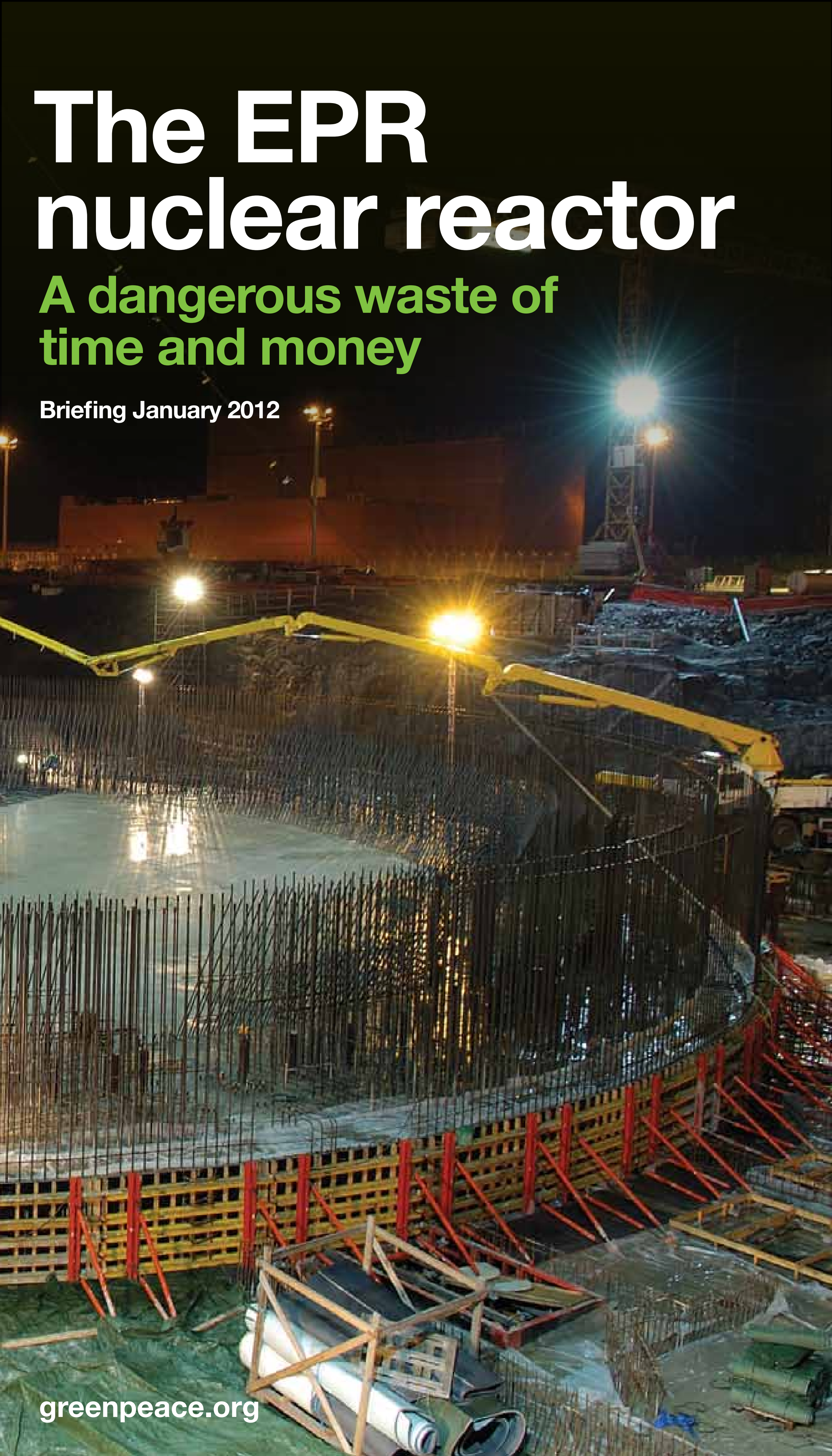
The EPR nuclear reactor

A dangerous waste of time and money

Briefing January 2012



greenpeace.org

GREENPEACE

Catalysing an energy revolution

The EPR nuclear reactor
A dangerous waste of time and money

The French EPR* is a nuclear reactor design that is aggressively marketed by the French companies Areva and EDF. Despite the companies' marketing spin, not only is the reactor hazardous, it is also more costly and takes longer to build than renewable-energy alternatives.

While no EPR is currently operating anywhere in the world, four reactors are under construction in Finland (Olkiluoto 3, construction started in 2005), France (Flamanville 3, 2007) and China (Taishan 1 and 2, 2009-10). The projects have failed to meet nuclear safety standards in design and construction, with recurring construction defects and subsequent cover-ups, as well as ballooning costs and timelines that have already slipped significantly.

* EPR: European Pressurised Reactor, sometimes marketed as an 'Evolutionary Power Reactor'

Countries where the EPR is under construction, where the reactor has been considered but rejected and where earlier plans are being reviewed or have been scaled back (as of January 2012)

Under construction: Finland | France | China

Rejected: United States | Canada | United Arab Emirates | South Africa | Italy | Lithuania

Plans reviewed/scaled back: India | China

The EPR nuclear reactor: A dangerous waste of time and money **is an update of the 2008 Greenpeace International briefing on this reactor. We have added some of the many new design and construction errors and the economic setbacks the EPR has run into. We also include more information on the tremendous gains in the cost performance of renewable energy and the increase level of investment.**

Hazards

Flawed and risky design

The EPR design, which was supposed to be completed and ready for construction in the early 2000s, remains unfinished. The design has numerous flaws:

- The EPR is the first reactor design proposed that is to be controlled by fully computerised systems both during normal operation and during accidents. Areva's original design for the computer systems has been found to violate just about every basic principle of nuclear safety, and many regulators are requiring an analogue back-up system. Using several complex software systems to control a nuclear power plant introduces an enormous amount of potential errors and unpredictable interactions. As of November 2011, no approved design of the control systems exists, even though Areva has been working on this system for years. In addition, in many of the EPR components Areva is proposing to use off-the-shelf computer systems that do not comply with nuclear safety standards.

