plutonium. A long delay after reprocessing increases the americium-241 content (plutonium-241 decay product), which increases the radiotoxicity of the fuel and diminishes its fissile properties. It is therefore useful for plutonium fuel production to use plutonium with a low burn-up rate, and which has not been stored too long since reprocessing. And, since it is in everybody's interest and there are large amounts of plutonium in stock, it is quite logical that AREVA NC actually sends back to client countries rather "fresh" plutonium, whatever its origin.

The 1978 agreement between France, IAEA and EURATOM is a *de facto* flag swapping authorization. It allows France to exchange foreign safeguarded nuclear materials and materials considered to be equivalent in a chosen facility. Therefore, once foreign nuclear materials are sent to France, AREVA NC processes them as it desires, and sends back materials considered to be equivalent.

In civil facilities this exchange of "equivalent" material can enable the use of embargoed material, as happened during the embargo of South African uranium in the late 1980s where Finland got what was actually South African uranium physically in France which was transformed, "flag-swapped", by the German uranium broker NUKEM into uranium of non-embargoed Niger origin.

The consequences for the French facilities are different, since there is no separation between civil and military installations. The 1978 agreement allows AREVA NC and the CEA to consider that once foreign nuclear materials under Safeguards enter French facilities, they lose their country specificity, i.e. their "flag". And as former EURATOM Safeguards director Wilhelm Gmelin put it: "We do not have any obligation to follow-up the origin of material."

In a 13 May 1983 working group organized by the Nuclear Control Institute in Washington D.C., on "Nuclear Explosives Control Policy", Bertrand Barré, nuclear attaché at the French Embassy in the US, made the following statement: "As a nuclear weapons State respectful of its international commitments, France would never use for military purposes any fissile material which, directly or through 'filiation', would be subject to a civilian use pledge". The meaning of "filiation" in French is radioactive decay, so this covers any radioactive nuclear substance, which derives by natural decay directly from a given material. Indirectly Barré's declaration states that France does not use civil nuclear material for military purposes if the civil material has not been subject to any irradiation. Thus civil nuclear material irradiated in a reactor is not influenced by this statement. Plutonium produced in French fast breeder reactors from peaceful-end-use-labelled fuel, and civil plutonium irradiating blankets in the fast breeder reactors, *could* accordingly be used in military programs. And to make things very clear, Barré stated further: "Beyond that, it is not France's policy to disclose which, if any, of its nuclear facilities are used for military purposes".

A EURATOM spokesperson, asked by the science journal *Nature* to comment on the findings of a WISE-Paris report on the Japanese-French Plutonium Connection[28], confirmed that "the possibility that foreign nuclear waste might end up in military programmes cannot be discounted (...) given the practice of 'flag-swapping' equivalent nuclear materials".[29]

The Plutonium Industry[30]

France initiated a spent nuclear fuel reprocessing program to provide plutonium for its nuclear weapons programs in Marcoule in 1958. Later, the vision of the introduction of plutonium fuelled fast breeder reactors drove the large-scale separation of plutonium for civilian purposes starting with the opening of the La Hague plant in 1966.

Military plutonium separation by France ceased in 1993 but civilian reprocessing continues. Virtually all other European countries, apart from the United Kingdom, have abandoned reprocessing. France’s last foreign reprocessing customers for commercial fuel are the Netherlands and Italy with negligible quantities under contract and provide no more than a few months of activity to the La Hague reprocessing complex.

France abandoned its fast breeder reactor program in 1998 when the only industrial scale plutonium fuelled breeder in the world, the 1200 MW Superphénix in Creys-Malville, was officially shut down permanently. Superphénix was a financial disaster. Started up in 1986 it produced some electricity only in six of the twelve years it was officially in operation. Its lifetime load factor was less than 7%. Plagued by technical problems and a long list of incidents, the cost of the adventure was estimated by the French Court of Auditors at FRF60 billion (close to €9.15 billion) in 1996. However, the estimate included only FRF5 billion (€0.760 billion) for decommissioning. That figure alone had increased to over €2 billion by 2003. At a lifetime power generation of some 8.3 TWh, Superphénix has produced the kWh at about €1.35 (to be compared with the French feed-in tariff of €0.55 per building integrated solar kWh).

Marcoule. France’s first reprocessing plant was the Usine de Plutonium 1 (UP1, Plutonium Factory 1) at Marcoule. Thirteen thousand tons of reactor fuel from gas-graphite plutonium production and power reactors were reprocessed there between 1958 and late 1997. Today the site hosts a huge decommissioning and clean-up effort. In 2003, the cost of clean-up, including waste management, was estimated to eventually reach about €6 billion. The clean-up is currently expected to last till 2040. In 2005, these costs and liabilities were transferred from AREVA NC to the CEA.

La Hague. Between 1966 and 1987, about 5,000 tons of gas graphite reactor (GGR) fuel and, between 1976 and the end of 2007, about 24,000 tons of light water reactor fuel (LWR) fuel were reprocessed in the UP2 and UP3 plants at La Hague. Small batches of breeder reactor and LWR mixed uranium-plutonium oxide (MOX) fuel also have been reprocessed. Over the last few years the two reprocessing lines together have processed about 1,100 tons annually.

Until around 2004, close to half of the LWR spent-fuel throughput at La Hague was foreign-owned spent fuel. Almost all of the foreign spent fuel under contract has been reprocessed. At the end of 2007, the total quantity of foreign fuel awaiting reprocessing was so small, in total about 6 tons, that AREVA NC indicated the quantity per client country in kilograms (see graph). It should be noted that, at the same time, the total quantity of spent fuel awaiting reprocessing at La Hague was 8,849 tons, and 99.8% of French origin.

[28] See Mathieu Pavageau, Mycle Schneider, "Japanese Plutonium and the French Nuclear Weapons Program", Paris, WISE-Paris, 9 August 1995.
[29] *Nature,* 31 August 1995
[30] This chapter is based on the summary of Mycle Schneider, Yves Marignac, “Spent Nuclear Fuel Reprocessing in France”, International Panel on Fissile Materials (IPFM), Princeton University, April 2008

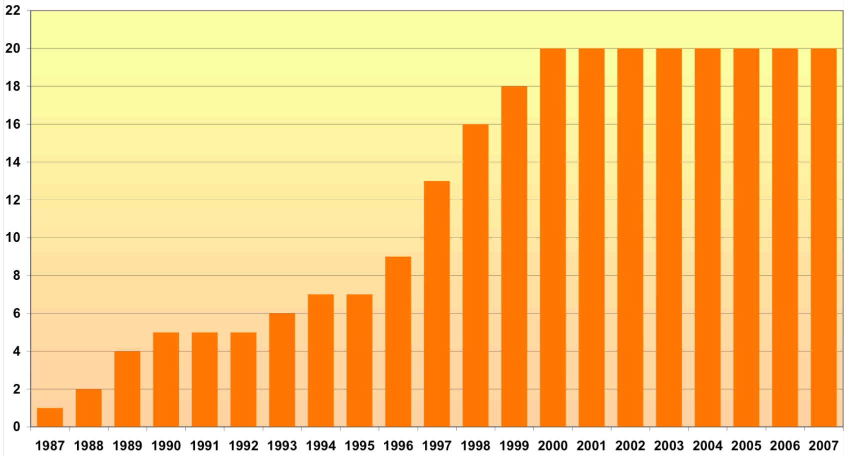
Table 1: Foreign Spent Fuel at La Hague (as of the end of 2007, in kilograms!)

Pays	Entreposés (kg ML)	Traitements prévus
Allemagne	63	2008
Australie	140	jusqu'en 2010
Belgique	440	jusqu'en 2012
Suisse	5 273	2008

Source: AREVA NC

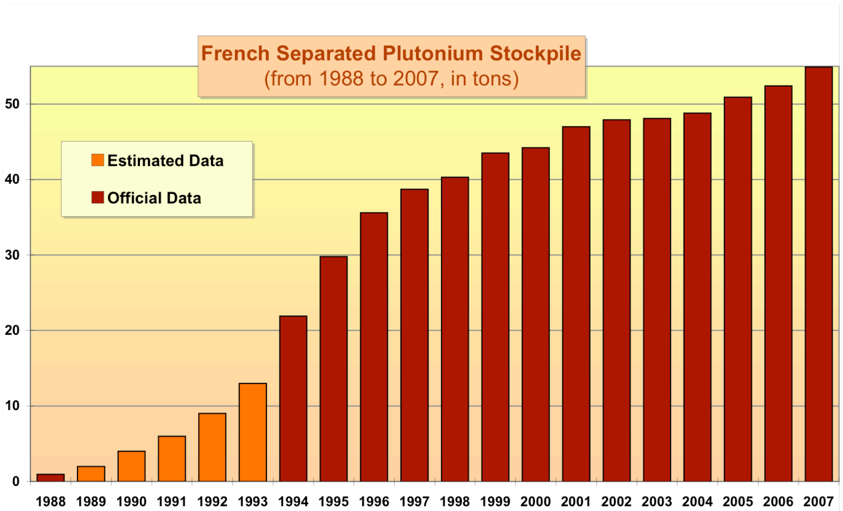
EDF has a large backlog of about 12,000 tons of spent fuel, three quarters of which are stored at La Hague, the equivalent of over ten years' throughput at the current rate of reprocessing. Since 1987, France has also built up a large backlog of almost 55 tons of its own unirradiated plutonium in various forms, of which more than half is stored as separated plutonium at La Hague. Plutonium is being used in MOX fuel in twenty 900-MWe LWRs that are operating with up to 30% MOX fuel in their cores. While there was no plutonium stock when the MOX program started in 1987 (see figures 1 and 2), stockpiling has increased every year since. In addition to the French stocks, AREVA's foreign clients currently store more than 30 tons of separated plutonium in France.

Figure 1: Number of French Reactors Loaded with MOX Fuel 1987-2007



Sources: COGEMA, ASN, WISE-Paris

Figure 2: Steady Growth of French Separated Plutonium Stocks 1988-2007



Sources: WISE-Paris, IAEA 2008

Economic Costs of Reprocessing in France: In 2000, an official report commissioned by the French Prime Minister concluded that the choice of reprocessing instead of direct disposal of spent nuclear fuel for the entire French nuclear program would result in an increase in average generation cost of about 5.5 percent or $0.5 billion per installed GWe over a 40-year reactor life or an 85 percent increase of the total spent fuel and waste management ('back-end') costs. [see CDP 2000]

Current projected costs by the industry and the Ministry of Industry show that, in addition to a number of other favourable assumptions, the investment and operating costs of a future reprocessing plant would need to be half the costs for the current La Hague facilities in order for reprocessing to cost no more than direct disposal.

Since 1995, EDF has assigned in its accounts a zero value to its stocks of separated plutonium, as well as to its stocks of reprocessed uranium.

With the liberalization of the electricity sector in the EU, the pressure to lower costs has increased significantly. EDF's massive subsidy of AREVA's plutonium industry is becoming unbearable and the EDF management has not yet signed on to a follow-up agreement that should replace the reprocessing / MOX fabrication contract that ended in 2007. In an unusual press statement[31] AREVA's CGT trade union section alleges that "in the difficult year 2007 EDF has not respected its contractual engagements. (…) The CGT is concerned that EDF's posture, including the request for drastic cost reductions in reprocessing-recycling, will not be without consequences on safety, security and working conditions". A few days later the negotiations collapsed. The two parties signed a provisional agreement for one year in order to avoid the worst case, which would have been the closure of the MELOX plant, because there was simply no contractual basis anymore. It is little surprising that even after over three years, as of the end of October 2008, no long-term agreement has been signed. Apparently the initial positions were very far apart: while EDF wished a 30% reduction over previous prices, AREVA wanted a 30% increase. The French government, majority shareholder of both companies, requested the managers to target the signature of an agreement by the end of 2008. However, while AREVA would like to sign on to a long-term package deal for reprocessing/MOX fabrication until the end of the operational lifetime of the La Hague facilities, around 2025, the final version might only cover the coming five years.

At the same time, EDF wishes to increase storage capacity at La Hague by a further 4,000 tons, bringing the total to some 17,700 t, equivalent to significantly over 100 reactor cores. The storage of such a large quantity of spent fuel, including a significant quantity of particularly radioactive spent MOX fuel, constitutes an unparalleled risk potential in case of accident or attack. If the water is drained from the storage pools, spent fuel assemblies could ignite spontaneously and release very large amounts of radioactivity into the environment.

Waste Volumes. A major argument made for reprocessing is that it would dramatically reduce the volume of radioactive waste. A number of serious biases have been found, however, in official comparisons made by EDF, AREVA and ANDRA, the organization responsible for radioactive waste disposal in France. These include:

- Exclusion of decommissioning and clean-up wastes stemming from the post-operational period of reprocessing plants.
- Exclusion of radioactive discharges to the environment from reprocessing. Their retention and conditioning would greatly increase solid waste volumes.
- A focus on high-level waste (HLW) and long-lived intermediate-level waste (LL-ILW), leaving aside the large volumes of low-level waste (LLW) and very low-level wastes (VLLW) generated by reprocessing.
- Comparison of the volumes of spent fuel assemblies packaged for direct disposal with those of unpackaged wastes from reprocessing, which overlooks for instance the fact that packaging reprocessing waste is expected to increase its volume by a factor of three to seven.

