# REPORT SUMMARY

## “Security of nuclear reactors and spent fuel pools in France and Belgium and related reinforcement measures”

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**Report commissioned by Greenpeace France**

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## Foreword

This report on the security of nuclear reactors and fuel storage pools in France and Belgium draws on the contributions of seven experts from France, Germany, the United Kingdom and the United States – specialists in nuclear safety, security, radioprotection and economics – to bring together the full range of expertise necessary to analyse the problem. Each contributor is only responsible for his/her contribution in the form it was commissioned and separately delivered to Greenpeace France.

This report looks at an eminently sensitive subject in an extremely delicate context. Critical analysis and independent expertise must, in line with this, be approached in a way which conciliates two conflicting requirements.

The first is that of democratic choice. The security of nuclear facilities in the face of external attacks must be open to public debate. There is no justifiable reason for this issue, a major factor in the assessment of risks related to different industrial and energy options, to be excluded from the democratic process. The public has a fundamental right to information about the risks associated with the operation of nuclear facilities, which includes assessing the risk of external attacks in all its dimensions. It is thus the responsibility of non-institutional experts to contribute to this debate.

The second requirement, equally fundamental, is the preservation of public security. Contributing to this debate in a way that enhances the risk of an external attack on nuclear facilities, or, even worse, favours the success of a possible attack by revealing any flaws in the system, is of course out of the question. It is therefore also the responsibility of non-institutional experts to ensure that the protection of such facilities is not impaired by the information they collect or the analyses they produce and make available to the public.

It is particularly difficult to strike this balance in the French context, since the authorities responsible for nuclear security systematically oppose any attempt to clarify the state of protection of nuclear facilities against malevolent acts with the argument of “defence secrecy”. This generalised reliance on secrecy is a formidable trap, for two major reasons.

First, it places any observer in an impossible bind by default: working on the basis of public information but in principle completely uninformed of the degree of vulnerability determined by the authorities and any related protection measures (since this information is confidential), the observer is still expected to identify the point at which highlighting and analysing this public information would compromise secrecy and therefore security. Above all, in the event that security vulnerabilities exist at nuclear facilities, and that current action by industrial operators and public authorities aims to hide such flaws for the sake of secrecy, rather than making the necessary reinforcements, how can this problem be addressed without weakening the system under the microscope?

It is essential, from the point of view of democratic principles as well as public security, that secrecy in no way be a screen for the authorities to hide such flaws instead of protecting the facilities effectively. This concern is at the heart of the work commissioned by Greenpeace France. This work looks at the current security situation at nuclear facilities and, more specifically, at spent fuel pools at nuclear plants (in France and Belgium) and at the La Hague reprocessing plant (in France).

This work was accompanied by very special precautions. The most obvious measure is to release only this summary to the public. Greenpeace will ensure the report is released to only a handful of its members working on the issue and to the relevant authorities in European countries concerned (France, Germany, Belgium, Luxembourg and Switzerland).

It should be noted that these precautions are not a reflection of the nature of the information used in the report. This information, whether it be elements taken from the publications of industrial operators or the authorities, databases, news articles or field observations, is entirely public, and, for the most part very easy to access. It is the vulnerabilities likely to be highlighted by the collection and analysis of this information that justify this precaution, since efforts to protect against such possible vulnerabilities depend primarily, and in an extremely fragile way, on secrecy (meaning, in this case, not discussing in public information which is though publicly accessible).

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## The challenge of nuclear security

Today, several factors contribute to making security at nuclear facilities, and more specifically in spent fuel pools, a major and fully relevant issue. First, of course, is the very high level of threat to security in France and Europe, which provides an incentive to imagine all the actions which criminal organisations or individuals claiming to belong to them may attempt. Nuclear power plants are, without a doubt, a risk in this context.

This is inherently due to the potentially dangerous nature of these facilities, because of the inventory of reactive and radioactive materials which they contain. At the biggest facilities – including power nuclear plants and fuel manufacturing and processing plants, and the main storage facilities for nuclear material – this inventory generates a risk of a serious or even major accident. Significant safety provisions, such as successive containment barriers, design and operation quality, and the installation of redundant back-up and emergency systems, are implemented to counter this risk. A malevolent act could, for example, precisely aim to incapacitate these systems to intentionally provoke an accident scenario which results in major leaks of radioactivity.