- The EPR design is not equipped to deal with a sustained blackout of the power supply to the reactor's emergency systems, a crucial design defect that caused the Fukushima nuclear disasters in March 2011. The EPR reactor's emergency diesel generators are insufficient to power many crucial subsystems needed to cool down the reactor. If the diesel generators malfunction, the reactor is designed to prevent a meltdown of the reactor and the nuclear waste ponds for only 24 hours before risking meltdown. In Fukushima, the blackout lasted 11 days. Once cooling is lost, an accident can proceed fast: in the Fukushima reactors, fuel was completely molten 11 hours after the meltdown started.

Negligence in construction

The EPR design is the world's largest nuclear reactor, and one of the most complex. The complexity of the reactor and the constant pressure to reduce costs have led to systematic cutting of corners and to cover-ups of defects in Finland and France, including:

- substandard concrete quality and quality monitoring;

- hiring inexperienced and incompetent subcontractors;

- working without approved blueprints and guidelines;

- substandard quality of welding work, due to a lack of training and oversight, as well as a lack of mandatory specifications for welding procedures, skipping mandatory quality controls and tests; and

- deliberately covering up structural defects. In both Olkiluoto and Flamanville, Greenpeace has recorded testimony from workers from the French companies working on the project giving orders to cover up defective concrete structures or to accept quality-control reports that show non-conformance with quality standards.

According to Finnish and French nuclear regulators, many of these violations have continued through 2011. See page 6 for details.

Information on EPR construction in Taishan, China is almost non-existent. However, documents describing a set of inspections in 2009 and 2010 by Chinese officials identify a chillingly familiar set of problems, including insufficient supervision, insufficient testing of concrete composition, hiring of inexperienced subcontractors, as well as recurring problems with storage and labeling of components.

In virtually all cases of quality problems, Areva's own inspectors have failed to detect violations or have tried to cover them up. As far back as 2006, the Finnish nuclear regulator said that the number of problems was so high that it is possible that not all of them have been detected. Defects left in the final structures can either initiate a nuclear accident, or fail under accident conditions, making matters worse.

Areva is trying to write off these design flaws and construction failures as first-of-a-kind problems that the company has now learned from. This is no different from what the company promised before the current failed projects, in a 2005 brochure:

"The EPR is the direct descendant of the well proven N4 and KONVOI reactors, guaranteeing a fully mastered technology. As a result, risks linked to design, licensing, construction and operation of the EPR are minimised, providing a unique certainty to EPR customers."

Increased hazards from accidents and nuclear waste

An EPR reactor, once in operation, would contain more radioactive substances than any currently operating reactor, three times as much as the first unit in Fukushima Daiichi. This is due to two things: the EPR is the largest reactor in the world, and it is designed to burn uranium more intensely than existing reactors. This causes the amount of readily released radioactive substances in spent fuel to increase. EU-funded research shows that the health risk posed by high-level nuclear waste from the EPR is up to seven times greater than that caused by waste from existing reactors. This has the potential to expose the public to unforeseen short- and especially long-term health hazards, as well as to enormous uncovered liabilities, since current nuclear waste disposal plans are not adequate to accommodate the more dangerous nuclear waste from the EPR.

If there is an accident in an EPR reactor, or in transporting spent fuel from an EPR, the radioactive releases and health impacts would be much larger than typical releases from currently operating reactors.

Defects in the EPR reactor

Since construction started in Finland in 2005, new defects in design and construction of the EPR have emerged every year, drawing an alarming picture of willingness to cut corners under cost pressure and lack of quality control. Rather than learning from mistakes in the first project, the builders of the EPR have repeated them in France and China.

Reactor

The world's largest reactor, with the largest amount of radioactive materials inside. Potentially could be run on MOX fuel with increased content of plutonium. The reactor vessel has to withstand very high pressures for 60 years under both normal operation and accident situations.

Sustained loss of external power to the reactor could lead to nuclear accident, as happened in Fukushima.

Flamanville 3: A 'series of malfunctions' was detected in an inspection of a factory working on the lid of the reactor pressure vessel. Required quality control procedures were not being followed in manufacturing.

