Lifetime extension of ageing nuclear power plants: Entering a new era of risk

Briefing of the report commissioned by Greenpeace

www.out-of-age.eu

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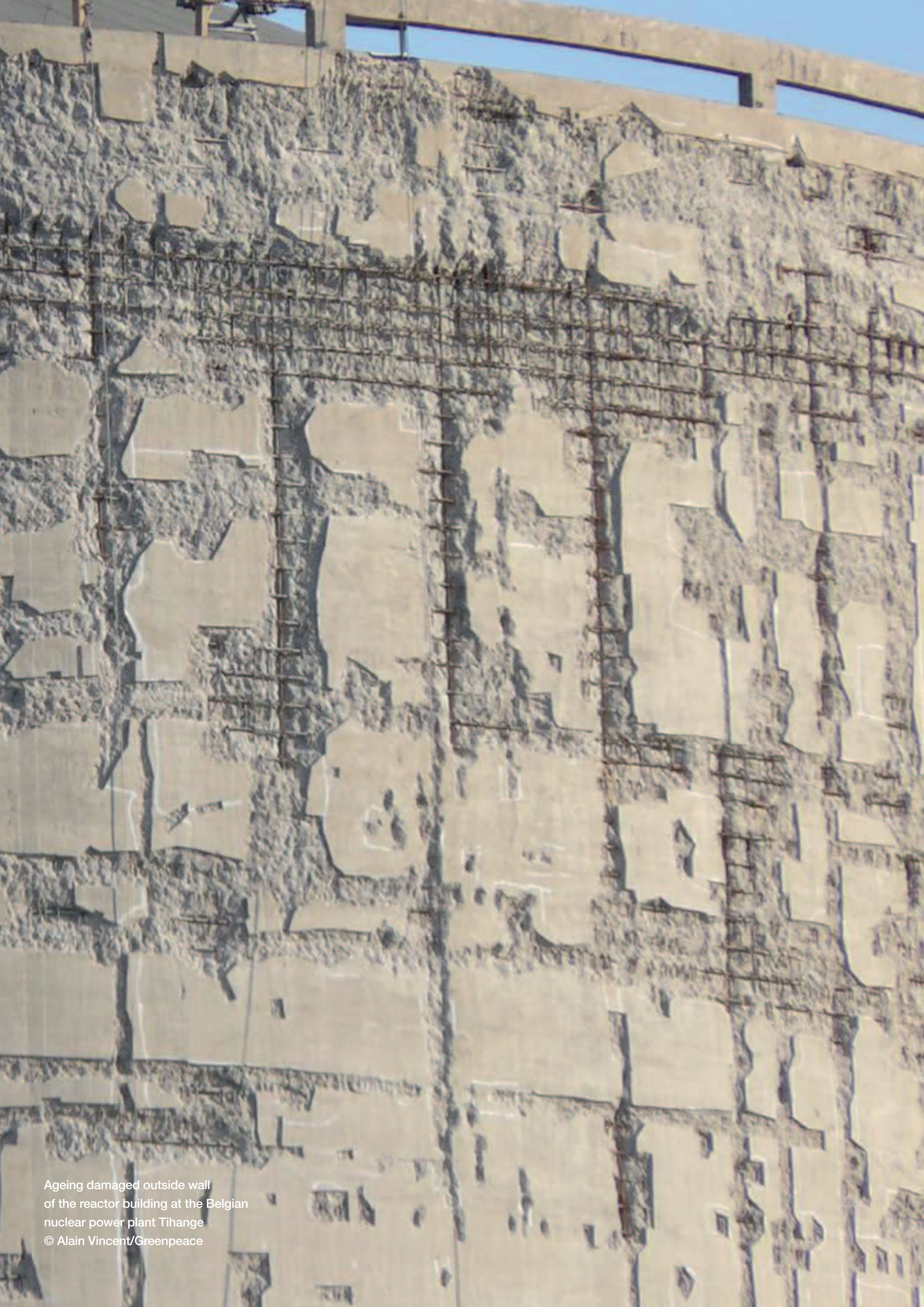

Ageing damaged outside wall
of the reactor building at the Belgian
nuclear power plant Tihange
© Alain Vincent/Greenpeace

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Steam generator replacement through a hole cut into the containment at the Belgian nuclear power plant Doel 2, 2004
© electrabel

Key elements

Electricity companies are currently seeking lifetime extension of no fewer than 46 old nuclear reactors. The ageing of nuclear reactors is an urgent issue in most European countries that operate nuclear power: Belgium, Finland, France, Germany, Hungary, Netherlands, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine and the United Kingdom.

Out of 151 operational nuclear reactors in Europe (excluding Russia), 66 are more than 30 years old and 25 more than 35 years. Seven of them are even older than 40 years.

