Fukushima Fallout

Nuclear business makes people pay and suffer

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Contents

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Cover image: Empty roads run through the southeastern part of Kawamata, as most residents were evacuated due to radioactive contamination.© Robert Knoth / Greenpeace

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Image: Kindergarten toys, waiting for Greenpeace to carry out radiation level testing.

Governments have created a system that protects the benefits of companies while those who suffer from nuclear disasters end up paying the costs.

The nuclear industry evades responsibility for its failures.

Image: Aerial view of the Fukushima Daiichi nuclear plant following the 2011 disaster.

Executive summary

From the beginning of the use of nuclear power to produce electricity 60 years ago, the nuclear industry has been protected from paying the full costs of its failures. Governments have created a system that protects the profits of companies while those who suffer from nuclear disasters end up paying the costs.

The disaster at the Fukushima Daiichi nuclear power plant in March 2011 proves again that industry profits and people pay. Almost two years after the release of massive amounts of radiation from the Fukushima nuclear disaster, hundreds of thousands of people are still exposed to the long-term radioactive contamination caused by the accident. The daily lives of victims are disrupted. They have lost their homes, their jobs, their businesses, their farms, their communities, and a way of life they enjoyed.

They are still unable to get fair and timely compensation. Yet at the same time, the nuclear industry continues to evade its responsibilities for the disaster. It is business as usual: nuclear companies are still operating as always by creating nuclear risks.

How is it possible that, apart from the now nationalised Fukushima operator TEPCO, the nuclear industry is not paying for the multibillions in damages of Fukushima? How is it possible that companies, such as GE and Hitachi, that got large contracts by building, supplying and servicing the Fukushima nuclear power plant, can simply continue their business as if nothing happened?

It has become painfully clear that systemic flaws in the nuclear sector make the suffering of victims worse. Many of them survive in improvised conditions, unable to return home or to rebuild their lives elsewhere.

Why does this happen? The nuclear industry and governments have designed a nuclear liability system that protects the industry, and forces people to pick up the bill for its mistakes and disasters. To safeguard the public from nuclear risks, the system needs to be fundamentally reformed to hold the entire nuclear industry fully accountable for its actions and failures.

In February 2012, Greenpeace released *Lessons from Fukushima*, a report that uncovered the key causes of the Fukushima accident, which lie in institutional failures of governments, regulators, and the nuclear industry. These included: failure to acknowledge nuclear risks, failure to enforce appropriate nuclear safety standards, failure to protect the public in an emergency situation, and failure to ensure appropriate compensation for the victims.

This new Greenpeace report demonstrates how **the nuclear sector evades responsibility for its failures**. The nuclear industry is unlike any other industry: it is not required to fully compensate its victims for the effects of its large, long-lasting, and trans-boundary disasters.

In this report, the current status of compensation for victims of the Fukushima disaster is analysed as an example of the serious problems due to lack of accountability for nuclear accidents. The report also looks into the role of nuclear suppliers in the failure of the Fukushima reactors.

In addition, this report addresses two main protections for the industry:

- Liability conventions and national laws limit the total amount of compensation available and protect nuclear suppliers, the companies that profit from the construction and operation of reactors, from any liability. This caps the funds available for victims at a fraction of real costs and removes incentives for supplier companies to take measures to reduce nuclear risks.
- The complexity of and multiple layers in the nuclear supply chain exacerbate the lack of accountability for nuclear suppliers. Even though hundreds of different suppliers are providing components and services that are critical for reactor safety, these companies cannot be held accountable in case of problems.

Fukushima two years later – people left in limbo

Chapter 1 of this report details the **struggle of nuclear victims for fair compensation**. Author Dr David McNeil, (Japan correspondent and co-author of *Strong in the Rain: Surviving Japan's Earthquake, Tsunami and Fukushima Nuclear Disaster*) evaluates the ongoing human consequences of the Fukushima accident. Victims and witnesses tell stories about the multiple problems with the compensation process. As Mrs Kameya (68) states: "People think we will get a lot of money when something like this happens but they're wrong."

In the wake of the disaster, the 160,000 involuntary and tens of thousands of voluntary evacuees fled from the radioactively contaminated zone. For them, starting a new life seems almost impossible and the compensation process is complicating, not easing people's lives.

People are left in limbo, stuck between past and future. The problems with the compensation process are manifold: the processing of claims is delayed, and the monthly payments are not enough to ensure people a living, let alone enough to set up a new life. Not everyone is eligible for compensation, and the lucky ones only get a fraction of the value of their lost homes. There has not yet been a single payment that fully compensates anyone for the loss of a house and property.

The compensation scheme is set up in a way that compensation is first paid with government-backed financing. But TEPCO's nationalisation in June 2012 makes it clear that eventually ordinary Japanese people will pay the bill for Fukushima. The utility's demand on the state-backed Nuclear Damage Liability Facilitation Fund for compensation payments mounted to ¥3.24 trillion ($36.5bn US dollars) by December 2012. At the same time, the Japanese government injected ¥1tn (about $12.5bn at 2012 exchange rates) into the utility in May 2012 to save it from bankruptcy, which totalled an estimated ¥3.5tn in public money to the utility since the Fukushima disaster began.

Nuclear suppliers escape responsibility

Chapter 1 also investigates the **role of the nuclear supplier companies** in the Fukushima reactors. The Fukushima Daiichi nuclear power plant consisted of six reactors, with units 1 to 5 based on the flawed Mark I design by the US company General Electric (GE). GE supplied the reactors for units 1, 2, and 6, and two Japanese companies supplied the others — Toshiba provided units 3 and 5, and Hitachi unit 4.

All suppliers that were involved in the Fukushima nuclear power plants, including GE, Hitachi and Toshiba, are currently exempted from responsibility for the March 11 disaster. In contrast, many are even **profiting from the disaster**. GE, Hitachi and Toshiba, along with many other suppliers, are currently involved in the clean up, which includes decommissioning the Fukushima reactors and decontamination of radioactively contaminated areas.

A report by the independent investigation commission of the National Diet of Japan says that reactor Unit 1 of the Fukushima power plant was purchased by TEPCO under a "turnkey" contract for construction "that placed all responsibility" on GE. Fukushima Unit 1 was the first Mark I reactor ever built, and experienced numerous difficulties. The seismic design criteria in Japan were stricter than for the original design, but incorporation of the Japanese specifications was problematic and ad hoc reinforcements were made during construction.

In the 1970s, GE engineer Dale G Bridenbaugh publicly questioned whether GE's Mark I reactor would stand up to a loss-of-coolant accident. The Diet report adds that the Mark I containment vessels at Fukushima were reinforced in the 1980s, "but the reinforcement did not cover severe accidents of this scale." The report concludes that during the Fukushima accident, the pressure inside the containment vessels substantially exceeded their designed capacity, up to almost twice the capacity in the case of Unit 1.

Former GE employees recall how TEPCO elected to overrule its own engineers and follow GE's original construction design and put the plant's emergency diesel generators and batteries in the basement of the turbine buildings, with devastating consequences during the accident. Former Hitachi engineer turned whistleblower Mitsuhiko Tanaka helped build the reactor pressure vessel for Fukushima reactor Unit 4. In the final stages of construction, the vessel's integrity was dangerously compromised, legally obliging Hitachi to scrap it. Facing bankruptcy, the company covered up the defect and the vessel was installed at Fukushima.

In September 1989, the US Nuclear Regulatory Commission (NRC) encouraged owners of Mark I reactors to install hardened vents to prevent catastrophic failure of the containment in case of an accident. These vents would enable controlled reduction of pressure. During the Fukushima accident, the hardened vents proved ineffective, and the absence of filters exacerbated the radioactive releases.

Nuclear liability conventions protect the industry, not the people

The nuclear industry is granted **unparalleled and unfair privileges**. In contrast to many other risk-involving industries, nuclear liability conventions have been established with the intent to protect the nuclear industry – this includes operators, suppliers as well as investors. The current agreements do not ensure that victims receive full and timely compensation in the event of a major accident.

In Chapter 2, Antony Froggatt (independent consultant, Senior Research Fellow at Chatham House, UK) gives an overview of the existing international nuclear liability conventions, and maps the impact of these problematic rules, such as capping total compensation, excluding suppliers from accountability, and allowing operators not to have sufficient financial security to cover the damages.

The core problems of nuclear liability are:

- The objectives of international liability conventions are competing, if not mutually exclusive. First, they limit the extent of possible compensation claims, creating an economic environment that allowed the nascent nuclear industry to flourish. Secondly, they are supposed to grant victims access to full and timely compensation in the event of an accident.
- Only the operator of a nuclear power plant can be held responsible for paying for damages. Nuclear suppliers, who build and service plants, do not have to pay anything.
- The total amount of compensation available is limited, but these limits are well below the true cost of a nuclear accident.
- Definitions of nuclear damage do not cover all damages caused by a nuclear disaster.
- Potential victims in other countries can only sue for compensation in the country where the nuclear accident happened, **not** in their own courts.

The experiences of the Fukushima disaster show that even the Japanese liability regime is highly inadequate and unjust, despite the legal requirement of unlimited liability for an operator. The financial extent of the damage is generally far beyond what an operator can pay. Since the Japanese law excludes supplier accountability, the magnitude of funds provided by the nuclear industry is restricted to a very small fraction of the costs of Fukushima.

It is clear that holding only the operator responsible for a nuclear accident: "minimises the burden upon the nuclear industry as a whole, as the various persons who contribute to the operation of a nuclear installation, such as suppliers and carriers, do not require insurance coverage additional to that held by the operator"[1], as was pointed out by OECD's Nuclear Energy Agency in 1993. This needs to be changed; **people must be the first priority**, not the benefits of the nuclear industry.

Making nuclear suppliers pay for their mistakes would not only benefit the potential victims by making more funds available, but would also increase accountability and transparency and create incentives for the companies across the nuclear supply chain to prevent failures.

There are only a few exceptions to the protection of the nuclear supplier industry. Recognising the fundamental unfairness, India adopted a nuclear law that allows nuclear operators to seek recourse in the event of "wilful act or gross negligence on the part of the supplier". Also the existing laws in both Russia and South Korea allow operators to recover damages from suppliers in the event of negligence.

Chernobyl and Fukushima are examples of how costly nuclear accidents can be, with estimated damages in the order of several hundreds of billions of euros. These figures deeply contrast with what the industry is currently required to pay (between €0.3-1.5bn).

To create a system that is fairer and puts people ahead of business, the following must happen:

- No limits to the total amount of compensation.
- Hold the whole nuclear industry, including suppliers, accountable.
- Ensure adequate financial coverage by companies. A major nuclear accident would almost certainly bankrupt any private utility.
- Allow people to recover all damages caused by a nuclear disaster.
- Increase transparency into costs and liability insurances.

Nuclear supply chain lacks accountability and transparency

In Chapter 3, Professor Stephen Thomas (professor at the University of Greenwich Business School, UK, working in the area of energy policy) explores the involvement of suppliers throughout the lifetime of a nuclear reactor, and their responsibilities in terms of nuclear risks. Risks of nuclear accidents are not only caused by the reactor operation, but also by design choices, construction quality, and maintenance, which are of critical importance.

The cause of a significant accident at a nuclear power plant is seldom clear cut, and may involve a combination of design, construction, operation, and maintenance errors. By comparison, it is usually relatively easy to apportion primary responsibility for, say a car or airplane accident, to design construction, operator or maintenance error.

A nuclear power plant is unique in terms of complexity, safety requirements, plant lifetime, costs and on-site construction work.

The supply chain for a nuclear power plant is very complex and in many cases non-transparent. The owner/operator of a plant carries final responsibility, but design, construction and maintenance include many different parties through many layers of contracting and subcontracting. Different suppliers are responsible for implementing elements critical for a plant's safety, but currently these suppliers ultimately cannot be held accountable in case of an accident.

This lack of accountability is further enabled by a lack of transparency regarding contracts and company relationships. This situation creates major challenges in ensuring sufficient quality control on critical safety features. It is often unclear (at least to the outside world) who carries the final responsibility in case problems were to occur with certain equipment or designs.

Many of those further down the supply chain will exit the business long before the end of the life of the plant, as was the case with the Dutch supplier of the flawed pressure vessels for the Belgian Tihange 2 and Doel 3 plants. In the case of the Fukushima disaster, even though it is known that certain design features caused serious problems during the course of the accident, those responsible for the design and engineering are not being held accountable.

Lessons to be learned

We learned from Fukushima that nuclear power can never be safe. The nuclear industry, largely protected from the financial liability for the Fukushima accident, continues to do business, while the Fukushima victims still lack proper compensation and support. Would things be different if the next big nuclear disaster happened in your country? You would likely be facing the very same problems.

We have to phase out dangerous nuclear power entirely, and do so as soon as possible. Yet, if there is another major nuclear accident, people could be given better protection if we hold the nuclear industry fully accountable and liable. We need to learn the lessons from Fukushima, and change the system in order to **make all companies in the nuclear industry responsible for the risks they create**.

More importantly, we have to use this critical moment to finally switch to a safe and affordable supply of electricity — renewable energy. Mature, robust and affordable renewable energy technologies are available and up to the task of replacing hazardous nuclear reactors. Over the last five years, 22 times more new power generating capacity based on wind and solar was built (281,000MW) compared to nuclear (11,750 MW).[2] Wind and solar plants alone, built in just one single year of 2012, are capable of generating as much electricity as 20 large nuclear reactors. This is where the opportunity stands for a future free of nuclear hazards.

1 NEA (1993), "NEA Issue Brief: An analysis of principal ipal nuclear issues International nuclear third party liability, No. 4 - 1st revision", Nuclear Energy Agency November 1993, accessed November 2012 http://www.oecd-nea.org/brief/brief-04-1.html

2 IAEA/PRIS (http://pris.iaea.org/public); Global Wind Energy Outlook 2012, GWEA (http://www.gwec.net/wp-content/uploads/2012/11/GWEO_2012_lowRes.pdf); Global Market Outlook for Photovoltaics until 2016, EPIA (http://www.epia.org/index.php?eID=tx_nawsecuredl&u=0&file=/uploads/tx_epiapublications/Global-Market-Outlook-2016.pdf&t=1359035167&hash=390c31d6e803e7c10b066e9ef72271831cf54c0d)

Image: Ms Satsuki Ikeda and her sons were evacuated from their farm in Iitate, 40km northwest of the Fukushima nuclear plant. The farm had been run by the family for nine generations.

The Fukushima nuclear disaster is a story about how the system fails to support people.

#1

Fukushima two years later: Lives still in limbo

by Dr David McNeill

Dr David McNeill is the Japan correspondent for *The Chronicle of Higher Education* and writes for *The Independent* and *Irish Times* newspapers. He is the co-author of *Strong in the Rain: Surviving Japan's Earthquake, Tsunami and Fukushima Nuclear Disaster*.

1.1 Introduction

The story about liability following the Fukushima nuclear disaster is really a story about people. It's a story about how the system, that is supposed to help people after such a disaster, fails to support them. It's a story about how bureaucracies — government and company — play by rules that at minimum are terribly frustrating for people, and at their worst are an impediment to getting help.

Nearly two years after the disaster, people are still desperate for the help they deserve. The victims are ignored, left to fend for themselves, and waiting and waiting for compensation and fair treatment. Some have resigned to getting little. Others are fighting the system. This story of the flaws in the system that is supposed to help people is likely to be repeated with any nuclear disaster anywhere in the world.

1.2 Stuck between past and future

Yukiko Kameya (68) was one of the 7,400 people living in Futaba town, Fukushima Prefecture, when the 11 March 2011 earthquake and tsunami struck, crippling the nearby Fukushima Daiichi nuclear plant.

"There was no information afterwards at all," she says, recalling how public safety officials told her the following freezing cold morning that "it was possible" that some radiation has escaped.

She fled with her husband, first to Namie, about seven kilometres away, then to the Tokyo suburbs. Almost two years later, she is still there. Like 160,000 nuclear refugees ordered to evacuate and tens of thousands of people who voluntarily left Fukushima Prefecture, she lives in temporary housing and has yet to be fully compensated for the loss of her old life.[1]

Four months after being forced to abandon her home and all she owned, in July 2011, the owner and operator of the Fukushima reactors, Tokyo Electric Power (TEPCO), sent the first of its payments. A total of ¥1.6m (about $18,000 US dollars) was deposited in Kameya's account[2], including ¥1m in "temporary" compensation. When she called TEPCO, she was told that that money was an "advance" and would have to be reimbursed from future payments. "It wasn't compensation," she says. "That's when I started to fight them." While those advance payments are common practice as the total damage is being determined, this terminology continues to confuse victims of the catastrophe.

Mrs. Kameya and her husband subsequently received ¥100,000 a month ($ 1,130) for "mental distress" for the first nine months (March – November 2011), plus living expenses, after submitting a complex application form. The original "advance" was subtracted from that payment. Late in 2011, she made another claim, patiently filing hundreds of receipts for petrol, taxi fares, clothes and even household utensils.

Last February, fed up with the compensation process, she hired a lawyer and demanded compensation of ¥350,000 a month ($4,000) for daily expenses. She says many of her Futaba neighbours are doing the same. "I accepted their way twice but I can't do that anymore." TEPCO has told her that they "cannot" pay ¥350,000.[3]

Like most of the refugees, she has calculated her own one-off round figure to reboot her life and cut all ties to TEPCO, the government and the endless paperwork: ¥20m (about $225,000). "It doesn't matter what the government says, we'll never go home. Most of us accept that." If awarded the money, Mrs. Kameya says she would move to Saitama (in Tokyo's northern suburbs), buy a small house and live out the rest of her life. But like many other victims, she is doubtful that the current compensation scheme will help her to set up a new life.

Other nuclear refugees are also losing hope. Hitoshi Sega ran a small restaurant near the power plant and now works as a public school cook in Iwaki city, about 40km south of the stricken plant. He has yet to be compensated for his lost business, since compensation for substantial assets is still in the assessment stage. Others have stopped claiming expenses, like Fumitaka Naito, who bought a farm in Iitate village in 2009. Iitate village, 40km northwest of the Fukushima nuclear plant, was initially designated outside the 20km compulsory evacuation zone, but later ordered to evacuate because of high levels of radioactive contamination.[4] He says TEPCO will only pay him an average of ¥14,000 to take a monthly trip home. "The money does not even pay for my gas."

And some do not know if they will ever get any compensation for their lost livelihoods, like Farmer Katsuzo Shoji. He was told to leave Iitate Village in April 2011 and still lives with his wife in temporary housing in Date, 40km from his contaminated home. Both have given up any thought of returning home. Shoji and his wife live on ¥100,000 a month from TEPCO, and have begun selling vegetables from a rented allotment. He has no idea when, how and how much he will get compensated for his house, farm, crops, and slaughtered animals. "What could it be worth now?" he asks – even though the basis for compensation will be what everything was worth before the accident occurred. "Even if we were allowed to return, nobody would buy my food."[5] And so on.