Nuclear security therefore consists in protecting facilities against the successful execution of such acts. It is partly based on traditional security measures, such as detection by means of intelligence, prevention through barriers or access controls, and the intervention of security forces present on- or off-site. It can also rely on the role of safety devices, such as a reactor's containment building, which also offer protection against external attacks.

However, most in-service nuclear facilities were designed at a time when threats were of a different nature: the means necessary for an attack capable of profoundly affecting these facilities could only be mobilised with the support of foreign States which were dissuaded by the threat of a military nuclear strike in return (in the case of a country like France). For these historical reasons, reinforcement against heavy attacks on civil engineering works and protection systems for nuclear safety was not – or only marginally – incorporated into the design of these facilities. The nature of the threat radically changed with the attacks of September 11, 2001: a criminal organisation with no ties to any State now has attack capabilities which are not neutralised by the initial design features of nuclear facilities.

## Spent fuel pools: a priority issue

This shortcoming is even more pronounced in the case of spent fuel pools (compared to reactors themselves). Based on safety analysis at the time of their construction, the risk of a runaway nuclear reaction in the pools was neglected and they were not equipped with a robust confinement building similar to those found in reactors. In 2011 however, the Fukushima disaster highlighted the risk, in these conditions, of a massive leak of radioactivity in the event of a sustained loss of cooling capacity of stored fuel. This type of incident, a potential goal of an external attack, would have consequences similar to those of a major accident at a nuclear reactor. EDF reactor pools, the inventory of which varies depending on several factors and must maintain a reserve (but several of which are close to saturation), are capable of storing several hundreds of tonnes of fuel – the equivalent of up to two-three reactor cores. The five pools at La Hague contain the equivalent of nearly one hundred-fifty 900 MWe reactor cores in total.

The EPR reactor under construction in Flamanville illustrates this concern. It has a reinforced concrete containment structure which encloses the fuel building, similarly to a reactor. This "airplane crash shell" to protect the pool was incorporated into the design of the reactor after September 11, as a direct response – though this was never ostensibly discussed during the decision-making process – to this new threat. Pools at reactors which are currently in service in no way benefit from the same level of protection.

The question of a possible reinforcement of civil engineering works and safety equipment at nuclear facilities in light of security considerations must therefore be asked. In France, however, doing so highlights an institutional conundrum relatively unique at the international level: the Autorité de sûreté nucléaire (ASN), the country's nuclear safety agency, does not have the authority to examine this type of security issue, while the entities responsible for monitoring nuclear security focus their role essentially on traditional protection methods (detection, prevention, interception…). As a result, no one appears to be really able to address the matter of reinforcement and emit directives.

This consideration is, however, of extreme relevance in the current French context. It should focus on three areas, in connection with the evolution of nuclear operations in France: (I) the fuel buildings of each reactor, and notably the thirty-four 900 MWe EDF reactors in relation to upcoming decisions on whether to extend their operating life beyond 40 years, conditioned on reinforcing their safety, in line with specifications issued by the ASN, to achieve a level of safety as close as possible to that of the EPR reactor; (ii) the spent fuel storage pools at the Areva NC La Hague reprocessing plants, the capacities of which have reached saturation in a context where decisions must be taken on the future of these equally ageing facilities; (iii) and the new project to build one or several centralised spent fuel pools, for which EDF recently submitted an application detailing safety provisions, in response to the need to reduce the fuel inventory of reactor pools and the lack of carrying capacity at La Hague.

## Feared accident scenario

In this context, Greenpeace France commissioned a range of analysis from several French and foreign experts on the possible risks and consequences of malevolent acts targeting spent fuel pools, this expertise being gathered in a technical report. This analysis focuses first on a detailed study of the conditions in which a sustained loss of cooling capacity can lead to a massive leak of radioactivity in these pools. The report then describes the type of threat of external aggression that is plausible today and considers in greater detail different types of attacks and different aspects to consider in assessing the possibility of actually carrying them out at a certain number of representative facilities. The report also recalls the radiological consequences to which such a scenario would likely lead.

Under normal conditions, spent fuel pools provide radiological protection against the radioactivity released by spent fuel. They also cool this fuel, which has a high thermal load, although it decreases over time.