→ **image 1: Age of nuclear reactors in Europe (page 6)**

In spite of upgrades and repairs, the overall condition of nuclear reactors deteriorates in the long term. The likelihood of an accident and the amount of potential complications increases.

Nuclear reactors contain components that cannot be replaced, including the reactor pressure vessel and the containment, whose condition deteriorates over time.

While replacement of old components may reduce some risks, it also introduces new ones: for example, in some cases large components are replaced by breaking through the reactor's containment, as a result of which the strength of this vital protective structure is inevitably impaired.

Most reactors for which lifetime extension is being sought also have their power capacity uprated – further increasing the stress on the already worn systems and components.

The increasing stockpile of spent nuclear fuel and high-level nuclear waste at many power plants, stored under outdated safety systems, adds a further layer of risk.

'Soft' factors, such as old-fashioned organisational structures and the loss of motivation and know-how as routine sets in and experienced staff retire, also undermine the overall safety level of ageing reactors.

Ageing nuclear power stations are far from meeting the state-of-the-art technological standards required for new reactors, and it is impossible to bring them up to those standards when extending their lifetimes.

In the event of a serious accident involving one or more nuclear reactors, the current European nuclear liability coverage is – depending on country – too low by a factor of between 100 and 1,000 to cover the likely costs. At the same time, the likelihood of a serious accident happening in Europe continues to increase as the reactor fleet grows older.

→ **image 2: Insured (covered) limits in Europe in case of a nuclear accident (page 7)**

Decisions to extend the lifetime of old reactors stand under pressure from economic and political arguments, because old reactors have already amortised their capital costs, making them relatively cheap to run. However, upgrading them to a level of safety required for new reactors (best available technology) would make them uncompetitive on the electricity market.

Involvement of the public and independent media can improve the quality of regulatory oversight of ageing reactors. Moreover, the public has the right under the Aarhus and Espoo Conventions to be consulted on political and corporate plans that include lifetime extension of ageing nuclear reactors.

