Nuclear Energy Phase-Out in France

Summary of the Study on Fast Nuclear Phase-Out within 5 or 10 years

Summary

Introduction

We are often led to believe that nuclear energy in France is a necessary evil as it produces 78% of our electricity. In actual fact, we could do without it.

This document is a synthesis of an Evaluation of Nuclear Phase-Out within 5 or 10 years published by the "Sortir du nucléaire" Network of NGOs. It shows that it is possible to forego nuclear energy completely in the short term. No magic is involved, only proven and recognised energy conservation and renewable energy technologies.

Yes, we live in the most nuclearised country in the world, but no, France is not condemned to remain Europe's energy dunce forever. We must not lose heart: nuclear energy phase-out is possible, and the first steps can be taken immediately.

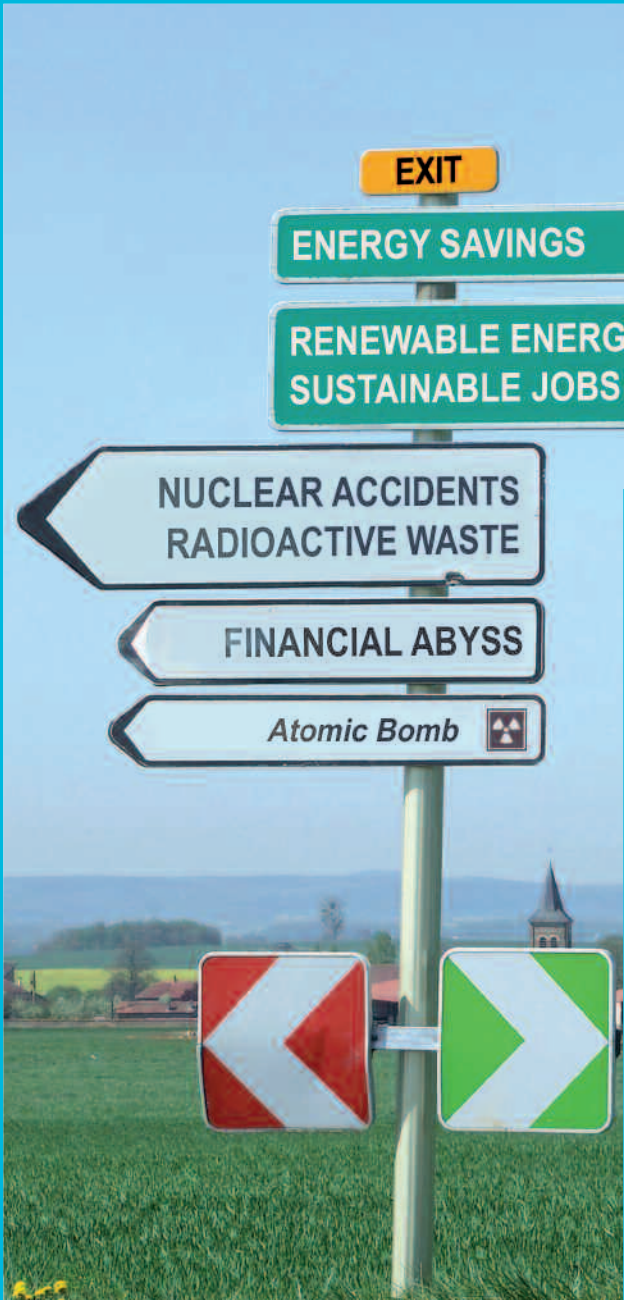
Why nuclear energy phase-out in 5 or 10 years?
Why two different time frames?

The " Sortir du nucléaire" Network designed this study to feed the nuclear energy phase-out debate and assist citizens in taking an enlightened decision instead of leaving them with no alternative but to make an arbitrary choice. This is why two possible phase-out scenarios are presented, along with a wealth of practical advice for those who wish to take action. Phase-out from nuclear energy in 25 or 30 years is very well documented, however, information is scarce concerning short-term phase-out. This study, fruit of the joint efforts of both experts and activists, will fill this gap.

This study is not the "Sortir du nucleaire" Network's official 'Phase-Out Action Plan'. The study's purpose is to prove that a fast nuclear energy phase-out is possible. There are no good or bad phase-out scenarios, be they with horizons of 5 or 25 years. There is only an urgent decision to be taken.

Citizens themselves must weigh each phase-out scenario's pros and cons and, ultimately, reclaim the energy consumption issue, which for too long now has been confiscated by industrial lobbies and the State.

I Why a Fast Nuclear Energy Phase-Out?



1 Danger

Nuclear energy is the most destructive technology ever created by man, as the dead of Hiroshima, Nagasaki and Chernobyl prove irrefutably.

Nuclear reactors in France are becoming increasingly old and are fragile. In 2006, 739 "incidents" occurred within our nuclear installations. And, who can hope to protect these reactors from the threat of a terrorist attack?

At any time, a nuclear accident could devastate our country irreversibly: is this acceptable? Radioactive and chemical discharges from the reactors poison our environment continuously. Each year, the reactors produce thousands of tons of highly radioactive waste. Such a deadly legacy to future generations is irresponsible. Moreover, the nuclear industry exposes tens of thousands of subcontractors to radioactivity in its pursuit of ever-increasing electricity production. Finally, nuclear technology, leading as it does to nuclear weapon proliferation, destroys all hopes of peace.

2 Cost

One just has to add the costs of nuclear waste management, nuclear plant decommissioning, uranium mining, reprocessing*, Mox* fuel, nuclear accidents, nuclear industry human health impacts, investments, research and electric heating (developed to create demand for surplus nuclear production) to realise that nuclear energy is anything but cheap. Nuclear energy phase-out would, to start with, contribute to the reduction of these often hidden but colossal costs, the total of which already exceeds one thousand billion (10^{12}) Euros.

3 Democracy

In which democracy have citizens never been able to have their say concerning energy choices? France. Yet, the French do not want nuclear energy: 78% of the population want to see renewable energies developed so that they become our main source of energy (Louis Harris Opinion Poll, 2007), and, in 2007, **60 000 people marched in the streets to protest against the construction of a new EPR** nuclear reactor. However, decisions concerning nuclear energy are always taken prior to public debate and energy policy is under the influence of the nuclear lobby. Nuclear energy and democracy do not seem to go hand in hand.

4 Prompt Nuclear Energy Phase-Out and Political Alternation

As everyone in France knows, political majorities change and only those who believe in political promises take them seriously enough to put them into practice. Therefore, a 5 or 10-year nuclear phase-out time frame is compatible with political responsibility:
nuclear reactor closure could not be delayed beyond decision makers' terms of office. These phase-out time frames, corresponding to one or two legislative or presidential mandates, would permit the implementation of a genuine energy mutation, and avoid future nuclear power revival by politicians in allegiance with the nuclear lobby.