The questions of victims illustrate how TEPCO's complicated compensation process is making life more difficult for those affected by the accident. Many of the tens of thousands who were either ordered to flee or who fled voluntarily from the contaminated zone around the Daiichi plant in March and April 2011 tell similar stories. They note multiple problems with the compensation process: delayed processing of claims; monthly payments too small to ensure a living, let alone start new lives; application forms too difficult to complete. Refugees in the appeal process have started to demand multiple times the amount TEPCO allocated to them. There has not yet been a single payment for assets and the housing evaluations are regarded as too low. The amount of potential demands for compensation has forced TEPCO to lengthen Japan's standard three-year legal time limit for claims.[6] The initial criticism focused on TEPCO's complicated application forms. In order to file claims for damages, victims needed to read through a 156-page instruction manual and fill out an application form extending to 60 pages. Now the forms have been simplified.[7] TEPCO's constant response to ongoing criticism of the process is "We are doing our best."[8]

The compensation scheme has been set up in such a way that compensation is first paid with government-backed financing.[9] This "Governmental Supporting Scheme for the Damages Caused by Nuclear Accident" was created in May 2011, and aims "to enhance governmental support for TEPCO to realise smooth compensation procedures for nuclear accident victims."[10]

In September 2011, Japan's government set up a new public-private agency, the Nuclear Damage Liability Facilitation Fund, to keep TEPCO on life support and oversee compensation, from a mix of public cash, bank loans (underwritten by the government), government-backed bonds and money from Japan's 10 electric power companies.[11] TEPCO has steadily increased its demands on the Fund to over ¥3tn (roughly $34bn), and more is expected. The cost of dealing with the accident forced the government to nationalise TEPCO in June 2012, "the biggest state intervention into a private, non-bank asset since America's 2009 bail-out of General Motors," said *The Economist*.[12] The utility's nationalisation makes it clear: ordinary Japanese people will pay the final bill for the Fukushima disaster.

1.3 "Permanent" compensation plan

In July 2012, a year and a half after the triple meltdown at Fukushima, TEPCO drew up its long-awaited plan on "permanent compensation", mainly for the assets of approximately 160,000 people ordered to evacuate.[13] The utility would pay fixed-asset prices for property but in most cases only "for the period during which the property is unusable."[14] The compensation scheme is based on a complex and disputed government system that divides the contaminated evacuated areas into three zones based on annual radiation levels of more than 50, 20-50mSv or less than 20mSv.

The government says that areas showing annual readings of less than 20mSv of radiation are "being prepared" for the evacuees' return.[15] What this means is that decontamination of these areas, designated *Hinan shiji kaijo kuiki* ("areas that will have the ban lifted") is "progressing", and is expected to finish in years or in some cases even months. In the meantime, evacuees can request two years' worth of compensation (a total of ¥2.4m) in advance. The government assumption that lies at the heart of this policy – that decontaminated areas can become habitable again – could keep many refugees' lives in a state of limbo for a long time. There are serious concerns about the efficiency of the decontamination efforts and the ability to make the areas safe to live in.[16,17] Former residents from these "less contaminated" areas can claim only for the use of their land, houses or businesses, not for the market value of their property. Many have protested this designation.[18]

For areas deemed "uninhabitable for at least five years" (over 50mSv), TEPCO announced that it would pay mandatory evacuees for the full cost of relocating and for fixed assets, but here again the calculation formula is mired in controversy. TEPCO uses local government taxation records to determine fixed-asset base prices, resulting in evaluations that are much too low, say many refugees. For example, Masumi Kowata (57), from Okuma, a town in Fukushima Prefecture, just 5km from the crippled plant, has been offered only ¥700,000 ($8,000) for her 180-year-old, 300m^2 house. She wants a real estate agent to assess the property, which she believes was worth at least eight times that amount before the accident, but she cannot persuade anyone to visit the contaminated zone.[19] Such stories are rife. Many thousands of evacuees have outstanding loans on land that was valued much higher than the property is worth today.[20] If the current value is used to determine the maximum compensation, these people will not be able to pay for the outstanding property loan, let alone pay for rebuilding their lives elsewhere.

The stage is set for multiple lawsuits that will drag on for years, says Yasushi Tadano, a Tokyo-based lawyer who launched a class-action compensation lawsuit against TEPCO in December 2012.[21] "The victims of this disaster often had large houses, rice fields, livestock and land and most had to move from that into small urban apartments or temporary housing," he points out. "The amount of compensation being offered is totally insufficient." He says lawyers will be asking for the difference between the government-assessed property values and the amount of money needed to build the same houses elsewhere.

Like many elderly refugees, Kowata says her health has been worsened by the stress of evacuation. Her husband has suffered kidney failure since the disaster. To pay for the costs of treatment, they have filed a compensation claim with TEPCO of ¥370,000 a month for the period between 11 March 2011 and November 2012, insisting that his condition is related to the enormous stress of the last two years. She has not received a penny from the company. But Kowata says she is lucky, since she is one of the small percentage of victims who were insured for the earthquake. So, she is receiving money from her private insurance company for the damage caused by the earthquake. While this covers her daily living expenses, it does not include the health treatment. "Many of the old people around here cannot even fill out the compensation form," she says.

TEPCO says it employs 12,200 people to directly process such compensation claims, including 3,500 of its own staff. But it cannot or will not answer the most crucial questions: Exactly how many people have applied for permanent compensation? What are the likely grounds for refusal or approval? How many refugees from the most contaminated areas are eligible for full compensation?[22] Off the record, company sources say most people who apply will get something but that few are likely to be completely satisfied.

Refugees who disagree with TEPCO's compensation scheme and have the energy to fight can take their complaints to the government-run Centre for Dispute Resolution for Compensating Damages from the Nuclear Power Plant Incident.[23] Established in September 2011 to ease the expected burden of lawsuits on public courts, the Centre has handled over 5,000 claims. About a quarter have been "settled", meaning disputes over living expenses (but not assets) have been resolved.[24] According to people close to the compensation issue, however, a growing number of refugees are bypassing both TEPCO and the Centre and negotiating directly with the aid of lawyers.

1.4 TEPCO's response

TEPCO has steadily increased its demands on the state-backed Nuclear Damage Liability Facilitation Fund, from an initial ¥1tn in October 2011, to a total amount of ¥3.24tn ($36.5bn) by December 2012. TEPCO made its latest demand of an additional ¥697bn for the Fund on 27 December. It is almost certainly not the last claim. The lawyer and head of the Japanese Bar Association, Yuichi Kaido previously told Greenpeace that the reported figure of ¥4tn in final compensation costs has "absolutely no basis in reality", meaning it is a completely unrealistic assessment of eventual compensation claims. TEPCO blames the rise on additional "compensation according to the redefined evacuation zone", additional "compensation for voluntary evacuees" and the "extended compensation calculation period", among other factors.[25] "If our current funds do not cover claims, we will apply to the Liability Fund for more," says TEPCO's compensation spokesperson Hiroki Kawamata.

The utility says that, by the end of 2012, it had paid out a total of ¥1,662.9bn in compensation to 160,000 "forcibly evacuated" refugees and to "voluntary evacuees," and to former or current residents mainly in Fukushima Prefecture who have been "inconvenienced" by the disaster.[26] It says women who were pregnant or families with young children in the prefecture at the time of the accident have received about ¥400,000 each; others have received one-off payments of ¥80,000.[27] Whether these payments are conditional on waiving future claims for illnesses caused by exposure to radiation, and mental distress, remains unclear. TEPCO said on one occasion that people cannot file future compensation for further illnesses arising from the accident, if they accept one-off payments now. On another occasion, TEPCO stated that it "does not in principle" rule out future claims.

TEPCO says a typical family of two adults and one dependent in the most heavily contaminated zone will receive a one-off payment of about ¥57m ($643,000).[28] That figure includes the loss of the use of their house and ¥6m per victim for “psychological damage” over the five-year evacuation. But the company admits that it has yet to pay a penny of compensation for fixed assets. “It has taken time to ask local governments to estimate the cost of assets,” explains TEPCO’s Kawamata.[29] He says payment will start “within the year.”

Legally, Japan has a three-year time limit on applications for compensation, a limitation clearly designed to help shareholders, says Tadano, and which is in any case unworkable. “Sixty-seven years after the bombing of Hiroshima and Nagasaki there are still people who claim their health has been harmed. Three years is clearly not long enough.”[30] TEPCO President Naomi Hirose has been forced to agree. He is also likely mindful of comparisons with Chernobyl, where victims who missed a deadline for applications were shut out of the compensation process. “We do not intend at all to say ‘that’s it’ after three years ... We hope not to create concerns among the people affected,” Hirose told Fukushima Governor Yuhei Sato during a January 2013 visit to Fukushima Prefecture.[31]

Japan’s Act on Compensation for Nuclear Damage (1961) obliges TEPCO and other nuclear utilities to arrange private insurance of roughly ¥120bn per site – now accepted as woefully inadequate, as the total costs of an accident would be much higher. Compensation and decontamination alone are currently estimated at ¥10tn ($113bn) by TEPCO officials, double the estimate of a few months ago.[32] Although modelled on the US Price-Anderson Nuclear Industries Indemnity Act, the Japanese legislation has a difference, it places unlimited liability on a utility that causes an accident.[33] If, however, liability exceeds the financial security amount, the government could support the utility if necessary.[34] In the event of a “grave natural disaster of exceptional character,” the company may be exempted from liability altogether. Where this exoneration applies, the government shall take “the necessary measures to relieve victims and to prevent the damage from spreading”.[35] Although TEPCO has not invoked this clause, the company has been nationalised, in effect transferring liability to the public.

In May 2012, the Japanese government injected ¥1tn (about $12.5bn at 2012 exchange rates) into the utility, “the biggest state intervention into a private non-bank asset since America’s 2009 bail-out of General Motors,” said *The Economist*.[36] The injection capped an estimated ¥3.5tn in public money given to the utility since the Fukushima disaster began. On 27 June, shareholders in the company officially accepted its nationalisation, giving the government majority control.[37] The government backing allows TEPCO to continue as a limited company with shares traded on the stock exchange, while preventing it from going bankrupt.

1.5 Suppliers escape liability

What about the liability of suppliers to the Fukushima plant? Ever since the Japanese nuclear programme began in 1955, Japan has pursued a familiar industrial strategy of mimicking foreign technology (mainly US, British and French), while incubating its own domestic manufacturers and suppliers.[38] By 2011, this strategy had made Japan into one of the world’s leading nuclear powers, led by Toshiba, Hitachi and Mitsubishi Heavy Industries. Construction giant Kajima, which helped build the Fukushima plant and many others, has also benefitted from this strategy.[39]

In 1957, Japan’s White Paper on Nuclear Energy set out the nation’s long-term goals of developing 7,000 megawatts (MW) of nuclear power by 1975. Electricity utilities were persuaded to invest in the Japan Atomic Power Company. The aim was to use 90% of domestic components and human resources.[40] Mitsubishi Atomic Power Industries and Sumitomo Atomic Energy Industries were inaugurated in 1958 and 1959, respectively, to develop nuclear technology. Toshiba and Hitachi began the same in the 1960s. Universities and manufacturers began training engineers in the 1960s.

The suppliers involved in the Fukushima disaster continue in business, and in some cases profit from the disaster.

Image: Public protest in Shibuya against the government's nuclear energy policies, and the restarting of nuclear plants.

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In 1963, Japanese manufacturers began partially constructing a Boiling Water Reactor (BWR) designed by General Electric (GE)-Ebasco. The decisions on what technology to use depended on commercial ties between US and Japanese companies. For example, Hitachi and Toshiba used technologies provided by GE, and Mitsubishi Heavy Industries (MHI) relied on Westinghouse. US firms quickly began to lag in investment and after the 1979 Three Mile Accident, which effectively froze US nuclear development; they fell well behind their Japanese competitors. In the words of former Hitachi engineer-turned whistleblower Mitsuhiko Tanaka, “the student became the teacher.”[41]

Tanaka’s experience illustrates the stakes, and risks in the then fledging industry. In the early 1970s, he helped build the 20 metre tall reactor pressure vessel inside the Fukushima Unit 4 at a huge foundry in Kure City, Hiroshima run by Babcock-Hitachi (the same foundry used to build the gun turrets for the world’s biggest battleship, the *Yamato*). In the final stages of making the $250m vessel, a blast furnace warped the metal, dangerously compromising its integrity and legally obliging the company to scrap it. The vessel is still at the core of Fukushima Daiichi Unit 4.[42]

Facing bankruptcy, Hitachi covered up the defect with Tanaka’s help, he says. “I suspect there are many more engineers like me in Japan.” The vessel was part of the Unit 4 reactor of the Fukushima Daiichi plant. GE supplied the reactors for Units 1, 2, and 6, and Toshiba for Units 3 and 5 (all six were GE designs). Tanaka left the company in 1977 to become a science writer and put the incident out his mind until he had a crisis of conscience watching the 1986 Chernobyl nuclear disaster unfold on TV. After he went public with his knowledge, Hitachi threatened him, he says. “They said: ‘Think about your family.’” Japan’s nuclear authorities released a statement a day later insisting there was no problem. “And that was the end of it,” recalls Mr. Tanaka.[43] Nobody pursued Hitachi for this cover-up he points out.

Kei Sugaoka, a Japanese engineer who worked at the Unit 1 site, and Katsunobu Onda, author of *Tepco: The Dark Empire*, questioned the integrity of the reactor after the 11 March quake, but before the tsunami.[44] The Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company (or the Diet Commission on the Fukushima Disaster), concluded that it was “impossible to limit the direct cause of the accident to the tsunami” without further evidence.[45]

The Diet Commission report notes that Unit 1 of the Fukushima Daiichi Nuclear Power Plant was purchased by TEPCO under a “turnkey” contract for construction in December 1966 “that placed all responsibility” on GE. The report says TEPCO chose GE not just because of the company’s technical achievements but also because they believed it would be cheaper to adopt a design of an already commissioned GE reactor in Spain, but Fukushima Unit 1 ended up being built first. “Instead of having the Spanish experience available to draw on, the Fukushima plant became the first facility to experience numerous difficulties.”[46]

The problems included seismic design standards that were stricter than for the original design of the Spanish reactor, entailing piecemeal modifications of supporting structures. Working inside the cramped Unit 1 containment vessel was considered particularly problematic. “The major problem here was whether the Japanese design specifications for anti-seismic design at the time were incorporated appropriately in the product design package from GE,” says the report, citing a former TEPCO vice-president, Ryo Ikegame, who worked at the Daiichi plant during installation. “According to Ikegame, they were not, and he indicated that ad hoc reinforcements were made during the construction.”[47]

In the 1970s, GE engineer Dale G Bridenbaugh publicly questioned whether the GE Mark I reactor used in Fukushima Units 1-5 would stand up to a loss-of-coolant accident.[48] The Diet report adds that Mark I containment vessels in Japan were reinforced against dynamic loads in case of loss-of-coolant in the 1980s, “but the reinforcement did not cover severe accidents of this scale.”[49] The series of reinforcements implemented included enhancing pipe penetration points where the strength margin was small, and adding parts to mitigate the dynamic loads. The report concludes that during the accident, the pressure inside the containment vessels substantially exceeded their designed capacity, up to almost twice the capacity in the case of Unit 1.[50] "We should also note that the MARK I type PCVs [pressure containment vessels] at the Fukushima Daiichi plant is smaller in volume than the improved version of MARK I, which contributed to the fast rise in pressure." In November 1987, Japan's NISA (Nuclear and Industrial Safety Agency) began an evaluation of the Mark I reactors to consider how much stress they could take before a loss-of-coolant accident would occur. The results of that evaluation have not been made public.

Another problem inherent to the Mark I reactor design is the occurrence of cyclical waves on the water surface of the reactor pressure-suppression pool during earthquakes.[51] The pool is meant to condense steam in case of an accident. When earthquake motion causes cyclical waves (called "sloshing"), the water surface in the suppression chamber shifts. As a result, the tips of "downcomer" pipes, through which steam is released into the water, could be exposed, releasing steam into the gaseous space of the suppression chamber. This causes the designed function of suppression to fail, resulting in over-pressure. Compared to other reactor designs, the Mark I type has the highest possibility of downcomer exposure. The Diet report recommends a "thorough study" on this problem.

From the start, former GE employees recall how TEPCO elected to overrule its own engineers and follow GE's original construction design by putting the plant's emergency diesel generators and batteries in the basement of the turbine buildings, with devastating results on 11 March 2011.[52]

Throughout the operation of Mark I reactors at Fukushima Daiichi, a steady stream of allegations emerged suggesting that problems were fixed *ad hoc*, or in some cases not at all, with the collusion of original suppliers and maintenance companies. Onda has spoken to a TEPCO engineer who said often piping would not match up to the blueprints.[53] In that case, the only solution was to use heavy machinery to pull the pipes close enough together to weld them shut.[54] Inspection of piping was often cursory and the backs of the pipes, which were hard to reach, were ignored. Repair jobs were rushed; no one wanted to be exposed to nuclear radiation longer than necessary.[55]

In September 1989 the US Nuclear Regulatory Commission (NRC) encouraged owners of nuclear plants with GE Mark I and II containment designs to install hardened (pressure-resistant) vents.[56] The NRC viewed controlled venting (release of radioactive gases to reduce pressure) as preferable to catastrophic failure of the containment. However, the NRC did not order the installation, but left the decision up to the reactor operators. Only after Fukushima has the NRC ordered that all GE Mark I and II reactors install reliable hardened vents.[57] But the NRC has not yet required that those vents be filtered, while most nuclear plants outside the US and Japan have included filters to reduce the release of radioactive contaminants. In January 2013, the commissioner of the new Japanese Nuclear Regulation Authority said that all Japanese BWR's will be required to install filters in their ventilation systems before they will be allowed to restart.[58]

Some engineers have called the installation of vents in the original flawed design a "Band-Aid fix" that failed at Fukushima.[59] In Japan, the hardened vents were eventually installed in the 90s, but filters were never installed even though the inefficiency of the existing filter system in Fukushima-type reactors was known and the technology was available.[60] During the Fukushima accident, the existing filtering system could not be used due to raised water levels in the containment vessel of the reactor. Also the hardened vents proved ineffective, as no manual operations were described for power loss situations.

According to Tanaka, there is a fundamental contradiction at the heart of pressure vessels: they are designed to keep radiation in during an emergency, but the same emergency can generate such pressures that an explosion is a risk. It was TEPCO's responsibility to install filters but it didn't, he says, because of their prohibitive cost.[61] During the Fukushima accident, then Prime Minister Naoto Kan famously had to order the Daiichi vents to be opened by hand on 12 March 2011.[62] In the end, venting in Unit 1 eventually succeeded, but venting in Unit 2 failed and in 3 only partially succeeded, according to Tanaka.

There are currently 10 Mark I-type reactors remaining in Japan, and 17 very similar GE Mark II reactors.[63] According to Tanaka, each one is the equivalent of a ticking time bomb. Not only are the companies involved in building, installing or maintaining these reactors all currently exempted from responsibility for the 11 March disaster, they are profiting from it, says lawyer Tadano. Toshiba and Hitachi lead the decommissioning of the Daiichi plant and Kajima is in charge of decontamination. The TEPCO group of companies is heavily involved in the clean up[64], which includes decommissioning of the Fukushima Daiichi plant and decontamination.

1.6 Conclusion

Thousands of nuclear refugees from the world's worst nuclear disaster since Chernobyl report multiple problems, including:

- Delays in processing their claims
- Inadequate amounts being offered
- Unclear procedures about waiving of future claims
- Not a single payment yet for lost or damaged assets
- Current three-year legal limit for claims

The suppliers and companies involved in the disaster, however, continue in business and in some cases profit from the disaster, backed by public money.