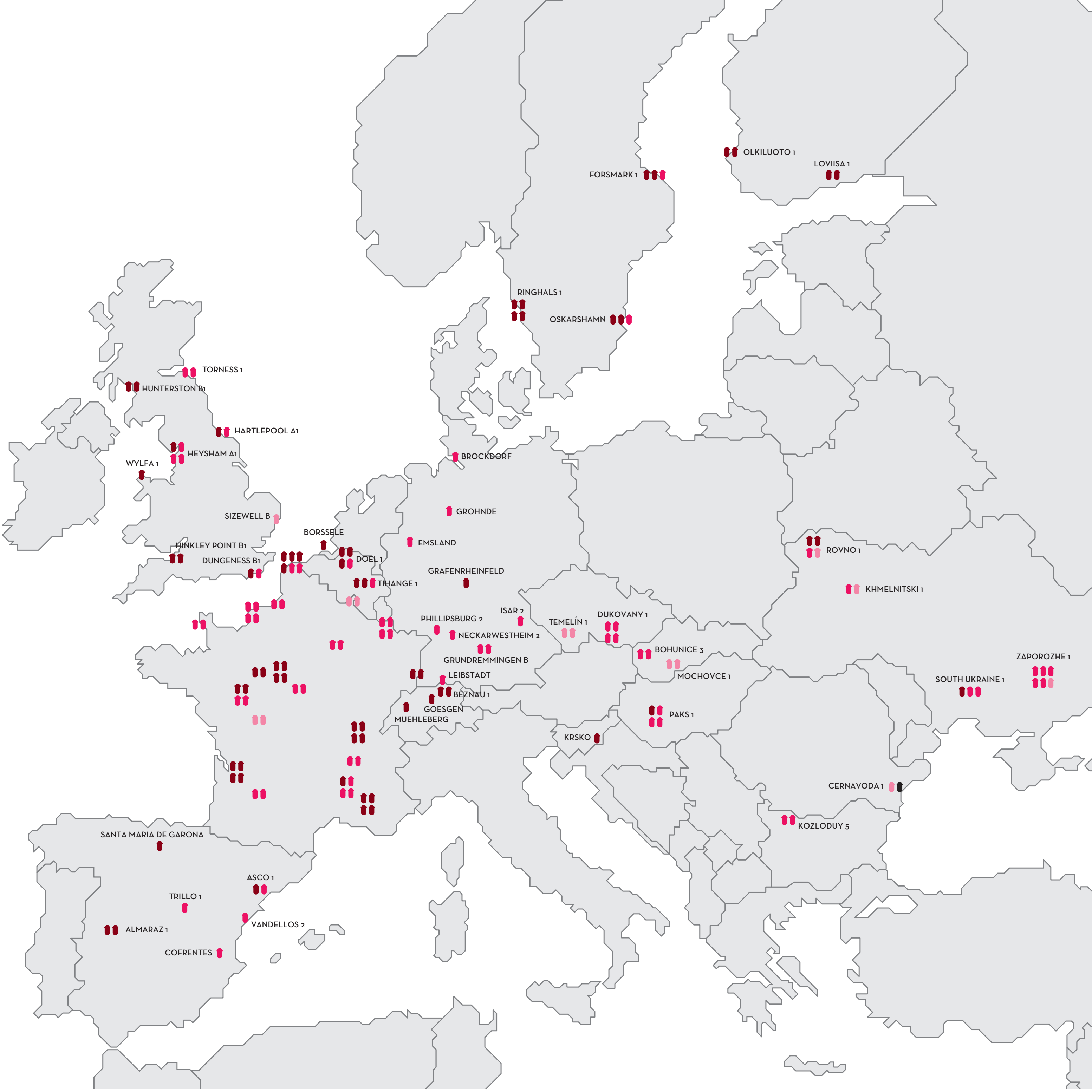


IMAGE 1

Age of nuclear reactors in Europe

less than 20 years old
14 european nuclear reactors are concerned

more than 20 years old
71 european nuclear reactors are concerned

more than 30 years old
67 european nuclear reactors are concerned (including 7 more than 40 years old)

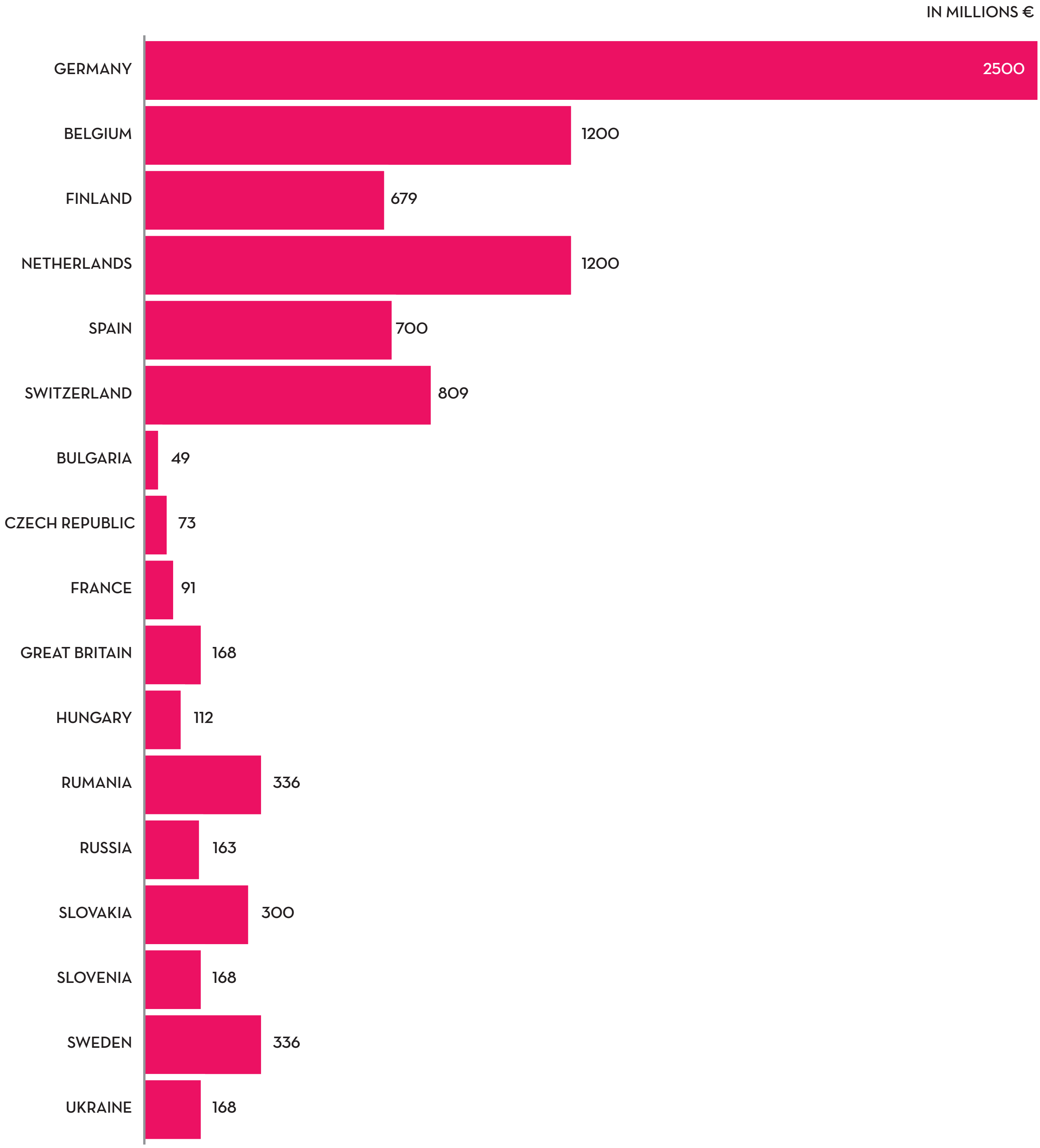


IMAGE 2

Insured (covered) limits in Europe in case of a nuclear accident

186 BILLIONS €

source: European Commission, 2013. Public consultation - Insurance and compensation of damages caused by accidents of nuclear power plants (nuclear liability). Brussels. http://ec.europa.eu/energy/nuclear/consultations/20130718_powerplants_en.htm