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[31] CGT-AREVA, "Négociations AREVA/EDF sur le retraitement recyclage des combustibles usés : le torchon brûle…", Press Release, 28 February 2008

- Failure to include the significantly larger final disposal volumes required for spent MOX fuel, because of its high heat generation, unless it is stored on the surface for some 150 years instead of the 50 years for low-enriched uranium spent fuel.

Radiological impact: The global, collective dose over 100,000 years--due primarily to annual releases to the atmosphere from La Hague of the low-level but long-lived emitters, krypton-85 (half-life of 11 years), carbon-14 (5,700 years) and iodine-129 (16 million years)--have been recently recalculated at 3,600 man Sv[32], which is in excess of the estimated impact of the 1957 Kyshtym nuclear accident that led to widespread contamination. Continuing discharges at this level for the remaining years of La Hague's operation theoretically could cause over 3,000 additional cancer deaths.

Research & Development

There is no comprehensive overview and analysis of public support of nuclear research in France. It is definitely one area where the overlap between civil and military applications played a significant role. An independent analysis carried out on R&D expenditures on nuclear issues in France from 1960 to 1997[33] illustrates that there is a fundamental lack of public statistical data on nuclear research expenditures but that most likely at least half of the research has been carried out under CEA public funding.
According to OECD-IEA figures exclusively based on data transmitted by the French government, between 1985 and 2001 nuclear fission has constituted between 75% and 86% (93% including nuclear fusion) of public energy research expenditures in France. It is only over the last few years that more resources have been allocated to other energy technologies, but mainly to fossil fuels (18%-22%). While efficiency and all renewable energies combined have increased from less then 1% each in 1997 to 8% and 5% respectively in 2005, the French research efforts in these areas remain remarkably low.

Oil, Energy Dependence and Nuclear Power

France has thus been able to conquer a relative energy independence and acquire competitive electricity favourable for the development of industry and employment.

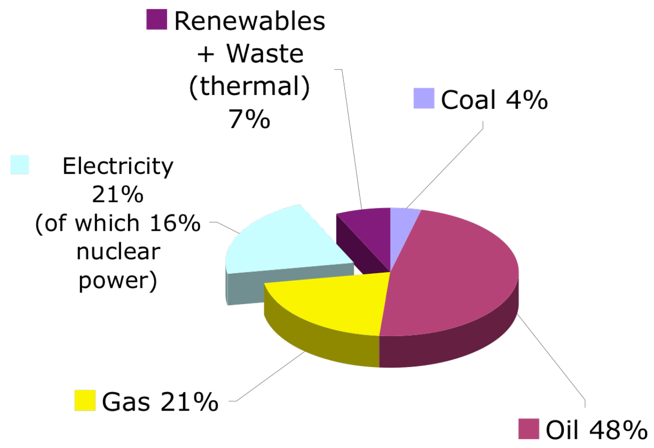
Draft bill on the public service on electricity and gas,
tabled by Nicolas Sarkozy,
then Minister for Finances, Economics and Industry,
on 26 May 2004

The disproportionate public research effort for the nuclear sector becomes even more obvious if one considers the fact that nuclear power only provides about 16% of final energy in France, while fossil fuels continue to cover three quarters (73%) of the demand. In 2007, after three decades of major nuclear power development, oil alone provides almost half (48%) of the final energy consumed in France.

Gaining energy independence through the massive development of nuclear power? That was the message in 1974 when the French government launched the first large-scale nuclear power program. The so-called oil crisis of 1973 had impacted on collective consciousness. The oil price skyrocketed, supply shortages appeared and neighbouring Germany even invented the car-free-Sunday.

[32] K.R. Smith, A.P. Bexon, K. Sihra, J.R. Simmonds (HPA), J. Lochard, T. Schneider, C. Bataille (CEPN), "Guidance on the calculation, presentation and use of collective doses for routine discharges", UK Health Protection Agency / CEPN, Radiation Protection n°144, commissioned by the European Commission, August 2006.
[33] Mycle Schneider (Dir) et al., "Research and Development on Nuclear Issues in France 1960 – 1997", commissioned by Energy Services, (Lohmar, Germany), WISE-Paris, February 1998

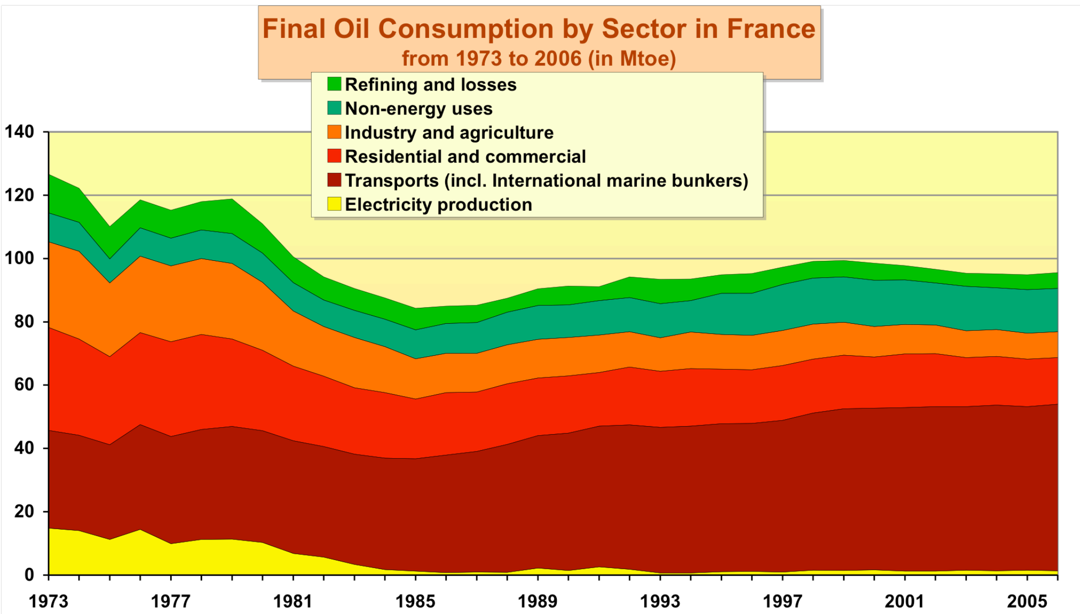
Figure 3: Final Energy Supply in France in 2007 (per fuel, in %)



© Mycle Schneider Consulting *Source: Ministry of Ecology, Bilan Energie 2007, 2008*

However, the French government's announcement that it intended to render France independent from oil through the development of nuclear energy remains astonishing considering the fact that electricity generation accounted for less than 12% of the oil consumption in the country in 1973 (see figure 4).

Figure 4: Oil Consumption in France



© Mycle Schneider Consulting *Sources: Observatoire de l'Énergie, 1992; DGEMP, 1998-2007*

It is remarkable to what extent the oil consumption in the country followed the oil price rather than the electricity supply policy. The key sector for oil consumption in the early 1970s was already the transport sector. The substitution of oil for nuclear power in the electricity sector was very successful and brought the electricity sector share in oil consumption down to 1.5% by 1985. At the same time, overall oil consumption hit a long time low. Between 1973 and 1985 the industry and residential/commercial sectors had saved double the amount of oil that the electricity sector had saved essentially through substitution. Four years of work of the French Energy Efficiency Agency (AFME) were harvesting spectacular results. But the 1985 counter oil shock, combined with a radical shift in government policy in 1986, led to the dismantling of the AFME and the energy conservation and efficiency policy. The result was the immediate resurgence of overall oil consumption. By the end of the 1990s the oil consumption corresponded again to the level of the early 1980s – in spite of the closure of some of the oil consuming heavy industries and the nuclear program.

In 2007 per capita oil consumption in France of 1.5 tonnes was *higher* than the EU average and higher than consumption in non-nuclear Italy and nuclear phase-out country Germany that are about 1.4 tonnes per person.[34]

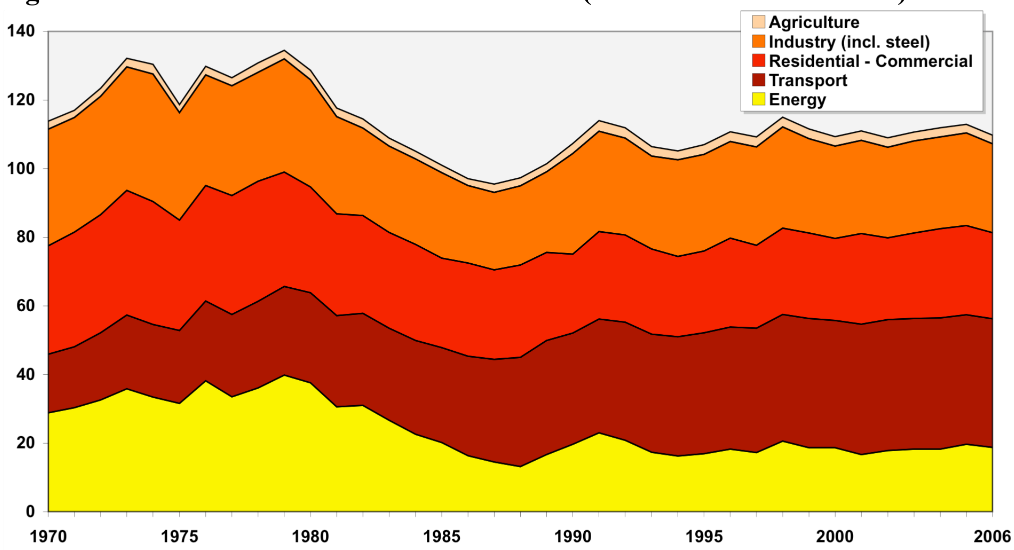
It is a clear historic lesson that if independence of oil imports had been really the driving force behind energy policy in France, the transport sector would have been focused on a long time ago.

As the oil consumption is sensitive to the oil price, the CO2 emissions have been sensitive to oil consumption. The respective graphs almost have the same shape (see figures 4 and 5). While per capita emissions remain significantly lower than in neighbouring countries, there is no identifiable structural emission reduction. France's *total* emissions of the six main greenhouse gases were 2 % below 1990 levels in 2005. This had little to do with the power sector. In fact, the emissions of public electricity and heat generation were 5% *above* the 1990 levels.[35] But large reductions were achieved for example in N_2O emissions from the adipic acid production.[36] In 2006, total greenhouse gas emissions were almost 4% below the 1990 level[37]. However, the decrease between 2005 and 2006 can be seen as rather exceptional (high hydro generation, lower fossil fuel use for power and heating, high oil prices…).

Per capita greenhouse gas emissions have decreased continuously since 1999 and in 2006 France registered the 8th lowest emissions in the EU27.

However, if one looks at provisional figures for 2007, CO2 emissions in particular, which account for three quarters of total greenhouse gas emissions of the energy transformation sector, are practically identical to 1990 levels and are 10% higher than in 1995.[38]

Figure 5: CO2 Emissions in France 1970-2006 (in million tons of carbon)



Sources: Observatoire de l'Énergie, DGEMP, 2001; MIES 2004; CITEPA 2007

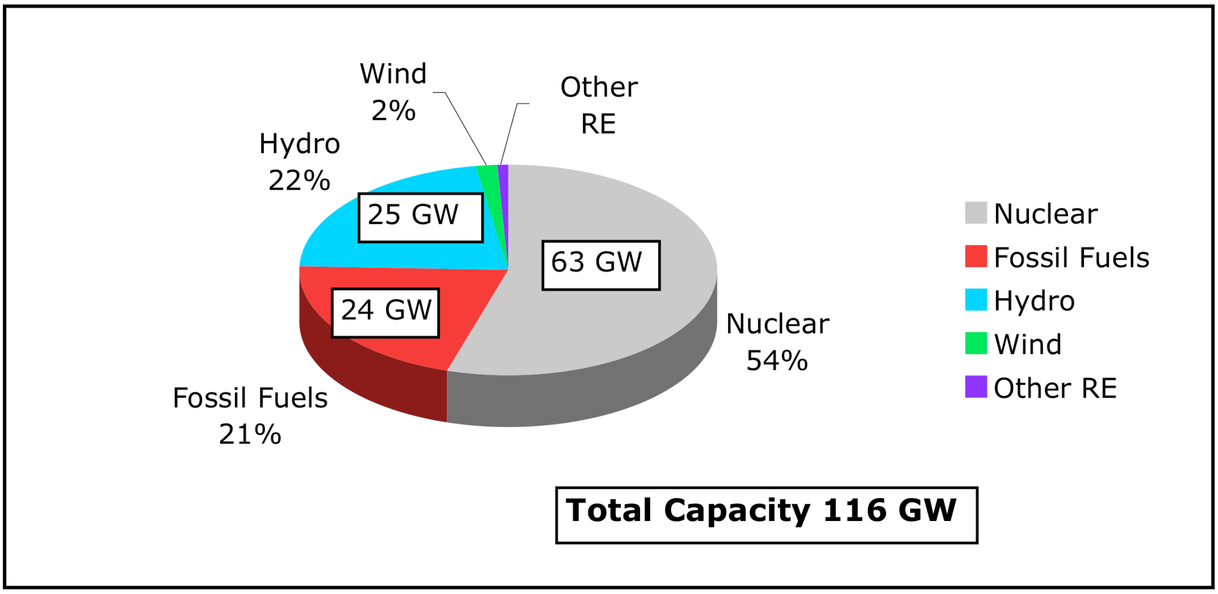
[34] Oil consumption figures according to BP, *Statistical World Review 2007*, 2008; population figures according to DG TREN, *EU Energy and Transport in Figures – Statistical Pocketbook 2007-2008*, 2008.
[35] Consumption of fossil fuels for power generation even increased by 24% between 1990 and 2007 (see figure 7).
[36] EEA, *GHG Emissions and Trends – Profile France,* 2008
[37] However, this is still only half of the average EU27 reduction level of 7.7%.
[38] Observatoire de l'énergie, *L'énergie en France – Repères,* MEEDDAT, 2008

Electric Heat and Power Trade

By the middle of the 1980s – when most of the currently operating nuclear plants in France were either already operating or in advanced building stage – it had become clear that the dimension of the nuclear generating capacity had been vastly oversized. France was not the only country whose energy technocrats had got it wrong. In most industrialized countries the dogma was to plan on the basis of a doubling of the consumption every 10 years. Instead there was a clear decoupling of economic development and energy consumption during the 1970s. However, the energy establishment did not adapt its planning and phenomenal overcapacities were built up in the power sector as well as in refineries and nuclear fuel industries all over Europe and far beyond. This was the death knell for any significant intelligent energy initiative based on efficiency and conservation.