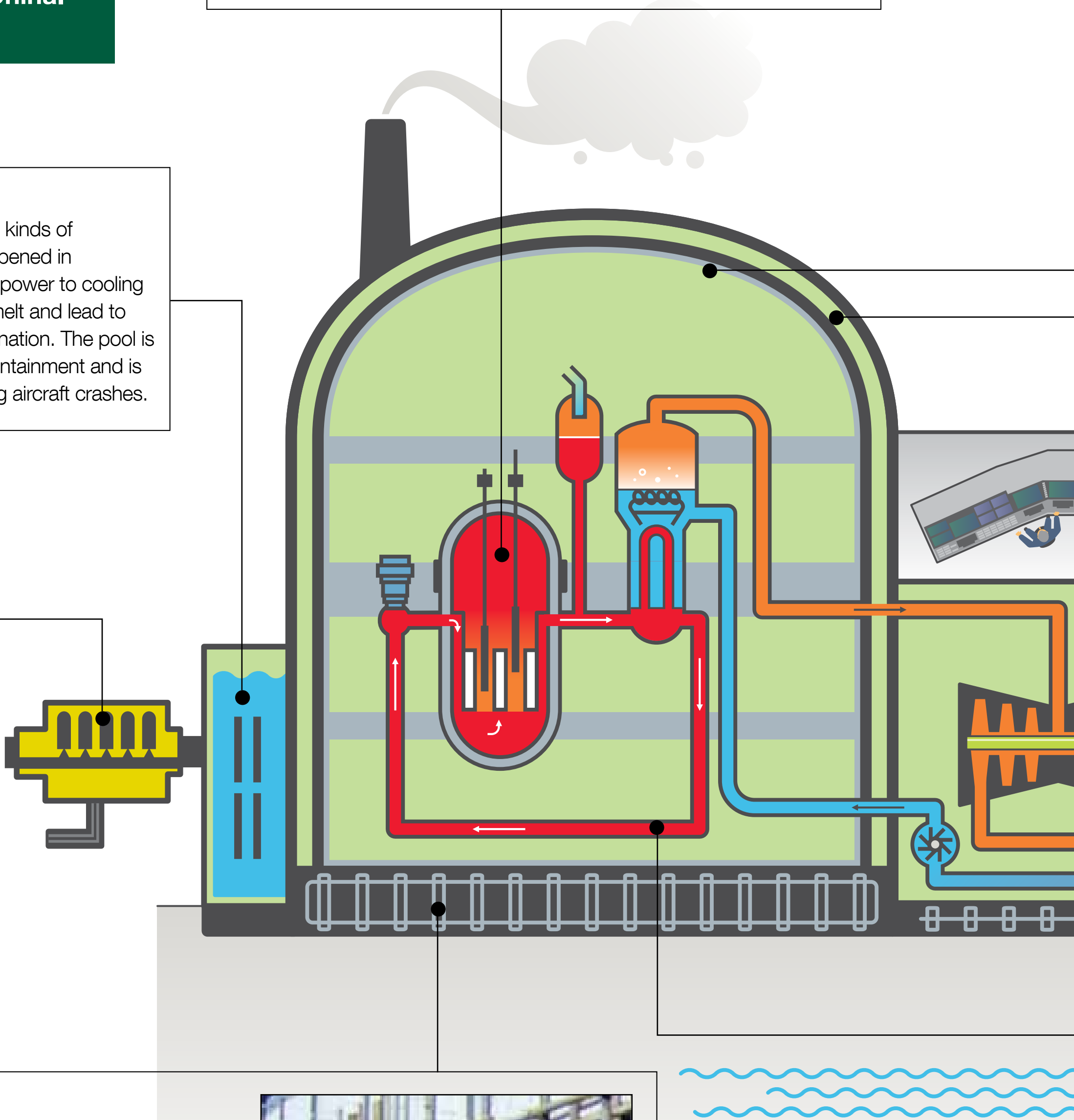
Spent fuel pool

Lacks precautions against the kinds of hydrogen explosions that happened in Fukushima. Sustained loss of power to cooling systems could cause fuel to melt and lead to massive leakage and contamination. The pool is located outside the reactor containment and is vulnerable to attacks, including aircraft crashes.

Back-up diesel generators

Needed to run emergency cooling systems in case electricity from the grid is lost.

The number and capacity of back-up generators was reduced from a predecessor of the EPR, the 30-year-old German Konvoi design. This makes the EPR vulnerable to the loss of power supply to provide cooling. The generator building is not protected against an aircraft crash.



Reactor base-slab

Failure can affect a power plant's stability and lead to release of radioactivity in an accident.

Olkiluoto 3: Concrete mixture was improper, with water content too high, leading to high chemical vulnerability and danger of cracking. Concrete samples 'disappeared' from the site.

Flamanville 3: Concrete mixture did not meet required standards, and base-slab has already developed cracks. Reinforcing steel bars were either arranged and welded improperly, or were completely missing. Repeated failure to improve quality forced state inspectors to order suspension of work for one month in May 2008. Later, several important measurement devices were found to have been dysfunctional for up to 15 days during pouring of concrete.

Taishan 1 and 2: Insufficient testing of concrete composition. Recurring problems with storage and labelling of reinforcing steel bars, as well as with construction records.

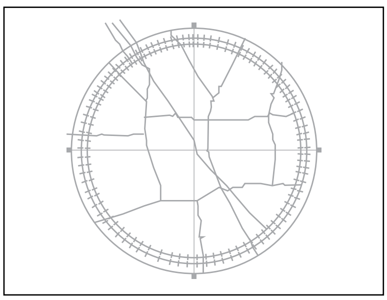


Image top Reinforcing steel bars in Olkiluoto
Image bottom Cracks in the Flamanville EPR basemat (ASN).

Containment steel liner

Failure leads to loss of air-tightness and possible release of radioactivity.

Olkiluoto 3: Welded with incorrect technique in a Polish machine yard that had no experience in nuclear construction. Welds were defective. Dozens of holes cut in wrong places. Liner badly stored and damaged in storm. Defects in welding continued during assembly of the liner in Olkiluoto.

Flamanville 3: Quarter of welds identified as deficient. Welding done by company without required qualifications.

Containment building

Failure leads to loss of air-tightness and possible release of radioactivity.