GERMANY
2500 MILLIONS €

ESTIMATED COST BY THE EUROPEAN COMMISSION
OF THE DAMAGES CAUSES BY FUKUSHIMA ACCIDENT

Fuel pool in French nuclear power plant Gravelines © Greenpeace

Executive summary

Nearly three years on from the Fukushima nuclear disaster, the 25 oldest nuclear reactors in Europe have all passed 35 years of operation. More than two-thirds of US nuclear reactors have received extended licences permitting 60 years of operation, far beyond their original design lifetimes. We are entering a new era of nuclear risk.

RISKS OF NUCLEAR AGE

Dipl.-Ing. Simone Mohr, Dipl.-Ing. Stephan Kurth, Dr. Christoph Pistner, Dipl.-Ing. Judith Breuer (Öko-Institut e.V., Darmstadt)

At the time of writing (January 2014) the average age of European nuclear reactors has reached 29 years. An increasing number are reaching their design lifetimes of 30 or 40 years. New nuclear reactor construction in the EU is not capable of replacing all the reactors that are approaching the end of their design lifetimes, and the Fukushima disaster acted as a brake on new build programmes. Nevertheless we are seeing an increasing demand for new strategies to avoid a phase-out of nuclear energy, especially in countries that have not developed viable alternatives.

The current strategy of nuclear operators in much of Europe, including Switzerland, Ukraine and Russia, is targeted at a combination of extension of reactor lifetime (also called Long Term Operation) and power uprating. These factors taken together may have an important impact on the safety of the operational reactor fleet in Europe.

→ **image 3 : Typical life cycle of a nuclear power plant (page 10)**

→ **image 4 : Schematic diagram showing the progression of nuclear reactor ageing (page 10)**

The design lifetime is the period of time during which a facility or component is expected to perform according to the technical specifications to which it was produced. Life-limiting processes include an excessive number of reactor trips and load cycle exhaustion. Physical ageing of systems, structures and components is paralleled by technological and conceptual ageing, because existing reactors allow for only limited retroactive implementation of new technologies and safety concepts. Together with 'soft' factors such as outmoded organisational structures and the loss of staff know-how and motivation as employees retire, these factors cause the overall safety level of older reactors to become increasingly inadequate by modern standards.

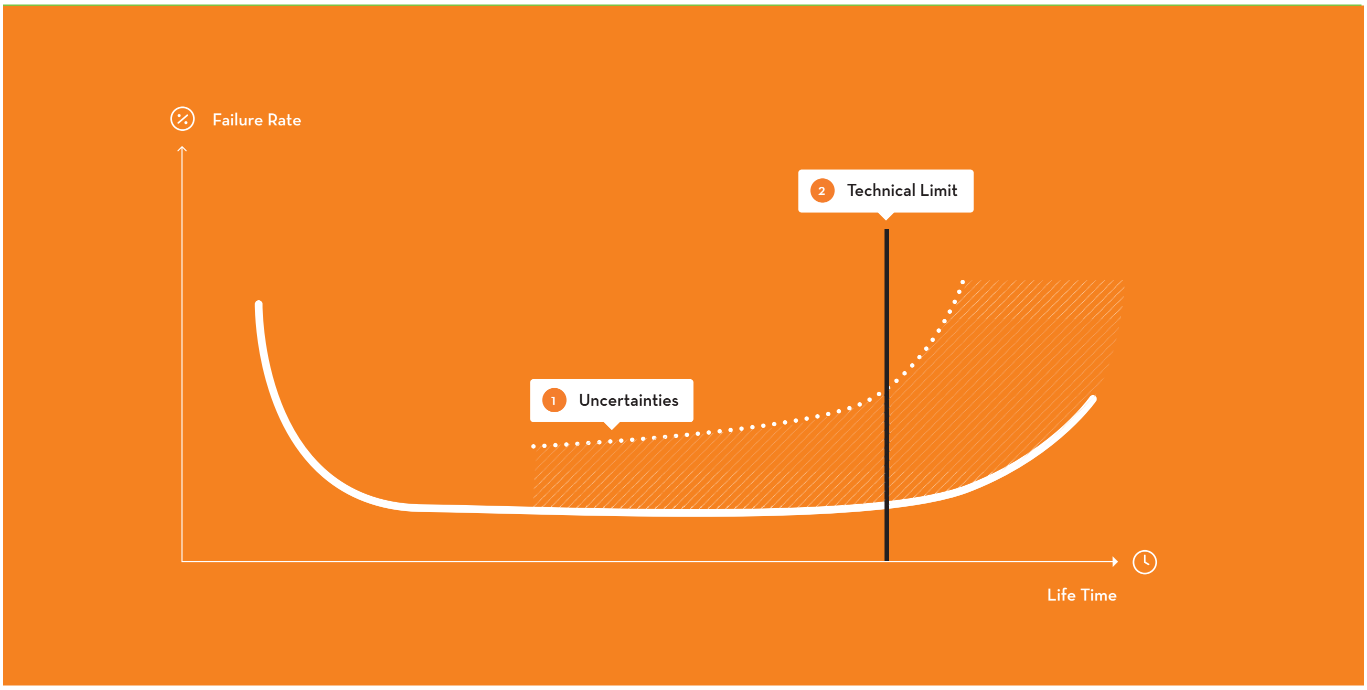
Measures to uprate a reactor's power output can further compromise safety margins, for instance because increased thermal energy production results in an increased output of steam and cooling water, leading to greater stresses on piping and heat exchange systems, so exacerbating ageing mechanisms. Modifications necessitated by power uprating may additionally introduce new potential sources of failure due to adverse interactions between new and old equipment. Thus, both lifetime extension and power uprating decrease a plant's originally designed safety margins and increase the risk of failures.