5 Nuclear Power and Climate Change

France's nuclear electricity does not prevent the country being heavily dependant upon fossil energies, with associated greenhouse gases (GHG) emissions worsening the impacts of climate change. Despite having the highest number of nuclear reactors per inhabitant (58 reactors) in the world, France's energy* consumption is still 75% dependent upon fossil energies.

Nuclear power provides only 2.5% of global energy consumption. At a planetary level, even if the number of nuclear reactors were tripled by 2030, greenhouse gas abatement would not reach 9% and uranium reserves would be exhausted within 30 years. **This is too little and too late for any significant impact. Nuclear power will not protect us from climate change.** Only energy consumption reduction and massive recourse to renewable energies will have a positive influence on the climate.

6 What are the Alternatives?

Until just a few years ago, nuclear lobby supporters still claimed that renewable energies could never replace nuclear energy, as renewable energy production would always remain insignificant. They were wrong: in 2005, Denmark produced close to 30% of its electricity from renewable energies. **Renewable energies have already left nuclear energy behind:** in 2004, according to the International Energy Agency (IEA), renewables provided for 12.8% of global primary energy* consumption, whilst nuclear energy provided 6.5%.

However, the priority is undoubtedly to put an end to energy wastage. Electricity consumption in France can be reduced by one third in just a few years, without reducing comfort levels.

Words marked with a * are defined in the glossary that can be found at the end of this document.

II How is a Fast Nuclear Phase-Out Possible?

Nuclear Phase-Out, Operating Instructions

Objective

To shut down the 58 nuclear reactors currently in operation in France.

Challenge

**France depends upon nuclear energy for 78% of its electricity production.
How can so much electricity be replaced quickly?**

Solution

- **Replacement of nuclear electricity with electricity produced from renewable and fossil energy sources.**
- **Improvement of power generation energy efficiency ratios* by retrieving waste heat (cogeneration).**
- **Energy savings though reduction of electrical appliance electricity consumption (from the light bulb through to the fridge)**
- **When producing heat, replacement of electricity by renewable energy and fossil energies.**

How is Electricity Measured?

**Electricity production and consumption are measured in watt-hours (Wh).
Electric power is measured in watts (W).**

1 watt-hour (Wh) = the electricity production (or consumption) over the period of one hour by a 1 watt machine.
1 kilowatt-hour (kWh) = 1000 Wh = the electricity production over the period of 1 hour by a 1 kW (1000 watts) machine.
1 megawatt-hour (MWh) = 1000 kWh = the electricity production over the period of 1 hour by a 1 MW (1 million watts) machine.
1 gigawatt-hour (GWh) = 1000 MWh = the electricity production over the period of 1 hour of a 1 GW (1 Gigawatt) machine.

When the timescale considered is of one year, the electricity production unit generally used is the TWh (Terawatt-hour) or billion (109) kWh. In this study, electricity savings and alternative electricity contributions are expressed in TWh per year.

- **A 900 MW nuclear reactor will produce 6 TWh if it is in operation for 6700 hours in a year.**
- **France's electricity consumption in 2006 was 478 TWh.**

1 Saving Energy

To withdraw from nuclear energy, we must first put a break on energy wastage.
Three quarters of France's homes leak heat to the outside, domestic electric appliances could function with half the electricity they do now and entire towns remain lit up day and night... **Putting a halt to our energy haemorrhage is a matter of urgency**. Substantial energy savings are within reach, and necessary investments will rapidly be retrieved as a result of the energy and production capacity saved. The approach applied here draws much of its inspiration from the negaWatt scenario* which advocates energy savings and energy efficiency*. **The issue is therefore not how to replace the totality of France's current electricity use, but rather how to eradicate all our superfluous consumption.**

In order to save energy, two types of electricity consumption need to be addressed:

Lighting and Appliance Electricity Consumption

— or the electricity used by appliances that can operate only with electrical supply (lighting, domestic electrical appliances, computers, etc.). The most economical provide equal service using far less electricity. To encourage swift replacement of the most voracious appliances, exchange for more economical appliances must be possible with an extra cash award. Furthermore an International maximum electric appliance consumption standard must be created. In addition, the most energy-guzzling electric appliances (halogen lamps, double-door fridges, etc.) must be taxed. Replacing just the most voracious fridges and freezers with the most efficient models would save the equivalent power production of 2 nuclear reactors [1], that is to say 12 TWh. Substitution of out of date appliances with more economical models would save 45% of total lighting and appliance electricity consumption.

Electrical Heating Consumption — or the electricity used to produce heat. It must be banned as only one quarter of the energy produced is actually used, the remaining energy being lost in electricity production and transmission. Using electricity for heating therefore causes colossal wastage and considerable expense to the consumer. Electricity is precious and should not be wasted. Electric heating installations, electric water heaters and electrical stoves must be replaced by renewable energy fuelled equipment (wood, biogas, solar energy) or, as a last resort, natural gas fuelled equipment. This switch in energy must be accompanied by a program to renovate the insulation of the most energy voracious homes, in particular those built prior to 1975.

[1] : This calculation is based upon the average production of a 900 MW nuclear reactor over a year in France, which is to say 6 TWh.

a Nuclear Industry and Electrical Sector Savings

a.1. The Nuclear Industry

Pointless power production needs to be eliminated by closing the uranium enrichment plants, which consume the production of 3 nuclear reactors, as well as the nuclear fuel production plants and spent fuel reprocessing plants.

Potential Nuclear Industry Power Consumption Savings: 21 TWh a year [2] over 5 or 10 years.

a.2. The Electricity Grid

Electricity transmission on the grid leads to unavoidable losses. Any reduction of these losses within such a short nuclear phase-out time frame will rely heavily upon the abandonment of electric heating. Indeed, electric heating requires large amounts of electricity to be transmitted over great distances during the coldest periods of the year. For a 10-year nuclear phase-out, replacement of the most energy-guzzling transformers increases possible savings.

Potential Transmission and Distribution Losses Reduction Savings: 3 TWh a year over 5 years and 6 TWh a year over 10 years.

a.3. Electricity Exports

They are the largest in Europe. When France's nuclear installations were built, 30 years ago, the French government overestimated future electricity consumption. As a result, there are too many nuclear reactors in France, and surplus electricity is sold abroad. Reducing exports, without stopping them completely, makes it possible, immediately, to save 11,5% of the national electricity production.