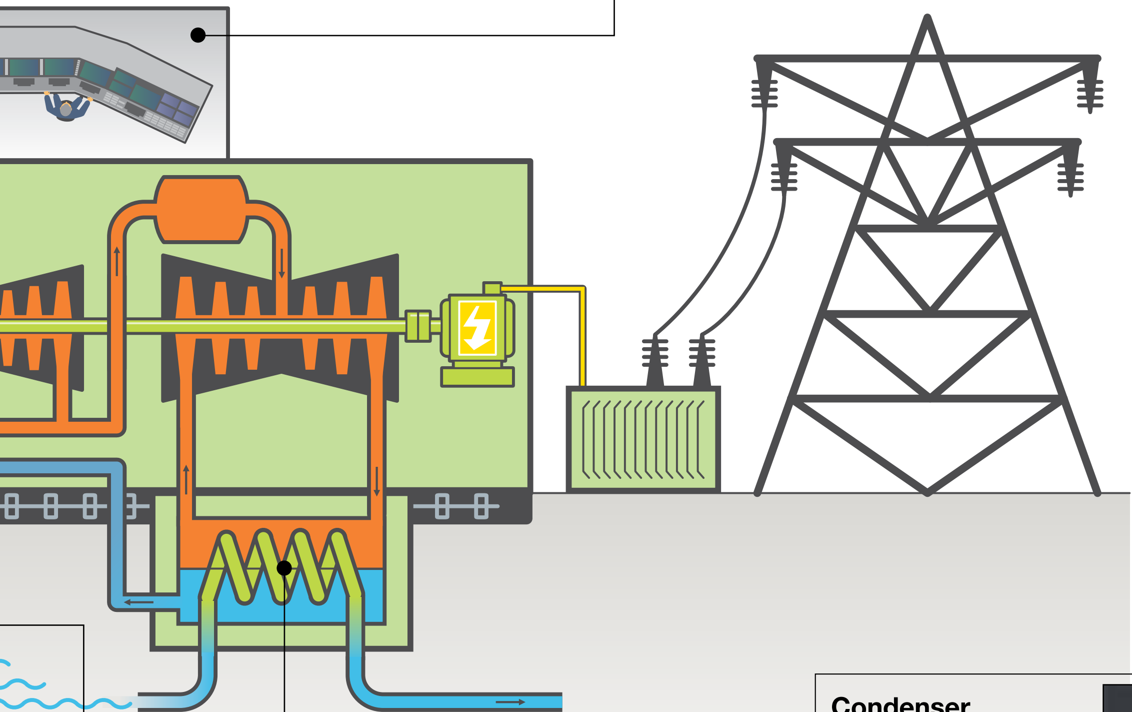
Olkiluoto 3: Evidence obtained by Greenpeace shows that the steel reinforcement of the reactor containment was welded for at least half a year without obligatory tests and paperwork. Tests to ensure the quality of welds were not carried out.

Flamanville 3: An onsite worker testified that widespread construction errors are being covered up. Structural defects have been hastily covered with concrete.

Image Olkiluoto EPR containment building

Computer systems

The 'nerve center' of a nuclear reactor, crucial for normal operation, as well as avoiding and mitigating accidents. The EPR is the first reactor design with fully computerised control systems, but Areva's original design is at odds with basic standards of nuclear safety (see page 3 for details).



Condenser

Olkiluoto 3: Anti-corrosion coating was damaged during work, leading to very visible corrosion. The damage was repaired by a non-authorised contractor.

Image Visible corrosion in Olkiluoto EPR condenser

Cooling system pipes and welds

Olkiluoto 3: Defective welds, unacceptable methods and lack of required tests and oversight were exposed in inspections in 2009, 2010 and 2011.

Huge primary pipes were found to have too large and irregular a grain size, and had to be recast. The problem was caused by the subcontractor attempting to save time and reduce costs. Subsequently, a subcontractor performed unauthorised, inadequately planned and supervised welds on the surface of the new pipes, potentially damaging them.

Flamanville 3: Large coolant pipes manufactured in 'total absence of identification and validation' of quality control actions.

EPR
Ballooning costs and construction times

The EPR projects in Finland and France have run into severe problems because of defects in the reactor design and the complete breakdown of quality control. This has led to the possibility of increased accident risk as well as skyrocketing construction costs and much longer completion times. While information from the third EPR project in Taishan, China, is almost non-existent, the first indications of similar problems emerged in September 2011.

The French Flamanville 3 EPR project was reported in July 2011 to have fallen two years behind schedule, after three and a half years of construction. In October 2011, after six years of construction, the owner of the Olkiluoto 3 in Finland announced that the project would be delayed by five years. An estimate commissioned by the French parliament put the current cost of Olkiluoto 3 at €6.6 m, €3.6 m more than originally estimated. The cost for the Flamanville EPR is already reported to have hit the €6 bn mark, up from the original estimate of €3.3 bn. These costs are at zero profit to Areva. To make a new project profitable, Areva will have to add a typical profit margin of 20-30%, bringing the price to between €7.5 and €8.5 bn. This is also in line with the prices bid by Areva in Canada, South Africa and the United Arab Emirates. Needless to say, none of those projects moved forward.

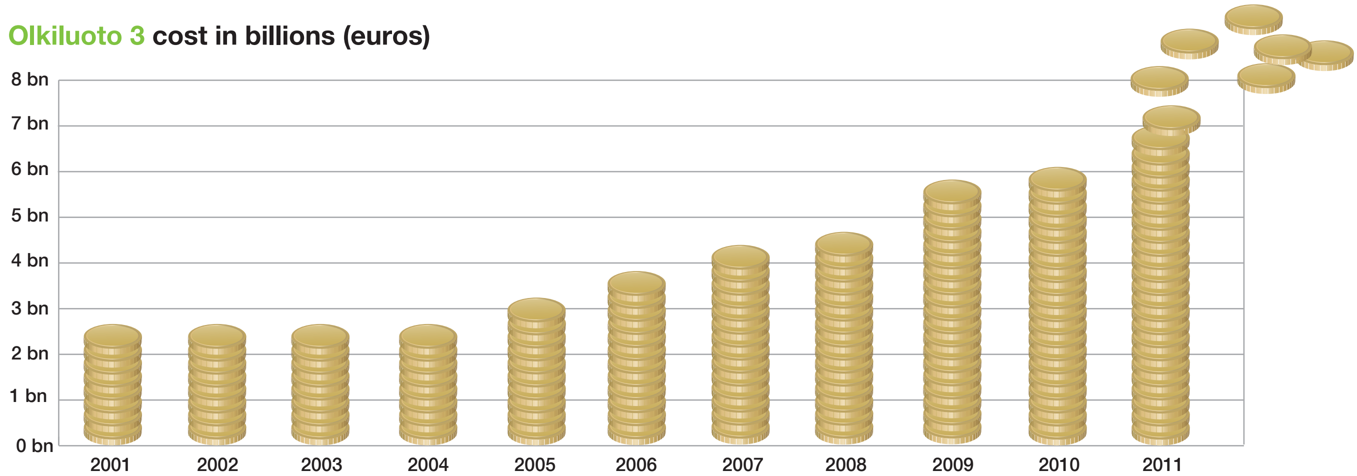
The investors of the first EPR project in Finland were supposed to be shielded from cost overruns. Regardless, Areva has taken the Finnish investors to court to get them to cover the ballooning costs. If the company wins the case, ratepayers will ultimately pay for the failure of the project. Areva recently doubled its claim against the investors from €1 bn to €1.9 bn, and Areva's total cost for the project is approaching double the contracted price of €3 bn.