Japan's nuclear accident law limits liability to TEPCO, blocking victims from going after its suppliers. There is no mechanism in the law either for targeting executives of TEPCO or any of the suppliers. Then Prime Minister Yoshihiko Noda waived responsibility for the disaster last year when he said "no individual" is to blame and that everyone has to "share the pain."[65] The Diet commission report took the same approach, blaming "culture".[66] Over half of the TEPCO board has since taken lucrative post-TEPCO positions elsewhere.[67]

Kameya says the disaster has taught her to fight for her rights, and stay tightlipped. "If I say how much I'm getting, or demanding, people will say, 'Why are you getting so much?' People think we will get a lot of money when something like this happens, but they're wrong, and it will probably take five or ten years to be compensated."

"I asked a TEPCO guy, 'If you had to run for your life and became a refugee, could you live like this, saving every receipt for food, gasoline and clothes?' He didn't answer me."

1 Personal interview, Tokyo, 28 December 2012

2 All currency conversions are approximate and were done around 22 January 2013, unless otherwise indicated.

3 Personal interview, Ibid.

4 Govt officially sets new evacuation zone, Yomiuri Shimbun, 23 April 2011. http://www.yomiuri.co.jp/dy/national/T110422004127.htm

5 Personal interview, 3 January 2013

6 The Mainichi. 2013. TEPCO intends to accept compensation claims beyond legal time limit. 10 January 2013. http://mainichi.jp/english/english/newsselect/news/20130110p2g00m0dm071000c.html

7 Japan Today. 2012. TEPCO again criticised over complicated compensation process. 13 March 2012. http://www.japantoday.com/category/national/view/tepco-again-criticized-over-complicated-compensation-forms

8 Personal interview with Hiroki Kawamata. TEPCO Compensation spokesperson, and Yoshikazu Nagai, corporate relations, 10 January 2013

9 Tokyo Electric Power Company (TEPCO). 2011. Annual Report 2011. pp.6 http://www.tepco.co.jp/en/corpinfo/ir/tool/annual/pdf/ar2011-e.pdf

10 Ibid.

11 The Asahi. 2011. Government Oks TEPCO compensation framework, 13 May 2011.

12 "TEPCO's nationalisation: state power," 11 May 2012. http://www.economist.com/blogs/schumpeter/2012/05/tepco's-nationalisation (4 January 2013).

13 Explanation and original press release on TEPCO homepage here: http://www.tepco.co.jp/en/press/corp-com/release/2012/1206837_1870.html (accessed 7 January 2013).

14 See Jiji, "Victims dissatisfied with TEPCO Compensation," 15 September 2012, in The Japan Times: http://www.japantimes.co.jp/text/nn20120915a8.html (3 January 2013).

15 The re-zoning is explained here: Ministry of Economy, Trade and Industry (METI). 2012. Evacuation Map. 15 June 2012. http://www.meti.go.jp/english/earthquake/nuclear/roadmap/pdf/evacuation_map_120615.pdf. See also: http://www.yomiuri.co.jp/dy/national/T111217003401.htm

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17 As Fukushima Cleanup Begins, Long-term Impacts are Weighed. 9 January 2012. http://e360.yale.edu/feature/as_fukushima_cleanup_begins_long-term_impacts_are_weighed/2482

18 See Jiji, Ibid.

19 Personal interview, 10 January 2013.

20 The Daily Yomiuri, "TEPCO must compensate nuclear victims quickly," 2 October 2012, http://www.yomiuri.co.jp/dy/editorial/T121001002720.htm (12 January 2013)

21 Personal interview, 10 January 2013

22 TEPCO says it has received a total of about 1,250,000 separate compensation claims but insists it cannot say how many individuals are involved because some are multiple claims. See: http://www.tepco.co.jp/comp/jisseki/index-j.html (13 January 2013).

23 Centre for Dispute Resolution for Compensating Damages from the Nuclear Power Plant Incident . 2011. http://www.mext.go.jp/a_menu/anzenkakuho/baisho/1310412.htm

24 Personal interview with Hiroki Kawamata. TEPCO Compensation spokesperson, and Yoshikazu Nagai, corporate relations, 10 January 2013

25 Summary of amounts claimed and press release can be found here: http://www.tepco.co.jp/en/press/corp-com/release/2012/1223937_1870.html (Accessed 12 January 2013)

26 TEPCO personal interview, Ibid.

27 Personal interview, 11 January 2013. Interim Guideline of the Funso Sinsakai dated 6 December 2011. http://www.mext.go.jp/b_menu/shingi/chousa/kaihatu/016/index.htm

28 "TEPCO may start lump-sum compensation in August," The Daily Yomiuri, 26 July 2012. Available online at: http://www.yomiuri.co.jp/dy/national/T120725005729.html. The compensation scheme assumes a140m^2 house valued at ¥8.61m built in 2007 on a 300m^2 housing lot valued at ¥3m.

29 Personal interview, 11 January 2013.

30 According to the recent OECD/NEA report, Japan's Compensation Act does not set a time limit on rights to claim compensation for nuclear damage. While Japan's Civil Code provides the terms for the extinction of rights to claim the general tort liability, a recent examination found that the 20-year time limit to claim compensation "would not substantially bar claims" by victims of late injuries. See: OECD/NEA (2012). Japan's Compensation System for Nuclear Damages. Legal Affairs 2012, pg. 19.

31 See "TEPCO intends to accept compensation claims beyond legal time limit," Mainichi Daily, 10 January 2013. http://mainichi.jp/english/english/newsselect/news/20130110p2g00m0dm071000c.html (Accessed 13 January 2013).

32 Asahi Shimbun (2012), "TEPCO seeks more government support as Fukushima costs soar", 7 November 2012. http://ajw.asahi.com/article/0311disaster/fukushima/AJ201211070086

33 See Kazuko Goto, "Japan's role as leader for nuclear non-proliferation," Federation of American Scientists," December 2012. A copy of the Japanese act can be found at: http://www.oecd-nea.org/law/legislation/japan-docs/Japan-Nuclear-Damage-Compensation-Act.pdf (23 January 2012).

34 Ibid

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38 See Goto, Ibid.

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40 Goto, Ibid.

41 Personal interview, 10 January 2013

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50 The National Diet of Japan Commission Report, Ibid, Chapter 2, p.95

51 The National Diet of Japan Commission Report, Ibid, Chapter 2, p.97

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55 Ibid.

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62 NUCLEAR CRISIS: HOW IT HAPPENED / Kan's visit 'wasted time', The Yomiuri Shimbun, 9 June 2012. http://www.yomiuri.co.jp/dy/national/T110608005066.htm

63 OECD-NEA, 'Implementation of Severe Accident Management Measures, ISAMM 2009', Workshop Proceedings, October 2010, Pg. 96. https://www.oecd-nea.org/nsd/docs/2010/csni-r2010-10-vol1.pdf

64 In addition to Toshiba and Hitachi, among the companies involved in decommissioning the Daiichi plant are GE Nuclear Energy, Taisei Kensetsu Kajima Kensetsu, Goyo Kensetsu (Penta-Ocean Construction Co.), Maeda Corporation, Takenaka Obayashi Corporation, Kumagaigumi Co. and Hazama Corporation. TEPCO Group companies include Kandenko, Todenkogyo Co., Tokyo Energy & Systems Inc., Tokyo Electric Power Environmental Engineering Co., Nakazatokoumuten Co., Atox Co, Taihei Dengyo Kaisha, Kataoka Co., Shin Nippon Technologies Co, Utoc Corporation, Shibakogyo Co., Japan Nuclear Security System Co., Tokyo Bosai Setsubi Co., Soushin Co., Utsue Valve Service Co. and Hanwa Ltd.

See: http://www.tepco.co.jp/nu/fukushima-np/roadmap/images/m121203_05-j.pdf (17 January 2013)

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The current nuclear liability conventions are intended to protect the nuclear industry, and do not offer sufficient compensation to victims.

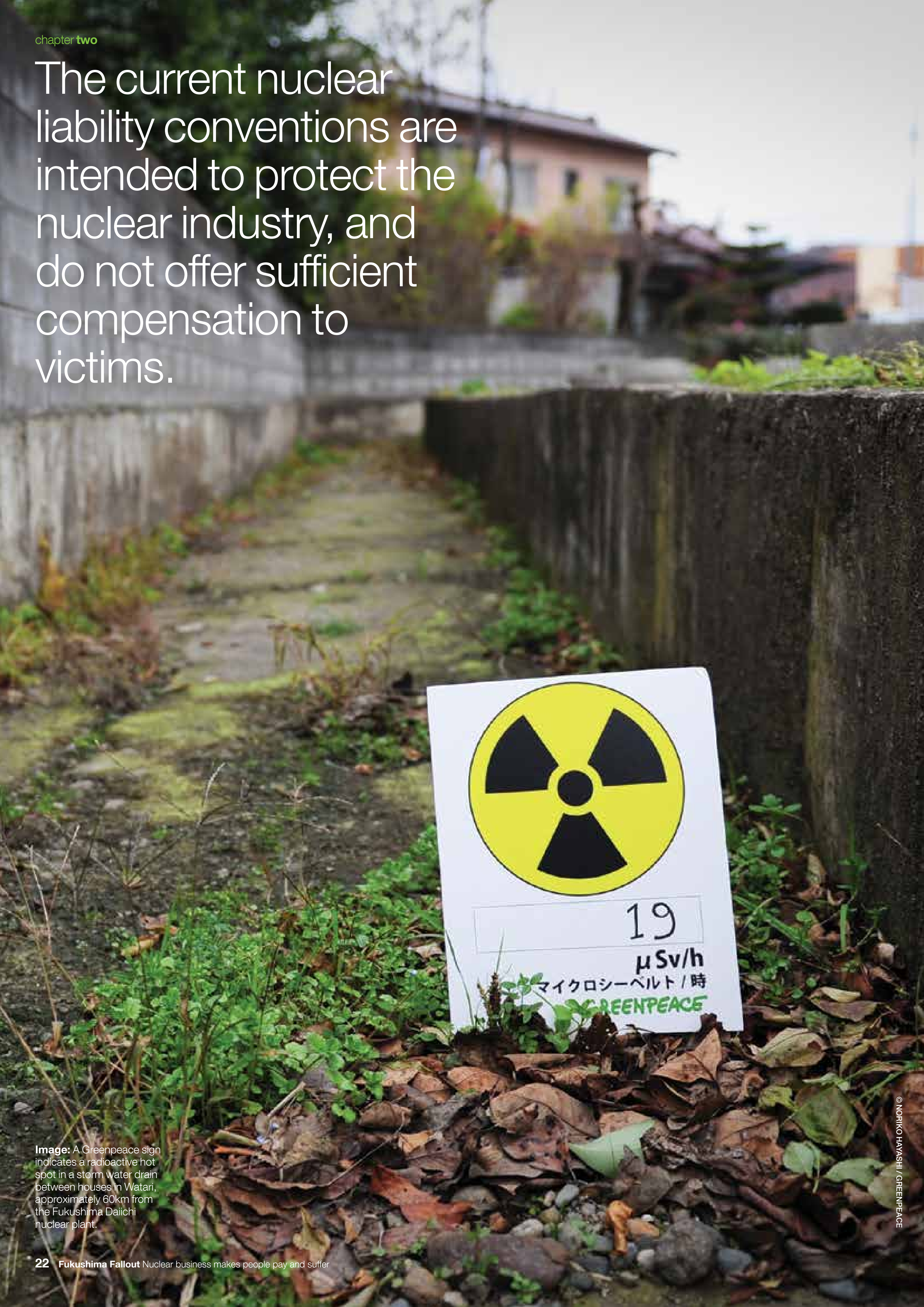

Image: A Greenpeace sign indicates a radioactive hot spot in a storm water drain between houses in Watari, approximately 60km from the Fukushima Daiichi nuclear plant.

#2

Summary and analysis of international nuclear liability

by Antony Froggatt

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2.1 Introduction

Nuclear power stations, as with all businesses, can damage the health and safety of their workers and, under more extreme circumstances, the general public and the wider environment. However, given the nature of the technology and fuel, nuclear power also has the potential for accidents that could lead to large and long-term trans-boundary impacts. This potential was recognised right at the start of the civil nuclear industry and international agreements were sought, both to enable potential victims to rapidly have access to compensation and to limit the extent to which the industry could be exposed to possible compensation claims.

At the heart of the problems around the approach to creating an international nuclear liability regime are competing objectives. To introduce a comprehensive liability regime it would be necessary for states that operate nuclear facilities, states involved in the supply of nuclear materials or services for these programmes and all other states that might be affected by a nuclear accident to be under the umbrella of the same liability and compensation regime. Currently, that is not the case.

For a liability and compensation regime to be attractive to states seeking to maintain or increase their nuclear power programmes, the requirements imposed by a liability and compensation regime must not be too burdensome[1]. Therefore, the signatories to the current conventions agree to a number of conditions such as: narrow definitions of nuclear damage and the length of time that compensation can be sought; that claims for compensation are channelled solely towards the operator; and that limits can be set on the total amount of compensation available. However, conversely, in order to be attractive for a state without nuclear power plants, liability and compensation conventions must offer sufficient compensation, and a regime must not introduce unacceptable restrictions or burdens for those seeking to obtain compensation for losses incurred. For such states, becoming party to one of the nuclear-liability conventions currently is not an attractive proposition.

The current nuclear liability conventions are unlike those of many other industries, as they are intended to protect the nuclear industry, and do not offer sufficient compensation to victims. This chapter gives an overview of the existing international nuclear liability conventions, and analyses the impacts of specific issues, such as capping the compensation available, and channelling of liability solely to the operator. In the conclusions, directions are given for the reform of domestic legislation on nuclear liability.

2.2 Overview of liability regimes[2]

2.2.1 International

There are two basic international legal frameworks contributing to the attempt to put in place the basis for an international regime on nuclear liability: Firstly, the Organisation for Economic Co-operation and Development's (OECD) 1960 Convention on Third Party Liability in the Field of Nuclear Energy (Paris Convention), and the associated "Brussels Supplementary Convention"[3] of 1963, and secondly, the International Atomic Energy Agency's (IAEA) 1963 Convention on Civil Liability for Nuclear Damage (Vienna Convention)[4]. The Vienna and Paris liability conventions are also linked by a Joint Protocol, adopted in 1988[5]. Despite this, however, only about half the world's 438 operational reactors are located in states that are contracting parties to one of the nuclear liability conventions[6], as many countries such as the US and Japan have not become part of either convention. All countries that operate nuclear power plants also have their own legal frameworks, which are not always fully compatible with the international conventions.

Negotiated at the time when the nuclear power industry was in its infancy, the Vienna and Paris Conventions had two primary goals: first, to create an economic environment where the nascent nuclear industry could flourish; and second, to ensure that clear procedures and some compensation would be available in the event of an accident. The first aim would be achieved by removing legal and financial uncertainties over potentially enormous liability claims that could arise in the event of an accident. For the industry, it was clear that nuclear power would only be viable if there were some financial protection for companies involved in the supply chain, as well as for investors who were placing their financial resources in a potentially dangerous and litigiously expensive sector.

While there are some differences in detail, the Vienna and Paris Conventions have features in common. In particular they:

- Allow limitations to be placed on the amount, duration and types of damage for which nuclear operators are liable;
- Impose a restrictive definition of nuclear damage[7];
- Require insurance or other surety to be obtained by the operator;
- Channel liability exclusively to the operator of the nuclear installation;
- Impose strict liability on a nuclear operator, regardless of fault, but subject to exceptions;
- Grant exclusive jurisdiction to the courts of one country for any given incident, normally the country in whose territory the incident occurs.

The accident at the Chernobyl nuclear power station in Ukraine in 1986 revealed a number of deficiencies in the international liability conventions. Most striking was that, compared with the damage caused by the Chernobyl accident, it was obvious that the liability ceilings were inadequate and that not all of the damage caused by Chernobyl was covered by the definition of damage applicable under either Convention. There were also problems with the limits on the time in which claims for compensation could be brought, the claims procedures, and the limitations on which courts had jurisdiction to hear claims. An international liability regime was not the only international framework that was seen to be lacking, and following Chernobyl efforts were made by the international community to modernise a number of conventions, including those on nuclear safety standards, on notification of the international community and on radioactive waste management.

On nuclear liability, as an interim step to creating a single treaty with global adherence, three steps have been taken. Firstly, the parties to both the Vienna and Paris Conventions adopted the 1988 Joint Protocol, which entered into force in 1992. The Joint Protocol created a "bridge" between the two conventions, effectively expanding their geographical scope. Doing so ensured that only one of the two conventions would be exclusively applicable to a nuclear accident. Secondly, some of the elements of the existing conventions were revised. The process of negotiating amendments to the Vienna Convention began in 1990 and concluded in 1997. Work then began officially in 1997 on revisions to the Paris Convention and in 1999 for the Brussels Supplementary Convention.[8] The revisions to the Vienna and Paris/Brussels Conventions increase the amount of compensation available (see Table 1), expand the time periods during which claims might be made and expand the range of damage covered by the conventions. The new liability and compensation amounts required under the revised Paris Convention would be at least €700m ($920m US dollars) and total compensation available under the revised Brussels Supplementary Convention would be €1,500m. Nonetheless, the overall amounts remain low when compared with the costs of the Chernobyl or Fukushima accidents. For Chernobyl, a large number of studies estimate the costs at between $75bn and $360bn (with considerable variation in exchanges rates). For Fukushima preliminary estimates from the Japanese Centre for Economic Research (JCER) suggested that the total costs would be in the range of ¥5,700-20,000bn (€48bn-169bn). Further, setting fixed compensation sums is not only arbitrary (in the absence of genuinely robust estimates of probable damage) but it is also unlikely to be valid over the longer term.

Finally, a new Convention on Supplementary Compensation (CSC)[9] was adopted in 1997 and is intended to be a free-standing instrument that may be adhered to by all states irrespective of whether or not they are Party to either of the existing nuclear liability conventions. Its objective is to provide additional compensation for nuclear damage beyond that established by the existing conventions and national legislation. Furthermore, it aims at broadening the number of countries within an international convention.
As a result, the industry would be protected from compensation claims outside these regimes. The CSC fixes the first tier of compensation at 300 million Special Drawing Rights (SDRs)[10] (roughly equivalent to €300m). If the operator is unable to meet this, the state in which the reactor is installed is required to make public funds available to cover the difference. If claims for compensation for nuclear damage exceed 300 million SDRs, the CSC requires that its member countries contribute to an international fund to provide additional compensation[11,12].

Table 1: Summary table showing liability and compensation amounts for different conventions (millions of euros (€)).

Convention	Operator liability & Installation state	Total combined contributions from Other States party	Total minimum compensation available	Number of Parties
Paris, 1960	€6 to €18	-	€6 to €18	15
Brussels, 1963	€202	€149	€357	12
Paris, 2004	€700	-	€700	3
Brussels, 2004	€1200	€300	€1500	3
Vienna, 1963	€50	-	€50	38
Vienna, 1997	€357	-	€357	10
CSC*, 1997	€357	Depends	€713	4

Source: International Atomic Energy Agency and Nuclear Energy Agency 2012

Although there are unifying features, the nuclear liability conventions do not provide a single comprehensive and unified international legal regime for nuclear accidents. As has been seen above, different countries belong to a variety of international agreements.

The goal of ensuring broad participation in the improved international conventions has not been achieved. As of May 2012, six countries have ratified the 1997 Vienna Convention; with a further four parties to this convention.[13] This was enough to bring the Joint Protocol to amend the Vienna Convention into force in 2003, but the lack of wide adoption remains problematic. There has also been a delay in the ratification of the revised Paris Convention and the revised Brussels Supplementary Convention.[14] In order for the Protocol amending the Paris Convention to enter into force it must be ratified by two-thirds of the Contracting Parties. For EU Member States, this was supposed to have taken place simultaneously by the end of 2006[15], but it has not yet been done. It is suggested that this will occur and that it will enter into force at the beginning of 2014[16].