Potential Electricity Export Savings: 63.3 TWh a year over 5 or 10 years [3].

a.4. Electricity Imports. A Workable Option

In order to avoid using our most polluting production plants, such as the old coal-fired or fuel oil-fired power plants, we have the option of importing electricity produced by our European neighbours, as of the very first year of nuclear energy phase-out: this economic option should be considered.

Potential Savings by Importing Electricity: 20 to 50 TWh a year.

[2] This is the production saved each year in TWh.
[3] This electricity production saving is not counted below in France's potential domestic energy savings

b Lighting and Appliance Electricity Savings

b.1. Street Lighting

This is an important source of energy savings. Replacement of the most energy-guzzling lamps, of electronic ballasts (electrical devices that improve lamp energy efficiency ratios* and accelerate ignition), as well as adjustment of lighting to actual needs thanks to the installation of regulators, will save 40 % of lighting electricity consumption within 5 years and 70 % within 10 years.

Potential Street Lighting Electricity Savings: 2.1 TWh a year over 5 years and 3.7 TWh a year over 10 years.

b.2. Professional Buildings

Significant electricity savings call for an Energy Consumption Threshold to be created and applied to electrical office appliances, such as lifts, ventilation systems, household type appliances and computers. This standard will be applied to all activity sectors. The oldest, most energy-guzzling appliances must be replaced with more economical appliances. Lighting must be systematically modernised by replacing filament lamps and halogens with energy saving light bulbs* or LEDs*.

Potential Professional Appliance Electricity Savings: 7.1 TWh a year over 5 years and 14.2 TWh a year over 10 years.

b.3. Households

Household Lighting

Household lighting consumes the production of two nuclear reactors. We propose that a scheme be set up to replace 5 filament lamps and/or halogens in each household by low energy light bulbs with an extra cash award upon replacement.

Household Electric Appliances

The most spectacular short-term household savings can be made by addressing refrigerators and freezers — the only electric appliances requiring permanent power supply. Replacement of the greediest appliances saves the output of one nuclear reactor in the 5-year scenario, that is to say 6 TWh, and the output of two nuclear reactors in the 10-year scenario, that is to say 12 TWh. The most energy-voracious washing machines and tumble-dryers must be replaced. Using common sense and preferring cold or lukewarm washing cycles will also reduce the electricity bill.

Information Technology and Home Entertainment Equipment

Computers, broadband Internet modems and flat screen televisions... these appliances consume more and more, regardless of whether they are switched on or off. Equipment should be replaced where necessary, however non-wasteful behaviour needs to be the priority. **Connecting all equipment to a power strip with an on/off switch, and switching it off after each use, would reduce standby consumption by an amount equal to the production of one nuclear reactor.** Here, individual and personal commitment is key, however a new manufacturing standard also needs to impose an appliance standby consumption threshold inferior to 1 Wh.

Potential Household Electricity Appliance Savings: 16.2 TWh a year over 5 years and 29.1 TWh a year over 10 years.

b.4. Industry

Setting a maximum energy threshold for all electricity-using industrial processes would reduce the consumption of engines, compressors, industrial refrigeration and lighting equipment. Lighting is where the fastest savings can be made.

Potential Industrial Equipment Electricity Savings: 4.3 TWh a year over 5 years and 5.2 TWh a year over 10 years.

C Electric Heating Savings

c.1. Households

As far as heating goes, electric heating is the most costly and wasteful of energy. Yet, 7 million households in France use electricity to heat themselves. As a result of the poor efficiency ratios of the large power plants [4] and losses on the electricity grid, three quarters of energy produced in the plants is lost. Less than 30% of the energy produced reaches the consumer in the form of electricity. Thus, the equivalent of the production of 13 nuclear reactors is almost entirely wasted on household space heating, water heating and air conditioning. This is why electric heating must be banned in new buildings and in refurbishments. Residential areas that have today entirely been assigned electrical heating must switch to wood and more generally biomass heating. Alternative energy sources for heat production are given below in the 2nd section presenting non nuclear electricity.

Solar water heaters replace electric water heaters. Regulations will make this replacement compulsory in all new buildings and, gradually, in old ones. Such regulation will use Spain's new Solar Thermal Ordinance as a model: all new buildings and buildings undergoing major refurbishment are obligated to use solar energy to supply 60% of their running hot water requirements. Air conditioning, a big electricity consumer, is replaced by a more common sense approach based upon: bioclimatic architecture* in design and construction, creating or fitting solar shading onto windows, or, still more straightforward, building insulation improvement - all measures which will save energy in both summer and winter.

The extent of energy wastage due to poor home insulation is an aberration For equal comfort levels, old homes consume three more times energy than homes built today. A nationwide old building refurbishment program will reduce energy consumption by improving wall insulation, doubling-gaze windows, and installing heat retrieval systems on ventilated air. With this program, 350 000 homes will be renovated every year. This program is coupled with a Building Energy Code* that fixes maximum non renewable energy consumption thresholds for space heating and water heating, in both new and old buildings. Energy audits are carried out systematically in order to detect energy losses.

Potential Household Electrical Heating Savings: 24 TWh a year over 5 years and 34 TWh a year over 10 years.

c.2. Professional Buildings

Air conditioning, as we have just seen for households, is a big energy consumer. It will only be used where absolutely necessary, such as in hospitals and old people's homes, for instance. Electric heating will have to

[4] A nuclear reactor transforms only 33% of the heat given off by nuclear fission into electricity. The remaining heat escapes into the environment.

be replaced by heating using renewable energies or natural gas (potential contribution detailed in the 2nd section). New regulation will create a tax incentive for switching to other energy sources. The solar water heaters made compulsory for refurbishments will produce most of the hot water. Cooking appliances that consume the least energy will replace electric cooking appliances.

Potential Professional Electric Heating Savings: 13.9 TWh a year over 5 years and 16 TWh a year over 10 years.

c.3. Commercial Stores and Supermarket Distribution

Electric space heating, water heating and cooling account for a significant share of commercial stores' electrical consumption. All in all, this sector's electricity consumption is equivalent to the production of over 6 nuclear reactors. Here again, electricity must be replaced by renewable energies for heat production, or if this is not possible in the short term, by natural gas (potential contribution detailed in the 2nd section).

Potential Commercial Electric Heating Savings: 3 TWh a year over 5 years and 8 TWh a year over 10 years.

c.4. Industry

Savings are possible mainly where electric water heaters and electric heating are used. Installation of efficient equipment increases energy efficiency ratios*. As in the cases of households and professional buildings, electric heating is replaced by heating with alternative energies.