→ **image 5: Plant power uprating (PPU) of reactors, source: Öko-Institut (page 11)**

Physical ageing issues include those affecting the reactor pressure vessel (including embrittlement, vessel head penetration cracking, and deterioration of internals) and the containment and the reactor building, cable deterioration, and ageing of transformers. Conceptual and technological ageing issues include the inability to withstand a large aircraft impact, along with inadequate earthquake and flooding resistance. Some reactor types, such as the British advanced gas-cooled reactors (AGC) and Russian-designed VVER-440 and RBMK (Chernobyl-type) reactors suffer specific problems.

IMAGE 3

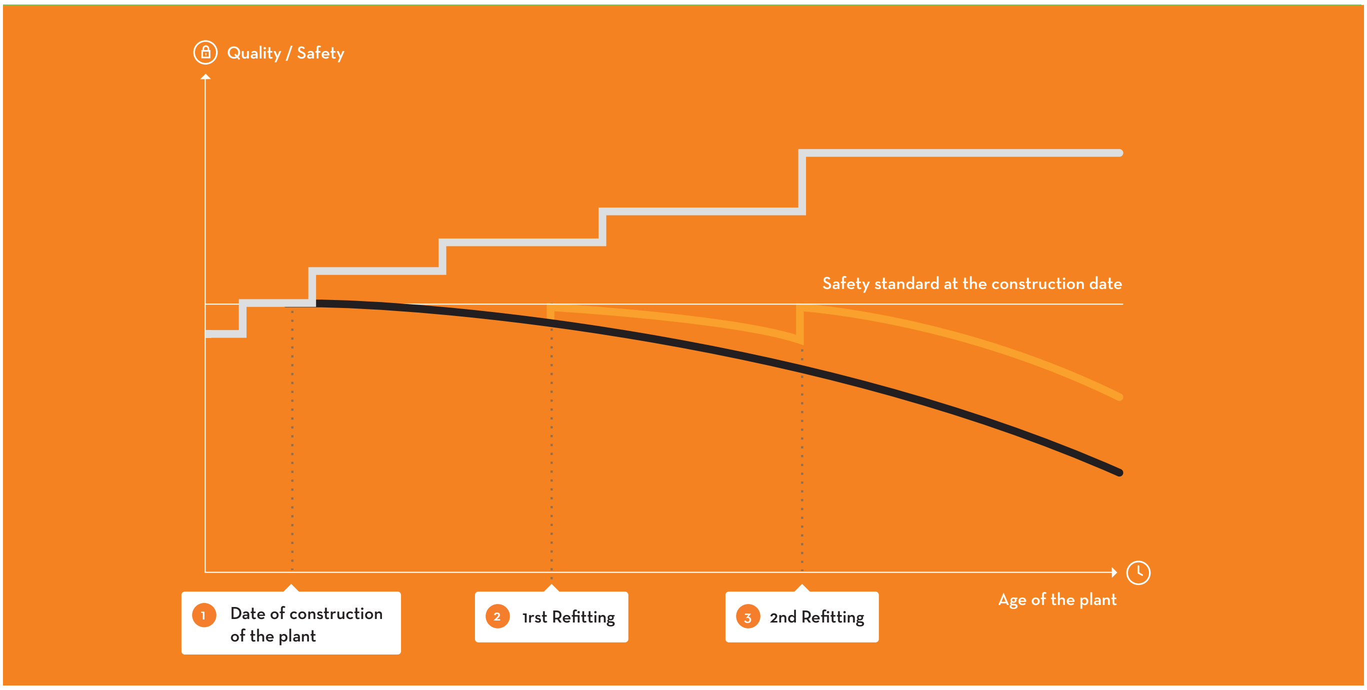
Typical life cycle of a nuclear power plant