For the Protocol amending the Brussels Convention, ratification by all contracting parties is required. Only four countries out of 15 (Argentina, Morocco, Romania and the US) have ratified the CSC[17], however, the CSC is set to enter into force on the 90th day after date of ratification by at least five states that have a minimum of 400,000 units of installed nuclear capacity (ie MWt -thermal[18])[19]. Although only four countries have ratified the convention, press reports suggest that Japan is now considering joining the convention[20]. (For a summary list of which countries have ratified each convention, see Table 2.) What is remarkable is that nearly 27 years after Chernobyl, 16 years after the adoption of the CSC, and nine years after the adoption of the 2004 Protocols to amend the Paris/Brussels convention, those enhancements have not entered into force. As a result, the situation has not changed significantly since the Chernobyl accident of 26 April 1986[21].

During the negotiations to revise the Vienna and Paris Conventions, representatives of the nuclear insurance industry stated that some of the proposed amendments would be problematic. In particular, the nuclear insurance industry was concerned that there was:

- insufficient private insurance market capacity to insure nuclear operators against raised liability amounts;
- an unwillingness of the market to cover extended/extinction periods during which an operator would be liable; and
- a difficulty in that private insurance could not cover all the categories included in the expanded definition of damage[22], such as damage to the environment.

The problems with private insurance can be seen to be, at least partly, a financial question. The UK government laid out the current difficulties in its 2007 consultation paper on the revision of the liability limit, when it said: "To the extent that commercial cover cannot be secured for all aspects of the new operator liabilities, the Government will explore the alternative options available – including providing cover from public funds in return for a charge"[23]. Already this has occurred as in the Netherlands the maximum liability is in line with the revised Paris Convention; however, under Dutch law a lower amount may be set for "low-risk" installations by ministerial order. So far, five installations have lower requirements, of between €22.5m and €45m. Furthermore, if an operator cannot obtain the financial security required by the Convention or it is only obtainable at "unreasonable cost", the minister may enter into contracts on behalf of the state[24].

2.2.2 National[25]

A number of countries have only domestic nuclear liability laws (e.g. Japan), therefore, the extent of the potential compensation to victims and the requirements on the operators are dependent on these national laws. In the event of an accident in a nuclear facility in one of these countries, the requirements and terms of the international conventions would not be applicable.

Some countries that do not have commercial nuclear power, but may have nuclear research reactors, also have national liability regimes. One of the most prominent is Austria, which is also active in its opposition to the use of nuclear power in neighbouring countries. In 1995 its parliament adopted a resolution in which the government was asked to revise its nuclear liability law. This led to a law in 1998 that was “in sharp contrast to the basic principles of international law”, in that liability was unlimited, legal channelling to the operator was largely eliminated, including a broadened definition of nuclear damage, and Austrian courts were given jurisdiction, if the damage occurs in Austria, regardless of the cause[26]. Even as revised, the levels of compensation are relatively low when compared to the likely costs of a serious accident (see section 2.3). By becoming a party to an international convention, a non-nuclear-power-generating state might actually restrict its possibilities for obtaining legal remedies in the event of an accident[27]. This is why the Austrian parliament’s 1995 resolution specifically ordered the government not to present the Paris Convention for ratification until essential improvements, namely the elimination of legal channelling, were made[28].

2.3 Capping of nuclear liability vs costs of nuclear accidents

One of the key elements of the international liability conventions is to justify national legislation by putting in place a ceiling on the costs that a nuclear operator must pay in the event of a nuclear accident that has impacts that require compensation to third parties. The limits put in place under the international conventions are in fact the minimum that a utility is liable for, but in most cases this has been taken to be the maximum. Only in a few cases does national legislation go beyond that required by the conventions, for example in Germany, Japan, and Switzerland, there is no limit on the liability of an operator[29,30].

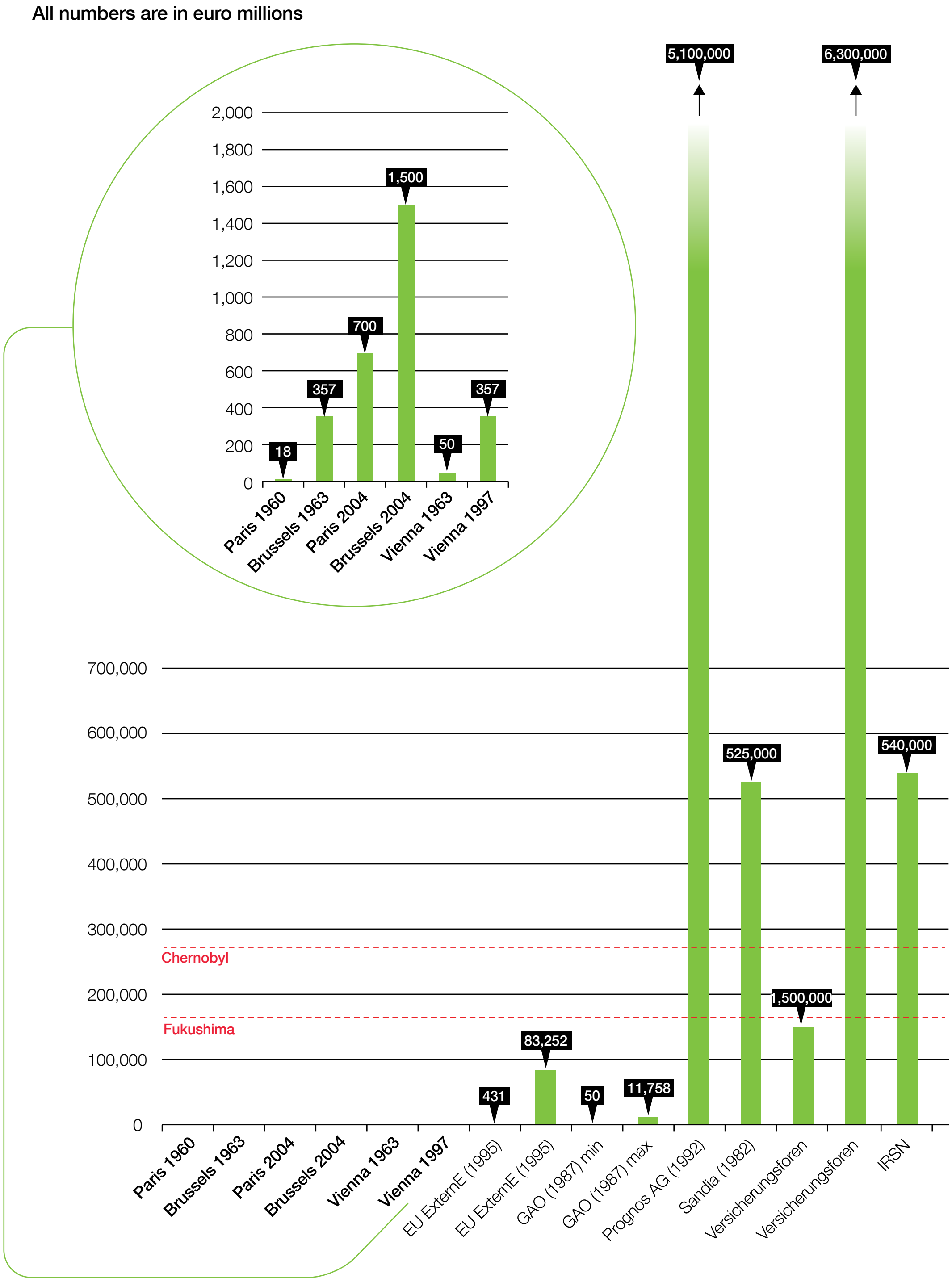
As noted in Table 1, the minimum requirements range between the different regimes, from €350m to €1.5bn. Even in an unlimited civil liability regime, the practical limits to the capacity of the nuclear insurance market and the assets of an operator (and, where these are also the object of channelling: suppliers and financiers) together impose a constraint on the magnitude of the funds that may be raised to compensate victims. In practice, the channelling of liability exclusively to the operator restricts the scale of the accessible funds to a very small fraction of the possible costs of a serious nuclear accident. Many nuclear countries have recognised this state of affairs and provide for guarantees of supplementary compensation for domestic victims using public funds. This is the case, for instance, in Germany and Switzerland (which have unlimited operator liability) as well as in the UK and France (which impose relatively low limits on operator liability).

However, these are insignificant in comparison to the differences between these thresholds and the theoretical costs of a large-scale accident, as can be seen in Figure 1.

In addition to the estimated cost of actual accidents, a number of theoretical assessments of accidents exist, including:

- The 1995 study by the EU ExternE project considered four reactor accident scenarios, which led to cost estimates for damage ranging from €431m to €83,252m.[31] It should be noted that these cost estimates exclude decontamination, although it is acknowledged that these costs “can rapidly be very high”, and that that there are major limitations to the economic evaluation[32], arising from:
  - Uncertainties on the impact (evaluation of source term, difficulties to estimate the environmental impacts due to the long-term contamination, uncertainties on the radiation health effects, etc.);
  - Uncertainties on the efficiency of countermeasures;
  - Economic evaluation of some social consequences is nearly impossible.

Fig 1:
Comparison of liability amounts in international conventions vs estimated costs of accidents.



Source: Greenpeace 2012. Note: The high estimates for the costs of Chernobyl and Fukushima are used as a reference (Chernobyl: €270bn, Fukushima: €169bn). The costs of the Fukushima accident are based on preliminary estimates.

- Following the Chernobyl accident, in 1987, the US General Accounting Office (GAO) conducted an analysis of the off-site financial consequences of a major nuclear accident for all 119 nuclear power plants then operating in the US. The estimates ranged per accident between a low of $67m US dollars (€50m) to a high of $15,536m (€11,758m).[33]
- An assessment conducted by Prognos AG in 1992 for the federal German government estimated the worst case accident scenario for the Biblis-PWR power station at $6.8tn (€5,100bn).[34]
- The so-called "Sandia Report" from 1982 concluded that a very large accident could cause damages in the order of $695bn (€525bn).[35]
- A study undertaken by Versicherungsforen Leipzig, for the German renewable energy sector in 2011, following Fukushima, assumed a cost range for a nuclear accident in Germany of between €150bn and €6.3tn.[36]
- The Institut de Radioprotection et de Sûreté Nucléaire (IRSN), which is the French public safety authority's Technical Support Organisation (TSO) on nuclear and radiation risks, in its November 2012 report on a major accident in France, suggested that the cost could exceed €540bn. This figure includes the cost of clean-up and compensation, loss of electricity, and the impact on the image of products, leading to a reduction in value. The leader of the study, Patrick Momal was quoted as suggesting that it would be an "unmanageable European catastrophe". He suggested that it could be costlier than that of Fukushima due to the higher population density and the fact that many power plants are inland.[37]

The actual costs associated with the Chernobyl accident are difficult to assess, and range from $75bn-$360bn (although exchanges rates vary considerably). An early estimate put the minimum near-term costs of the Chernobyl accident to be in the neighbourhood of $15bn, with longer-term costs of $75bn–$150bn.[38] A 1990 report prepared by Yuri Koryakin, the then chief economist of the Research and Development Institute of Power Engineering of the Soviet Union, estimated that the costs from 1986 through to 2000 for the former Soviet Republics of Belarus, Russia, and Ukraine, would be 170bn-215bn roubles (at the then official exchange rate this would be equivalent to $283bn-$358bn)[39]. The Belarus government estimated the total economic damage caused between 1986 and 2015 would be $235bn (1992 June prices)[40]. Another estimate suggests overall economic costs in Ukraine alone of $130bn[41]. In part due to the changing political situation in the region in the early 1990s and the changing currencies and exchange rates, it is impossible to put a precise figure on the cost of the Chernobyl accident. However, what seems clear is that it was the most costly nuclear accident to date, with costs in the order of hundreds of billions of dollars US, a figure which far exceeds most legislative requirements.

The final costs of the Fukushima accident are also unclear given the uncertainties over the number of affected people and the future for evacuated areas and their populations. An early estimate by the Japanese Centre for Economic Research suggested that the total costs would be in the range of ¥5,700bn-¥20,000bn (€48bn-€169bn). The estimated cost was broken down into three cost components: compensation for the purchase of land ¥4,300bn (€36bn); compensation for lack of income ¥630bn (€5.3bn); and the costs of decommissioning and decontamination between ¥740bn-¥15,000bn (€6.3bn-€127bn)[42].

In April 2012, in its annual report, TEPCO stated that the company was committed to providing prompt compensation for those affected by the accident in accordance with the 1961 Nuclear Damage Compensation Act. Based on guidelines from the Committee for Adjustment of Compensation for Nuclear Damages Disputes of 5 August 2011, TEPCO has assumed that the initial cost of compensation amounts to ¥2,644bn (€22bn)[43]. This includes ¥1,174bn (€10bn) for individual compensation, ¥986bn (€8bn) for businesses, plus ¥484bn (€4bn) for other expenses[44]. Of this, TEPCO will be responsible for nuclear damages amounting to ¥2,524bn (€21bn) after deducting ¥120bn it received in compensation pursuant to the provision of 1961 Nuclear Damage Compensation Act[45].

However, the ¥2,644bn is not the final figure, and annual payments are also expected, with ¥161bn (€1.4bn) allocated in the company accounts for further compensation in the first quarter of FY 2012[46]. It is noted by TEPCO that: "The Company records the estimated amount as far as reasonable estimation is possible at this moment, although the estimated compensation amounts might vary depending on the extent of accuracy of reference data and agreements with the victims from now on."[47] In November 2012, TEPCO officials suggested the costs of compensation and decontamination could reach ¥10tn (€85bn)[48].

The Committee for Adjustment of Compensation for Nuclear Damages Disputes estimated that the total costs of decommissioning the six units at Fukushima Daiichi would be around €13bn. However, the Commission was unable to determine and did not include the costs of decontamination[49].

To put these figures into context, according to the Japanese Cabinet Office's report released three months after the nuclear accident, the total estimated loss to tangible (direct) assets from the earthquake and tsunami, not including those arising out of the nuclear accident, was around ¥16.9tn (€143bn), which represents around 3.3% of GDP. While the insured loss stemming from the earthquake and tsunami is estimated at ¥3,000bn (€25bn), possibly making it the world's second most costly insurance loss since the 1970s[50].

2.4 Economic impact of capping liability

Actual experience and numerous studies have shown that the compensation required in the event of an accident with large-scale, off-site releases far exceeds even the revised limits of the international conventions. Therefore, in an age of increasing awareness of the consequences of environmental damage and a market economy, the concept of creating an artificial ceiling on the amount of compensation that utilities are required to pay out is unjustified.

As the compensation costs of accidents with off-site consequences exceed by orders of magnitude the liability requirements on the utilities in the international conventions, it might be assumed that the conventions were unfit for purpose and need to be adjusted to reflect the greater possible compensation claim. However, in fact it has the reverse impact: the conventions are successful in protecting an operator from damage claims.

The third-party liability ceilings placed upon nuclear operators by national legislation reduce their insurance premiums. Little data is publicly available on the actual costs of individual utilities for their third-party insurance liability and the specific details of the liability cover, and there is certainly no published comparison. However, *ad hoc* country data is available and includes:

- In the US, the Nuclear Regulatory Commission (NRC) requires all licensees of nuclear power plants to show proof that they have the primary and secondary insurance coverage mandated by the Price-Anderson Act. Licensees obtain their primary insurance through American Nuclear Insurers. The average annual premium for a single-unit reactor site is $830,000 (€630,000)[51].
- In 2011 in Canada, Ontario Power Generation Ltd paid $809,626 Canadian dollar (€623,000) for its nuclear liability, which covered 10 units at two power stations[52].
- The total insurance costs in the UK are estimated in a study commissioned by the Department of Energy and Climate Change (DECC) to be £10,000 per annum per MW of installed generating capacity. DECC's conclusion was that: "this demonstrates that total insurance costs, of which nuclear third party liability is only one element (other elements includes non-nuclear third party cover, business interruption, machinery breakdown, construction risks, crime etc.) are a very small proportion of the costs of electricity generation from nuclear plant"[53].

The studies cited below present data on the economic impact of increasing or removing the ceilings on liability. Some also present the costs for requiring private insurance.

A brief analysis published in 2003 suggested that if Electricité de France (EDF), the main French electric utility, were required to fully insure its power plants with private insurance but using the current internationally agreed limit on liabilities of approximately €420m, it would increase EDF's insurance premiums from €c0.0017/kWh[54], to €c0.019/kWh, thus adding around 0.8% to the cost of generation. However, if there were no ceiling in place and an operator had to cover a significant off-site release of radiation, it would increase the insurance premiums to €c5.0/kWh, thus tripling the current total generating costs[55].

A more comprehensive analysis, undertaken by Versicherungsforen Leipzig, looked at the insurance costs in Germany. This both highlighted the variables and costs associated with a cost-reflective insurance regime, and concluded that the insurance premium would increase the cost by a range of around €0.14 to €67.3/kWh[56].

The JCER study suggests that, if the anticipated costs for Fukushima (¥5.7tn-¥20tn, €48bn-€169bn) were required to be met by all of TEPCO's reactors operating for a 10-year period, it would add ¥6.8-¥23.9/kWh (€0.06-€0.22/kWh), while, if the cost were allocated to all nuclear power plants, it would add between ¥2.0-¥6.9/kWh (€0.02-€0.06/kWh), compared to quoted nuclear generating cost of around ¥6/kWh[57] (€0.05/kWh).

The UK Government undertook an assessment on extending the liability cover required by nuclear operators to meet the new requirements of the revised Paris Convention. Following discussions with the industry, DECC suggested: "that meeting the proposed changes to the regime, namely that operators will now be liable for 6 categories of damage instead of three (consequential economic loss is already covered), including personal injury now extended to 30 years, and that the level of liability will increase substantially from £140m to €1,200m. The estimates provided by industry suggest there would be an increase in insurance premium costs from 2 to 10 times the current levels, averaging 7.5 times current costs"[58].

2.5 Liability channelling

The Vienna Convention states (Article II, Par 5): "Except as otherwise provided in this Convention, no person other than the operator shall be liable for nuclear damage."

The major regimes all act to channel liability exclusively towards the operator and no other parties involved in the construction and maintenance of a nuclear installation may be held liable for any damages. The Vienna Convention provides for very limited rights of recourse of the operator towards any third party. Basically, according to its Article X, the operator shall have a right of recourse only "if this is expressly provided for by a contract in writing". Consequently, if a claim for damages is filed directly against such a third party, such claim should be basically dismissed by the court[59].

The justification for the channelling of liability onto the operator is that it simplifies and, therefore, expedites actions for damages brought by victims. It is further said that channelling also "secures as far as possible a fair and equal treatment of all potential victims, and is therefore also advantageous for every single victim"[60]. However, as the Nuclear Energy Agency points out, it also "minimises the burden upon the nuclear industry as a whole, as the various persons who contribute to the operation of a nuclear installation, such as suppliers and carriers, do not require insurance coverage additional to that held by the operator"[61].

The ability to seek compensation recourse with parties other than the operator in the event of an accident would not only benefit the potential victims, but would also increase accountability and transparency and help ensure an adequate safety culture is adhered to across the supply chain. Furthermore, the channelling of liability restricts the number of avenues open to potential victims to seek recourse, and, with a large number of claims and limited funds available, may mean that those affected are unable to receive adequate compensation.

