2016

Hinkley Point C

UNDERESTIMATED LONG TERM RISKS AND COSTS

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Inhalt

1 Introduction

The UK is currently planning to build six new nuclear power plants with a total of 13 reactors. Most advanced is the preparation of the construction of the NPP Hinkley Point C with two EPR reactors at the site in Somerset. The main focus of this study is on the newbuild project Hinkley Point C. The project and its specific conditions, the so-called Contract for Difference (CfD) are presented in chapter 2. In addition the other EPR projects are explained, which are under construction in other countries and became known for cost overruns and construction delay due to mainly technical problems. Two more planned newbuild projects in the UK are also part of this chapter.

Chapter 3 is about the accident risk posed by the operation of Hinkley Point C, as well as about the general accident risk of the NPP operation and the transport and storing of spent fuel assemblies (e.g. terror attacks). Chapter 4 provides an overview over the dangers posed by the so-called normal operation of nuclear power plants.

Chapter 5 provides an overview over the situation of radioactive waste management in the UK and explains the plans for interim storages and final disposal of those amounts and the additional amounts of waste from NPP. The chapter focuses on the additionally generated waste and the spent fuel assemblies produced in the new planned NPP in particular, what ratio those amounts represent in comparison to the already existing amounts in the UK and what the possible impacts might look like. Also the current status of final disposal search is explained and the consequences of the planned new nuclear power plants on the site selection procedure in the UK are discussed.

Chapter 6 is devoted to the necessary costs for the management and the final disposal of radioactive waste in particular. The issue of additional costs for the taxpayers is in the focus; as well as the open issue whether enough reserves will be accumulated and secured for the final disposal.

Chapter 7 is taking a look at the currently planned new build projects in the EU, which might be realized as a consequence of the Hinkley Point C state aid decision.

This study also summarizes the current status of planning the new build projects. At this point it is not possible to seriously assess which projects actually will be realized.

This study has been commissioned by Greenpeace Energy.

2 New Nuclear Power Plants in UK

The **United Kingdom** operates 16 reactors[1] at eight nuclear sites, which provided 17.2 percent of country's electricity in 2014. Meanwhile, renewables' share of electricity generation increased from 14.9 percent to 19.2 percent in 2014, overtaking nuclear generation for the first time in decades.[2]

The oldest reactor (type Magnox) will be permanently shut down at the end of 2015. Most of the Advanced Gas-cooled Reactors (AGR) are also near the end of their design life. The two Dungeness-B reactors extended operation time to 2028. Further operation time extensions of 5 to 7 years are planned by their owner EDF. The newest plant, Sizewell-B, is the only PWR in the U.K. and was completed in 1995. Its operation time will end in 2035, but a 20-year operation time extension is envisaged.

In 2006, the Labour Government started to organize the framework of a new build program. Government ministers have consistently said that 16 GWe of new nuclear capacity should be built at five sites by 2025, though this target date has slipped to 2030.

The eight potentially suitable sites for new NPPs by 2025 are exclusively current or past nuclear power plant sites in England or Wales, except for one new site, Moorside, adjacent to Sellafield. [3]

2.1 Four EPRs - Hinkley Point C und Sizewell C - EDF Energy

Present plans are for four EPR nuclear reactors to be built by EDF Energy at Sizewell in Suffolk and **Hinkley Point C** in Somerset. The company applied for consent to construct and operate the first two (3260 MWe) at Hinkley Point in October 2011. EDF Energy was given planning permission to build two reactors at Hinkley Point. In April 2013 the EIA process was concluded in 2013.

The **licensing procedure** for new NPP takes place in a two-phase process in UK: In the first phase – Generic Design Assessment (GDA) – the reactor is assessed site-inpendently. In December 2012 the UK EPR was granted the Design Acceptance Confirmation. [4]

China General Nuclear Power Corporation (CGN) und EDF announced in October 2015 in London their agreement about investment and building an operation of the new NPP Hinkley Point C. EDF would retain 66.5% of the Hinkley Point C project, China General Nuclear Power Corporation (CGN), would take 33.50%.[5] Moreover the investment agreement laid the foundation for the construction of further nuclear power plants in Sizewell and Bradwell.