© GREENPEACE / CHRISTIAN ASLUND

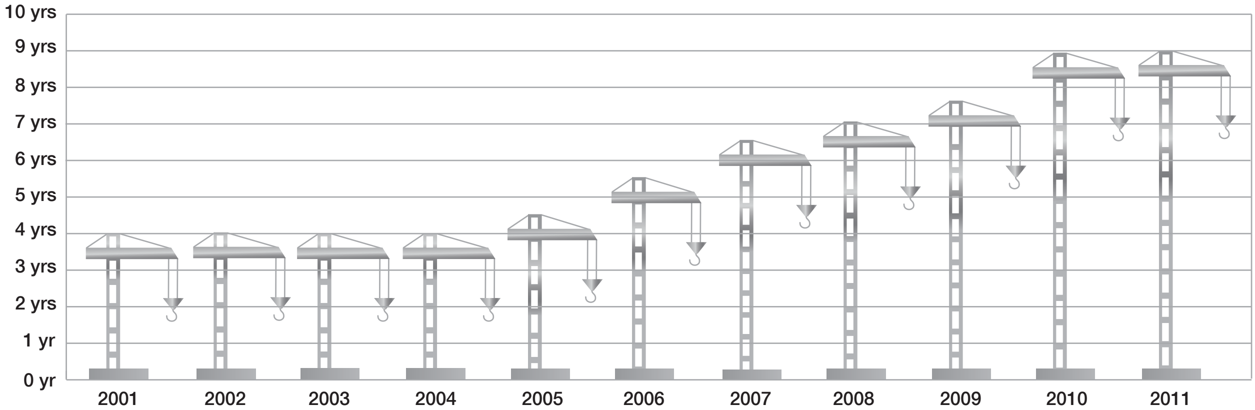
image Many of the design flaws that led to the Fukushima Daiichi nuclear disaster also exist in the EPR.

Fig 2. **The cost and construction time for the first EPR reactor in Finland have more than doubled from initial estimates and contract terms. The overruns are borne by taxpayers and electricity users.**

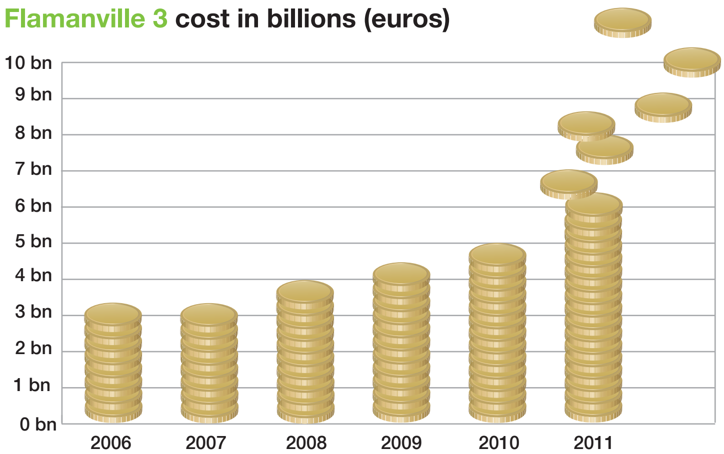
Olkiluoto 3 cost in billions (euros)



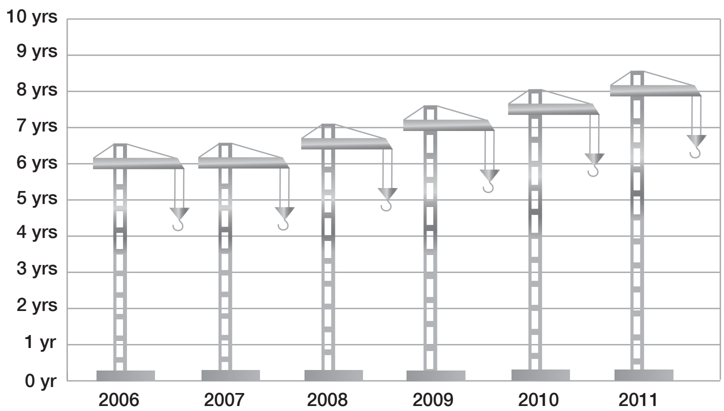
Olkiluoto 3 construction time (years)



Flamanville 3 cost in billions (euros)



Flamanville 3 construction time (years)