A liability regime and in some cases being a signatory to the international conventions are often a requirement for foreign participation in nuclear projects. For example, the European Bank for Reconstruction and Development, one of the few International Financial Institutions to lend for nuclear power, has a requirement that the government in which the project is located must have acceded to the Vienna Convention and have corresponding national legislation[62]. The US Export Credit Agency[63] only requires that "the host country must have a regime acceptable to ExIm Bank governing liability for nuclear damage"[64], rather than becoming party to a specific convention.

However, not all national regimes recognise the necessity for channelling liability. India's new nuclear law, of 2011, specifically allows nuclear operators to seek recourse in the event of "wilful act or gross negligence on the part of the supplier", while the existing laws in both Russia and South Korea allow operators to recover damages from suppliers in the event of negligence[65].

In other, non-nuclear, sectors the legal and economic ramifications are not restricted to the operator, as has been seen in the case of the *Deepwater Horizon* oil spill, where affected parties have sought compensation not only from BP, the operator of the rig, but also from the rig owner, Transocean, and from Halliburton, the supplier of cement for the well[66].

2.6 Other areas of contention

There are a number of gaps and restrictions in the current national and international liability regimes. One of the most important relates to the environment. The revised conventions have changed the scope of liability and include loss of life or personal injury, loss of or damage to property, economic losses, loss of income, cost of preventative measures and the cost of measures of reinstatement of impaired environment. On this last point, however, it has been noted that "almost all forms of environmental liability are currently uninsurable"[67]. This is said to be for a number of reasons, including that there is not direct economic interest in the environment, and it is, therefore, impossible to provide an "insurable interest"[68].

As well as issues around the definitions of damage, problems remain in the current conventions relating to the length of time that claims can be made. The 1963 Vienna Convention states (Article VI) that: "Rights of compensation under this Convention shall be extinguished if an action is not brought within ten years from the date of the nuclear incident." This was revised in the Joint Protocol so that in respect to loss of life and personal injury claims may be made 30 years from the date of a nuclear incident, and, with respect to other damage, 10 years from the date of the nuclear incident. The extension of loss of life and personal injury claim periods reflects the latency period of many radiation-induced illnesses; however, restricting all other potential claims to 10 years does not reflect the extent of possible secondary effects of radiation in the wider environment. However, even this revision is an area of concern for insurers as the industry's "loss history from so called 'long-tail' liability insurance (i.e. where insurance exposure is not extinguished after a period of a few years) has been poor and it continues to be a challenging environment"[69] as it can potentially require compensation decades after incidents which increases the economic risks.

The international conventions also act to make the courts in whose territory the nuclear accident occurred have exclusive jurisdiction. This, therefore, restricts the ability of potential victims in other countries to seek recourse in their own courts. This is one reason why "there is a clear perception among non-nuclear states that the Paris and Brussels conventions are balanced in favour of the nuclear industry"[70].

The ability to seek compensation recourse with parties other than the operator would also increase accountability and transparency, and help ensure an adequate safety culture.

Image: Greenpeace checks radiation levels in Iitate village, 40km from the Fukushima nuclear plant. Greenpeace has been conducting ongoing radiation monitoring in the Fukushima region since the disaster in 2011 to monitor and assess the ongoing threat to the population and environment.

2.7 Conclusion

The current national and international nuclear liability laws and conventions do not ensure that victims receive full and timely compensation, and that all liabilities are indeed covered in the event of a major accident.

The liability regimes do not ensure that utilities are able to meet their economic responsibilities to compensate and to "clean up" in the event of a major accident. Rather, the current regimes primarily serve to protect the industry – this includes operators as well as nuclear suppliers – and are discriminatory against potential victims and the environment.

The experiences of Fukushima, as well as academic studies, show that even the Japanese liability regime is highly inadequate and unjust, despite the unlimited and strict liability to the operator, primarily given the operator's limited financial security compared to the financial extent of the damage. This is explained in more detail in Chapter 1.

Following the Chernobyl nuclear accident, the reform of the international nuclear liability regimes was begun, but more than 25 years later very little progress has been made. What is remarkable is that nearly 27 years after Chernobyl, 16 years after the adoption of the CSC and nine years after the adoption of the 2004 Protocols to amend the Paris/Brussels conventions, those enhancements have not entered into force. As a result, the situation has not changed significantly.[71] Most importantly, only about half of the world's nuclear power plants are operating in states that are parties to one of the nuclear liability conventions. Furthermore, many of the proposed deficiencies acknowledged at the time of Chernobyl have not been addressed; as only the revised Vienna Convention has entered into force, with all other conventions remaining as they were prior to 1986. The full implications of this situation have not been adequately highlighted following Fukushima, in part due to limited transboundary contamination resulting from Japan's geographical isolation.

National governments, parliaments and nuclear operators should seek to reform their domestic legislation to include the following factors:

- The current ceilings on compensation to third parties affected by nuclear accidents, facilitated by the international regimes, will restrict potential victims and those affected by the accident gaining the necessary compensation and should be removed.
- The channeling of liability solely towards the operator is unnecessary and unreasonable. The ability to seek compensation recourse in the event of an accident would not only benefit the potential victims, but would also increase accountability and transparency in such an event and would help ensure an adequate safety culture was adhered too across the supply chain.
- Increase transparency into the costs and scope of utilities and nuclear companies nuclear liability insurance. This would enable comparison, both within the nuclear industry and between hazardous industries.
- Ensure adequate financial coverage. The lack of adequate financial coverage is a significant distortion of the electricity market. Other energy sources are required to make additional payments or pay higher taxes for the pollution or environmental damage they cause, for example for the costs of their emissions. Without state intervention, even large and previously financially viable utilities, such as TEPCO, would be unable to survive a major nuclear accident. A major nuclear accident, as a result of the extensive loss of confidence, revenues and reputation, would almost certainly bankrupt any private utility.
- There is a growing recognition that the financial impact of off-site radiological releases goes beyond those areas actually directly affected. In particular, the complex nature of manufacturing processes can mean that loss of a particular industrial plant has much wider economic implications due to disruption of components in supply chains. Furthermore, restrictions on agriculture produce or a fall in their value has been seen to occur well beyond the areas of initial contamination.

Table 2: Signatories on international conventions and their operator liability and financial security limits

Country	Paris Convention	Brussels Supplementary Convention	Vienna Convention	Protocol Amending Vienna Convention	Joint Protocol	Convention On Supplementary Compensation	Operator Liability	Financial Security Limited
Argentina			X	X		X	54.9	54.9
Armenia			X				-	Not Specified
Belarus			X	X			Unlimited	Not Specified
Belgium	X	X					297	324
Bolivia			X				Unlimited	Not Specified
Bosnia-Herzegovina							Unlimited	Not Specified
Brazil			X				USD 160 million	USD 160 million
Bulgaria			X		X		49	49
Cameroon			X		X		Unlimited	Not Specified
Chile			X		X		51	51
Croatia			X		X		44	44
Cuba			X				Unlimited	Not Specified
Czech Republic			X		X		307	307
Denmark	X	X			X		65	65
Egypt			X		X		Unlimited	Not Specified
Estonia			X		X		Unlimited	Not Specified
Finland	X	X			X		191	191
France	X	X					91	91
Germany	X	X			X		Unlimited	2,500
Greece	X				X		16	Not Specified
Hungary			X		X		109	109
India						x	252	Not Specified
Italy	X	X			X		5	5
Japan							Unlimited	920
Korea							325	30
Latvia			X	X	X		6	6
Lebanon			X				Unlimited	Not Specified
Lithuania			X		X		5	5
Macedonia			X				Unlimited	Not Specified
Mexico			X				Unlimited	Not Specified
Moldova			X				Unlimited	Not Specified
Montenegro			X				Unlimited	Not Specified
Morocco			X	X		X	Unlimited	Not Specified
Netherlands	X	X			X		340	340
Niger			X				Unlimited	Not Specified
Nigeria			X				Unlimited	Not Specified
Norway	X	X			X		65	65
Peru			X				Unlimited	Not Specified
Philippines			X				3	Case by case
Portugal	X						16	Not Specified
Poland			X	X			164	164
Romania			X	X	X	X	164	164
Russia			X				Unlimited	Not Specified
Serbia			X				Unlimited	Not Specified
Slovak Republic			X		X		75	75
Slovenia	X	X			X		164	164
Sweden	X	X			X		326	326
Switzerland	X						Unlimited	661
Turkey	X				X		16	Not Specified
Ukraine			X		X		164	164
United Kingdom	X	X					156	156
United States						X	11,900	300
Uruguay			X				Unlimited	Not Specified

Source: NEA (2011). Nuclear Operator Liability Amounts and Financial Security Limits. As of June 2011.
Amounts in € million, unless otherwise indicated.

1 Carroll, S. (2008) “Perspective on the Pros and Cons of a Pooling-type Approach to Nuclear Third Party Liability” Nuclear Law Bulletin 81 (2008)

2 Parts of this text are taken from “Nuclear Third Party Insurance The Nuclear Sector’s “Silent” Subsidy

State of Play and Opportunities in Europe”, by Simon Carroll and Antony Froggatt, March 2008

3 “Convention Supplementary to the Paris Convention of 29th July 1960 on Third Party Liability in the Field of Nuclear Energy“. http://www.iaea.org/Publications/Documents/Treaties/parisconv.html

4 “Vienna Convention on Civil Liability for Nuclear Damage”, adopted in 1963, see http://www.iaea.org/Publications/Documents/Infcircs/1996/inf500.shtml

5 “The Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention“, September 1988. The Joint Protocol entered into force on 27 April 1992. http://www.iaea.org/Publications/Documents/Infcircs/Others/inf402.shtml

6 INELX, “Civil Liability for Nuclear Damage: Advantages and Disadvantages of Joining the International Nuclear Liability Regime A paper by the International Expert Group on Nuclear Liability (INLEX) http://ola.iaea.org/ola/treaties/documents/liability_regime.pdf

7 Nuclear damage” means -

loss of life, any personal injury or any loss of, or damage to, property which arises out of or results from the radioactive properties or a combination of radioactive properties with toxic, explosive or other hazardous properties of nuclear fuel or radioactive products or waste in, or of nuclear material coming from, originating in, or sent to, a nuclear installation;

any other loss or damage so arising or resulting if and to the extent that the law of the competent court so provides; and

if the law of the Installation State so provides, loss of life, any personal injury or any loss of, or damage to, property which arises out of or results from other ionizing radiation emitted by any other source of radiation inside a nuclear installation.

8 “The 1997 Protocol to Amend the 1963 Vienna Convention“, see

http://www.iaea.org/Publications/Documents/Infcircs/1998/infcirc566.pdf;

the 2004 Protocol to Amend the 1960 Paris Convention see

http://www.oecd-nea.org/law/paris_convention.pdf; and

the 2004 Protocol to amend the 1963 Brussels Supplementary Supplementary Convention, see

http://www.oecd-nea.org/law/brussels-supplementary-convention-protocol.html

9 “1998 Convention on Supplementary Compensation for Nuclear Damage“, see

http://www.iaea.org/Publications/Documents/Infcircs/1998/infcirc567.pdf

10 The SDR is an international reserve asset, created by the IMF in 1969 to supplement its member countries’ official reserves. Its value is based on a basket of four key international currencies, and SDRs can be exchanged for freely usable currencies. (for more explanation see: http://www.imf.org/external/np/exr/facts/sdr.htm

11 McRae, B. (2007) “The Convention on Supplementary Compensation for Nuclear Damage: Catalyst for a Global Nuclear Liability Regime”, Nuclear Law Bulletin No. 79 (June 2007)

12 The specific formula of contributions to this fund is explained in Article IV of the CSC http://www.iaea.org/Publications/Documents/Infcircs/1998/infcirc567.pdf

13 IAEA (2012), “Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage“, 29 May 2012. http://www.iaea.org/Publications/Documents/Conventions/protamend_status.pdf

14 The Protocol to the Paris Convention and the Protocol to the Brussels Supplementary Convention were opened for signature on 12 February 2004, but neither of these instruments had entered into force.

15 OJ (2004), “Council Decision of 8 March 2004 authorising the Member States which are Contracting Parties to the Paris Convention of 29 July 1960 on Third Party Liability in the Field of Nuclear Energy to ratify, in the interest of the European Community, the Protocol amending that Convention, or to accede to it“, Official Journal of the European Communities, 2004/294/EC of 8 March 2004

16 Burges Salmon (2012), “Revised Energy Bill Published”, Nuclear Law Newsletter, Burges Salmon, December 2012 http://www.burges-salmon.com/Sectors/energy_and_utilities/nuclear/Publications/Nuclear_Law_December_2012.pdf

17 IAEA (2011), “Convention on Supplementary Compensation for Nuclear Damage”, 20th September 2011 http://www.iaea.org/Publications/Documents/Conventions/supcomp_status.pdf

18 The power in MW of an electricity generating plant may be expressed as MWe or MWt (alternatively MWth). MWe is the more common and represents the electrical output power of the plant. MWt is the thermal input power developed by the furnace or nuclear reactor. The output power MWe is generally only about 30% or 40% of the input power MWt. The operating capacities of the four countries are Argentina (935 MWe), Morocco (0 MWe), Romania (1300 MWe) and the United States (101 465 MWe).

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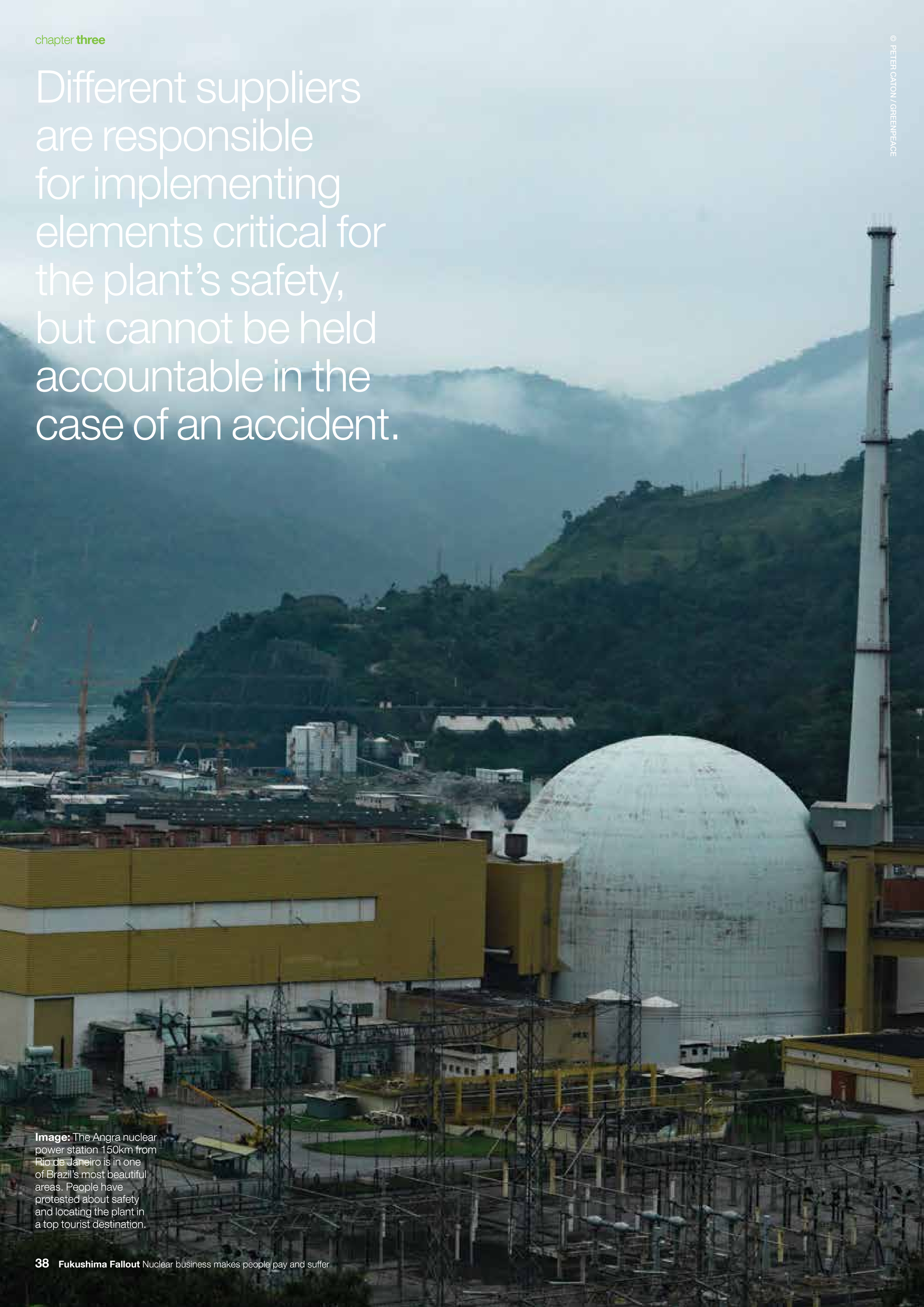


Different suppliers are responsible for implementing elements critical for the plant's safety, but cannot be held accountable in the case of an accident.

Image: The Angra nuclear power station 150km from Rio de Janeiro is in one of Brazil's most beautiful areas. People have protested about safety and locating the plant in a top tourist destination.

#3

The nuclear power plant supply chain

by Professor Stephen Thomas

Professor Stephen Thomas is Director of Research at the Business School of the University of Greenwich, UK, and he has carried out research on energy policy and particularly nuclear power for more than 30 years.

3.1 Introduction

This chapter examines the supply chain for each of the three main elements – construction, operation and maintenance, and decommissioning – of the life cycle of a nuclear power plant. It covers mainly the construction phase, which is the most complex, and also covers the operating phase, which is somewhat simpler. These are the reactor life cycle phases most likely to result in damages and liability issues in the near future that could be traced back to the suppliers of the equipment, materials and services. The decommissioning phase and long-term waste disposal are covered only briefly (see Box 1) because there is little commercial experience of decommissioning and the field of companies involved is not well established. Also decommissioning and waste disposal are less likely to result in short-term damage and liability issues, even though waste disposal in particular can cause damages for future generations.

A nuclear power plant is, on a number of criteria, very different to any other piece of industrial equipment. Its unique features include:

- **Safety requirements**. A failure at any stage in the life cycle of a nuclear power plant from start of construction to completion of decommissioning could have catastrophic consequences far beyond the bounds of the plant.
- **Cost**. The cost of a new nuclear power plant is in the order $10bn US dollars. The cost of decommissioning a plant is not well established because there is little if any representative experience of fully decommissioning a full-size commercial plant, and many of the key operations required – for example, robotic cutting up of highly contaminated materials – have not been demonstrated.
- **Plant lifetime**. The time from start of construction (typically 5-10 years to reach commercial operation), through operation (typically expected to be 40-60 years) to completion of decommissioning (expected to be up to 100 years from end of operation to release of site for unrestricted use) could be in excess of 150 years. In addition, the highly radioactive waste produced in a nuclear power plant will need to be safeguarded for hundreds of thousands of years.
- **Complexity**. A nuclear power plant comprises a vast number of components and materials, many of which are critical for safety and reliability. Many parts of the plant are difficult to access once the plant has been commissioned, and checking build quality or making modifications may be effectively impossible.

Box 1

Decommissioning

Decommissioning is the least proven of the three stages in the life cycle of a nuclear power plant. It is conventionally divided into three phases with periods of surveillance and storage in between.