In France the nuclear overcapacities were and remain tremendous. They were estimated already by the middle of the 1980s at 12 to 16 nuclear reactors. While in the US 138 units in total were cancelled in various stages of planning and construction, in France the state owned EDF did not abandon any project. Between 1977 and 1999 EDF started up 58 PWRs[39] with a total capacity of 63 GWe (net). As of the end of 2007, France had a total installed power generating capacity of some 116 GW (see figure 6), adding 24 GW of fossil fuelled capacity (coal 8 GW, oil 6 GW, gas and others 10 GW) and 25 GW of hydro to the nuclear plants. Other renewable energy sources have remained marginal with less than 3% of installed capacity (mainly wind).

Figure 6: Electricity Generating Capacity in France in 2007

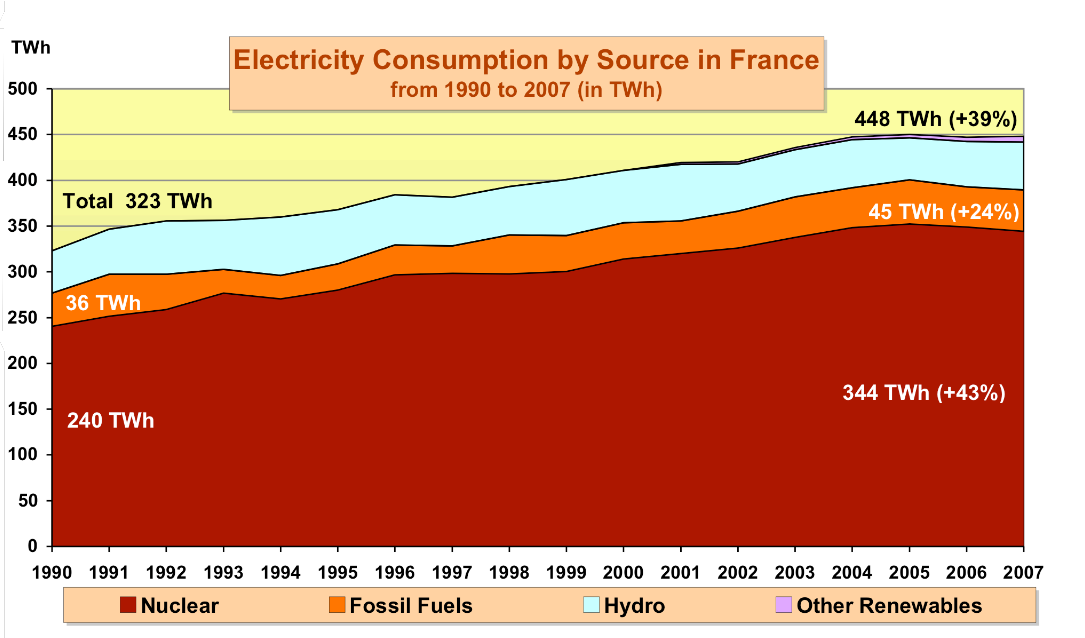


© Mycle Schneider Consulting *Source: RTE 2008*

In 2007 nuclear plants generated 76.9% of the electricity in France, fossil fuel plants (coal, gas, oil) produced 10.1%, hydro plants 11.6% and other renewables (essentially wind) 1.4%.

[39] 34 x 900 MW, 20 x 1300 MW, 4 x 1500 MW

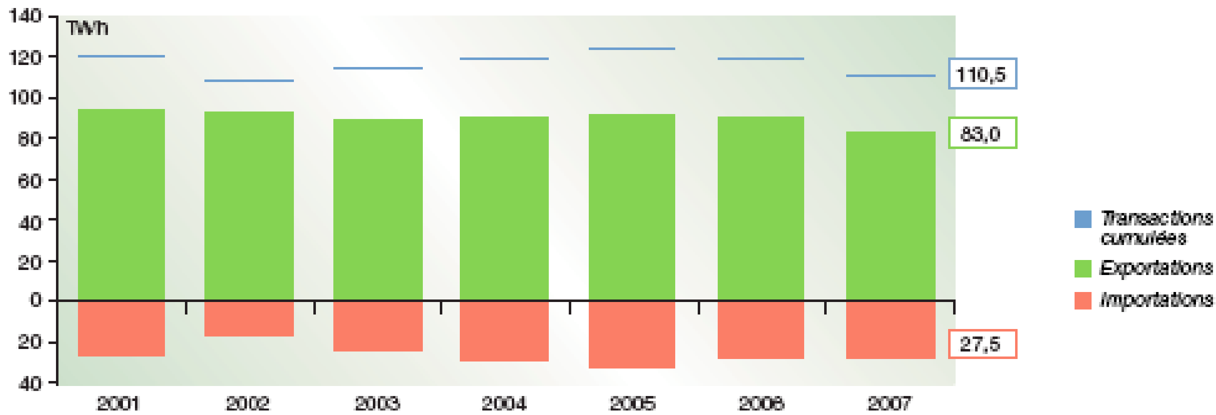
Figure 7: Evolution of French Electricity Consumption 1990-2007 (by source, in kWh)



Source: RTE, Résultats Techniques du Secteur Electrique en France 2007, 2008

Instead of downsizing its nuclear plans in the 1980s, the public power company developed a very aggressive two front policy: long term base load power export contracts and dumping of electricity into competitive markets like space heating and hot water heating. Foreign clients requested stiff conditions on supply guaranties. The French government did not hesitate to elevate the supply priority for foreign power customers to the level assigned to a French hospital. Foreign utilities in Belgium, Germany, Italy, Spain, Switzerland and the UK were satisfied and agreed on large-scale long-term electricity purchase agreements. While France had a balanced import-export balance in the 1970s, in the 1980s France turned into the largest net power exporter in Europe. By the early 1990s the net exports reached 50 TWh and they peaked at 70 TWh in 1995 (15% of total generation or 20% of national consumption), a value exceeded once in 2002 with an exceptional 76 TWh. Since then, there has been a clear tendency towards a stabilization (at 80-90 TWh) and more recently towards a decline of exports but an increase in imports (around 25-30 TWh), thus net exports fluctuating around 60 TWh. In 2007 France exported only 83 TWh and the net exports were at 55.5 TWh, the lowest figure in 15 years. In 2007 the maximum daily capacity mobilized for exports was 14 GW but the import maximum reached 12 GW.

Figure 8: French Power Exports and Imports 2001-2007



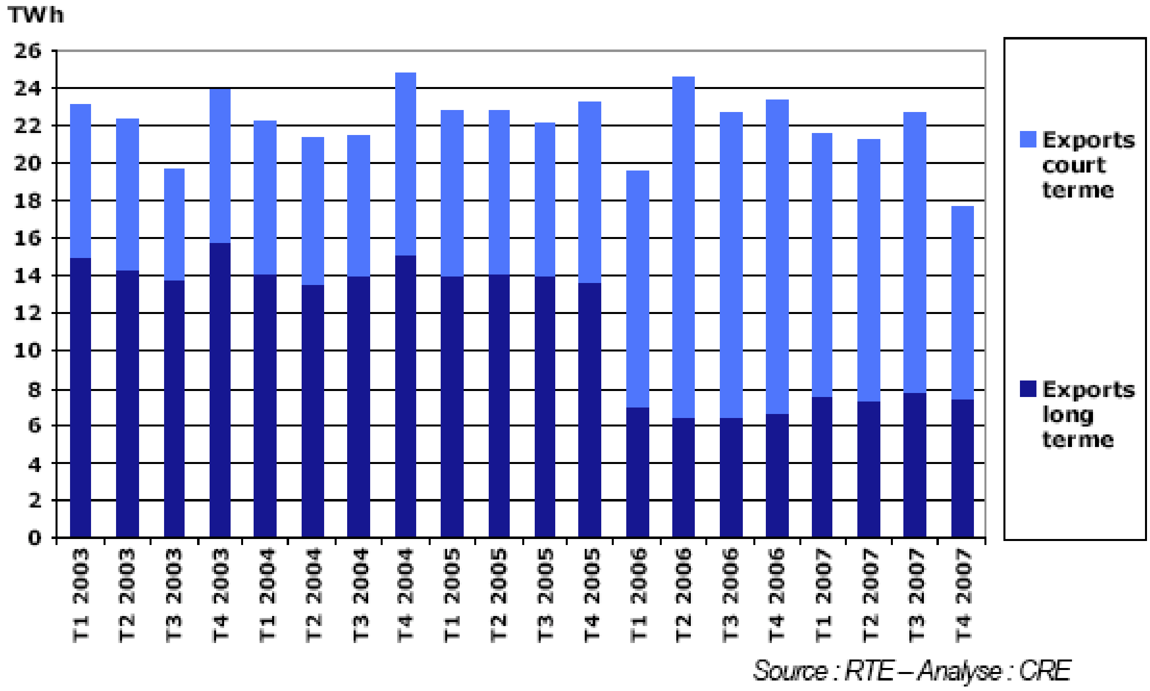
Source: RTE 2008

The electricity trade balance of the first 10 months of 2008 indicates a prolonging of the tendency. Exports declined by 3% compared to the same period in the previous year while imports increased by 56%.

A critical analysis of the impact of French electricity exports was carried out by independent think tank INESTENE in 2002[40]. The report estimates that the power exports, analyzed over the years 1995 to 2001, were a major loss maker. According to INESTENE, the official revenues from exports did not cover the official nuclear generating costs. In addition, detailed modelling reveals that nuclear power covered less than three quarters of the electricity that was exported, one quarter being covered by coal fired power plants and around 3% by fuel oil, at much higher cost. In addition, INESTENE has made its own cost assessment factoring in the costs of electricity transport, the specific costs of the share of fossil fuel power, specific costs of nuclear power (research, fuel, investment, dismantling, insurance, external costs). According to the INESTENE calculations annual losses vary between a minimum of €800 million and a maximum €6 billion.

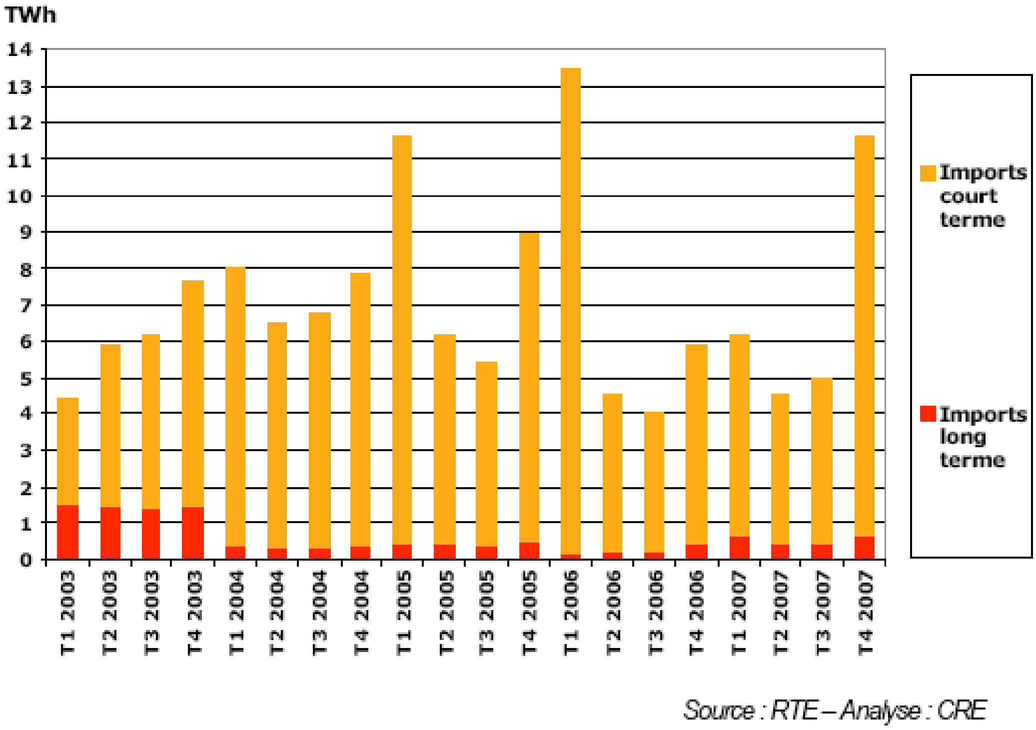
In 2005 many of the long-term export contracts were not renewed. While long-term contracts represented about two thirds of the total volume until 2005, they represented a little over one third in 2006 and 2007. This means that the electricity market became much more volatile for France. Exports plunged in 2007 and imports went up significantly in the last quarter of 2007 (see following figures).