Sources : Residual Risk report, 2007, based on IRSN

IMAGE 4

Schematic diagram showing the progression of nuclear reactor ageing



Source: Öko-Institut

Without refitting
Safety level when a plant is getting older

With refitting
Safety level when ageing effets are treated

Required safety level
Safety requirements according to the state of the scientifiz and technical knowledge

IMAGE 5

Plant power uprating (PPU) of reactors

Nuclear power plant uprated from 0% to 5%

Nuclear power plant uprated from 5 to 10%

Nuclear power plant uprated from 10 to 20%

Nuclear power plant uprated more than 20%

Retrofits already recommended after the Three Mile Island accident in 1979 and the 1986 Chernobyl disaster have still not been implemented in every European nuclear power plant. Ageing management programmes so far implemented have not been sufficient to avoid the occurrence of serious ageing effects. Concrete examples exist where ageing of the workforce and consequent atrophy of the knowledge base as staff retire may affect occurrence of failures, as well as problems with retrofitting and refurbishment. Furthermore, there are considerable disparities in the responses of different operators and regulatory authorities to identified ageing problems.

Spent fuel storage presents a special risk for ageing nuclear power plants due to the build-up of large amounts of spent fuel. Examples of problems include inadequate protection against external hazards and the risks of a long-term loss of cooling (due to poor redundancy and low quality standards in spent fuel pool cooling systems), both issues illustrated by the Fukushima catastrophe. The re-racking of spent fuel elements into more compact storage units to increase the space available for the larger than expected amount of spent fuel is a further source of risk.

Site-specific risks change over time. New insights into earthquake risk require higher protection standards which cannot be fully met by modification of older nuclear power plants. The lack of emergency preparedness evident during the Fukushima disaster forces a reassessment of risks including those of flooding and loss of external infrastructure. Especially when seen in the light of the implications of climate change in terms of extreme weather and sea level rise.

The Fukushima disaster also highlighted the risk of an external event compromising multiple reactors at the same time – a situation hardly any multi-unit site is prepared for. Sources of common-cause failures include shared cooling inlets, pumping stations, pipelines, electricity infrastructure and so on – issues that were not sufficiently addressed in, for instance, the post-Fukushima EU Stress Test of nuclear reactors.

Perceptions of the most suitable locations for nuclear power plants have also changed over time. Many older plants are located in highly populated areas, obviously making emergency preparedness much more complex than for plants situated far from population areas, and greatly increasing the potential for harm.

The EU Stress Test furthermore did not explicitly cover ageing-related issues. The use of the original design basis to determine the robustness of reactors was particularly unsatisfactory, because design deficiencies and differences between different reactors were not fully taken into account. Because beyond design basis events had not been systematically analysed before, too little documentation was available and expert judgement played too large a part.

ECONOMICS OF NUCLEAR AGEING

Prof. Stephen Thomas
(University of Greenwich)

If the cost of modifications is relatively low, life-extended nuclear power plants can be highly profitable to their owners because the capital cost of the plant (making up most of the cost of a unit of nuclear-generated electricity) will already have been paid off, leaving only the operations and maintenance cost to be paid. Other advantages to the owner include the fact that the plant is a known quantity.

The economic risks depend on technical, regulatory and political factors. In practice, plants are not retired on the basis of their design life, but according to these other factors.

In the USA, reactor retirements have mostly been due to economic reasons (including the prohibitive cost of repair), though some have been because of design reasons. In Germany most closures have stemmed from political decisions, though a few have been design-related. Elsewhere, reasons have been mainly economic (France) or technical and economic (Canada, Spain, the UK), political (Italy, Sweden) or political and design-related (Japan, largely in the wake of the Fukushima disaster).

National regulators are constantly increasing safety requirements, but for ageing reactors these can never be set at the level of the best available technology. For instance, design lessons from the 1975 Browns Ferry accident were applied to most designs developed after that, but those from the 1979 Three Mile Island accident and the Chernobyl (1986) and Fukushima (2011) disasters can only be taken into limited account.

Lifetime extension becomes an issue at different points in a reactor's life, depending on the country. In France, where licenses are open-ended, the decisive moment is the regulatory Periodic Safety Review (PSR), conducted every 10 years. The most recent PSR and the post-Fukushima EU Stress Test prescribed upgrades representing a total planned investment in EdF's operational reactor fleet of around €50bn over the next 30 years. However, there is no clarity as yet about whether French reactors will receive a 20 yeas life-time extension as EdF has requested. In the USA, nuclear reactors operate under a 40-year licence. Well before the expiry of this licence, if lifetime extension is desired, a request must be made to the Nuclear Regulatory Commission for a 20-year extension. While the first such assessments took a few months, they are currently taking several years. So far, all reactors for which this assessment has been completed have had a 20-year extension granted. Nevertheless three plants (Vermont Yankee, Kewaunee and Crystal River) recently closed before lifetime extension was obtained because of excessive costs in the context of low electricity prices. San Onofre in California closed even before an extension was applied for, because of the cost of repairs.