Phase 1 mainly involves the removal of the spent fuel, which is dealt with under the second (O&M) stage. This is an operation that has been carried out throughout the life of the plant and is, therefore, technologically well proven. Once the fuel has been removed, the vast majority of the radioactivity has been removed from the plant and the plant no longer needs to be staffed as for an operating reactor because there is no longer any risk of a criticality. There is, therefore, an incentive to complete this operation quickly. Even though the vast majority of the radioactivity is in the fuel, the remaining structure is very hazardous and exposure to it would be damaging to health.

Phase 2 involves the removal of the uncontaminated structures, leaving mainly the reactor. This is essentially a normal demolition job and is not therefore technologically novel. There is no particular incentive to carry out the job quickly, although once it is done, the remaining plant is much cheaper and easier to monitor because the contaminated components can be sealed off and made largely inaccessible.

Phase 3 involves the cutting up and disposal of the contaminated structures. It is likely to require robotic techniques, not yet proven, and will generate a significant quantity of radioactive waste. There is little representative experience of phase 3, involving a full-size reactor that has completed a full operating life (those retired early will be much less contaminated and, therefore, easier to decommission).

The International Atomic Energy Agency identifies three strategies for decommissioning: immediate dismantling; “safestor” (enclosure for several decades prior to phase 3); and entombment.[1] The third, which involves covering over the plant, does not appear to be an option that any country has adopted.

In Europe, France, UK, Italy and Spain have not started phase 3 at any of their retired plants. Only Germany has experience of phase 3, mainly at the five reactors in former East Germany at the Greifswald site.

In the US, 22 commercial reactors have been retired and of these 12 are using the ‘safestor’ approach and, therefore, have no experience of phase 3. Of the 10 going for immediate dismantling, only seven are commercial-size reactors (>100MW) and most of these had not operated for a full life, so commercial experience is minimal.[2]

- **Need for user skills**. The reliability and safety of a nuclear power plant depends crucially on the user (i.e. the operator) providing exceptionally high-quality skills for operations and maintenance, and for managing contractors involved in construction, maintenance and decommissioning.
- **Large amount of site work**. Most of the cost of construction of a nuclear power plant is incurred at the site, and relatively little in the more controlled environment of a factory. This provides a particular challenge for the management of the construction process.

The utility (owner/operator) bears ultimate responsibility for a plant. International conventions (the Paris and Vienna Conventions and the Paris/Brussels protocol) channel liability for third-party damage to the operator of a plant, and limit the liability of the operator to an amount (on the order of $1bn) that is very small in comparison with the potential costs of a major accident.[3] In general, under these conventions suppliers responsible for design, construction and maintenance of a nuclear plant cannot be held liable for damages arising from their work.

Only in India has supplier liability been a particular issue of debate, resulting in the Civil Liability for Nuclear Damage Act, 2010. The Act places responsibility for any nuclear accident with the operator and limits total liability to 300 million Special Drawing Rights (SDR) (about €300m). However, the Act allows the operator to have legal recourse to the supplier for up to 80 years after a plant starts up if the "nuclear incident has resulted as a consequence of an act of a supplier or his employee, which includes supply of equipment or material with patent or latent defects [or] sub-standard services". This potential supplier liability may mean orders for nuclear power plants for India from foreign suppliers will not be commercially feasible.[4]

Details of the nuclear liability conventions and laws and their implications on the nuclear sector are covered in Chapter 2[5]. It is clear that the current nuclear liability conventions protect the industry by excluding supplier liability from the financial consequences of a nuclear accident, and by limiting liability for operators. No other industry enjoys this level of protection from the consequences of its actions.

This chapter explores the involvement of suppliers throughout the lifetime of a nuclear reactor, and their responsibilities in terms of nuclear risks. Risks of nuclear accidents are not only caused by the reactor operation, but design choices and construction quality are also of critical importance. For example, as was clearly demonstrated by the Fukushima disaster, the characteristics of a nuclear site need to be accurately assessed so the plant can be designed and built to resist any credible conditions such as earthquakes, flooding etc.

3.2 Construction

The construction of a nuclear power plant can be divided into three main categories of activity:

- design, engineering and procurement;
- supply of equipment (e.g. the reactor vessel), raw materials (e.g. steel and concrete) and basic goods (e.g. cabling and pipework); and
- management and execution of on-site construction (civil engineering).

A breakdown of the construction cost of a nuclear power plant, a Pressurised Water Reactor (PWR), is shown in Table 3. The PWR is the most widely used design in the world. This example relates to a Russian PWR reactor design called VVER. Different technologies, such as the other main design, the Boiling Water Reactor (BWR), will have a somewhat different breakdown of costs, as will other vendors' designs of a PWR, but this breakdown will be reasonably representative of other designs and vendors. What exactly is included in each category is not clear. For example, it is not clear what category architect engineering falls into: design of the overall design, excluding the nuclear steam-supply system[6] (NSSS), or the supply of the reactor vessel. However, the key points are that the design and supply of the NSSS represents only a small fraction, about 15%, of the cost of a plant. The cost is dominated by on-site engineering, such as construction, cabling, and installation.

Nuclear Engineering International's Yearbook provides a somewhat different breakdown of the elements, and for each reactor, names the supplier of the service. Table 4 illustrates the diversity of arrangements for a range of nuclear power plants. It shows five plants ordered in different eras, in different countries and under different procurement philosophies. The owner is generally the operator of the plant. Where a plant is owned by more than one company, one is designated as the operator of the plant or a special company is set up to operate the plant (e.g. Borssele, the Netherlands). The main contractor is normally known as the vendor and these are well-known names with a long history in the nuclear sector. However, sometimes ownership

Table 3: Cost breakdown of a nuclear power plant

Activity	% of plant cost	Possible supplier
Reactor design	?	Vendor
NSSS supply	15	Vendor, specialist suppliers
Architect engineering	?	Vendor, architect engineer, utility
Civil engineering	50	Civil engineer, utility
Electrical equipment	9	Specialist supplier
Turbine generator	6	Specialist supplier
Valves	6	Specialist supplier
Instrumentation & control	6	Vendor, specialist supplier
Other equipment	5	Specialist suppliers
Cooling	3	Specialist suppliers
Fuel	?	Vendor, specialist supplier

Source: S Boyarkin 'Presentation to the 7th Energy Forum' Eastern Institute, Sopot, Nov 29-30, 2012

Table 4: Suppliers of services for selected nuclear power plants.

	Fukushima 1	Columbia	Shin Kori 4	Dampierre 1	Borssele	Doel 3
Country	Japan	USA	Korea	France	Netherlands	Belgium
Year of order	1966	1971	2007	1973	1969	1974
Commercial operation	1971	1984	2014	1980	1973	1982
Owner	Tokyo Electric	Energy NW	KHNP	EDF	Essent/Delta	Electrabel
Operator	Tokyo Electric	Energy NW	KHNP	EDF	EPZ	Electrabel
Main contractor	GE	GE	Doosan	Framatome	KWU	Framaceco
Architect engineer	GE	Burns & Roe	KOPEC	EDF	KWU	Tractebel
Reactor system	GE Getsco	GE	Doosan	Framatome	KWU	Framaceco
Reactor vessel	IHI GE Getsco	CB&I	Doosan	Framatome	RDM	COP/Fram
Core internals	GE	GE	Doosan	Framatome Creusot	Borsig	Fram/ACE
First fuel	GE	GE	KNF	FBFC/Fram	KWU	FBFC/Fram
Steam raising	GE, Getsco	GE	Not known	Framatome	Balcke	COP
Turbine generator	GE	Westinghouse	Doosan	Alsthom	Siemens	Alsthom/ ACEC
Civil engineering	GE, Getsco	Bechtel	Not known	GCMB	Bredero	AMGC

Source: Nuclear Engineering International (2011). World nuclear energy handbook. Global Trade Media.

changes and capabilities move. For example, the main contractor for Doel 3 (Belgium) was formed by a consortium of Framatome (France, later known as Areva), ACEC and Cockerill. Neither of the latter two companies now exists in anything like their form when the plant was ordered.

A series of five plants ordered by the Washington Public Power Supply System became so notorious for cost overruns that only one of the five plants – the Columbia power plant – was actually completed. The owner's philosophy was dominated by competition considerations and all activities possible were put out to competitive tender. By comparison, the Korean plant, Shin Kori 4, was supplied by a much tighter supply chain, dominated by the utility, Korean Hydro & Nuclear Power Company (KHNP) and the main equipment supplier and vendor, Doosan with other services supplied by Korean "national champion" companies such as Korean Nuclear Fuel (KNF) and Korean Power Engineering Company (KOPEC). A similarly concentrated picture would apply for plants built in France. In the Netherlands, the Borssele plant was supplied by KWU (Germany), a company dominated by Siemens, which specialised in design rather than equipment supply, with the notable exception of the turbine generator. The Doel plant was ordered before the French nuclear power plant supply industry had been fully established so the equipment and services came from a wide range of suppliers, most of which do not now exist in anything like their form then.

3.2.1 Design, engineering and procurement

The design, procurement and engineering activities can be split into three roles: the reactor vendor, the architect engineer (A-E), and the engineering, procurement and construction (EPC) contractor. The boundaries between these roles are sometimes blurred, and there is overlap between the set of companies involved. For example, a reactor vendor like Mitsubishi could carry out all three activities, while Bechtel could be the A-E and the EPC contractor. The supply of the first fuel charge is conventionally included in the construction cost, but the suppliers are the same as those involved in supplying new fuel during the life of the plant and are considered in the Operations and Maintenance (O&M) section.

3.2.1.1 Vendors

The vendor market in its current form was largely set by 2006 when the Westinghouse (based in US) nuclear division was taken over by Toshiba (Japan). The world market, which by then was, and remains, extremely small, was dominated by three established companies with markets in the West: Toshiba, supplying PWR and BWR technology; Areva (France), supplying PWR and, potentially BWR technology; and Hitachi-GE supplying BWR technology. Three further suppliers, Atomstroyexport (ASE, Russia), supplying VVER (the Russian version of the PWR) technology; China, supplying PWRs; and Korea, supplying PWRs are now an increasing presence on the world market. Atomic Energy of Canada Ltd (AECL), now privatised and owned by the Canadian company SNC Lavalin, and Mitsubishi continue to offer plants but with limited chance of success. India supplies its home market with scaled-up versions of the Canadian-designed CANDU reactor it imported in the 1960s, but there appears no prospect of it being able to export these designs. China is the most complex and potentially the most significant of the new suppliers, and it is dealt with separately. Table 5 gives an overview of the designs available and their status.

Toshiba

In 2006, Toshiba bought the Westinghouse reactor division from British Nuclear Fuels Limited, a publicly owned nuclear company. By then, Westinghouse included the reactor supply divisions of Combustion Engineering (US) and ABB (Switzerland/Germany/Sweden), which was formed from the merger of the reactor divisions of Brown Boveri and Asea. Up to that time Toshiba (and its Japanese competitor Hitachi) had BWR technology licences with GE, and orders for Japan were split between Hitachi and Toshiba. Another design, Advanced Boiling Water Reactor (ABWR) technology, was jointly developed by GE, Hitachi and Toshiba. Toshiba ended its licence agreement with GE, and is now offering ABWR technology in competition with Hitachi-GE.

Toshiba's ABWR has been chosen for the US South Texas project, although it is unlikely that this project will proceed. The ABWR received approval from the US regulator, the Nuclear Regulatory Commission (NRC), in 1997, which expired in 2012. Toshiba applied for the approval to be renewed in 2010, and has submitted proposed design modifications so that the design meets current standards, but approval has not been given yet. In January 2013, there was no NRC target date for completion of this review.

The other main design Toshiba offers apart from the ABWR is the AP1000, already under construction in China (two each at Haiyang and Sanmen) since 2009, and first concrete is expected in 2013 for reactors in the US (two each at Vogtle and Summer).

In December 2012, Toshiba announced it was seeking to sell a 36% stake in its Westinghouse division. It was reported that three companies, including Chicago Bridge and Iron Company (CBI) — a Dutch-owned company based in the US — were interested in purchasing a 20% stake, and three other companies were interested in a 16% stake. Toshiba was reported to be expecting ultimately to retain only a 51% stake in Westinghouse.[7]

Areva

Areva NP was formed in 2002 from the nuclear divisions of Framatome and Siemens. Framatome was by then part of the Areva group, largely owned (92%) by the French government. Areva (66%) and Siemens (34%) merged their reactor supply businesses to form a joint venture, Areva NP. In 2009, Siemens announced its intention to withdraw from this joint venture and Areva NP is now wholly owned by Areva. It offers the European Pressurised water Reactor (EPR), the Atmea1 design (in a joint venture with Mitsubishi, Atmea) and potentially, the ACPR1000 in joint venture with CGNPC (China). It is also offering a BWR design, Kerena, although this is not available for purchase yet.

Table 5: Current Generation III/III+ designs on offer.*

Vendor	Design	Sales	Generic review
Toshiba/Westinghouse (Japan/US)	AP1000 (PWR)	USA (2), China (4)	US complete 12/11. UK process suspended
Toshiba/Westinghouse (Japan)	ABWR (BWR)	Earlier model to Japan (4)	US approval expired 2012. Renewal applied for 10/10. No completion date specified
Hitachi GE (Japan/US)	ESBWR (BWR)	-	US awaiting final rule-making
Hitachi GE (Japan/US)	ABWR (BWR)	Earlier model to Japan (2), Taiwan (2)	US approval expired 2012. Renewal applied for 12/10. No completion date specified
Areva (France)	EPR (PWR)	Finland (1), France (1), China (2)	UK approval 2013 US approval 2014
Areva (France)	ATMEA1 (PWR)	-	Not started
Areva (France)	Kerena (BWR)	-	Not started
ASE (Russia)	AES-92	India (2)	Not known
ASE (Russia)	AES-2006	Russia (5), Turkey (4), Vietnam (4)	Not known
Mitsubishi (Japan)	APWR	-	US approval 2015
Korea	AP1400	Korea (3), UAE (4)	Not started
AECL	Enhanced Candu 6	-	Not started

Source: Author's research.

** The nuclear industry has been developing nuclear technology for decades. Generation III and III+ designs are allegedly improvements on the Generation II deisgn, but the distinction from Generation II is arbitrary. Generation II, the most common design, was developed in the 70s and 80s, Generation I in the 50s and 60s.*

Box 2

The UAE nuclear order from Korea

In December 2009, the UAE ordered from Korea four nuclear reactors using AP1400 technology, beating opposition from consortia led by EDF (including GDF Suez, Areva, Total) with the EPR and GE-Hitachi (ABWR).[14] The contract is with the Korea Electric Power Corp (KEPCO) to build and operate the plants, the first coming on line in 2017 and the last by 2020. KEPCO will provide design, construction and maintenance for the nuclear reactor and will subcontract some of the work to equipment suppliers such as Hyundai, Doosan and Samsung. The terms of the deal and what is included are not clear although the contract is reported to be worth $20.4bn US dollars. The Korean bid was reported to be $16bn lower than the French bid, and the GE-Hitachi bid was reported to be significantly higher than the French bid.[15] It appears not to be a whole project "turnkey" (fixed price) deal. Korean companies will hold an equity stake in a joint venture with UAE public companies, which will operate the plants after their completion. Construction work on the first of these at the Barakh site started in July 2012.

Other export markets Korea has competed in, so far unsuccessfully, include Turkey and Jordan. The design being built in Korea and UAE, without a "core-catcher" and a "double containment", probably would not be licensable in Europe. Areva was particularly bitter about losing the tender to a design it claimed had much lower safety standards than their EPR. Their then CEO, Anne Lauvergeon, likened the APR1400 to "a car without seat belts and airbags".[16] Nevertheless, UAE's newly formed Federal Authority for Nuclear Regulation (FANR) has required changes to the reference design (the South Korean plants Shin Kori-3 and -4) to reflect the lessons from Fukushima. It had not been determined by September 2012 who would pay these extra costs.[17]

Some of the finance for the UAE project came from the US ExIm bank on the basis of the benefits to the Westinghouse company (owned by Toshiba), now owner of the technology licence following the absorption of the Combustion Engineering nuclear division into the Westinghouse reactor business, even though this is now owned by Toshiba. Westinghouse will provide the reactor coolant pumps, reactor components, controls, engineering services, and training.[18] The ExIm bank provided a $2bn direct loan to the Barakah One Company of the UAE to underwrite the export of American equipment and expertise. There is a lack of clarity over the ownership of Barakah One.[19] The partners in the project are KEPCO and Emirates Nuclear Energy Corporation (ENEC). KEPCO is entitled to take a share of ownership in the Barakah plant but, by September 2012, it was not clear whether they had taken one.

Hitachi-GE

After the take-over of Westinghouse by Toshiba and its emergence as a competing supplier of BWR technology, GE and Hitachi set up joint ventures in 2007. GE-Hitachi, 60% GE, 40% Hitachi, covers its US operations and Hitachi-GE, 80% Hitachi, 20% GE, for the rest of the world[8]. Both joint ventures market their BWR designs, the Economic Simplified Boiling Water Reactor (ESBWR) and the ABWR.

The ESBWR is a passive-safety design that was reportedly near completion of its regulatory review in the US in 2012. However, there was a delay and it is not clear when final approval will be given.[9] While there was some interest among US utilities, none of them appear likely to proceed and one switched to the older ABWR design supplied by Toshiba.

The ABWR received approval in 1997 from the US regulator, the NRC, which expired in 2012. Like Toshiba, Hitachi-GE applied for the approval to be renewed in 2010, and has submitted proposed design modifications so that the design meets current standards, but approval has not been given yet. In January 2013, there was no NRC target date for completion of this review. Hitachi-GE was chosen as the preferred supplier for a reactor to be built in Lithuania, but an order now seems unlikely after a referendum on nuclear power in October 2012 came down decisively against it.[10] In 2012, Hitachi-GE bought Horizon, a joint venture set up by two German utilities, RWE and EON, to build nuclear power plants in the UK.[11]

KEPCO/Doosan

After buying plants from Westinghouse, Framatome and AECL, the Korean nuclear industry (made up of the utility, Korean Electric Power Company and the equipment supplier Doosan) began to take a larger part in nuclear orders for Korea using Combustion Engineering technology. Initially they used an old design, System 80, which evolved into their OPR (Optimised Power Reactor) of 1,000 megawatts (MW) with 12 orders for Korea. The later Combustion Engineering System 80+ design received generic approval from the NRC, US regulatory authority, in 1997 (this expired in 2012) and the Korean nuclear industry bought a technology licence for this design from Westinghouse.

For the future, the most important Korean design is the AP1400 derived, under licence from Combustion Engineering, from the System 80+ design. The licence now resides with Toshiba/Westinghouse, although they are no longer marketing the design. Construction work in Korea on the first two units of this design (Shin-Kori 3 & 4) started in 2009. Construction on a third (Shin-Ulchin) started in 2012. Korea emerged as a potentially significant exporter of nuclear technology with its winning of a competitive tender in UAE in 2009 (see Box 2). In 2010, Korea claimed it would submit the AP1400 to the US NRC for generic design review in 2012.[12] By November 2012, the target date for submission was March 2013.[13]

AtomStroyExport (ASE)

After nearly two decades of limited marketing effort following the Chernobyl disaster, the Russian nuclear industry began to compete aggressively in export markets with its VVER technology, buoyed by the resumption of ordering in Russia. Since 2007, construction of seven new reactors has started in Russia, five using ASE's latest design, AES-2006, and two using an earlier design. For some markets, such as Jordan, it is offering the earlier AES-92, already built in India (Kudankulam) which was awaiting commercial operation in January 2013.