Figure 9: French Electricity *Exports* According to Long- and Short-Term Commitments
(in TWh per Trimester)



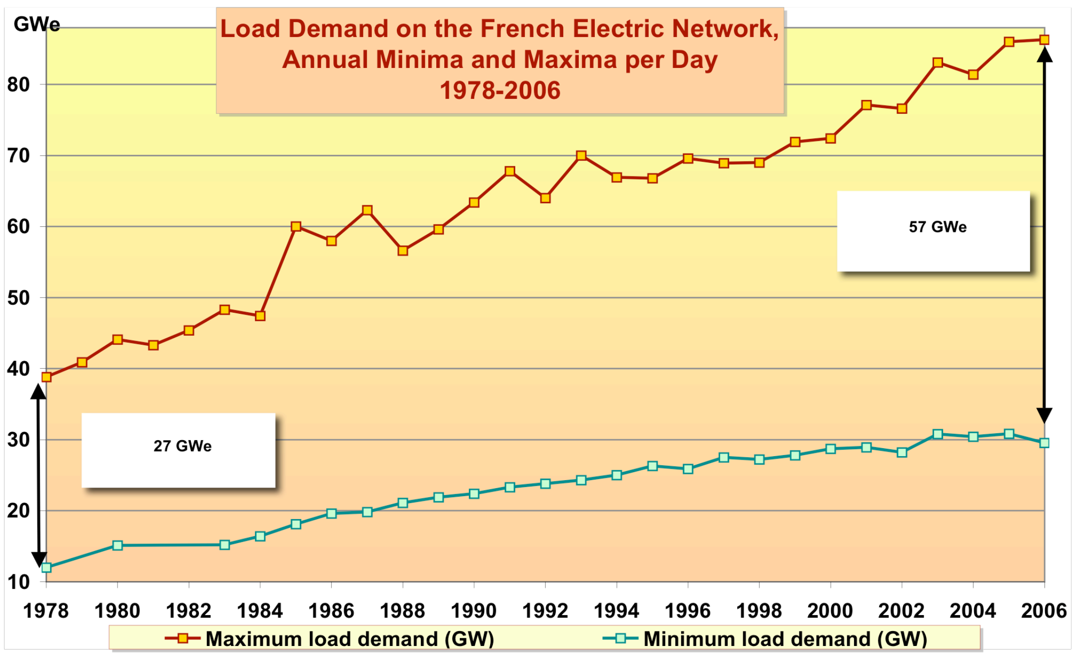
[40] Antoine Bonduelle, « Exportations de courant électrique : Qui perd, qui gagne ? », commissioned by Greenpeace France, INESTENE, Paris, November 2002

Figure 10: French Electricity *Imports* According to Long- and Short-Term Commitments
(in TWh per Trimester)



It is obvious that import and export are not the same kind of electricity. France still has a huge overcapacity in base load power but increasingly lacks peak load capacity. Seasonal peak load exploded in the 1980s and 1990s in particular as a consequence of large-scale introduction of electric space heating. Not only did the daily load maximum more than double to almost 89 GW in early 2008, but also the difference between the lowest load day in summer and the highest load day in winter more than doubled to reach 57 GW by 2006.

Figure 11: Seasonal Peak Load Explosion in France



© Mycle Schneider Consulting *Sources : EDF, RTE 2007*

Such a load curve is highly uneconomic, because it requires a significant generating capacity for very short operational periods or the importation of peak load power at very high cost. Between 2005 and 2007 France imported an average of close to 30 TWh per year, of which 17.5 TWh from Germany alone[41]. The exact costs of the power imports are not public. However, short-term peak load deliveries can be many times more expensive than base load exports in the framework of multi-annual agreements.

The peak load problem became so urgent that in 2006 EDF decided to restart 2,600 MW of mothballed oil fired power plants, the oldest of which had started up in 1968 and added them to the thermal power plant fleet that had started up between 1950 and 1984. The new-old oil capacity can be compared to that of the new nuclear project at Flamanville with 1,600 MW under construction since December 2007. Over the past few years France has already generated twice as much electricity from oil-fired power plants as the UK and the situation is likely to become worse. At the same time, independent power producers have gained ground in France. The company POWEO alone aims at 3,400 MW of installed capacity by 2012 of which 600 MW of renewable energy.[42] The rest of POWEO's new capacity will be essentially natural gas peak load plants. The company calculated that the investment was worthwhile based on an operating time of 100 hours per year[43].

Electric space heating is not only uneconomic it is also an energetic absurdity and highly polluting. Instead of using primary energy directly (natural gas, oil, biomass…), mainly fossil fuels, including coal in foreign countries, are burnt in power plants. Around three quarters of the energy is lost in the form of waste heat and distribution losses before the electricity is re-transformed into heat in people's homes (see figure 12). An assessment published by Gaz de France in 2007 puts the nuclear share of each additional kWh consumed by electric space heating as low as 10%. The high ratio of fossil fuels in the mix would lead to specific emissions of over 600 g of CO2 per kWh, more than ten times the official average emission per kWh. Even the French Secretary of State for Ecology, Nathalie Kosciusko-Morizet calls the development of electric space heating an "error". She considers it "a French folly" to transform electricity into heat, and "even an aberration from a thermo-dynamic point of view".[44]

What if…? Optimized Equipment and Economic Evaluation

The vastly over-dimensioned nuclear generating capacity clearly entailed the strategic choices to massively export power and to penetrate the market for heating. While EDF's commercial strategy on thermal uses did not have much success in the industry, up to 70% of new housings were equipped with electric space heating and today over one quarter of French homes are electrically heated.

An independent analysis published in 2006[45] looked into the question of what the French electricity generating system development would have looked like if it had been optimized and power exports had not been developed. A second exercise looks in addition at what the generating park would have looked like if electric space heating had not been encouraged and massively implemented.[46]

The results show that, under optimized economic conditions, as of the early 1980s the construction rhythm of nuclear plants would have slowed down significantly. No more than 33 GW of nuclear power would have been built compared to the 63 GW realized 36 units would have been built instead of 58. In addition, the model suggests investing in new fossil fuel capacity starting in the early 1990s in order to cover the electric space heating needs.

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[41] The *net* imports from Germany over that period averaged 8 TWh!

[42] POWEO, Press Release 31 January 2007

[43] The year has 8,760 hours. 100 hours thus correspond to a load factor of hardly more than 1%. It is obvious that POWEO speculates on competing with EDF for higher load factors.

[44] Le Monde, 7 October 2008

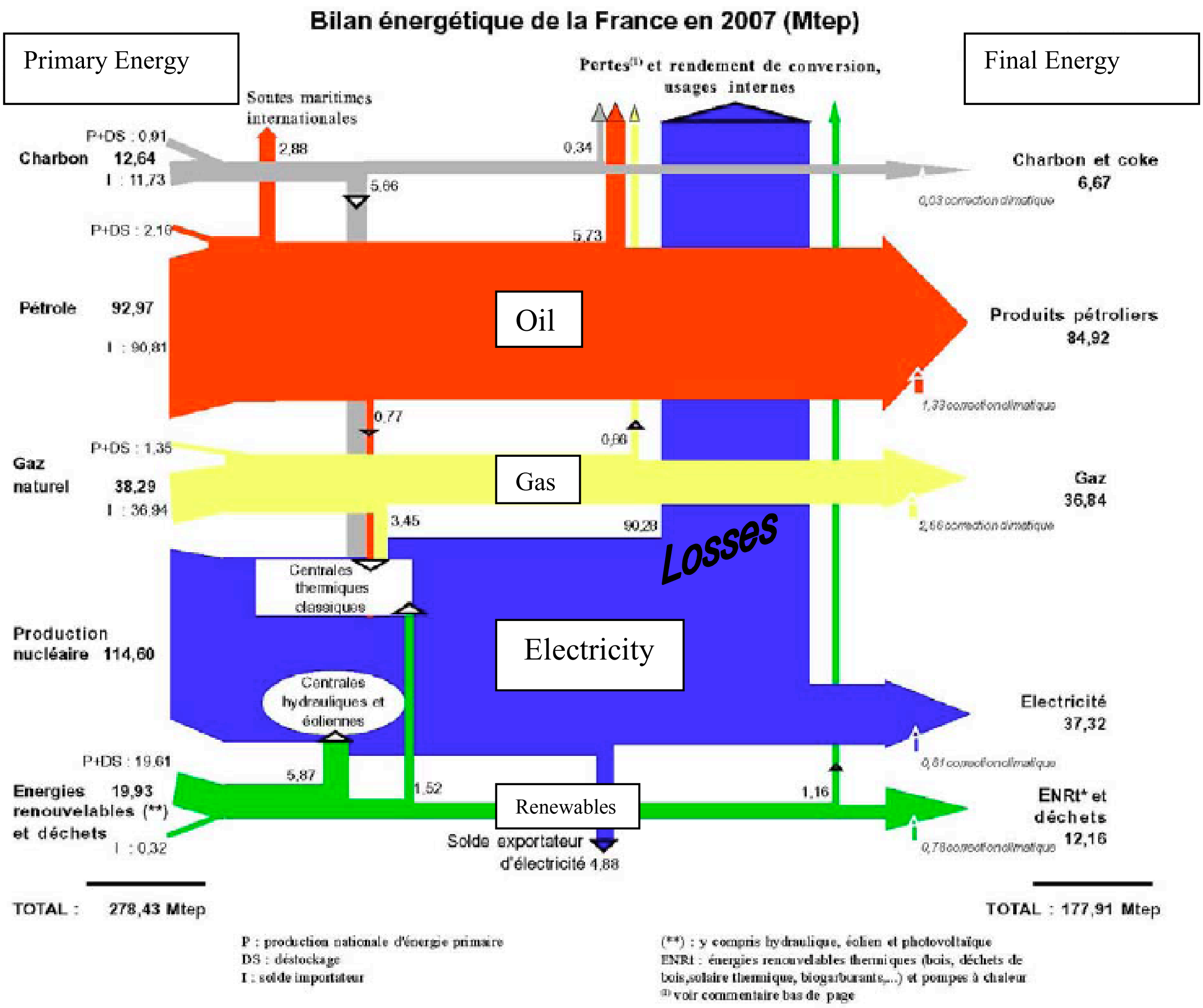
[45] Antoine Bonduelle « La surcapacité nucléaire, quelle aurait pu être une stratégie d'équipement optimale ? », La Revue de l'Energie N°569 p.30-38, Paris, January-February 2006,

[46] The exercise has been carried out with the ELFIN (ELectricity FINancing) model, developed by the US EDF (Environmental Defense Fund).

The second scenario also envisages that the electric space heating, consuming close to 60 TWh annually by the end of the 1990s, was not developed. While the seasonal peak use implies a large share of non-nuclear components[47], essentially fossil fuels, without construction of new coal fired power plants, the scenario would still have resulted in less nuclear power. In other words, without power exports and electric space heating an economically optimized French nuclear program would have been limited to less than 30 GW, the equivalent of the 34 x 900 MW reactors, the last of which was connected to the grid in 1987. The constant invitation to waste electricity in the form of heat[48] (space heating, hot water, cooking) has constantly guaranteed the French household the highest consumption level in Europe since 1976. Today, per capita electricity consumption in France is some 25% higher than in Italy (that phased out nuclear energy after the Chernobyl accident in 1986) and 15% higher than the EU27 average.

The energy flow sheet hereunder illustrates the phenomenal system losses of the power generating system (blue section). Only 27.5% of the energy contained in the primary resources injected (left side) is available in the form of final energy (right side).

Figure 12: Energy Flow Sheet France (in Mtoe)



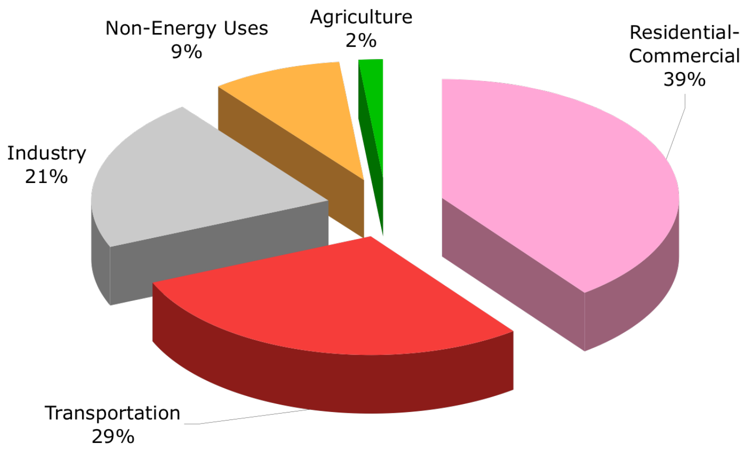
Source: Observatoire de l'énergie, L'énergie en France – Repères, *MEEDDAT, 2008*

[47] The evaluation is complex and all the data is not on the table. See GDF, « Le chauffage au gaz naturel pour réduire les émissions de CO2 », July 2007

[48] Heat generation by electricity is necessarily significantly more wasteful than using the primary energy direct to generate heat (e.g. oil central heating, gas stove), because thermal power plants lose between 45% and 75% of the primary energy in the form of waste heat (unless they are combined heat and power plants.)

At the same time the energy flow sheet illustrates why oil remains the main energy source in France as in most of the other industrialized countries. In 2007, electricity represented 21% of the final energy consumed of which nuclear power generated 77%.