In the feared scenario, a sustained loss of cooling occurs due to a breach and subsequent loss of water at a rate faster than it can be replaced, leading to a partial or total uncovery of the fuel. Under the effect of the fuel's own heat, possibly made worse by corrosion, the fuel rods cladding warps, breaks and finally burns, causing fusion in the fuel itself, and leaking a large fraction of their content. The report examines in detail the different parameters which can influence the occurrence and degree of seriousness of such a scenario, such as the leakage rate and breach location, the availability and configuration of partitioning and reinjection systems, the amount of residual heat in the stored fuels, the configuration and density of fuel in the racks, and the presence in the inventory of MOX, which is made from reprocessed plutonium and is hotter and more reactive in general.

This assessment concludes, firstly, that the course of an accident and its final scale can strongly depend on these different factors. As a result, individuals with criminal intent in possession of the necessary skills could seek to use these factors to their advantage, for example by timing their attack and choosing a type of damage with the goal of maximizing the severity of the accident and the radioactive release which the attack leads to. This effect could be reinforced by the neutralisation, during the same attack, of technical or human systems designed to respond to problems in the pool in the event of such an accident.

## The possibility of success of an attack

The next question is whether an external attack would be likely to generate the type of targeted damage needed to bring about such a scenario. The point here is not to discuss whether criminal organisations are likely or not to attack nuclear facilities in Europe. While it is true that active groups have not opted for this type of attack in recent years, we cannot ignore the possibility of this idea being developed, as various signs of interest in nuclear facilities and activities on the part of criminally-minded individuals would suggest.

The point is to assess the extent to which criminal organisations would be capable of securing and using the means necessary for such an attack if they planned one. In this respect it is hard to ignore a trend towards increased access to means of action which are more and more diffuse, diversified and discreet, as well as more and more powerful, whether it be the ability to divert tools used in civil settings such as drones, trafficking light and heavy weapons, or remote means of disruption via computer networks.

The report explores various attack scenarios involving instruments to which criminally-minded individuals are currently believed to have access. Given the known or estimated thickness of the walls in the buildings concerned, and of the pools themselves, such attacks, if carried out effectively enough to counter security forces present or which arrive on site (which is not a major obstacle), will be capable of producing damage to the structures and facilities of spent fuel pool buildings which leads to the scenarios feared.

In addition to this generic assessment is a more specific review of the conditions in which such means could be used against a certain number of facilities (e.g. The Bugey, Cattenom, Fessenheim, Gravelines plants, the La Hague plant in France, and the Doel and Tihange plants in Belgium).

Certain known weaknesses are common to all facilities, such as a lack of protection other than beams and metal siding on the roofs of fuel buildings. Other conditions obviously vary from site to site, making different attacks more or less difficult. It is possible to imagine that individuals planning to attack a nuclear facility would be able, based on the same type of assessment, to select the site or sites with the most favourable conditions.

## Possible radiological consequences

Without the protection of an enclosure designed to withstand attacks, fuel storage buildings at nuclear plants and the La Hague reprocessing plant are vulnerable to attacks that are likely to cause significant damage. Targeted and sized to create the worst situation possible, such an attack could maximise the accident scenario in which fuel is uncovered, heats to the point of fusion and a significant fraction of its radioactivity is released. For example, in the worst conditions described above, all of the cesium-137 contained in the fuel, the main factor of population exposure in such an accident scenario, is likely to be released. Given the lack of containment, due to the initial design of the building and the damage caused by the attack, a large fraction of this cesium and other leaked radionuclides would escape the building. This situation would lead to a massive amount of radioactivity being leaked into the environment.

In the early days of the Fukushima Daiichi disaster, the Japanese government sought to estimate the consequences of the worst possible scenario, which consisted of accumulated releases caused by a loss of containment in reactors 1 to 3 of the plant and the dewatering of fuel in the pools of reactors 1 to 4, the latter being the most heavily loaded since the reactor core had just been discharged there. Radioactive fall-out significantly higher than natural radioactivity was then projected up to 250 km from the plant, for the most part released from the pools, and particularly from the pool in unit 4.

Ex post analysis of what this accident could have been, and the projection of what could be a similar accident at facilities covered in this report, confirm that its impact would far exceed that of the most serious foreseeable accidents involving a reactor core, and potentially affect several million people in a 75 to 150 km range. Given the lack of a population protection and emergency response plan on that scale, and the disruption to emergency response which an external attack could cause, the radiological consequences of such a situation could potentially be unprecedented.