Atomic Energy of Canada Ltd (AECL)

Atomic Energy of Canada Ltd continued to win a trickle of orders for its CANDU reactors from 1980 onwards, for example in China and Korea, although both countries seem to have abandoned further orders of the CANDU. With no orders for its home market for 30 years and limited future prospects, AECL, previously owned by the Canadian federal government, was sold to the Canadian engineering company SNC Lavalin for a minimal amount ($15m Canadian dollars) in 2011.

While it still appears in bidding lists, for example to Jordan and Romania, the prospects of further orders are limited and the technologies it offers are based on designs first offered more than 35 years ago. It appears to have abandoned or at least put on ice its new generation designs, the ACR700 and ACR1000.

Mitsubishi

After the purchase of the Westinghouse reactor business by its Japanese competitor, Toshiba, in 2006, continuing a relationship with Westinghouse was not viable for Mitsubishi and it began to market reactors independently, initially its APWR design. This had been under development since 1980 but promises of orders for Japan had not been fulfilled. Two planned orders (Tsuruga) have been continually delayed and may not proceed after the Fukushima disaster. Further modifications were undertaken and the APWR (1,700MW) began the process of generic review by the NRC in 2007. In 2012, the NRC was forecasting completion of the review in 2015, but the one US utility, Luminant, interested in the design is not close to ordering the two units (Callaway) it plans.[20] The joint venture, Atmea, between Mitsubishi Heavy Industries and Areva was announced in 2007, when they stated that a 1,000MW design, to be called Atmea1, would be developed using technology from both companies. By 2012, there was some interest in this design from markets such as Jordan, Turkey and Argentina, but the detailed design work had not started in 2012 and the design has not started a generic review anywhere yet. Until such a review is complete, exporting will be difficult.

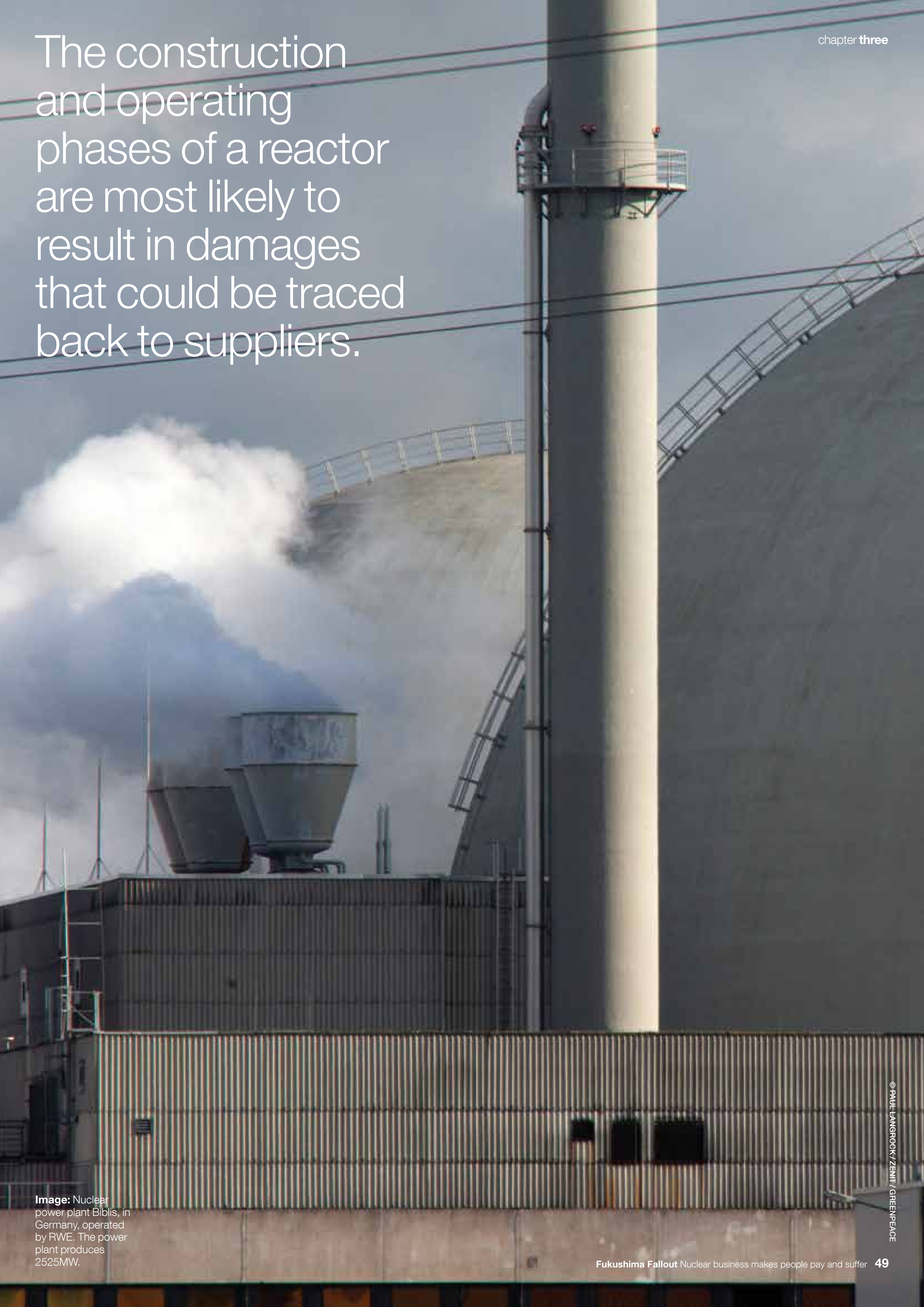
China[21]

China is potentially the most important new vendor to emerge on the world reactor market. After nearly two decades of ambitious forecasts of nuclear ordering not being achieved, China began to order large volumes of plant in 2008. From 2008-10, construction was started on 25 units. Of these, 19 were supplied by Chinese vendors, 15 using the CPR1000 design and two using the similar CNP1000 design and two using the smaller CNP600 design. It also imported four reactors from Toshiba/Westinghouse (AP1000) and two from Areva (EPR), with strong technology-transfer provisions. Its older CNP300 and CNP600 designs appear to still be available. Construction was started on two export orders to Pakistan for the CNP300 design in 2011 and construction on two CNP600 reactors in China was started in 2010.

Table 6: Chinese-designed reactors

Vendor	Design	Intellectual property	Sales	Markets	Status
CGN	CPR1000	Licensed from Areva	18	China	Still available
CGN	ACPR1000	Joint development with Areva?	0	China +	Not licensed
CNNC	CNP300	Indigenous	5	Pakistan, China	Still available
CNNC	ACP300	Indigenous	0	China +	Not licensed
CNNC	CNP600	Indigenous	6	China	Still available
CNNC	ACP600	Indigenous	0	China +	Not licensed
CNNC	CNP1000	Licensed from Areva	2	China	Development stopped
CNNC	ACP1000	Indigenous	0	China +	Not licensed
SNPTC	CAP1400	Joint development with Westinghouse	0	China +	Not licensed

Source: Author's research.



The construction and operating phases of a reactor are most likely to result in damages that could be traced back to suppliers.

Image: Nuclear power plant Biblis, in Germany, operated by RWE. The power plant produces 2525MW.

There is considerable development, not covered here, of fuel-cycle activities and Chinese companies have been active buying uranium resources, for example, in Kazakhstan. The programme to develop high-temperature reactors in China (using the German pebble bed design) was resumed in January 2013 after a delay following the Fukushima disaster with start of construction of a 200MW demonstration plant at Shidao Bay but this design is some way from commercial deployment.[22]

Fast-reactor designs are also being developed but do not appear to be close to commercial deployment, or a high priority, and are also not discussed further. For the future, the most relevant designs are Chinese designed PWRs, the AP1000 and the EPR. Table 6 shows the status of the designs already built and proposed for China.

The future world market for vendors

The so-called "nuclear renaissance", first talked about more than a decade ago, was expected to see a revival of nuclear ordering in the West, based on new reactor designs offered by the traditional Western vendors, for example, Areva's EPR, Westinghouse's AP1000 and GE's ESBWR. This surge of orders in the West has not happened and the reactor market, in terms of vendors and designs, is dramatically different to that of only a decade ago. The main changes include:

- Increased control of the main vendors by Japanese companies. Westinghouse was taken over by Toshiba; Toshiba has split from GE and is now competing against it for BWRs; Hitachi seems to dominate the joint ventures with GE for sales of BWRs; Mitsubishi is trying to establish itself as a frontline vendor through its APWR and through its Atmea joint venture with Areva;
- Before the Fukushima disaster, Japan seemed poised to make a major effort for the first time to enter the international market with much stronger coordination and support from the Japanese government, for example, with loan guarantees. If this support is not maintained, it is not clear how successful Japanese companies will be in winning exports;
- China, with its complete supply chain, has emerged as a potentially important vendor although, until China resumes ordering reactors following its halt on orders after the Fukushima nuclear disaster, it will not be clear which technology/technologies will be offered. The options include: the EPR and AP1000 under licence, the CAP1400 jointly with Westinghouse; a 1,000MW design, yet to be defined jointly developed with Areva[23]; or indigenous designs, the ACP1000 and ACPR1000;
- Korea has emerged as a global vendor of nuclear power plants with the winning of a large order for its AP1400 for UAE;
- Russia has moved outside its traditional markets of Eastern Europe and former Soviet Republics to markets in developing countriess, such as Vietnam. It would also like to get a foothold in the West, for example, via entry to the UK market;
- India remains a potentially large market for reactors and has a reactor supply industry but seems a long way from being able to compete on international markets.

Shifting of roles

A key issue in reactor orders is the availability of finance and it is now clear that, unless there is a strong and credible guarantee that full cost recovery from consumers will be possible, reactor orders will only be possible with state, or state-backed finance. Vendors seem, for the first time, willing to take equity stakes in reactors. Examples include Russian companies in Turkey, Hitachi-GE in Lithuania, Chinese companies in the UK, Areva in the UK and Korean companies in the UAE. This further blurs the line between operators and suppliers, raising additional questions about who carries responsibility and could be held liable in case of accidents. It remains to be seen whether vendor ownership of operating plants is a viable business model. As was demonstrated by the collapse of British Energy in 2002, when a fall in the wholesale electricity price led to it reportedly losing £2m a day,[24] electricity generation is a huge cash flow business and if a project goes badly, even a large vendor would be in serious difficulties.

In Russia, the Turkish Akkuyu project for four reactors of Russian design will be a Build-Own-Operate (BOO) deal, the first time this model has been used for a nuclear plant. The company that will own the plant is a Russian consortium dominated by the Russian reactor supply company, Rosatom (92.85%) with minor holdings from Inter RAO (the Russian utility) and AtomStroyExport.[25]

The Russian consortium is arranging financing of the project, backed by a 15-year Power Purchase Agreement (PPA) with Turkey's state electricity wholesaler Tetas, for around half the total output — 70% of the first two Akkuyu units and 30% of the second two. The power is to be sold at a weighted average price of $123.5/MWh, with a ceiling of $153/MWh.[26] If construction costs overrun or if operating costs are higher than expected, the Russian owners could lose large amounts of money. Where PPAs become uneconomic, the plant owners have typically tried to renegotiate the terms, shifting the risk to consumers.

In Lithuania, Hitachi-GE was expecting to take 20% of the Visaginas plant comprising one ABWR. Lithuania was expected to take 38% and Latvian (22%) and Estonian (20%) were expected to take the rest of the equity.[27] However, a referendum in October 2012 before the agreement was finalised was decisively against the project, and there seems little prospect it will now go ahead. It is therefore not clear whether the proposed model was viable.

In the UK, Hitachi-GE bought Horizon, a joint venture set up by two German utilities, RWE and E.ON, to build nuclear power plants in October 2012.[28] However, before Hitachi-GE can build in the UK, the ABWR will have to go through the UK's Generic Design Assessment process, likely to take about five years. So it is too early to say what the form of Hitachi-GE's involvement in the UK would be. Russian and Chinese companies and Areva were also reported to have bid for Horizon.[29]

3.2.1.2 Architect engineering

The role of architect engineering (A-E) is particularly prominent in the US where, in the past, utilities have not had the size and capability to design power plants of all types, and used specialist architect engineers to integrate the elements of a nuclear power plant into an overall design. Most utilities had long-term relationships with their favoured A-E, which in turn might tend to use the same equipment vendor, and nuclear power plants were built using the same model. Some of the larger utilities, like the Tennessee Valley Authority (TVA), did their own A-E but for those that did not, about a dozen A-Es were involved in the US nuclear power programme.[30] Some of these are still active, such as Bechtel, while others have exited the business, for example Stone & Webster.

The lack of standardisation among US plants and cost overruns are often blamed on the A-E, which generally has no incentive to use standardised designs and in some cases, simply produced poor designs.

In some cases, the vendor takes this role, for example Siemens or Areva, while in others the utility takes the role, for example EDF. One of the factors behind the problems at the Olkiluoto plant in Finland (see 3.2.4) is often said to be Areva's inexperience in this role[31].

3.2.1.3 Engineering, procurement, construction (EPC) contractors[32]

The EPC role of overall project management has become more prominent as attempts are made to introduce nuclear power into markets in smaller or less developed countries where the utility may have limited capability and the industrial base is not very strong. An effective EPC contractor is likely to need strong skills in project and construction management in the nuclear industry and from other complex projects, as well as good skills in procurement to ensure the complex supply chain is well managed.

The field of companies involved in EPC include utilities such as Korean Hydro and Nuclear Power Co (not only for plants to be owned by themselves), architect-engineers such as Bechtel, specialist nuclear companies such as AtomTechnoProm and nuclear vendors, although this is not common.

3.2.2 Equipment and materials supply[33]

The World Nuclear Association (WNA) portrays the supply chain as a pyramid with six tiers and it gives two examples of this chain.[34] From the bottom, these tiers are:

- Raw material suppliers and miners (e.g. silver, zinc etc);
- Processors/fabricators (e.g. alloys);
- Sub-component suppliers/distributors (e.g. control rods and heavy forgings);
- Original equipment manufacturers (e.g. rod cluster control assembly);
- System integrators (e.g. reactor pressure vessel and steam generator);
- Technology vendor, supplier of the nuclear steam-supply system (NSSS).

A nuclear power plant contains millions of items, each with its own supply chain.

The major discrete items of equipment in a nuclear power plant are: the turbine generator; the reactor pressure vessel; the containment structure; the reactor internals and reactor pumps; and valves. All these items must be specifically designed for nuclear power plants.[35] The discrete items of equipment can be divided into three categories according to how safety-relevant they are, and to how specific they are to a particular reactor design:

- Nuclear industry-grade components specific to the reactor design (e.g. the reactor pressure vessel);
- Nuclear industry-grade components not specific to the design (some valves and pumps); and
- Commercial-grade components (e.g. the turbine generator).

The nuclear industry-grade components specific to the reactor design are nearly all in the nuclear island — the reactor area where systems producing heat, through nuclear reaction, deliver heated water to the conventional island, where electricity is produced. The nuclear industry-grade components not specific to the design are found in the nuclear island, the conventional island and in the balance of the plant. The commercial-grade components are mostly in the conventional island and the balance of the plant, although there are important items, such as cranes and electrical power systems, in the nuclear island. This means that major systems comprise items of differing grade, supplied by many different suppliers.

Items of safety significance generally have to be produced in a facility that has been certified as meeting the required standards by a credible authority. For example, in the US, facilities have to be given approval by the American Society of Mechanical Engineers (ASME). Setting up production facilities was, therefore, a major commitment for a component supplier.

In the main period of nuclear ordering in the 1970s in the US and from 1975-85 in France, vendors and suppliers had a sufficient volume of orders to set up production-line facilities, but as ordering rates have fallen, components have to increasingly be fabricated on a one-off basis, increasing their cost. Regulation and certification by, for example ASME, should ensure the quality is equivalent.

Design-specific nuclear industry-grade components will generally have to be produced in production facilities designed to produce that specific item. When designs change, the facilities supplying the equipment likely will also change. This means that even when there is a large and reasonably assured design for nuclear power plants, as for example in China, the supply chain may still not be adequate if the design to be used has not been decided. If the design changes, the supplier will have to make major investments in production facilities.[36] For US, European and Japanese vendors, where it is not clear there is a substantial market for any of their designs, it will be a major risk for equipment suppliers to invest in production facilities.

3.2.2.1 The nuclear reactor

The reactor itself is a hugely complicated piece of equipment whose supply is the sole responsibility of the vendor, who will sub-contract individual parts to specialist contractors. It comprises a reactor pressure vessel, its internal structures (such as the reactor core shield) and immediate auxiliary hardware (such as the driving mechanism for control rods). The reactor is surrounded by other vital devices and components, such as primary cooling pipes, coolant pumps, pressuriser, injector of boron, and in most designs also steam generators that separate the primary circuit from a secondary one.

3.2.2.2 The reactor vessel

The reactor vessel is perhaps the most extreme example of a nuclear-specific component (see Box 3). Production requires highly specialised skills and facilities, in particular ultra-heavy forging presses. In 2012, there was reported to be only one supplier, Japan Steel Works, which had a capacity of three vessels a year (see Box 3), to supply the pressure vessel for an EPR. The World Nuclear Association[43] reported there were nine specialist steel-supplier companies with facilities able to produce large forgings, in Japan, China, Russia, Korea, France, Germany, India, Czech Republic and the UK.

There is then a second field of about 20 largely different companies that use these forgings to produce the pressure vessels. Some of these are different divisions of a reactor vendor (e.g. Areva and Mitsubishi Heavy Industries), while some are specialist companies, such as Babcock & Wilcox (US).

3.2.2.3 The containment

The secondary containment is a reinforced structure that envelops the reactor and other parts of the NSSS, in order to protect them from external events but also to contain any radiation leaks that may occur from the primary circuit. It is an airtight chamber, often composed of single or double pre-pressed (or reinforced) thick concrete walls and ceiling, integrally attached to the reactor's basemat. For better air tightness, the secondary containment often has a steel liner on its internal surface. It is supplied and built as a part of the civil engineering work at the nuclear power plant, though it has to meet very high industrial standards.

The containment usually also has accompanying devices, such as spraying systems to suppress the internal pressure, and hydrogen re-combiners to prevent accumulation and explosion of hydrogen, in the case of a major accident. The containment also needs to have a number of penetrations to allow the piping carrying steam to reach the conventional parts of the power plant, as well as enabling access for staff, machinery (exchange of fuel or components) and electric cables. Additional pieces of equipment are supplied to keep those penetrations airtight.

Each reactor design has a separate supply chain comprising a large number of companies of various types. The WNA gives examples of six of the companies involved in the supply of the containment structure for Areva. These include three French companies (e.g. Bouygues Construction), a Swiss company (VSL International), a German company (Babcock Noell Nuclear Gmbh) and a Chinese company (SEPCO).

3.2.2.4 Steam generators

Steam generators are required in PWRs in which the reactor coolant water goes through a secondary circuit (the steam generators) in which the steam to drive the turbines is produced. In BWRs, the reactor coolant water drives the turbines directly. Steam generators also require large forgings, for example, the four steam generators in an EPR weigh about 500 tonnes each. The WNA lists about 16 suppliers, with considerable overlap between suppliers of steam generators and the suppliers of containment vessels.