Figure 13: Final Energy Consumption in France in 2007 (by sector, in %)

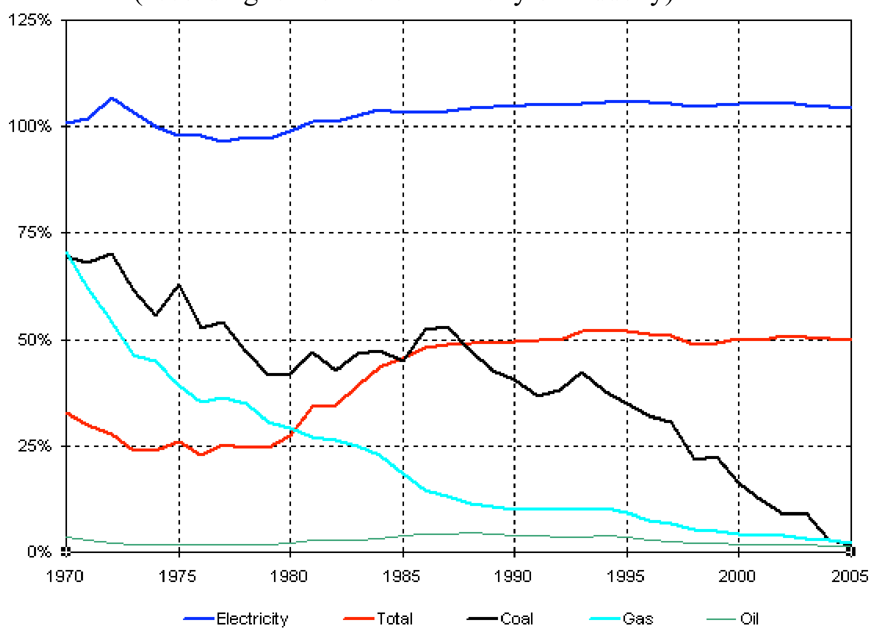


 Source: DGEMP, Bilan énergétique pour la France 2007*, 2008*

Energy Independence – From 50% to 8.5%

It is remarkable to what extent the myth of "energy independence" through nuclear power has survived the last 35 years. One of the reasons is the artistic manipulation of basic data by the State administration and the energy industry.

Figure 14: Energy Independence Trends by Energy Source 1970-2005
(according to the French Ministry of Industry)



Sources : Ministry of Industry 2008[49]

Figure 14 illustrates that, according to French official accounting, *primary* electricity (essentially hydro and nuclear) has been around 100% import independent before the first large scale nuclear

[49] http://www.industrie.gouv.fr/cgi-bin/industrie/frame23e_loc.pl?bandeau=/energie/anglais/be_us.htm&gauche=/energie/anglais/me_us.htm&droite=/energie/anglais/accueil.htm

program was launched in 1974. The graph suggests that overall energy independence has doubled between until 1990, when all but six nuclear units had come online, to stabilize at around 50%.

However the figure hides a number of serious biases that can be illustrated for the year 2007, when the French Ministry of Industry indicated energy independence as 50%:

a) Electricity exports should be excluded, because they do not influence energy independence. Thus 56.8 TWh or 4.9 Mtoe should be substracted.
b) The auto-consumption of the nuclear sector is around 18 TWh or 1.6 Mtoe (most of which is consumed by the uranium enrichment plant EURODIF alone) and should be deducted.
c) The degree of energy independence should be calculated on the final energy side. The two-thirds of energy wasted by nuclear plants (roughly equivalent to the oil consumption of the French automobile fleet) are incorporated in the ratio between energy produced and consumed nationally. The OECD's International Energy Agency equivalence introduces a lower ratio in final energy, accounting the nuclear power contribution at 0.086 toe of final energy per MWh. If calculated on the final energy side, the independence level shrinks to less than 24%.
d) Finally, all primary nuclear resources, the uranium, are imported. France stopped mining uranium in May 2001. While the production of energy from imported oil, gas and coal is accounted for as imported energy, this logic is not applied to uranium. The argument is on one hand that the international conventions would consider uranium as primary material, not as energy source and on the other hand that there are a number of politically stable, diversified sources for natural uranium that make its supply very secure. A third argument is that there is significant value added through transformation (conversion, enrichment). Those are valid arguments. However, they could also be applied to other energy sources and in particular to coal for diversity of supply and to oil for transformation (refining). If France did account for its uranium imports as such, the energy independence figure would obviously plunge.
e) However, some of the energy is generated by the reuse of plutonium and reprocessed uranium. In total, 22 French light water reactors are licensed to use plutonium fuel (MOX). About 100 t of MOX, which generate 30-40 TWh of electricity, are used per year. Two reactors at the Cruas nuclear power plant use reprocessed uranium that generates 13 TWh (figure 2005). Plutonium and reprocessed uranium generate around 50 TWh or hardly more than the equivalent of 10% of the final energy contribution of renewables. In total, the level of energy independence on the final energy side would be around 8.5% in 2007.

Table 2: Adjusted Level of French Energy Independence in 2007

	Mtoe	Level of Energy Independence
Nuclear Primary Energy Generation + other Primary Energies (Renewables, etc)	114.6 21.8	50.4%
a) Electricity exports 56.8 TWh	- 4.9	
b) Nuclear auto-consumption ca. 18 TWh	- 1.6	
Primary Energy Generation/Independence	129.9	48.0%
c) Nuclear final energy contribution + Renewables[50] + Coal, oil, gas	28.7 11.9 2.0	
Final Energy Generation/Independence I	42.6	23.9%
d) - Uranium imports e) + Plutonium & reprocessed uranium credit	- 28.7 +1.3	
Final Energy Generation/Independence II	15.2	8.5%

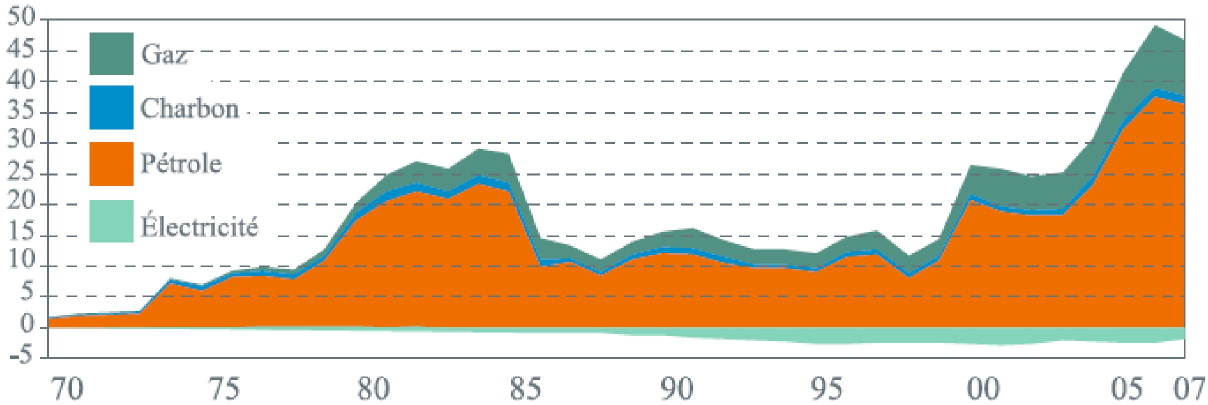
Source : Mycle Schneider Consulting 2008

[50] Respective national generation shares: renewables 97.7%, gas 2.4%, coal 1.2%, oil 1.2%.

Low Electricity Prices – High Energy Bills

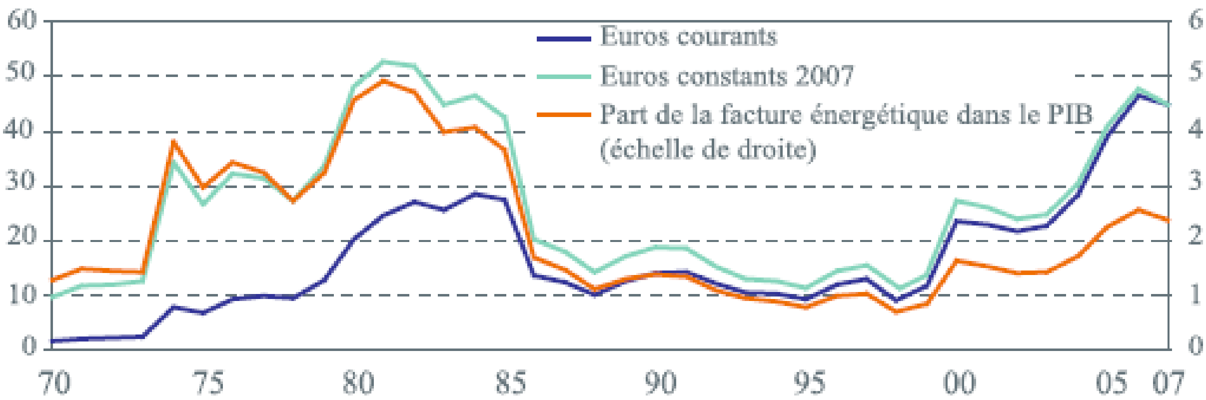
Since 1970 the French national energy bill has followed the oil price. This has not changed much since the launch of the massive nuclear program in 1974. The bill increased with the oil shocks in 1973 and 1979 and went down after the counter-oil shock in 1985. In 2006, in constant 2007 euros the bill was almost as high as in the early 1980s (see following figures).

Figure 15: The French National Energy Bill 1970-2007
(in billion current € by primary energy)



Source: Observatoire de l'énergie, L'énergie en France – Repères, *MEEDDAT, 2008*

Figure 16: The French National Energy Bill 1970-2007
(in billion constant $€_{2007}$, current € and as share of the GDP)



Source: Observatoire de l'énergie, L'énergie en France – Repères, *MEEDDAT, 2008*

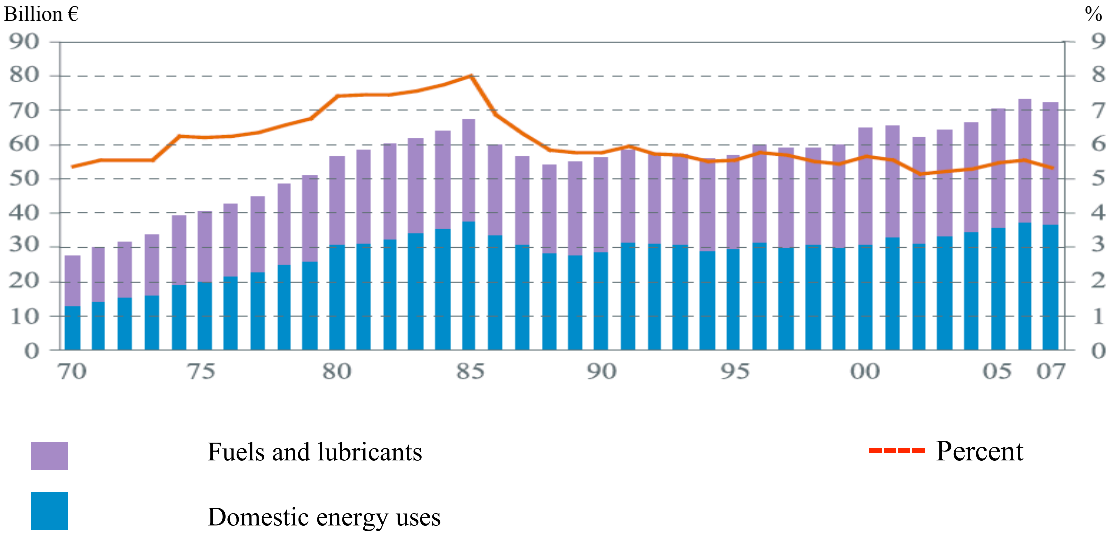
French electricity prices are relatively low. However they are not the lowest in the EU. In the case of household consumer prices, for a standard consumer of 3,500 kWh per year, the price was 0,1211 € per kWh at the beginning of 2007. That puts France at the 13th position of the 27 EU member countries, in the same range as Spain or the UK. The price comparison according to Purchasing Power Standards (PPS) advances France to the third place behind Greece and Finland, but only marginally cheaper than the UK or Spain.

The average French industrial consumer with an annual consumption of 2,000 MWh paid 0.0587 € per kWh at the beginning of 2007, which puts France at the 6th position in the EU. The comparison according to PPS brings France to the fourth place, behind Finland, Denmark and Sweden.

Residential Sector

France has a relatively large per capita electricity consumption. The low power prices played their role in that development, as can be seen also in countries like Finland and Sweden. However, the *average* consumption level of a French household is relatively meaningless as consumption is highly sensitive to the question whether the household is equipped with electric space and service water heating or not. Consumption rises sharply in that case. Cheap electricity does not mean low energy bills.

Figure 17: Household Energy Consumption and Share in Total Household Consumption 1970 to 2007 (in billion Euro and percent)



Source: Observatoire de l'énergie, L'énergie en France – Repères, MEEDDAT, 2008

French households have never before spent as much on energy as they have in the past three years (see figure above). The relative share of the energy expenditures in the total household budgets has moved little since the late 1980s and has remained between 5% and 6%. It followed the oil price shocks in 1973 and 1979 as well as the counter-oil shock in 1985 when slumping oil prices led to a drop by more than 2% in the relative burden of the energy bill.