Potential Industrial Electric Heating Savings: 3.9 TWh a year over 5 years and 4.8 TWh a year over 10 years.

Total Potential Energy Savings

With energy savings alone, 16 nuclear reactors are shut down within 5 years, while 23 nuclear reactors are shut down within 10 years.
In this way, 20% of French electricity consumption can be saved each year in the 5-year scenario, while 30% can be saved in the 10-year scenario. All this energy will therefore not need to be produced.

France's electricity consumption would drop from 478 TWh a year in 2006 to 382 TWh a year in the case of a 5-year nuclear phase-out, and from 478 TWh to 367 TWh in the case of a 10-year nuclear phase-out.

2 Providing Non Nuclear Electricity

Energy conservation has great potential. However, electricity still needs to be provided. So much the better!

France disposes of renewable energy sources that have not yet been tapped. The large-scale development of wind energy, biomass and photovoltaic solar energy would unleash an electricity production equivalent to that of 14 nuclear reactors over 5 years and 25 nuclear reactors over 10 years.

However, in such a short time frame, and despite significant energy conservation efforts, renewable energies cannot technically produce sufficient electricity to satisfy total needs. Temporary recourse to fossil energies can provide for this nuclear energy phase-out transition period.

a Renewable Energies

Renewable energies have enormous potential. In theory, the solar energy reaching the planet in one hour could provide for one year of global energy demand. **Renewable energies — from sunlight, heat or wind - are practically inexhaustible. They also help create sustainable and local jobs, do not pollute, cost less and are infinitely less dangerous than nuclear or fossil energies.**

Today, the renewable energy sector is very dynamic and can provide for a significant chunk of a big industrial nation's energy consumption, thereby reinforcing that nation's energy autonomy. In 2007, renewable energies, not including the hydroelectric capacity developed close to 50 years ago, represent less than 1 % of France's electricity production.

a.1. Wind Energy

France's wind energy potential is the second largest in Europe. Indeed, France is the second windiest country in Europe, with three long marine coastlines. Several expert studies have concluded that onshore wind energy production could provide 85 TWh a year, whilst offshore wind energy, if developed ambitiously, could provide almost completely for France's electricity consumption (477 TWh a year). In 2007, only 2 GW of wind turbines had been installed in France, compared to 20 GW in Germany.

Onshore, the construction of wind turbines is needed to provide 11.8 GW within 5 years, and 24.3 GW within 10 years. Offshore, the construction of ten wind farms, each totalling 20 km in length, is needed over 5 years (15 over 10 years) to provide 10 GW within 5 years and 15 GW within 10 years. Admittedly, this is ambitious, yet it is entirely plausible:

- The 1 GW "London Array" offshore wind farm under construction in the Thames Estuary proves the feasibility of large-scale offshore wind farm construction..

- In order to play its part in achieving the EU-wide '20 % renewables by 2020' target (upcoming European Framework Directive), France will need to build wind energy up to 13.5 GW by 2010 and 17 GW by 2015.

Potential Wind Energy Contribution: 63 TWh a year within 5 years and 118 TWh a year within 10 years. This is equivalent to the electrical production of 10 nuclear reactors within 5 years and 20 reactors within 10 years.

a.2. Hydroelectricity

On average, hydroelectricity* provides 10 % of France's electricity. France's hydroelectric capacity was mostly developed prior to the Second World War and up until the 1960s. Today, the operation regimes of the large hydroelectric dams have reached peak capacity and it is no longer possible to build new installations without endangering the environment.

Therefore, actions considered here concentrate upon the optimisation of existing installations. Hydroelectric electricity production can be increased by improving turbine efficiency ratios in small and medium sized installations, and by curbing the internal energy consumption of hydroelectric sites. Furthermore, the production of small, mini or micro hydro installations can be increased significantly. Many rivers can be equipped with small or very small turbines without endangering the natural environment.

Potential Additional Hydroelectric Contribution: 3.4 TWh a year in the context of a nuclear phase-out within 5 years, and 7 TWh a year within 10 years. This is equivalent to the electrical production of 0.5 nuclear reactors within 5 years and 1 reactor within 10 years.

a.3. Solar Photovoltaics

Solar photovoltaic technology - transforming light into electricity - is developing strongly across the world. In France, it is barely implanted. Yet, there is significant photovoltaic potential in France: just over 2% of France's surface area - 11 440 km2 - is built up. Installing 5000 km2 of photovoltaic panels on this surface would provide an electrical production equal to 450 TWh. This is almost France's entire electricity consumption in 2006.

A true photovoltaic economy must be developed in France: through the construction of 4 photovoltaic module production plants within 5 years and 19 production plants within 10 years. Each manufacturing plant's annual module production would reach 500 MWp*. In the early stages of nuclear phase-out, photovoltaic modules must be installed south of the Geneva-La Rochelle latitude, in order to benefit from the best sunlight conditions and consequently higher electricity production than in the north of France. The solar photovoltaic investment economic support system must be reinforced, to ensure the most homogeneous and equitable distribution of solar installations. The photovoltaic kWh feed-in tariff must remain high. S**tate,**

regional and municipal subsidies are indispensable. Regulations must encourage the installation of photovoltaic modules on each new or renovated building. In the medium-term, solar electricity production on public buildings will provide the State with a full return on its investment.

Potential Solar Photovoltaic Contribution: 3.2 TWh a year within 5 years and 15.2 TWh a year within 10 years. This is equivalent to the electrical production of 0.5 nuclear reactors within 5 years and 2 reactors within 10 years.

a.4. Solar Thermal

This simple and low-cost technology absorbs solar heat and produces hot water for heating and domestic uses. Essentially, its purpose here is to replace electric heating and electric water heating. As solar thermal installations do not produce electricity but enable electricity to be saved, their contribution has been counted above in electric heating savings.

a.5. Biomass

Biomass refers to all living or recently dead biological material, vegetable or animal, used as fuel to produce energy. This includes, on the one hand, solid biomass: wood and its residues (pellets and chips), and, on the other hand, biogas, which is methane released during the decomposition of organic waste (manure, straw, wood, etc.). Biomass potential is considerable in France. Indeed, France possesses the third largest forest area in Europe and over 50 % of its total surface area is dedicated to agriculture. **Forestry, harvest residues and organic wastes can in time, without endangering natural resources, provide 20 % of France's total energy consumption.**

Using biomass as en energy source creates sustainable and local employment and reduces greenhouse gas emissions. Biomass's carbon footprint* is neutral: during its combustion, biomass releases the CO_2 absorbed during its growth.