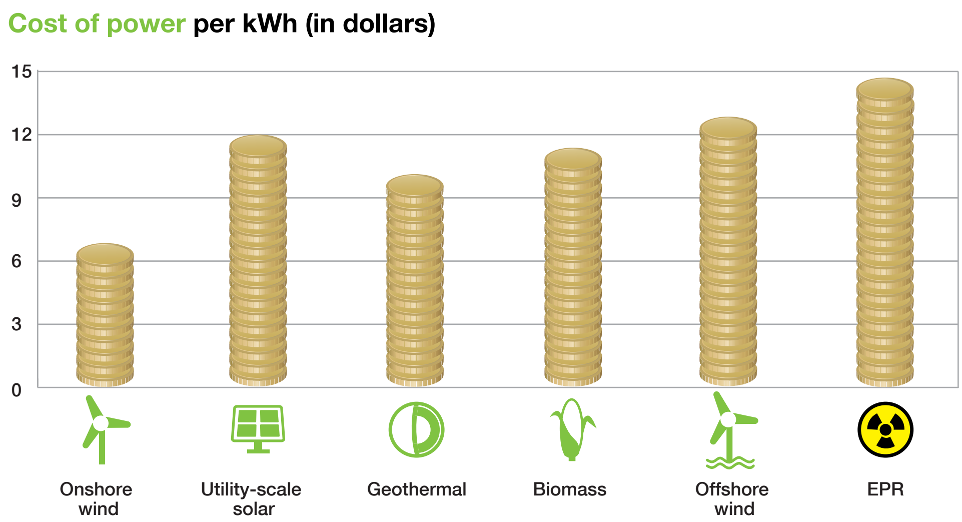


Nuclear power and climate change
Too little, too late

According to the International Energy Agency, to avert catastrophic climate change the world has only until 2017 to stop investments in fossil-fuelled power plants and start reducing global emissions of heat-trapping gases. A single new nuclear power plant takes more than a decade to go from inception to operation. Building a thousand large new reactors, as suggested by some scenarios put forward by the International Energy Agency, would take at least four decades and yet only cut global CO_2 emissions by a mere 4.5%.

This means new nuclear reactors will make zero contribution to meeting the climate change deadline, but nuclear investments would divert money and time from renewable energy and energy-saving technologies — the technologies that can deliver more solution per dollar, and do it much faster.

Fig 3. **Projected cost of electricity from different sources in 2015. An increasing range of modern renewable energy technologies can provide power at a cheaper cost per kilowatt-hour than the EPR. These technologies don't have risks related to large-scale disasters and toxic waste, and can be deployed much faster to provide the same amount of power as an EPR reactor.**



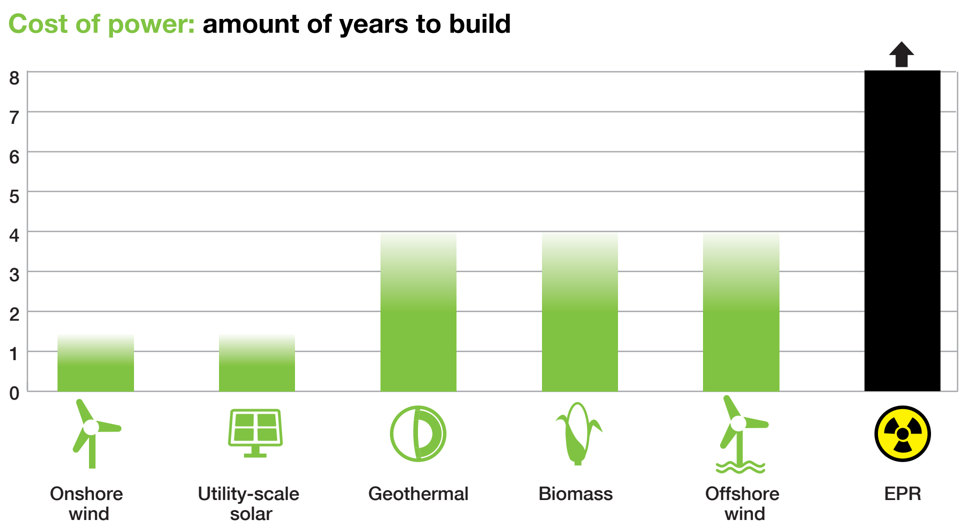
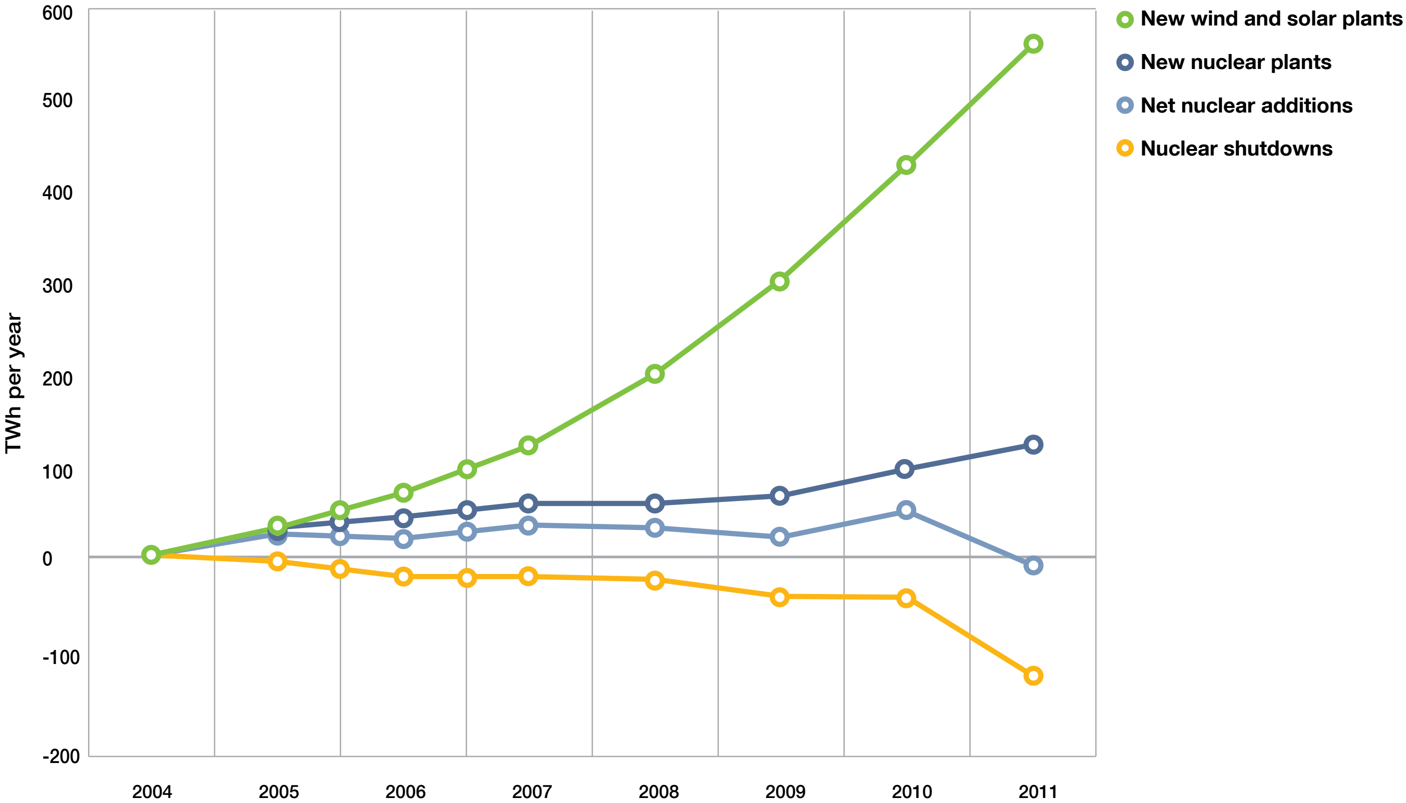