High energy bills hit the poor significantly harder than the rich. In 2006 the 20% of the French households with the highest income spent 6% of their income on energy, slightly less than in 2001, while the 20% with the lowest income had their share increased from 10% to 15% over the same period. The income of the rich grew faster than the energy prices, which was not the case of the low-income households. In the case of electricity alone, the difference between high and low income households even reaches a factor of three, with respectively 2% and 6% of the total budget.[51]

In spite of the significant share in the budget, poor people in France cannot cover their basic energy service needs. "The statistics of the National Housing Agency (ANAH) drawn from the housing inquiry are affirmative: three million French are cold in winter".[52] According to studies carried out by EDF, three million *households,* about 10%, are considered in a precarious energy situation, 500,000 households have access to the "tariff of primary necessity" and 300,000 households receive support from EDF's Solidarity Fund to cover their energy bills.[53] According to the Ministry of Economy, the total number of households eligible for the tariff of primary necessity, which was introduced in 2005, was two million as of August 2008. Households with a monthly income of less than 621 € are eligible and reduction levels are:

- 30% for an individual;
- 40% for un adult with one child, a couple without children or with one child or for one adult with two children;
- 50% for a couple with two or more children.

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[51] ADEME, "Le poids des dépenses énergétiques dans le budget des ménages en France", ADEME & VOUS, Stratégie & Etudes, n°11, 3 April 2008
[52] PUCA, ANAH, ADEME, "Appel à proposition de soutien à l'innovation PREBAT – Comité bâtiments existants – Réduction de la précarité énergétique", July 2007
[53] ibidem.

The impossibility of poor households paying their energy bills – and in particular their electricity bills in the case of electric space heating – also drains public social funds from the General Councils, the Family Social Assistance Fund (CAF) and others.[54] The number of demands for social assistance to pay energy bills increases by 15% every year.[55]

Depending on the source of the statistics, public expenditure from social funds for energy bills totals €150 million to over €200 million per year. Electric space heating that equips more than a quarter of French housings and hot water production represent half of the electricity consumption of the residential sector. In the private collective housing sector the level of equipment with electric space heating even reaches 40%.[56] This is quite logical since the investment in electric systems is low compared with central heating systems, which is in the interest of the building owner, but the operating costs are the highest, which is at the expense of the inhabitants.

Industrial Sector

Concerning the French industrial sector, it has been continuously argued that the low cost of nuclear generated electricity was instrumental in supplying industry with low priced power and made it particularly competitive.

Two developments cast serious doubts about this argumentation:

• The electricity consumption in the French industry has been decreasing significantly over the past years. Between 1996 and 2006 the industry decreased consumption at an average of 0.5% per year, following the general trend in the EU away from heavy towards service sector industries. In the five years the decline accelerated to 1.9% per year.[57]

• France has constantly aggravated its foreign trade deficit, which it is estimated to have reached almost €40 billion in 2007. This result can be compared to the just under €200 billion trade surplus of Germany. The first semester of 2008 brought a new record trade deficit for France with over €24 billion while Germany raised its surplus to over €103 billion.

The nuclear policy does not seem to influence either the capacity to keep electricity intensive industry in the country or the foreign trade balance. It should be recalled that Germany has a legally binding nuclear phase-out policy in place. Non-nuclear countries like Greece and Denmark also provide cheap power and keep the per capita consumption below the EU average.

Limited Risk Insurances

France is a signatory to the 1960 Paris Convention and to the 1963 Brussels Convention on civil liability. The conventions allow signatory states to adapt the regulations according to their individual needs and wishes. One such condition is the capping of operator liabilities that has been reviewed and modified many times. In the case of France's EDF the limit had been fixed at €91 million for "any single incident on its installations", the lowest limit in Europe, according to a recent academic analysis:[58]

> "Of the total liability of €91 million today EDF covers only €31 million through insurance and the remaining €60 million through its own reserves. This is striking since we noticed that the price which EDF pays today for its insurance cover is the excessively high amount of €6.4 million per year. Compared to the objective value of the risk the premium paid for nuclear insurance to cover only the €31 million damages for the 58 French nuclear reactors is

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[54] PUCA, op.cit.
[55] ADEME, "Regards sur le Grenelle", September 2008
[56] Virginie Christel, et al., "Energie domestique – Des budgets sensibles aux prix des énergies importées", Ministère des Transports, de l'Equipement, du Tourisme et de la Mer, SESP-en bref, January 2006
[57] RTE, "Statistiques de l'énergie électrique en France", June 2007
[58] Karine Fiore, Michel Faure, "The civil liability of European nuclear operators: which coverage for the new 2004 Protocols? - Evidence from France", Faculty of Law, Maastricht University, 2007

excessively high. Indeed, we estimate that the objective value of the risk per year to be around €17,980 million, whereas the insurance premium actually paid is €6.4 million a year. The value of the premium actually paid hence for a large extent does not correspond with the objective value of the risk."

In case an event leads to costs beyond the operator's cap, the French state covers an additional €140 million, which can be increased by a further €150 million by the other contracting parties. In 2004 the obligatory liability cap for the operator under the Paris and Brussels conventions was raised to €700 million, the state intervention level to €500 million and the contracting parties' additional coverage to €300 million.

Table 3: Liability Coverage Caps Before and After the 2004 Convention Amendments
(in million euros)

	Paris (1960) and Brussels Conventions (1963) (caps for France, 1968 law amended)	Modification Protocol of the Paris and Brussels Conventions (2004)
Operator's liability cap	91	700
State intervention	140	500
Contracting Parties coverage	150	300
TOTAL	381	1500

Source: Fiore and Faure, 2007

A Chernobyl size large-scale nuclear accident in France would most likely lead to hundreds of billions of euros of damage. Even after the increase by a factor of four of the total coverage, the total sum available of €1.5 billion remains small, less than half to be provided by the operator.

A study for the European Commission suggested that if EDF was required to fully insure its power plants with private insurance but using the current internationally agreed limits on liabilities, it would increase EDF's insurance premiums from €c0.0017/kWh, to €c0.019/kWh, thus adding around 0.8% to the cost of generation. However, if there was no ceiling in place and an operator had to cover the full risk of a worst-case scenario accident, it would increase the insurance premiums to €c5.0/kWh, thus tripling the current total generating costs.[59]

Decommissioning and Waste Management Cost Assessment and Fund Management[60]

The operation and decommissioning of nuclear power infrastructures leads to long-term liabilities. The sums involved are very significant. The French Court of Accounts has calculated back-end liabilities totalling €65 billion (undiscounted) for the three main French nuclear operators EDF, CEA and AREVA as of the end of 2004[61].

After national public and parliamentary debates new legislation on nuclear waste research and management adopted on 15 June 2006 includes specific wording on the financing of decommissioning and waste management operations. Key articles of the new Law on the Program Relative to the Sustainable Management of Radioactive Materials and Wastes (hereafter New Waste Law)[62] includes

[59] "Solutions for environment, economy and technology", Report for DG Environment, *Environmentally harmful support measures in EU Member States,* European Commission, January 2003, page 132, quoted in Antony Froggatt, Simon Carroll, "Nuclear Third Party Insurance: The Nuclear Sector's 'Silent' Subsidy - State of Play and Opportunities in Europe", 5 November 2007

[60] This chapter is largely based on Mycle Schneider, "Country Report France", MSC, October 2006, contribution to Wolfgang IRREK (Dir.), Mycle Schneider et al., "Comparison among different decommissioning funds methodologies for nuclear installations", commissioned by the European Commission, coordinated by Wuppertal Institut, Wuppertal, March 2007, 170 p.
http://www.wupperinst.org/en/projects/project_details/index.html?&projekt_id=167&bid=137

[61] The figure is even higher, almost €70 billion, if one does not take into account some overlap stemming from doubling provisions due to joint operation by several operators of some facilities.

[62] Loi de programme relatif à la gestion durable des matières et des déchets radioactifs, 15 June 2006

the legal requirement to elaborate a National Plan for the Management of Radioactive Materials and Wastes and a National Inventory of Radioactive Materials and Wastes. Both are to be updated every three years. The National Radioactive Waste Management Agency ANDRA has to set up an internal restricted fund in order to finance the storage of long lived high and medium level wastes. The fund will be fed by contributions from the nuclear operators under bilateral conventions. The nuclear operators have to set up internal restricted funds covered by dedicated assets managed under separate accountability. A National Financing Evaluation Commission of the Costs of Basic Nuclear Installations Dismantling and Spent Fuel and Radioactive Waste Management has been established that is comprised of representatives of the National Assembly and the Senate as well as the Government and a number of experts that have to be independent of the nuclear operators and the energy industry.

While the new legal framework considerably changes the basis for the future availability of sufficient funding for nuclear decommissioning and waste management activities in France, a large number of uncertainties remain. These include:

a) The cost calculations underlying the provisions are non-transparent and there is no public access to the data; the administrative authorities do either have limited manpower[63] or are not consulted.[64] In the past, some cost calculations have proven wrong by an order of magnitude or more.
b) The spent fuel management policy choice has extreme impact on future costs. The final disposal cost estimates for long lived high and intermediate level wastes vary by a factor of four or almost 45 billion Euro between 13.5 and 58 billion. The current limitation of the reference scenario to the all-reprocessing option – evaluated as the cheapest geological disposal option[65] – has not been justified.
c) There is considerable opposition against the funding scheme adopted (internal restricted), which led the largest opposition group (Socialist Party) in the French National Assembly in a surprise move to abstain from voting for the New Waste Law. Two other parliamentary representations (Communist Party[66], Green Party) voted against the law.
d) There is opposition against the current backend strategy (reprocessing plus geological storage) from the civil society (NGOs, independent scientists, consumer groups). The implementation of a second laboratory, legally required under 1991 legislation and firmly requested by trade unions and independent experts, has not been possible due to fierce local opposition. Policy changes in the future due to public pressure or legal claims are difficult to exclude.
e) The current cost estimates are based on the opening of a final geological disposal site for long lived intermediate and high level wastes in 2020. After six years the laboratory project at Bure was already more than two years behind schedule.
f) Safety analysis based modifications of the technical specifications in waste conditioning, packaging and storage can have significant impact on costs.[67]
g) The conditioning, sometimes reconditioning, and packaging of some waste categories (bitumen, graphite, spent MOX) is still only in its development phase. Cost calculations necessarily have large uncertainties associated.
h) Following the shutdown over a two-year period of a nuclear facility (for example after an incident or an accident), the safety authorities can order the final closure and decommissioning of the facility. This could severely impact cost calculations and availability of backend funding.

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[63] For example, approximately one dedicated full time staff person per key operator in the Industry Ministry.
[64] The Nuclear Safety Authorities were not invited to join the Industry Ministry led Working Group that elaborated the reference cost scenario for geological disposal in 2005 (see [DGEMP 2005])
[65] according to [DGEMP 2005] ; this is highly contradictory to a number of other national and international studies, for example [CDP 2000] and [Girard 2000]
[66] Traditionally very pro-nuclear, the Communist Party spokesperson in her vote explanation has called the text "insufficient in research and financing".
[67] The decrease of the admitted surface temperature of high-level waste from 150°C to 90°C multiplied the storage cost for this waste category by a factor of four.

i) Some materials currently not classified as waste might have to be managed as waste in the future (for example reprocessed and depleted uranium, a portion of separated plutonium, spent plutonium fuels and plutonium waste).

Between Productivity and Nuclear Safety – A Fragile Balance

The drop of the availability factor is an alarm signal for safety and is a wake-up call: are we paying sufficient attention to staff competence as well as to maintenance quality and material aging?

Pierre Wiroth
Inspector General for Nuclear Safety
and Radiation Protection, EDF
January 2008

The French nuclear power plants have a relatively low load factor. Historically this has mainly been caused by the huge overcapacity. France is the only nuclear operator in the world that shuts down units on summer weekends because of lack of demand. Over 40 units are operated on load following mode, which allows for the power output to be modified on the short term within a ca. 5% margin. Until the end of 2006 French reactors showed a cumulated lifetime energy availability of 77.3%. While the availability had increased since 2000 from 80.4% to 83.6% in 2006, in 2007 the load factor dropped by 3.4% to 80.2%. The important difference between this drop and earlier developments is that the origin is clearly of technical nature this time, which raises the question whether EDF's reactor fleet would actually be able to reach availabilities in the order of over 90% like the best in the world.

EDF estimates that it will take until 2010 to solve the recent technical problems of its steam generators[68] that are the main cause of the availability drop. The available industrial capacity limits the number of units to be subject to chemical cleaning to 5 to 6 per year. While the exact number of affected units is not yet known, at least 15 of the 900 MW and 1300 MW units have already been identified and the safety authorities classified the issue as "generic" in 2007.

EDF estimates that the steam generator issue will cost another 2% of availability at least in 2008 and 2009. The accumulation of technical problems could drive the load factor down to as low as 79% in 2008. An internal note of EDF's financial department directorate from the end of 2001 put the loss at €76 million per percent point. This figure has no doubt significantly increased with the climbing electricity prices over the last few years.

The steam generator plugging is only one of the latest of a list of serious generic problems that hit the French reactor fleet.[69] While there is no doubt that the high level of reactor standardization has multiple technical and economic advantages, it has also brought along the problem of systematic multiplication of problems into large parts of the reactor fleet.

The overall number of safety relevant events has increased steadily from 7.1 per reactor per year in 2000 to 10.8 in 2007, even if EDF stresses that the number of serious events is on the decline.