In France, we mostly burn wood in open burners (your standard chimney), and energy efficiency ratios for this type of combustion are mediocre. In the next few years, a label guarantying the high efficiency of wood burning installations, modelled upon the "Flamme Verte" label, must become compulsory for all installations. It will then be easier to carry out an extensive program in old housing to replace electric heating with high efficiency wood boilers and wood burning stoves.

In general, biomass fuelled electricity production uses cogeneration technology (this technology's contribution is explained in the next section). Electricity savings achieved thanks to biomass are counted above in electric heating savings.

a.6. New Renewable Energies

New solutions are appearing on the horizon, including geothermal energy, tidal energy and wave energy. Tidal turbines are amongst the latest innovations: their submerged turbines tap strong submarine currents. These energies have incredible potential, however it would be hazardous to count on such recent technologies to supply electricity within the context of a rapid nuclear phase-out: their development is not yet sufficiently advanced (with the exception of geothermal energy which needs over 15 years for prospecting and development). Therefore, their contribution is limited to that of a hundred experimental tidal turbines with a relatively low production of 60 GWh a year within 5 years and 120 GWh a year within 10 years.

Our study does not call upon air-source heat pumps. This technology uses electricity to tap the heat stored in ambient air. These heat pumps have mediocre efficiency and require a lot of current. **Electricité de France (the main French electricity provider) actively supports the development of air-source heat pumps, as, in effect, they use up surplus electricity, yet still manage to give a green touch to nuclear electricity, all at the consumer's expense.**

Such electric heating, disguised as renewable energy heating, must be replaced as a matter of urgency by solar thermal heating installations or biomass boilers (wood, straw, etc.).

Total Potential Renewable Energy Contribution

Renewable energies could produce 155 TWh a year within 5 years and 227.8 TWh a year within 10 years. This is equivalent to the electric production of 30 nuclear reactors within 5 years and 38 nuclear reactors within 10 years.

In total, renewable energies could contribute 40 % of electricity production within 5 years and 60% within 10 years [5].

[5] Hydroelectric and cogeneration biomass production included.

b Cogeneration: Simultaneous Electricity and Heat Production

Cogeneration involves electricity production with an engine and retrieval of waste heat which would otherwise just escape. The engine can be fed with wood, natural gas or any other fuel. Fuel is saved as it is used to produce both electricity and heat. Cogeneration energy efficiency ratios* vary between 80 and 90 %, whilst classical engine efficiencies struggle to exceed 40 %. Fossil energy cogeneration reduces the greenhouse gas emissions that would otherwise be associated with separate electricity and heat production. Heat retrieval during electricity production is possible with a classical engine, a gas turbine or even a fuel cell*.

Cogeneration plants quickly become profitable thanks to the profits from the sale of surplus electricity. Small-scale cogeneration production requires lower investment than that required by large-scale plant energy production as energy no longer needs to be transmitted over long distances, thereby allowing for savings equivalent to approximately 10% of the electricity cost.

b.1. Biomass Cogeneration

Priority is given to development of cogeneration electricity production with biomass as fuel. Electricity production using biomass is a technical reality. In 2006, in Germany, electricity produced from biogas was already equivalent to the production of one nuclear reactor. In 2005, Finland, whose forest area is roughly equivalent to that of France, produced 10 TWh from wood energy.

France's significant biomass resources and their ease of access mean that this energy's potential can be developed almost entirely within a 5-year nuclear phase-out time frame. Electric heating can be replaced by heat produced by biomass.

Potential Biomass Cogeneration Plant (solid biomass and biogas) Contribution: 18.2 TWh a year within 5 years and 19.3 TWh a year within 10 years. This is equivalent to the electricity production of 3 nuclear reactors within 5 or 10 years.

b.2. Natural Gas Cogeneration

Natural gas cogeneration electricity production in the tertiary* and residential sectors would primarily serve to replace natural gas and oil boilers, and only very little to replace electric heating, whose replacement is ensured by biomass cogeneration installations or other renewable energy sources (simple wood boilers, solar panels).

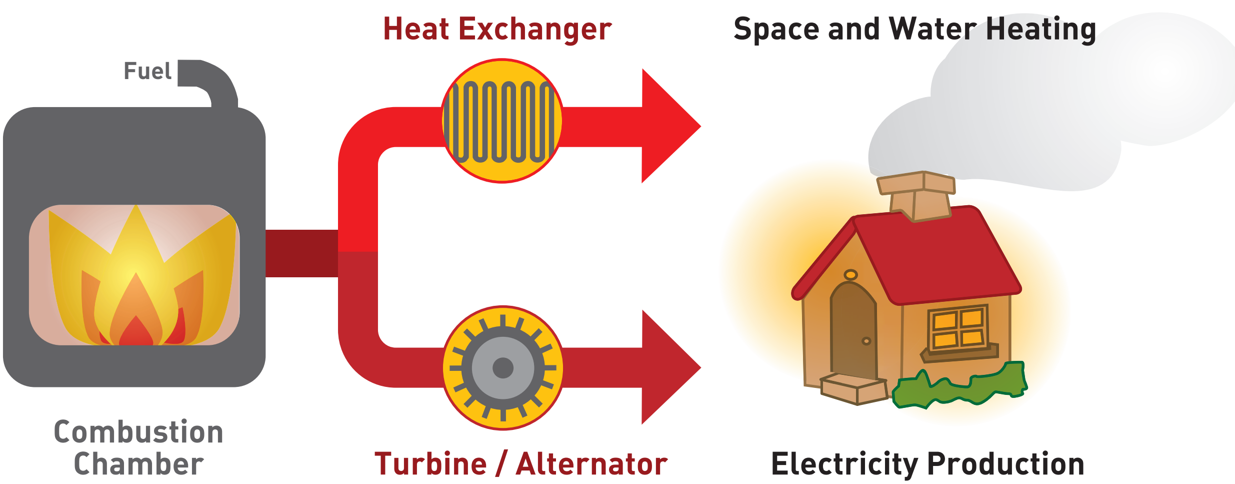
Potential Tertiary Sector Cogeneration Contribution: 6.9 TWh a year within 5 years and 13.4 TWh a year within 10 years. This is equivalent to the electricity production of 1 nuclear reactor within 5 years and 2 reactors within 10 years.

In the residential sector, several million homes are concerned by the replacement of natural gas and oil boilers by cogeneration installations.

Potential Household Natural Gas Cogeneration Contribution: 7.5 TWh a year within 5 years and 38.4 TWh a year within 10 years. This is equivalent to the electricity production of 1 nuclear reactor within 5 years and 6 reactors within 10 years.