image Olkiluoto 3 EPR in Finland

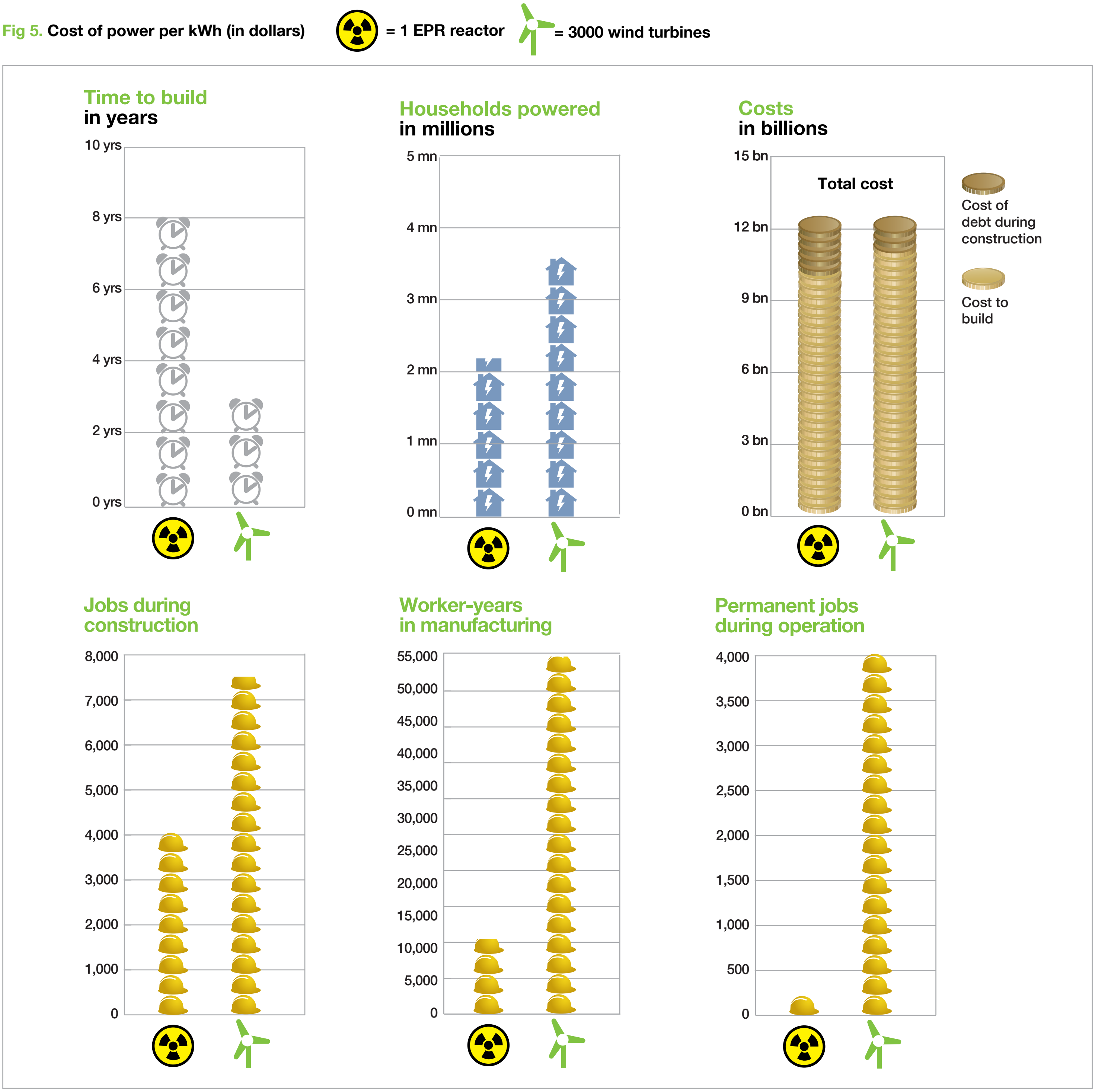
Fig 4. **Since 2004, wind and solar power have added over five times more electric output globally than nuclear power. When shutdowns of old plants are taken into account, nuclear generation has not increased at all over this period. *2011 figures are forecasts as of December 2011. 600 TWh a year is sufficient to power 100 million typical US households.**

Additions to global electric output since 2004



Which one would you invest in?
Costs and benefits of onshore wind versus the EPR

Fig 5. **Cost of power per kWh (in dollars)**



Contamination hazards from uranium mines to reactor accidents to nuclear waste production.

Clean, safe power without fuel and without worries.