EDF's Inspector General for Nuclear Safety and Radiation Protection states in his report on the year 2007 that the new organization leading to a massive reduction of the costly stocks of replacement pieces for the nuclear power plants has led to a situation where "to dispose of them in time has become a major problem for the sites and between the sites".[70] The Inspector reports of astounding cases where:

[68] The problem consists of extensive (up to 80%) plugging of the tube sheet penetrations. The phenomenon is estimated to evolve by 5% per year. The problem not only reduces the power output of the generator through the drop in heat exchange capacity, it also constitutes a safety problem because the tubes are affected by vibratory fatigue significantly faster. The phenomenon can thus lead to tube cracking within months (as happened at the Cruas power plant).

[69] The most serious problem is probably the sump clogging issue that highlighted the fact that recirculation of primary cooling water would not have worked as anticipated in the case of a large loss of coolant accident. It was discovered in December 2003 and affected all of the 34 units of the 900 MW series.

[70] Rapport de l'Inspecteur Général pour la Sûreté Nucléaire et la Radioprotection 2007, EDF, January 2008

• pieces that were to be replaced are put back in place due to lack of spare parts;

• temporary advise is elaborated to compensate over the long term for the absence of spare parts;

• plant outages are stretched due to delays in parts delivery and lead to costly time losses of subcontractors;

• unavailability of small consumables (screws, grease…) has become "a source of incomprehension and irritation".[71]

Between 10,000 and 12,000 events are identified in EDF's plants every year of which 600 to 800 are considered "significant events"[72]. However, power reactors are only part of the French nuclear establishment. The summer of 2008 attracted great attention to facilities that had been entirely unknown to the French public previously. A uranium spill was discovered in July at the clean-up company SOCATRI's[73] Tricastin site. Access to drinking water and any use of groundwater were banned in several surrounding municipalities. SOCATRI has issued a press release expressing its "regrets for the inconvenience generated by the incident and its media consequences".[74] Wine makers in the area have drawn the lessons of what is perceived as bad publicity and the well known "Côteaux du Tricastin" will change its appellation as of the 2009 harvest.

The SOCATRI accident was revealed after the site had already exceeded regulatory annual emission limits the previous years. Carbon-14 emissions exceeded limits in 2006 and 2007 by a factor of 30 and 42 respectively. Tritium discharges were also exceeded by a factor of 6 and 5 respectively. Rather than treating the problem at the source, SOCATRI has requested – and obtained – increased discharge limits. In February 2008, the safety authorities granted the new annual limits: the carbon-14 limits (3,400 mega Becquerel) constitute an increase by a factor of 40 over the previous limit; the tritium limits (10 giga Becquerel) were boosted by a factor of 24.[75]

Only ten days after the Tricastin incident another uranium leak was identified at a fuel fabrication plant at Romans-sur-Isère. The safety authorities consider that the leak could have been ongoing for over ten years and the amount of uranium spilled could be as much as 800 grams of uranium enriched at around 50% that cumulated in sludge around the leak site in an underground pipe.

Members of Parliament from all political parties have requested the creation of a parliamentary enquiry committee to investigate the circumstances of the multiple accidents and short-comings of the safety schemes.

EPR – European Problem Reactor?

« At the moment, AREVA has submitted half of the plans to us. Nuclear reactors are not built without plans, at least not in Finland. »
Martin Landtman
EPR Project Manager, TVO
Olkiluoto, Finland, February 2008

Olkiluoto-3, Finland

In August 2005 started the construction of the first European Pressurized Water Reactor (EPR) in Finland. The Olkiluoto-3 project has been plagued with difficulties since the first concrete was poured.

The utility TVO signed a turn-key contract with the Franco-German consortium Framatome-ANP, now AREVA NP (66% AREVA, 34% Siemens) to supply a 1600 MW EPR. The Bavarian

[71] ibidem
[72] for details, see Mycle Schneider et al., "Residual Risk – An Account of Events in Nuclear Power Plants Since the Chernobyl Accident in 1986", commissioned by MEP Rebecca Harms, May 1987 (http://www.greens-efa.org/cms/topics/rubrik/6/6659.energy@en.htm)
[73] SOCATRI is a subsidiary of the enrichment consortium EURODIF S.A.
[74] SOCATRI, Press Release, 11 July 2008
[75] CRIIRAD, "Tricastin SOCATRI: ça continue !", 7 August 2008

Landesbank – the Siemens headquarter is located in Bavaria – granted a loan of €1.95 billion, over 60% of the contract value, at a particularly preferential interest rate of 2.6%. The French public COFACE export credit agency covered an additional €720 million loan.

Three years after construction start the project is over two years behind schedule and at least 50% over budget, the loss for the provider being estimated at €1.5 billion. The reactor is now scheduled to come online in 2012. It remains unclear who will cover the additional cost. While TVO is insisting on the fix price conditions, AREVA has indicated that it will try to recover at least part of the additional costs.

In an unusually critical report the Finnish safety authorities, as early as one year after construction start, pinned down a number of reasons for the delays:

> "The time and resources needed for the detailed design of the OL3 unit was clearly underestimated, when the overall schedule was agreed upon (...). An additional problem arose from the fact that the supplier was not sufficiently familiar with the Finnish practises at the beginning of the project. (…) The major problems involve project management (...). The power plant vendor has selected subcontractors with no prior experience in nuclear power plant construction to implement the project. These subcontractors have not received sufficient guidance and supervision to ensure smooth progress of their work (...). As another example, the group monitored manufacturing of the reactor containment steel liner. The function of the steel liner is to ensure the leak-tightness the containment and thus prevent any leaks of radioactive substances into the environment even in case of reactor damage. The selection and supervision of the liner manufacturer was left to the subcontractor who designed the liner and supplied it to FANP [AREVA NP]. The manufacturer had no earlier experience on manufacturing equipment for nuclear power plants. Requirements concerning quality and construction supervision were a surprise to the manufacturer (...)."[76]

On the attitude of AREVA NP as the vendor, the Finnish safety authorities note:

> "At this stage of construction there has already been many harmful changes in the vendor's site personnel and even the Site Manager has retired and [has been] replaced. This has made overall management, as well as detection and handling of problems difficult. (…) The incompetence in the constructor role becomes obvious in the preparations for concreting of the base slab. (…) The consortium has a habit of employing new people for problem solving, which seems to have resulted in even more confusion about responsibilities."[77]

The situation has not much improved since two and a half years after construction start the TVO project manager complains that AREVA has submitted only "half of the plans".

Flamanville-3, France

On 3 December 2007, the first concrete was poured at the Flamanville-3 EPR project in France. The nuclear safety authorities carried out an inspection the same day. The inspectors note in their report that the quality control procedures for the base slab concrete are "unsatisfactory". Basic technical specifications and procedures have not been respected including the concrete mixture, the input level and the concrete test sample filing.[78]

A second inspection, carried out on 13 December 2007, aimed at the verification of the potential interaction of the building site with the operating two nuclear units. It revealed numerous cases of errors, violations of regulations and lack of basic safety culture, including the erroneous assumption that the roof of the nuclear auxiliary building would be of reinforced concrete, a crane operator's access permit that had expired by over a month, the total ignorance of the unit 2 operators about the

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[76] STUK, Press Release, 12 July 2006, http://www.stuk.fi/stuk/tiedotteet/2006/en_GB/news_419/ ; STUK, "Management of Safety Requirements in Subcontracting During the Olkiluoto-3 Nuclear Power Plant Construction Phase", Investigation Report 1/06, translation dated 1 September 2006; for full report see http://www.stuk.fi/stuk/tiedotteet/2006/en_GB/news_419/_files/76545710906084186/default/investigation_report.pdf

[77] ibidem

[78] ASN, DCN-Caen, Inspection letter to the Flamanville-3 project manager, dated 25 January 2008

potential impact of the building site (aside from the use of explosives for site preparation) and the lack of updating of the safety analysis of units 1 and 2.[79]

Several subsequent inspections revealed a number of additional anomalies that illustrated “a lack of rigor in the construction of the building site, difficulties in the management of external subcontractors and organizational deficiencies”; and on 23 May 2008, ASN ordered the cessation of concreting of all safety relevant parts of the plant.[80] Conditional restart of most of the concreting operations was granted on 17 June 2008, after EDF had transmitted a plan to upgrade quality control and organization. By the end of September 2008, ASN still considered the organization "perfectible". ASN Inspectors had discovered that the documentation on welding "does not allow the justification of conformity with the referential".[81]

At the end of October 2008 the nuclear safety authorities identified quality control problems at the builder AREVA. The Italian AREVA sub-contractor Società delle Fucine did not apply the obligatory fabrication procedures. ASN gave AREVA two months to prove that the pieces forged by the Italian company are compatible with the required technical specifications. Otherwise the forgings have to be redone.[82]

Finally, the problems are not linked only to the reactor project itself. The existing high power lines would not be sufficient to export the electricity from the new plant. An additional line is in the planning process. The local population disapproves. On 29 February 2008, the citizens of Chèvreville, a 200-person village on the planned track of the power line, decided unanimously (90% participation in a local referendum) to boycott the municipal elections of 9 March 2008 in order to protest the electricity grid extension.[83]

The two companies EDF and AREVA are in fierce competition to bring the first EPR online. EDF did not appreciate AREVA's offering the Olkiluoto project as a turnkey facility, because previously EDF was responsible for overall construction oversight and AREVA's role remained limited to manufacturing. In an unprecedented move, EDF felt obliged to put out a press release claiming that the Flamanville project is still on schedule, thus providing a firm rebuttal of a statement by AREVA CEO Anne Lauvergeon who had stated in a radio interview that the project would be one year behind schedule.[84]

Competence Erosion and Workforce Concerns

The French EPR project was not initiated because of the need to build new base-load power generation capacity. As demonstrated in previous chapters, there is still significant overcapacity available and it would be economically inconceivable to build a nuclear plant for power export only. Also, it is quite commonly agreed that the nuclear share has gone too high in France if compared with an ideal generating mix. Finally, the reactors are expected to operate for at least 40 years while the current average age of the French units is 23 years, the oldest having operated for 30 years[85]. In other words, even at current consumption levels there is no need for replacement capacity until long after 2020.

The main reason why EDF is building the EPR is that there is widespread concern over the potentially devastating impact of the widening competence problem. In France, the situation is not much better than in other countries. There is a generational gap between the scientists, engineers and technicians that have conceived, built and operated the current generation of nuclear facilities and tomorrow’s workforce needs. About 40% of EDF’s current staff in reactor operation and maintenance will retire by 2015. Starting in 2008, the utility will try to hire 500 engineers annually. Reactor builder AREVA

[79] ASN, DCN-Caen, Inspection letter to the Flamanville director and the Flamanville-3 project manager, 26 December 2007
[80] ASN, Lettre d'information N°2, 2 June 2008.
[81] ASN, Letter to Director of Flamanville-3 construction project, 30 September 2008
[82] ASN, Note d'information, 27 October 2008
[83] AFP, 6 March 2008
[84] EDF, Press Release, 12 November 2008
[85] apart from the Phénix FBR that started up in 1973 and is expected go off line in 2009

has already started hiring on a large scale. It signed on 400 engineers in 2006 and another 750 in 2007. The level of success of the hiring efforts is not known. It is obvious that the biggest share of the hired staff is not trained nuclear engineers or other nuclear scientists. The CEA affiliated national Institute for Nuclear Sciences and Techniques (INSTN) has only generated about 50 nuclear graduates per year. EDF has called upon the institute to double the number over the coming years.[86] Other engineering schools generate a few dozen graduates more but nothing in the range needed. Many of the graduates have gone into other professional sectors in the past. The main operators have started a full-scale "seduction" campaign. In November 2007 the twenty nuclear engineering students at the Ecole des Mines in Nantes were picked up by an EDF hostess who accompanied them to Paris where they were given a full day's program at EDF expense. AREVA did the same combined with a visit to the La Hague reprocessing plant. Three promotional conferences per week are no exception for the nuclear students in Nantes.

"Today competence renewal is the first management concern", states EDF's Inspector General for Nuclear Safety. "At all levels management is concerned about immediate and future problems that the competence renewal brings along."[87] The Inspector notes that "this concern is today generalized amongst all the nuclear stakeholders, suppliers, subcontractors, safety authorities, in France and elsewhere".

The situation is aggravated by the fact that the "internal transfer market is closed", every site retaining its skilled workers in the "fear that they won't be replaced". Several nuclear power plant sites reported that in the course of the year "they did not get a single response to their vacancy announcements". The EDF Safety Inspector urges the reconstitution of "resource and time margins that don't exist any more within numerous departments and professions".