Total Potential Cogeneration Contribution: 33 TWh a year within 5 years and 71.5 TWh a year within 10 years.

Diagram illustrating Cogeneration Principle



C Fossil Energies

c.1. Existing Power Plants

In order to withdraw from nuclear energy in the short term, it is necessary to resort to fossil energy fired power plants (collectively referred to as conventional thermal power plants). This is due to the considerable proportion of France's electric production that is of nuclear origin (78%): a temporary recourse to fossil energies is unavoidable, particularly in a 5 year phase-out time frame in which energy savings and renewable energies cannot fulfil their potential to the same extent they can in a 10 year time frame. Most French conventional thermal power plants are old and polluting. Bringing them up to anti-pollution standards would reduce the damage caused, but cannot reduce CO_2 emissions. They are therefore not an option in the long term. Nuclear phase-out in 5 years requires that France resort massively to the existing thermal power plants, to the maximum of their production capacity, that is to say 160 TWh a year.

In the case of a 10 year nuclear phase-out, such a massive recourse to old non cogeneration fitted fuel, coal or natural gas fired power plants can be avoided: 90% of existing power plants would be closed permanently. Only recent installations or recently cleaned up installations would remain in service. These remaining installations would produce 13 TWh.

Existing Conventional Thermal Power Plant Contribution: 160 TWh a year within 5 years and 13 TWh a year within 10 years.

c.2. New Power Plant Construction

Building new natural gas power plants is the least of two evils: capital investment costs are far lower than those required for nuclear reactors, CO_2 emissions are half those of coal fired power plants, and pollutant emissions are very low. What is more, in the medium term, natural gas power plants could be supplied with biogas, thereby ensuring sufficient development for the biogas production sector..

Natural gas fired power plants would predominantly use the combined cycle* (two turbines instead of one) which provides a high electric efficiency ratio (over 55%). In this way, these power plants would contribute 43 TWh a year within 5 years and 64 TWh a year within 10 years. **The investment necessary for these installations is less than half the investment required for the construction of 5 EPR*** nuclear fission reactors, for a higher electrical output. Building these combined cycle natural gas power plants on the sites of closed nuclear power stations is an option to be considered, as nuclear power plant steam turbines could then remain in use. Savings would be possible on construction costs and would accelerate the commissioning of the natural gas power plants. Furthermore, connecting natural gas power plants to the existing electric network would generate additional savings.L

With approximately thirty single turbine natural gas power plants, electricity consumption peaks could be managed. Equipped with high yield combustion turbines (from the aeronautics industry), they would contribute 5 TWh a year within 5 years and 10 TWh a year within 10 years.

Construction of new coal-fired power plants should be avoided because of coal combustion's high CO_2 emissions. A combined cycle coal power plant equipped with the most efficient pollution abatement technologies would be needed for a 5-year phase-out, but resorting to coal is not necessary for a 10-year phase-out.

Fossil Energy Contribution: 227.3 TWh a year within 5 years and 139.2 TWh a year within 10 years. Fossil fuels would account for 60% of the electricity production for a 5-year nuclear phase-out, and 30% for a 10-year nuclear phase-out [6].

[6] These total figures include cogeneration electricity production from fossil energies.

III What can be Achieved?

Nuclear Phase-Out within 5 years

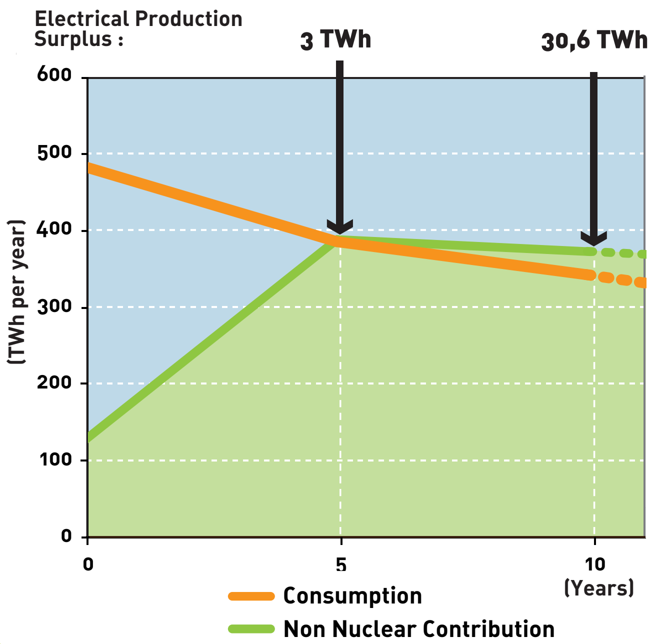
This phase-out time frame involves a 20% reduction in consumption compared to current consumption (2006). Renewable energies would provide for one third of electricity needs and fossil energies for the remaining two thirds. The actual increase in France's fossil energy consumption for electricity production would be 38%. Greenhouse gas emissions (GES) would be significant but temporary. Non nuclear electricity production would slightly overshoot demand, by 3 TWh per year. This difference would help reduce fossil energy use.

Nuclear Phase-Out in 10 years

This phase-out time frame involves a 30% reduction in consumption compared to current consumption (2006). Renewable energies would provide for two thirds of electricity needs and fossil energies for the remaining one third. France's net fossil energy consumption for electricity production would increase by 20%.
Electricity production would overshoot demand by 30 TWh per year. This difference would help reduce fossil energy use.

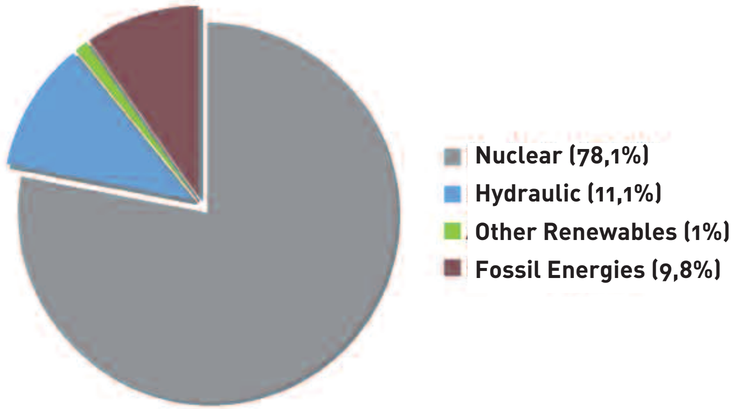
(En TWh per year))	In 5 years	In 10 years
Energy Savings	161,8	205,3
Renewables Contribution	155,6	227,8
Thermal Fossil Contribution	227,3	139,2
Non Nuclear Contribution	382,9	367
Overshoot	3	30,6