Unlike the reactor vessel, which is a life-limiting component – in other words, if the vessel is not serviceable, replacing it is not an option – steam generators can be replaced and because these have not proved as durable as expected, there is a substantial market in replacement steam generators. These can be supplied by the original equipment supplier or by a competing company. Suppliers listed by WNA include:[44]

Box 3

The reactor pressure vessel

Complexity of manufacture

The reactor pressure vessel is one of the most safety-sensitive components in a PWR. If the integrity of the reactor vessel cannot be guaranteed, the safety of the plant is in serious doubt because the assumption is that if there is a flaw in the vessel it will rupture before it leaks, so there will be no advance warning.

The issues in 2012 surrounding the pressure vessels supplied by Rotterdamse Droogdok Maatschappij (RDM) illustrate the complexity of the issues. In 2012, inspections at the Doel 3 plant revealed thousands of cracks in the pressure vessel. The reactor was closed pending investigations into the extent and severity of the cracks and the future of the 21 reactors worldwide with reactor vessels supplied by RDM.[37] Similar flaws were found in Tihange-2 whose pressure vessel was also supplied by RDM.[38] These were a very diverse set of reactors ranging in size from about 50MW to 1,300MW, using three different technologies and from about 6 different vendors. By December 2012, it was still not decided whether Doel 3 and Tihange-2 would be allowed to go back into service. The vessel was supplied by RDM which had met the ASME (American Society of Mechanical Engineers) requirements of the day.[39] However, the manufacture of the vessel was more complicated than that. It was reported that[40]: "In the case of Doel 3, the raw materials for the reactor shells was supplied by Krupp, the forging by RDM, the cladding and assembling by Cockerill for the lower part (two core shells, transition ring and bottom plate) and by Framatome (now Areva NP) for the upper part comprising the RPV head, nozzle shell, and the final assembly."

It is believed the cracks were created during the manufacturing process, but it is far from clear at time of writing who was responsible for the errors that caused them. They were only revealed because of the use of a new ultrasonic sensor so it may not be possible to determine when these flaws occurred.

Specialised facilities

In recent years, there has been considerable publicity about bottlenecks in the supply chain because the dearth of orders has led to closure of many of the certified manufacturing facilities. Of particular concern is the manufacture of the pressure vessel, for which only one supplier, Japan Steel Works (JSW) has the facilities to produce the ultra large forgings needed to produce a reactor vessel in one piece for the very largest reactors, such as the Areva EPR. The alternative of welding together a vessel made up of several parts is usually seen as less desirable.[41] The capacity of JSW was only three vessels per year. Despite the obvious risk of a bottleneck, no other company was willing to make the investment of $900m US dollars in a 14,000 tonne steel press. JSW built another one that came on-line in 2010.[42] Plans by Doosan (Korea) and Sheffield Steelmasters (UK), which has a 30-year-old press of 13,000 tonnes, to build similar presses did not materialise. However, the global re-evaluation of nuclear power following on from Fukushima has meant that orders have dried up and the second JSW press might not have been justified.

- China: China First Heavy Industries, Dongfang Electric Corporation, Dongfang Heavy Equipment Limited, Harbin Boiler Company;
- Korea: Hyundai Heavy Industries, Doosan;
- Areva (France);
- Babcock-Hitachi KK (Japan);
- AtomEnergoMash (Russia);
- DCD Dobryl (South Africa); and
- ENSA (Spain).

Tubing for steam generators is supplied by another set of companies including: Vallourec and Vanatome (France); Alfa Laval (Sweden); Armatury (Russia); Larsen & Toubro (India); Sandvik (Sweden); and Sumitomo (Japan).

3.2.2.5 Pumps and valves

Pumps and valves are found in many systems of a nuclear power plant, in some cases in safety-related areas. A typical PWR or BWR has about 5,000 valves and 200 pumps. The WNA lists more than a dozen suppliers of the more specialised types of pumps. Some are specialist pump companies (e.g. Curtiss-Wright), while others are divisions of diversified companies that include reactor vendor divisions, e.g. Areva and Mitsubishi. The main pump suppliers include: AtomEnergoMash, HMS Pumps (Russia); Areva (France); Dongfang Electric Corporation and Shanghai Electric Heavy Industry Group (China); and Mitsubishi and EBARA (Japan).

Specialist valves and actuators (motors that drive valves) are supplied by specialist companies including some that also supply pumps (e.g. Flowserve). The WNA lists 16 suppliers of valves and actuators including: Arako spol s.r.o. (Russia), AUMA (Germany), Armatury (Russia), Larsen & Toubro (India) and Samshin Ltd (Korea).

3.2.2.6 Turbine generators

The turbine generators, that convert energy into electricity, have traditionally been the major item in a thermal power station, and they remain a major item of expenditure for a nuclear power plant. Many of the original nuclear vendors were suppliers of turbine generators for fossil-fired plants, e.g. Siemens, GE and Westinghouse.

There about a dozen suppliers of turbines for large reactors and several of these also supply the reactor. These include: Dongfang Electric Corporation, Harbin Electric and Shanghai Electrical (China); Bharat Heavy Electricals, and Larsen & Toubro (India); OMZ and AtomEnergoMash (Russia); Alstom (France); Doosan (Korea); Mitsubishi (Japan); Siemens (Germany).

3.2.2.7 Raw materials and small components

Large amounts of raw materials such as steel and concrete, with stringent specifications, are required in the construction of a nuclear power plant. In recent years, there have been serious problems at the construction sites of the Olkiluoto (Finland) and Flamanville (France) EPR plants because of poor quality control in the pouring of the concrete base-mat.[45]

A typical PWR or BWR includes 210km of piping and 2,000km of cabling with varying functions and specifications. This is mostly nuclear industry-grade non-specific or commercial-grade and is, therefore, open to a large number of potential suppliers. Responsibility for ensuring the quality of the materials and components varies according to how the project is carried out, but lies broadly with the company carrying out the EPC (engineering, procurement and construction) functions.

3.2.3 Civil engineering

As Table 3 illustrates, the on-site installation and construction represents by far the largest element of the cost of a nuclear power plant, and is notoriously the most difficult cost element to control because of the large number of sub-contracts involved, and because a construction site is much more difficult to manage than the more controllable environment of a factory. The companies involved are large engineering companies, not particularly dependent on the nuclear industry, with experience in large projects, such as rail links and other types of power plants. In recent years, companies such as Kajima (Japan), Daewoo and Samsung (Korea) and Bouygues (France) have taken this role. Their contribution and in particular their quality control is crucial to the overall quality of the plant.

3.2.4 Problems in the construction phase

Few nuclear projects are built to time and cost, and many substantially overrun their forecast construction time and cost. These problems were well illustrated by the severe problems with the construction of an Areva-supplied EPR at the Olkiluoto site in Finland.

Problems at Olkiluoto have occurred since the project began in 2004. The main concerns are about the strength of concrete, welding quality, delays in engineering design, supplier inexperience and poor control over subcontractors[46]. The problems continue, pushing the expected completion date to 2014 from the original 2009.[47] The costs have more than doubled to about €8.5bn from the original estimate of €3.2bn.[48]

In Korea in 2012, it was discovered that more than 5,000 small components installed at units 5 and 6 of the Yeonggwang plant were certified with forged safety documents. The plants had already entered service and were shut down for nearly two months while investigations took place and these parts were replaced.[49] Korea's high level of dependence on nuclear power meant the closure of these plants jeopardised the security of electricity supply in Korea.

3.3 Operations and maintenance (O&M)

The supply chain for the O&M phase is somewhat simpler than for the construction phase but more difficult to define. It involves: the day-to-day operation; routine maintenance, usually on an annual basis; repair and replacement of failed equipment, sometimes during routine maintenance and sometimes, if the failure is safety related or serious, in an unplanned outage; supply of new fuel; and dealing with spent fuel.

Unlike construction where the activities and equipment needed are largely predictable and predetermined, not all the activities and purchases for the O&M phase are predictable. Refuelling and some routine maintenance are relatively predictable but some operations such as a non-routine repair or replacement will be determined by the plant's operating history, and repairs may have to be planned and carried out by methods designed specifically for the plant. This makes the field of companies involved in the O&M phase more difficult to define.

3.3.1 Operation

This is invariably the responsibility of the owner/operator (utility), which must satisfy the national regulator that the operators are suitably qualified and competent. For the future, if the arrangements proposed for Turkey, the UAE and perhaps Vietnam are followed elsewhere, the operator may be a foreign company, and suppliers themselves may have a share and thus be co-owners of the operator.

In most countries, reactors are owned and operated by a single large utility (e.g. France, Czech Republic, Hungary, Korea, Brazil, Mexico and Belgium) or a small number of large utilities (for example, Japan, Germany, Spain and Sweden). In the US, there are a large number of utilities owning nuclear power plants ranging from very large utilities, for example the Tennessee Valley Authority (TVA), to very small utilities for which a single reactor represents a large proportion of their total assets. There has been some consolidation of ownership. For example, PECO (Philadelphia), which owned (or owned majority shares in) six nuclear reactors merged in 2002 with Unicom, which owned 10 nuclear power plants to form Exelon. Exelon took over a number of other nuclear plants in the US and merged with another utility, Constellation, in 2012, making it the largest nuclear power plant owner in the US with about 19GW of installed nuclear capacity.[50] The new company is also called Exelon.

Generally, the largest utilities, especially those with strong government backing, are more heavily involved in the supply chain. For example, the French utility EDF carries out its own architect engineering and is heavily involved in the design process for the nuclear steam-supply system (NSSS). Smaller utilities are more likely to sub-contract activities in the O&M phase.

3.3.2 Routine maintenance

This is usually carried out during a refuelling outage which takes place at 1-2 year intervals. It is often carried out by the utility but can be carried out by specialist contractors, including the vendor and equipment suppliers.

3.3.3 Equipment repair and replacement

Depending on the complexity of the operation, this may be carried out by the utility, for simpler repairs, or for complex operations (e.g. replacement of the steam generators) by specialist companies, including the original equipment supplier. The contractor may be selected by competitive tender.

3.3.4 Problems in the operating phase

If O&M is not carried out to the highest standards, there can be severe or potentially severe consequences. The Browns Ferry (US) fire of 1975, when an electrician's candle disabled the safety systems for the three reactors on site, was close to causing a major accident.[51] The investigation by the President's Inquiry into the Three Mile Island (US) accident (the Kemeny Commission)[52], which resulted in a meltdown of much of the fuel, found the accident was the result of a complex combination of equipment failure and human issues.

The Davis Besse (US) plant came close to a serious accident because maintenance procedures had not identified cracking and thinning of the reactor vessel head.[53] Had the vessel head failed, there would have been a serious loss-of-coolant accident.

3.3.5 Supply of fuel

Supply of fuel is itself at the end of a supply chain. This includes: mining and processing of uranium; converting the uranium to uranium hexafluoride; enrichment to increase the percentage of the "fertile uranium isotope from 0.7% to about 3.5%"; reconversion, and mechanical processing to manufacture the fuel rods. This supply chain is not elaborated in detail here but most of the elements have their own issues. All will leave facilities that at the end of their life will need careful decommissioning.

Image: In Finland, the construction of the Olkiluoto 3 reactor is well over budget and years past its original completion date.

The cause of a significant accident at a nuclear plant may involve a combination of design, construction, and operator or maintenance errors.

Mining is a massively disruptive process involving the removal of large quantities of rock and soil and leaves a waste stream, tailings, which if not handled carefully can pollute ground water.[54] The main uranium-producing countries are Canada, Russia, Namibia, Australia, Kazakhstan and it is produced by mining companies such as RTZ (multinational), Cameco (Canada), Areva (France), ARMZ (Russia), Kazatomprom (Kazakhstan) and BHP (Australia). Conversion to uranium hexafluoride is carried out by a large number of companies, including mining companies (Cameco), diversified nuclear companies (Areva) and specialist companies.

Enrichment involves extremely expensive facilities and uses huge quantities of energy. It is also a militarily sensitive technology as it can produce weapons grade materials. The main global suppliers are Eurodif (France), Urenco (UK, Netherlands, Germany), Minatom (Russia), JNFL (Japan) and USEC (US).

Fuel fabrication and supply is sometimes carried out by a division of the reactor vendor, e.g. Westinghouse, or by a specialist company, e.g. TVEL (Russia). Only a handful of the countries with nuclear power plants have domestic fuel-fabrication plants. The main ones are: Canada (GE); France (Areva); Germany (Siemens); Japan (MNF – Mitsubishi and NFI – Toshiba); Korea (KNFC); Russia (Mashinostroitelny); UK (NDA); and the US (GE, Siemens, Westinghouse, Areva).

While in principle the delivery of nuclear fuel is a service that can be switched to alternative suppliers, in practice this is highly impractical and complicated. Fuel rods and their assemblies are highly specific for each of the reactor designs, and it may take a number of years before an alternative supplier develops and fine-tunes fuel rods suitable to a given reactor. In reality, operators are therefore stuck with one fuel supplier over the lifetime of their reactor.

There have been a number of scandals on the supply of nuclear fuel. In 1999, it was discovered that British Nuclear Fuels (BNFL) had falsified quality-assurance data for fuel containing plutonium (so-called Mixed Oxide or MOX fuel) shipped to Japan.[55] BNFL was forced to take back this fuel.

The Czech Temelin nuclear plant provides a good example of the difficulties of switching fuel supplier. In 2006, the Czech utility was forced to turn back to its original Russian fuel supplier for its Russian-designed reactor because of concerns about the rigidity of the Westinghouse-supplied fuel, which was deforming and preventing correct insertion of the control rods.[56]

3.3.6 Spent fuel

Spent fuel removed from a reactor generates large amounts of decay/residual heat and, therefore, needs to be actively cooled for several years until this heat generation has decayed sufficiently so that the risk of a meltdown (in case of cooling failure) no longer exists.

After the initial cool-down period (typically 3-5 years), spent fuel is stored onsite at interim storage, transported to a central interim storage elsewhere, or sent to reprocessing facilities. There are three main ways in which spent-fuel storage can be carried out:

- Initial storage in wet spent-fuel pools that are built onsite, in the vicinity of the reactors. Most western reactor designs situate the pools outside of the containment, in an auxiliary building, while Russian designs locate the pools inside the containment. The pools and their cooling systems are an integral part of the reactor design, construction and supply; they often share the same power backup systems, water supply systems, and ultimate heat sinks with nuclear reactor islands. Hence, suppliers of reactors are also involved in spent-fuel storage.

Box 4

Final disposal of spent fuel

There are two main options for dealing with spent fuel: direct disposal, or reprocessing. Direct disposal in a high-level waste repository is the preferred option for most reactor owners. No high-level waste – a category that includes spent nuclear fuel – final repository, where the waste must be isolated from the environment for about 250,000 years, has been constructed yet and it may be decades before any such facility exists. Until then, the costs and the technology will remain unproven. The field of companies offering this service is undeveloped but given the extraordinary safety requirements, such companies will inevitably be closely associated and often fully owned by government.

Spent-fuel direct disposal has not been demonstrated anywhere yet and most countries that are expecting to follow this route are many years away from even selecting a site.

Reprocessing on a commercial basis is only carried out in three countries: France (La Hague), UK (Sellafield) and Russia (Chelyabinsk and Krasnoyarsk). These facilities are owned by the national governments. Japan has almost completed a large reprocessing plant, Rokkasho. The plant is reported to have been 99% complete since 2007, but its start-up has continually been delayed (19 times by October 2012) and, by then, its projected start date was October 2013.[61] Its owner, Japan Nuclear Fuel Limited, is mainly owned by the 10 privately owned, major Japanese electric utilities. Other countries, such as India, have smaller facilities but these are not open to international customers, and they may have dual military/civil purposes.

- After the initial cool-down period, the interim storage of spent fuel can continue to be based on pools filled with water – i.e. wet storage. This practice is linked to most of the Russian-designed nuclear power plants. One of the suppliers of those interim wet storage systems (pools) is Skoda JS.[57]
- Interim storage can also be in dry casks. The fuel is stored in heavy, self-sufficient containers that need no additional, active cooling, or the presence of water. Thus they can be stored under open air, or at shallow underground facilities. There are several companies producing the casks, such as Gesellschaft fur Nuklear-Service (Germany), Holtec Intl, NAC Intl. and Areva-Transnuclear NUHOMS. Skoda JS also obtained a licence to fabricate the German-designed dry storage casks.

Spent fuel is expected to either be reprocessed or disposed of directly (see Box 4). Reprocessing is particularly contentious because it is a hazardous process, and because it produces separated plutonium, which represents a major weapons-proliferation risk. Direct disposal raises fewer proliferation concerns but the requirement to identify sites and package the waste, which also applies to waste from reprocessing, so that there can be near certainty that the material will remain isolated from the environment for the several hundred thousand years it will take for the material to cease to be hazardous.

Spent or partially used fuel that is not in the reactor may represent a significant hazard as was demonstrated at the Fukushima disaster.[58] A less widely publicised accident occurred at the Paks plant (Hungary) in 2003. Here, fuel assemblies were removed from the reactor for cleaning in a cleaning tank.[59] The cooling system proved inadequate and the 30 fuel assemblies in the tank were all damaged, some severely, leading to the release of some radioactive material. The accident was blamed on the supplier of the tank, Areva (France), who paid compensation reported to be $4.5m. The plant (Unit 2 of the four-unit site) was off-line for more than three years.[60] The loss of income from the lost output for those three years will have far exceeded the compensation paid.

3.4 Conclusions

A nuclear power plant has several unique features: complexity; extent of and potential cost of accidents; importance of user skills; lifetime; cost; and the importance of site construction work. This means that the cause of a significant accident at a nuclear power plant is seldom clear-cut and may involve a combination of design, construction, operation and maintenance errors.

By comparison, it is usually relatively easy to apportion primary responsibility for, say a car accident to design, construction, operator or maintenance error.

In addition, international conventions and national laws limit (in the case of operators) or absolve (in the case of suppliers) from the financial consequences of accidents caused by their errors in a way that applies to no other industrial activity. Without this level of insulation from the consequences of any accidents, it is clear no commercial company could justify owning or supplying a nuclear power plant.

The supply chain for a nuclear power plant is very complex and in many cases non-transparent. The owner/operator of a plant carries final responsibility, but design, construction and maintenance include many different parties through many layers of contracting and subcontracting. Different suppliers are responsible for implementing elements critical for the plant's safety, but these suppliers ultimately cannot be held accountable in case of an accident.

This lack of accountability is further enabled by lack of transparency regarding contracts and company relationships. This situation creates major challenges in ensuring sufficient quality control on critical safety features. It is often unclear (at least to the outside world) who carries the final responsibility in case problems were to occur with certain equipment or designs.

Many of those further down the supply chain will exit the business long before the end of the life of the plant, as was the case with RDM, the supplier of the flawed pressure vessels for the Belgian Tihange 2 and Doel 3 plants. In the case of the Fukushima disaster, even though it is known that certain design features caused serious problems during the course of the accident[62], those responsible for the design and engineering are not being held accountable.

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4 Nuclear Engineering International 'Focus on India - New-build - Two paths.' August 2012, p 26

5 Antony Froggatt, see Chapter 2 of this report.

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32 For a detailed review of the role of the EPC contractor, see World Nuclear Association (2012) 'The World Nuclear Supply Chain Outlook 2030' World Nuclear Association.

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People must be the first priority, not the benefits of the nuclear industry.

Image: A Greenpeace radiation expert checks contamination levels at a house in Watari, approximately 60km from the Fukushima Daiichi nuclear plant.

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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