Very few nuclear reactors have been retired because they have reached the end of their licensed or designed lifetime. Much more probable life-determining factors are: the economics of the plant; the existence of national phase-out policies; serious and unexpected equipment failures; and, for older designs in particular, existence of design issues that make continued operation unacceptable. However, in the 15 years since lifetime extension began to occur, the perception of the risk of granting a reactor a significantly longer life has increased. Permission for a reactor to operate for 60 years appears to be far from a guarantee that it will actually complete a 60-year life. A longer permitted lifetime has given utilities a reason to justify upgrades aimed at improving the economics of a plant, such as power upgrades. However, as the risks and costs of lifetime extension have become clearer, the case for this additional discretionary investment has weakened.

LIABILITY OF AGEING NUCLEAR REACTORS

Prof. Tom Vanden Borre (University of Leuven), Prof. Michael Faure (University of Maastricht)

The increasing risk posed by the ageing of nuclear reactors should be reflected in an increase in insurance premiums to cover the costs of a possible nuclear accident. Countries should only opt for reactor lifetime extension if the provision to compensate victims, of any accident, is substantially improved. Suppliers should be allowed to be held liable for accidents, and plant operators should face unlimited liability. Such increased liability will not only be beneficial for the victims of a nuclear accident but will also have an important preventive effect.

The principles of nuclear liability, fixed in the Paris and Vienna Conventions, include strict liability (liability for loss or damage regardless of negligence or other culpability); legal channelling of liability to the nuclear operator, with consequent exclusion of the supplier's liability; liability limitation for the nuclear operator in amount and time; compulsory coverage by financial security (insurance); and exclusive jurisdiction in the country of accident. Newer conventions such as the Convention on Supplementary Compensation (CSC) and the Protocols to the Paris and Vienna Conventions do not alter these principles. None of the Conventions, however, caters for reactor ageing issues.

The USA is not party to the Paris or Vienna Convention. Its Price-Anderson act enables nuclear operators to pool their liability resources. It provides for retrospective insurance for a top-up sum of liability in the event that an accident actually occurs. The amounts generated by this system are substantially higher than those under the international conventions; but conversely the nuclear operator's liability is capped just as it is under the conventions.

Given that the costs of a nuclear accident are potentially much higher than those covered in the limited liability coverage, liability limitation (capping) effectively gives the nuclear industry a two-fold subsidy: the limit itself, leading to lower insurance costs; and either top-up coverage by the state (in the case of Europe) or the opportunity to defer a portion of insurance costs to second-tier retrospective coverage (USA). These legal regimes thus protect nuclear operators and artificially decrease their risk costs, potentially creating three types of distortions:

1. The reduced cost of insurance gives nuclear energy an artificial competitive advantage because other electricity generation technologies (and market operators) have to internalise their full risk;

2. The liability cap reduces an operator's economic incentive to reduce the risk of a nuclear accident.

3. The cap, coupled (in the case of Europe) with inadequate top-up coverage, may result in a lack of or insufficient compensation for victims in the event of an accident.

The increasing risk posed by nuclear ageing should lead to an increase in operators' insurance premiums. With ageing nuclear reactors, adequate financial security to cover the costs of a potential accident becomes even more a necessity. It is important for society as a whole that objective calculations are made of the damage that a nuclear accident could potentially cause, and on that basis alternative systems of financing the coverage have to be investigated. It is obviously important to accompany this with a mandatory financial security requirement for operators, but the higher resulting costs resulting from such an analysis should not be a reason to limit liability. Pooling of the financial security by operators may be a good alternative to the current European nuclear insurance pools.

A new compensation model for nuclear damage should keep the positive elements of the international nuclear liability conventions: strict liability and compulsory liability insurance. It is especially important that compulsory insurance protects victims against insolvency of the operator. Conversely, the conventions, even as revised by their relevant protocols, allow for only up to about one per cent of the cost of an accident to be compensated for. The alternative is obvious: unlimited liability should be introduced.

Legal channelling of all liability to the operator is problematic. From the viewpoint of victims it would be preferable to be able to address a claim against several persons or corporations, as this would increase their chances of receiving compensation. It would also have a preventive effect since all parties bearing a share of the risk would have an incentive to avoid damage.

Countries considering plant lifetime extension should end funding part of the liability coverage with public means, extend liability to suppliers, and introduce unlimited liability for operators, while requiring the latter to have third-party liability insurance coverage or other financial security of a realistic level in terms of the actual scope for damage. Several possible financial schemes exist to fulfil this objective.