Energy Savings and Power Consumptio over 5 or 10 years



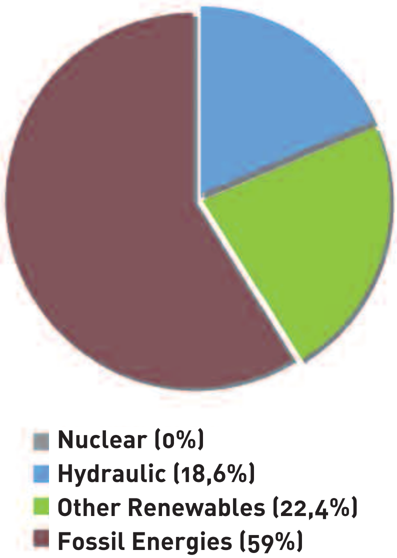
Share of Different Energy Sources in France's Total Electricity Production

In 2006



In 5 years

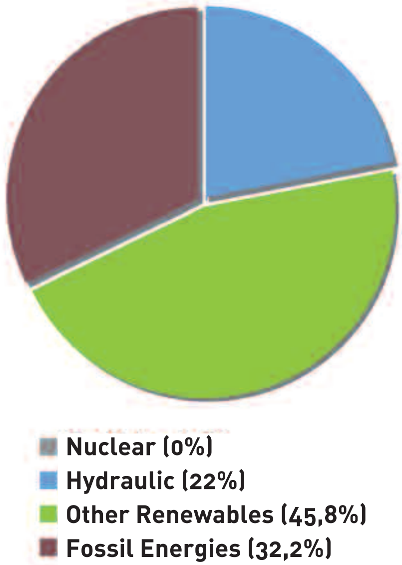
20% Electricity Savings Compared to 2006



It is assumed, for a 5-year phase-out, that the surplus production of 3 TWh is used to reduce fossil energy use.

In 10 years

30% Electricity Savings Compared to 2006



It is assumed, for a 10-year phase-out, that the surplus production of 30.6 TWh is used to reduce fossil energy use.

Advantages of Nuclear Energy Phase-Out in 5 or 10 years

The risk of a nuclear accident decreases as soon as the first nuclear reactors are closed, and practically disappears when all nuclear power plants have been closed.

Energy savings and renewable energy development will create employment.
A nationwide old building refurbishment program would alone create 100 000 jobs, while the development of renewable energies would create at least another 100 000 jobs within 5 years. Utopia? Only 7 years after deciding to withdraw from nuclear energy, Germany's renewable energy sector had created 235 000 permanent jobs.

Energy independence would improve: in 2006, France imported 88% of the energy resources [7] necessary for its electricity production. A 5-year nuclear phase-out would bring these importations down to 60 %, while a 10-year nuclear phase-out would bring them down to 30%. Energy savings and renewable energy use would compensate for the cost incurred by the country's energetic makeover. In the medium term, France's energy bill would decrease.

Security of supply would be reinforced with a more balanced energy mix, as several sources of energy would combine to supply France's electricity once the country had completed its nuclear energy phase-out, instead of the current situation in which one entirely imported energy source, uranium (see pie charts on previous page), provides 78 % of the country's electricity.

[7] The resources referred to here are uranium, oil, natural gas and coal.

Potential Electricity Savings and Non Nuclear Electricity Contribution Summary Table (in TWh)

			10 year Estimation	10 year Estimation
Electricity Savings	Electricity Supply	Nuclear Cycle	21	21
		Pertes électriques	3	6
		Echanges et exportations	63,3	63,3
	Demand Reduction	Tertiary	26,1	41,9
		Household	40,2	63,1
		Industry	8,2	10
		Total Savings	**161,8**	**205,3**
Non Nuclear Contribution	Renewables	On-shore Wind	32,2	61,6
		Off-shore Wind	30,8	57
		Hydroelectricity	70,5	74
		Photovoltaic	3,2	15,2
		Tidal	0,6	0,6
		Geothermal	0,1	0,1
	Cogeneration	Biomass Cogeneration	18,2	19,3
		Tertiary Cogeneration	7,3	13,8
		Household Cogeneration	7,5	38,4
	Fossil	Combined Natural Gas Cycle	43	64
		Single Turbine Natural Gas	5	10
		Existing Conventional Power Plants	160	13
		"New" Coal	4,5	0
		Nuclear	0	0
		Total Non Nuclear Contribution		**367**

IV Compensating for Additional CO_2 Emitted by Recourse to Fossil Energies

Fossil energies would provide for 60 % of electricity production for a nuclear phase-out within 5 years and 30% within 10 years. Phase-out within 5 years would cause significant greenhouse gas (GHG) emissions as France's existing thermal power plants would be up and running all year round. These GHG worsen the effects of climate change. Therefore, in parallel to nuclear phase-out, measures [8] must be taken in the sectors responsible for highest emissions of GHG: that is to say transportation, the building sector and intensive agriculture.

- **Limitation of the excessive use of fertilisers in agriculture through taxes and the reward of sober methods. By decreasing fertiliser application, and thereby fertiliser production, the equivalent of 24 Mt* of CO_2 emissions could be avoided.**

- **Limitation of private vehicle gasoline consumption to 4 litres per 100km would reduce averageCO_2 emissions from 180 grams per km to 120 grams per km. This would enable 46 Mt* of CO_2 emissions to be avoided.**

- **Réduire de 10 km/h la vitesse sur les autoroutes éviterait chaque année l'émission de 4 Mt* de CO_2 dans l'atmosphère.**

Following through forcefully with the application of these three measures would enable GHG emissions provoked by a 5-year nuclear phase-out (highest CO2 emissions) to be compensated entirely. Measures to obtain GHG emission permits under the Kyoto Protocol are also envisaged: they are discussed in detail in the complete study of an exit in 5 or 10 years.

Furthermore, **an old building refurbishment program and the tightening of the Building Energy Code would significantly reduce fossil energy consumption, and consequently CO2 emissions** by between 3 and 4 Mt* of CO2 a year. A fast nuclear phase-out in France would, in the medium term, enable GHG emissions to be significantly reduced as it would release financial and research opportunities for renewable energies (opportunities which are today choked by the nuclear sector that monopolises almost all energy budgets). Obviously, the objective of short-term nuclear phase-out is not to replace an almost "exclusively nuclear" approach by an "exclusively fossil" one, but to work towards "exclusively renewable" empowerment.