Public Opinion

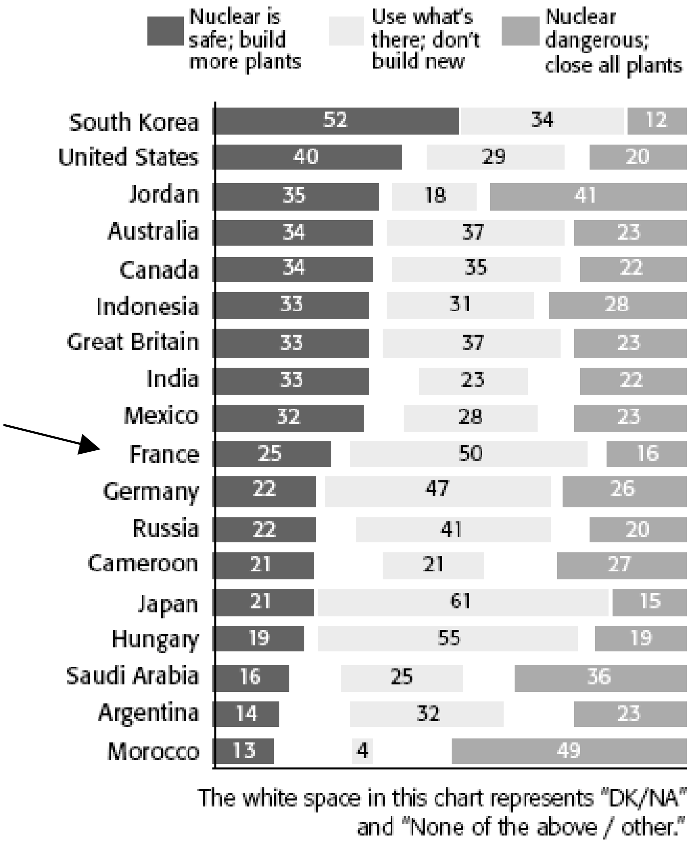
The French public's attitude towards nuclear energy is similar to the average in the EU. In a 2005 study commissioned by the IAEA[88] only 25% of the French people polled expressed support for additional nuclear power plants (versus 40% in the US for example, see figure 18), while 50% were in favour of operating current units but not building new ones and 16% were in favour of shutting down all operating plants. The result is remarkably close to responses from Germany, with respectively 24% for new build, 50% for operating what's there but against new build and 26% in favour of closure of existing plants.

[86] GIGA, "L'industrie nucléaire française : perspectives, métiers / Le besoin d'EDF en 2008", October 2007, http://www.giga-asso.com/fr/public/lindustrienucleairefranc/emploisperspectives1.html?PHPSESSID=2f7kmsonapea7ihktecmvdks45

[87] This and following quotes from "Rapport de l'Inspecteur Général pour la Sûreté Nucléaire et la Radioprotection 2007", EDF, January 2008

[88] GlobeScan, "Global Public Opinion on Nuclear Issues and the IAEA - Final Report from 18 Countries", commissioned by the International Atomic Energy Agency, October 2005

Figure 18: Lack of Support for New Build



Source : GlobeScan, "Global Public Opinion on Nuclear Issues and the IAEA", IAEA, October 2005

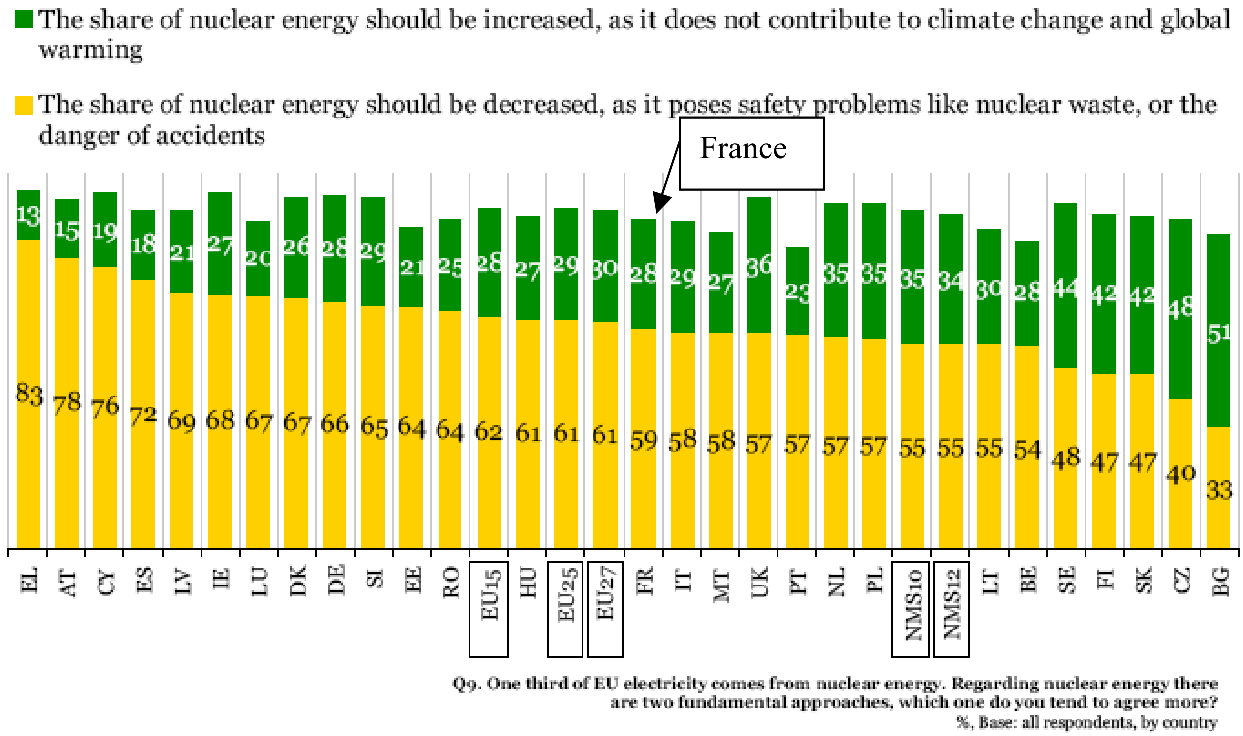
A 2007 poll carried out on behalf of the European Commission confirms the trend (see figure 19)[89]. In France 59% of the people polled were in favour of a reduction of nuclear power in the power mix while only 28% were favoured an increased role for nuclear energy in order to combat climate change. The French result is close to the EU27 average where 61% favour a decrease and 30% an increase of the nuclear share.

In a June 2008 poll for the European Commission[90] on the general question whether fairly in favour or totally in favour of energy production from nuclear power stations average positive opinions in the EU27 increased by 7% to 44% compared to a precedent study from 2005. But while in 20 countries favourable opinions increased, in France the share did not move from the previous level at 52%. A total of 82% of the French – the second highest level behind Greece and Sweden – totally agreed or tended to agree with the statement that "there is no safe way of getting rid of high level radioactive waste". French citizens represented the second largest share in the EU27 (behind Luxemburg) to disagree with the suggestion that "deep underground disposal represents the most appropriate solution for long-term management of high level radioactive waste". At the same time it is remarkable that France has the largest share of people polled in the EU that agrees with the erroneous claim that "some radioactive waste is currently placed deep underground at special disposal sites".

Apparently the French public does not trust the official information that it receives. The government receives the lowest marks with 30%, even behind AREVA with 32%, when asked about the credibility of various information sources on nuclear issues. The highest ratings are for environmental organisations with 79%, followed at a fair distance by the nuclear safety authorities with 62%.[91]

[89] Gallup, "Attitudes on issues related to EU Energy Policy", commissioned by the European Commission, DG TREN, April 2007
[90] "Attitudes towards radioactive waste", commissioned by the European Commission, DG TREN, Special Eurobarometer 297, June 2008
[91] Le Monde, 20-21 July 2008

Figure 19: Public Opinion in the EU on Nuclear Power



Source : Gallup, Attitudes on issues related to EU Energy Policy, European Commission, DG TREN, April 2007

Conclusions

There is no doubt that the French nuclear program represents a remarkable scientific, technological and engineering performance. The implementation of a complex chain of facilities from uranium mining to waste disposal, from uranium conversion to reprocessing, from uranium enrichment to reactor operation over a period of five decades is the result of undisturbed persistence. The program has been designed, developed and implemented under the guidance of a powerful technocrat elite, beyond governmental changes and outside parliamentary decisions and control. “What are those parliamentary debates good for?”[92] remarked Pierre Guillaumat in an interview in 1986.[93] The CEA’s General Administrator in the 1950s, later minister of industry and defence and godfather of the Corps des Mines, the state elite that engineered the civil and military nuclear programs, did not believe in consulting public opinion. “No, I have never seen it except in Offenbach… In hell there is public opinion, elsewhere I have never seen it”.[94]

The autocratic decision making process guaranteed the long-term implementation of the nuclear program in France. But the lack of democratic control mechanisms also led to a number of misconceptions, costly strategic errors, painful side effects and a significant dependence on a single source of electricity.

A number of specific conditions have impacted on the costs of nuclear power in France and biased official cost figures. Those include:

- From the start, the French civil nuclear program has largely benefited from military developments and programs.

[92] “A quoi ça sert ces débats parlementaires ?”
[93] Interview with Georg Blume and the author, published in Damocles, n°67, Autum 1995
[94] Reference to Jacques Offenbach’s Orpheus In The Underworld: “Hello, I'm Public Opinion”

• Until recently, no general legislative act regulated the nuclear sector. This is certainly one of the reasons why licensing procedures were difficult to challenge in court and thus did not lead to costly delays due to legal quarrels as in other countries.

• Access to information on nuclear issues has been restricted. It remains to be seen to what extent the 2006 Nuclear Transparency and Safety Act provides a basis for change. So far, experience provides reasons to remain sceptical.

• The plutonium industry is a typical example of civil-military cross-subsidizing. It is also symptomatic of the incapacity of the establishment to adapt long-term strategies to changed realities. About 55 tons of French plutonium have been cumulated as well as over 12,000 t of spent fuel. In addition, over 30 tons of foreign plutonium are stored in France.

• International safeguards arrangements were designed in a way that leaves the use of dual use facilities and materials up to France, which drastically reduced operational costs of facilities that otherwise would have had to separate civil and military material flows.

• At least three quarters of public research and development expenditures on energy between 1985 and 2001 went to nuclear fission. Little has changed since.

• Risk insurance levels have never reflected any realistic assessment of the potential consequences of a major accident. France has persistently practiced the lowest maximum liability limits in Europe.

• Decommissioning and waste management cost assessments leave a very large margin of uncertainties.

• New projects like the Franco-German EPR in Finland profit from very low interest, state guaranteed bank loans.

The massive development of the nuclear program in France has been launched in 1974 as a response to the oil crisis in 1973. The record of the implementation of that program is far from convincing:

• The connection between oil and nuclear power is a widespread myth. In 1973 power generation represented less than 12% of the final oil consumption in France.

• In 2007 nuclear power provided 77% of the electricity but only 16% of final energy in France. Almost three quarters of the final energy consumed in France is provided by fossil fuels, close to half by oil. France has a *higher* per capita consumption of oil than neighbouring nuclear phase-out countries Italy and Germany or the average EU27.

• The official "energy independence" level of 50% is highly biased. Disregarding electricity exports and auto-consumption and calculating independence levels on the final rather than on the primary energy side brings it down to 22%. Taking into account the fact that all of the consumed uranium is imported brings the French energy independence level down to 8.5%.

• Nuclear plants covered a large part of the artificially boosted increase in electricity consumption rather than substituted for other energy sources.

• The massive introduction of electric space heating (now >25% of housings) has led to an explosion of peak load, which in turn is leading to a highly uneconomic power consumption pattern. Electricity is also the most polluting heat form – much higher induced greenhouse gas emissions than gas or even oil heating – because of massive system losses.

• France's greenhouse gas emissions have practically stagnated since 1990. Provisional figures for 2007 suggest that CO2 emissions were 10% *higher* than in 1995. Emissions are highly sensitive to the climate and to the technical availability of nuclear power plants.

• Expensive peak load power imports (virtually all on a short-term basis) are increasing fast and old oil-fired power plants (2,600 MW, one originally started up in 1968) are being re-activated.

• Electricity prices remain relatively low by EU standards. However, cheap electricity is not equal to low energy bills. In 2007 the French national energy bill reached the level of the early

1980s. Two million French households are eligible for "primary necessity tariffs" because they cannot pay their electricity bills.

• Assistance for the payment of electricity bills not only costs dozens of millions of euro to EDF but also drains regional and national social funds. Cost estimates are as high as €150 million to over €200 million per year. The number of requests for assistance increases by 15% per year.

• Cheap power does not seem to lead to the anticipated and acclaimed industrial competitiveness. The French foreign trade deficit is estimated to have reached a record €40 billion in 2007 (to be compared to the €200 billion trade surplus of neighbouring nuclear-phase-out country Germany). 2008 promises new records.

The current state of the nuclear program, new build projects and the French promotion of nuclear technology around the world raise a number of questions:

• The high level of standardization provides the opportunity to effectively learn from experience. On the other side it increases significantly the risk of costly and potentially dangerous generic faults. The recently discovered steam generator plugging issue is only one of the latest in a series of safety relevant generic problems.

• The hunt for cost savings in the nuclear sector has led to side effects like a massive reduction in stocks of spare parts, which has led to supply bottleneck situations in various nuclear power plants.

• The maintenance of a high level of competence in the workforce has become the most urgent management issue for EDF. By 2015 about 40% of the nuclear operating and maintenance staff will be eligible for retirement. Already several power plants sites are experiencing “no reply” situations as a result of vacancy announcements.

• After three years of construction, the new-build flagship project, the Franco-German AREVA-NP EPR in Olkiluoto, Finland, is over two years behind schedule and at least 50% or €1.5 billion over budget.

• The French nuclear safety authorities raised quality control issues within days of the start of the French EPR construction project at Flamanville and have not stopped since.

• The promotion of nuclear technology and the transfer of know-how could increase the risk of nuclear weapons proliferation and inadequate safety conditions in new-comer countries.

Finally, the majority of French citizens when polled have been remarkably consistent and quite in line with the rest of the European Union, in their scepticism over the long-term nuclear power option. A 2007 study for the European Commission revealed that 59% of the French citizens polled were in favour of a reduction of nuclear power in the energy mix while only 28% were in favour of increasing the nuclear share.

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