Greenpeace Solutions

The EPR and the nuclear industry have failed to deliver on promises about affordable electricity and managing nuclear risks. Greenpeace has detailed the solutions for a prosperous, safe future based on 95% renewable energy by 2050 in the Energy [R]evolution energy scenario. We are calling on governments and companies to make this vision a reality by:

Ending the nuclear age

- **Phase out existing reactors.**
- **Stop construction on the unfinished EPRs and abandon plans for new construction of commercial nuclear reactors.**
- **Stop international trade in nuclear technologies and materials.**
- **Phase out all direct and indirect subsidies for nuclear energy.**

Creating a renewable energy future

- **Divert state funding for energy research from nuclear and fossil fuel energy technologies towards clean, renewable energy and energy efficiency.**
- **Set legally binding targets for renewable energy.**
- **Adopt legislation to provide investors in renewable energy with stable, predictable returns.**
- **Guarantee priority access to the grid for renewable generators.**
- **Adopt strict efficiency standards for all electricity-consuming appliances.**

The Energy [R]evolution website
www.energyblueprint.info

References

1 Joint statement by nuclear regulators of UK, France and Finland – HSE, STUK, ASN (2009). Joint Regulatory Position Statement on the EPR Pressurised Water Reactor. http://www.hse.gov.uk/newreactors/pressurised-water-reactor.htm

2 Dr. Colin Hirsch (2010). Assessment of I&C Problems of the EPR. Commissioned by Greenpeace Nordic.

3 STUK (2011). Annual report on regulatory oversight of nuclear safety. www.stuk.fi/ydinturvallisuus/ydinvoimalaitokset/raportointi/fi_FI/nvr1-2011/

4 Dr. Helmut Hirsch in collaboration with AY Indradiningrat and T Wenisch: Selected Aspects of the EPR Design in the Light of the Fukushima Accident. Report for Greenpeace International.

5 E.g. ASN inspection letter http://www.asn.fr/index.php/content/download/30447/195294/file/INSSN-DCN-2011-0649.pdf. STUK 2011: Annual report on regulatory oversight of nuclear safety. www.stuk.fi/ydinturvallisuus/ydinvoimalaitokset/raportointi/fi_FI/nvr1-2011/, and STUK report on first quarter of 2011, www.stuk.fi/ydinturvallisuus/ydinvoimalaitokset/raportointi/fi_FI/nvr1-2011/.

6 The Independent (2011). Report raises concerns over safety of nuclear plants. 10 September 2011. http://www.independent.co.uk/news/uk/home-news/report-raises-concerns-over-safety-of-nuclear-plants-2352222.html

7 Finnish Radiation and Nuclear Safety Authority STUK (2006). Management of safety requirements in subcontracting during the Olkiluoto 3 nuclear power plant construction phase. Investigation report January 2006.

8 Framatome ANP: EPR; brochure, March 2005

9 Posiva (2008). Expansion of the Repository for Spent Nuclear Fuel. Environmental Impact Assessment Report. http://www.posiva.fi/publications/Posiva_YVA_selostusraportti_en_lukittu.pdf.

10 Nagra (2004). Estimates of the Instant Release Fraction for UO2 and MOX Fuel at t=0. http://www.nagra.ch/documents/database/dokumente/%24default/Default%20Folder/Publikationen/e_ntb04-08.pdf.

11TVO (2011a). Regular operation of Olkiluoto 3 nuclear power plant unit may be postponed further. 12 October 2011. http://www.tvo.fi/www/page/3697/

12 Reuters (2011). Areva EPR bill seen at 6.6 bln eur. 12 October 2011. http://af.reuters.com/article/commoditiesNews/idAFL5E7LC4J420111012

13 Nuclear Engineering International (2011). EDF delays Flamanville 3 EPR project. 20 July 2011. http://www.neimagazine.com/story.asp?sectioncode=132&storyCode=2060192

14 TVO (2011b). OL3 - Pending Court Cases and Disputes, Supplier Updated Its Monetary Claim. 27 June 2011. http://www.tvo.fi/www/page/3627/

15 The companies have at last acknowledged a new construction delay to the project in June 2010, when the Finnish investor TVO said construction would not be completed before the end of 2012, delaying electricity production until the second half of 2013 (http://www.tvo.fi/www/page/3447/). The plant was originally meant to go online during the first half of 2009. At the same time, Areva announced a writedown of €367m, bringing the total cost overrun to €2.6 bn (http://www.areva.com/mediatheque/liblocal/docs/pdf/finances/hors-mediacenter/rapports-annuels/H1_2010_Financial_Report_AREVA.pdf), on top of a contracted price of €3 bn.

16 IEA (2010). Energy Technology Perspectives. Paris, France.

17 The capital cost of the EPR is assumed to be €8 bn, construction time 8 years and capacity factor 90%. Renewable energy capital cost projections and capacity factors based on Greenpeace's [E]nergy Revolution scenario, methodology and other assumptions as in US Energy Information Agency Annual Energy Outlook 2011. EIA methodology does not account for nuclear power's higher risk and resulting higher cost of capital, underestimating real cost. Prices in 2009 dollars.

18 BP Statistical Review of World Energy (2011). IAEA PRIS. Assumed average capacity factors: nuclear 90%, wind 27%, solar PV 22%.

19 Assuming 70:30 debt-to-equity ratio and 7% interest rate for both projects. Cost of equity not included. Wind turbines have 3 MW capacity, assumed 27% capacity factor and overnight cost of $3.8 m per turbine installed. Electricity consumption 6 MWh per household per annum.

GREENPEACE

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

Published in January 2012 by

Greenpeace International
Ottho Heldringstraat 5
1066 AZ Amsterdam
The Netherlands

greenpeace.org

For more information contact:
enquiries@greenpeace.org

Written by:
Lauri Myllyvirta

Edited by:
Brian Blomme

Designed by:
Atomo Design

Cover photograph:
© TVO / Hannu Huovila

JN 399