Increase in GHG emissions would be transitory as the purpose of the use of the conventional thermal power plants is to provide electricity in the interval between fast phase-out from "exclusively nuclear" electricity production on the one hand, and massive electricity production from renewable energies on the other hand. **This surplus in CO2 emissions is however insignificant compared to the total worldwide emissions of GHG: the use of fossil energies in the context of a 5 year nuclear phase-out would increase global GHG emissions by just under 0.1%.** France's phase-out from nuclear electricity production will not accelerate climate change.

[8] Ces mesures s'inspirent des propositions du Réseau Action Climat (RAC). « Changement climatique, dix mesures prioritaires dans les programmes électoraux pour 2007 », 2007, RAC.

Conclusion

Contrary to what many would have us believe, **it is possible to withdraw from nuclear energy in the very short term.** However, make no mistake, **such a decision is a political one not a technical one**. A decision that requires strong collective intent and more than a little elbow grease. Individual behaviour is the key to success, as half of French power consumption originates from citizens. This summary does not provide an in-depth evaluation of the actions that would enable a nuclear phase-out in 5 or 10 years. These actions are thoroughly developed in the study itself.

To start with, here are some simple ideas that would go a long way towards facilitating prompt nuclear phase-out:

There will be no nuclear energy phase-out unless there is abrogation of the Primary Energy Law (the Loi d'orientation sur l'énergie voted in 2005) as it in effect gives sacred status to nuclear energy. What is needed, quite to the contrary, is a law that taxes polluting energies in favour of renewable energy development. A Building Energy Code imposing energy consumption thresholds that would halve building energy consumption is imperative. To accelerate the uptake of energy savings, a new electricity pricing policy rewarding economical behaviour would be more than welcome.

In the next few years, France will need to renew its apartment housing stock. Let us use this opportunity to change the way we build. It is possible to launch an ambitious economical apartment housing construction program that would generate important energy savings, whether these buildings be halls of residence, old people's homes or young worker hostels. These buildings would be exemplary, both in terms of their energy savings, and of their renewable energy use. The additional construction cost of such buildings amount to less than 10 %, while the annual energy bill savings generated amount to 70%.

There will be no nuclear energy phase-out if we do not learn to save energy. This is why Energy Efficiency Advice Centres (EEAC), which offer free, impartial advice on all aspects of energy savings and renewable energies, must be created in all cities with over 10 000 inhabitants.

Finally, if France were to put an end to nuclear armament, nuclear waste burial and 4th generation* nuclear reactor research programs, to stop EPR* construction, and furthermore to withdraw from the experimental ITER* fusion project, the funds necessary for infinitely more useful, social and democratic research on sobriety, energy efficiency and renewable energies would be released.
It is high time we changed our way of producing and consuming energy.

The "Sortir du nucléaire" Network

Glossary

Bioclimatic Architecture: Architectural principles that work with natural forces and integrate geographical situation, orientation and building insulation into design in order to reduce energy consumption.

Building Energy Code: Code regulating the energy consumption of buildings with the objective of improving building energy efficiency.

Carbon Footprint: Measure of the impact human activities have on the environment in terms of the amount of greenhouse gases emitted. Measure can be applied to individual products or activities.

Combined Cycle Natural Gas Turbine Plant: A power plant in which a gas turbine generator generates electricity, and the waste heat is used to make steam to generate additional electricity via a steam turbine. This last step increases the plant's electricity generation capacity.

Energy: The capacity to do work. Energy can be drawn from different types of matter (wood, oil, uranium, etc.), different sources (wind, sun, tides, etc.) and manifest itself in different ways (electrical, chemical or mechanical energy, etc.).

Energy Efficiency: To use less energy (input) for the same service rendered (output). A class A++ refrigerator uses half the electricity a class G refrigerator uses to keep food cold.

Energy Efficiency Ratio: is the ratio between primary energy consumption and production of secondary energy(ies). An energy efficient engine transforms more calorific (primary) energy into mechanical energy than does an ordinary engine.

Energy Mix: The different sources of energy used for energy production in France.

EPR: Nuclear fission reactor similar to the 58 reactors in operation in France. EPR means European Pressurized (water) Reactor.

Energy Saving Light bulb: A light bulb that uses 5 times less energy and has a rated lifetime 10 times greater than a normal (incandescent) light bulb.

Energy Sobriety: Conscious restraint in energy use in order to stop energy waste. Turning off the lights when leaving a room is an example of energy sobriety.

4th Generation Nuclear Reactor: Nuclear fission reactor using liquid gas or metal coolant, and fuel highly enriched in plutonium.

Hydroelectricity: Electricity produced by capturing the force or energy of moving water (mostly rivers, waves and tides).

Hydrogen Fuel Cell: A device that converts chemical energy directly into electric energy and heat energy, using hydrogen as fuel. The energy conversion process is very efficient.

ITER: Experimental nuclear fusion reactor. ITER means International Thermonuclear Experimental Reactor.

LED: A light emitting diode (new type of light bulb) that uses 10 times less energy and has a rated lifetime 100 times greater than a normal (incandescent) light bulb.

Mox: Nuclear reactor fuel enriched in plutonium.

Mt: Abbreviation for megaton. Measurement unit equal to 1 million tons.

MWp: The Watt-peak (Wp) is used to measure the maximum power output of photovoltaic modules. Wp is the power provided by a module when it receives 1000 watts per m2 of solar irradiance at 25°C ambient temperature. MWp means megawatt-peak, which is one million watt-peak.

NegaWatt Scenario: 2000-2050 scenario for achieving energy consumption reduction and replacement of fossil and nuclear energies using energy savings and renewable energies. Web site: www.negawatt.org

Primary energy: Energy that has not been subjected to any conversion or transformation process, and has not been transported to the consumer. Raw petroleum, that has not yet been extracted or refined, is a primary energy.

Reprocessing (plant): Chemical separation of any plutonium from spent nuclear reactor fuel. The process is expensive and causes colossal discharges of radioactivity and chemical substances into the environment.

Secondary energy: Form of energy generated by the conversion or transformation of primary energy. A hydroelectric dam produces electricity (secondary energy) using the force or energy of moving water (primary energy).

Tertiary Sector: Economic activity sector composed of the service industries. This sector includes, amongst others, wholesalers, retailers, administrations and banks.

Translated in english by Naomi Lebegue and Nabil Kerbati

This summary of the 5 or 10 year Nuclear Phase-Out Evaluation is available for 4 € in French (including 3 € for shipping).

The complete 5 or 10 year Nuclear Phase-Out Evaluation is available for 13 € in French (including 3 € for shipping).

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