Countries should opt for reactor lifetime extension only if arrangements for the compensation of victims in the event of an accident are substantially improved. A higher level of liability would not only benefit the victims of a nuclear accident but would again have an important preventive effect. Pooling unlimited liability across Europe would encourage operators to monitor one another, since they would be reluctant to allow a bad risk into their system.

In conclusion, there are strong reasons for the EU's current state funding of financial security against a nuclear accident to be replaced by a collective system funded by the EU nuclear operators. Reactor lifetime extension should only be allowed if such an enhanced approach to nuclear accident compensation is adopted.

POLITICS, PUBLIC PARTICIPATION AND NUCLEAR AGEING

Ir. Jan Haverkamp (Greenpeace, Nuclear Transparency Watch)

There are various routes by which the public can influence decisions on the lifetime extension of nuclear reactors. Nuclear safety is the most obvious consideration, but economic or political arguments can play an overriding role, as for example during the German discussions on a nuclear phase-out. A high level of transparency (requiring public and media access to information) and public participation in decisions around ageing nuclear reactors can help to ensure the priority of nuclear safety. In Europe (excluding Russia, which is not considered here because it is not a party to the Aarhus and Espoo Conventions), reactor lifetime extension decisions have been recently concluded, are currently under consideration or will come under consideration in the coming three years in Belgium, the Czech Republic, France, Spain, Hungary, the Netherlands, Sweden, the UK, Switzerland and Ukraine. The point at which lifetime extension of a nuclear reactor becomes necessary for its continued operation is determined by the length of its operating licence (in countries where these are time-limited); or, in the case of an unlimited operating licence, by the national regulator after a periodic safety review, or on the basis of a political decision. The potential cost of upgrades, the likely cost recovery time, and the operator's ownership status and political influence can all act to reduce the priority accorded to nuclear safety during lifetime extension decisions. The independence of nuclear regulators is an important factor in counterbalancing such pressures. Public access to information (transparency) as guaranteed under the Aarhus Convention can also help, as can public participation and provisions to ensure that account is taken of critical public opinion. Referenda are a less clear-cut instrument.

Public participation under the Aarhus and Espoo Conventions and their implementing EU Directives can also influence decisions on the future of a country's ageing reactor fleet during strategic environmental assessment of national energy policies. A recent decision by the Espoo Convention Implementation Commission furthermore makes an environmental impact assessment including public participation compulsory for decisions concerning nuclear plant lifetime extension. Citizens of states party to these conventions also have avenues of legal recourse when they are not sufficiently included in these decision processes.

Greenpeace demands

Greenpeace is concerned about the new era of nuclear risk we are currently entering. it therefore demands the following urgent actions from european governments and nuclear regulators:

Phase out nuclear power and enhance the development of renewable energy and energy efficiency. The Greenpeace / EREC Energy [R]evolution scenario[1] shows that this is possible while at the same tackling climate change.

Clear, binding and ambitious climate and energy targets on EU and national level. This includes for 2030 a reduction of carbon emissions by at least 55% (compared to 1990), a share of renewable energy in the total energy consumption of at least 45% and a reduction of final energy consumption by 40% (compared to 2005). Nuclear power has no place in these targets.

Close reactors that are older than their initial design lifetime immediately. Greenpeace calls on nuclear regulators not to grant any lifetime extensions beyond that point.

Insist that the level of technical risk reduction of operational nuclear reactors is set according to best available technologies (BAT). Reactors that cannot meet this standard should be closed.

Ensure that when the process of preparation for lifetime extension, or a periodic safety review or other inspection, reveals a reactor to need a safety upgrade, the reactor's operation is halted until the necessary upgrade has been implemented.

Ensure full transparency and full public participation in decision-making, including in transboundary Strategic Environmental Assessments of national energy strategies that make provision for lifetime extension of old nuclear reactors; and transboundary Environmental Impact Assessments preceding all lifetime extension decisions for old nuclear reactors.

Implement a fundamental reform of the nuclear liability regime. The ageing nuclear fleet puts citizens at an ever-increasing risk. Currently, profits are privatised while the risks are socialised. Nuclear liability legislation must be based on the needs of potential victims. Liability must be strict and unlimited in time and scope, it must stipulate liability of suppliers as well as operators, and ensure full insurance of all potential costs of an incident or accident.

Guarantee the independence of nuclear regulators and implement feedback mechanisms in the form of full transparency and public participation, in order to guard against pressure from economic and political interests to compromise on nuclear safety.

1 See: http://www.energyblueprint.info

Gravelines nuclear power plant, France
© Greenpeace / Micha Patault

Greenpeace is an independent global campaigning organisation that acts to change attitudes and behaviour, to protect and conserve the environment and to promote peace.

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