A major international banking group is calling on shareholders to sell their holdings in French energy giant EDF just days after it signed a deal with its Chinese partner China General Nuclear Corporation (CGN) to build a new nuclear power station in the UK. A research note from Harold Hutchison, utility

[1] Dungeness B-1&2; Hartlepool A-1&2; Heysham A-1&2, Heysham B-1&2; Hinkley Point B-1&2; Hunterstone B-1&2; Sizewell B; Torness-1&2; Wylfa-1
[2] Schneider et al.: World Nuclear Industry Status Report 2015; July 2015; http://www.worldnuclearreport.org/
[3] World Nuclear Association (WNA): Nuclear Power in the United Kingdom http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/United-Kingdom/ (updated 30 October 2015)
[4] Office for Nuclear Regulation (ONR): UK European Pressurised Reactor (UK EPR); (updated 29 October 2015); http://www.onr.org.uk/new-reactors/uk-epr/index.htm
[5] World nuclear news: china agrees to invest in new UK nuclear plants, 21 October 2015; http://www.world-nuclear-news.org/NN-China-agrees-to-invest-in-new-UK-nuclear-plants-2110155.html

analyst with Investec said: "A long-dated project is the last thing that EDF needs, given the existing pressures on its balance sheet." [6]

The French nuclear energy sector has been in trouble with the EDF partner, Areva, which has had loss of about US$ 4.8 billion in 2014. Thus, EDF has to buy the majority stake in the reactor business of nuclear group Areva, as was announced on June 3 2015. The French state is currently holding an 87% share in Areva and 85% of EDF. [7]

Although it was originally claimed that Hinkley Point C would cost only £10 billion[8] and be "cooking Christmas dinners by 2017", its completion date is now likely to be well after 2025, and its cost has increased to £24.5 billion (about € 31,2bn).

The Hinkley EPR project is now under sustained attack − and not just from the traditional anti-nuclear voices.[9]

2.1.1 Contract for Difference (CfD)

The special feature of the Hinkley Point C project is the so called **Contract for Difference (CfD). This contract provides the operator of the nuclear power plant with a fixed price paid to the producer for the electricity generated for 35 years.** If the market price will be lower than the guaranteed tariff, the operator will receive the difference from the state.

In October 2013, EDF and the UK Government have reached a deal after months of negotiations. The **CfD will see a subsidised rate for electricity - (rising with inflation) of £92.50 per megawatt hour (MWh)[10]: twice that of the current wholesale cost of UK electricity of £45 per MWh.** If the price was to be above **£92.50 per megawatt hour, EdF would pay back the difference to the government.** In addition, state guarantees and a financial compensation are foreseen if the nuclear power plant would be shut down for political reasons.

The CfD was to subsidise operating costs to give certainty to investors, who were concerned they would not see repayment of their investment. From the perspective of potential investors in Hinkley, concerns that they might not see a return on their investment appeared well founded. Professor Stephen Thomas (University of Greenwich) explains: The impact of a CfD is to shift risk from the owner of the plant to consumers. No company anywhere has seriously tried to finance a nuclear plant to operate unprotected in a competitive electricity market, probably because it is known such a plant cannot find financing on the market. [11]

It is not surprising EDF lobbied for a guaranteed price for electricity; the potential for a large scale nuclear operator failing is a recent experience in the UK - as happened with British Energy when, in 2002, the price of electricity fell significantly. In 2004, the company British Energy was forced to

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[6] The Guardian: Broker tells investor to sell EDF shares because of Hinkley Point costs; 22 October 2015; http://www.theguardian.com/business/2015/oct/22/broker-tells-investors-sell-edf-shares-hinkley-point-costs
[7] Wirtschaftsblatt: Energieversorger EDF übernimmt Reaktorsparte von Atomfirma Areva; 03.06.2015; http://wirtschaftsblatt.at/home/nachrichten/europa/4746879/Energieversorger-EDF-ubernimmt-Reaktorsparte-von-Atomfirma-Areva
[8] Comment: The 2008 government white paper claimed that the construction cost will be £2 billion per reactor.
[9] Wise/NIRS: EPR fiasco unravelling in France and the UK: Nuclear Monitor; No. 812; 15. Oktober 2015
[10] Note: This is the 2012 price, the current level is already more than £100/MWh.
[11] Subsidising the nuclear industry', briefing for government, Tom Burke, Tony Juniper, Jonathon Porritt, Charles Secrett; 26. März 2012; http://tomburke.co.uk/wp-content/uploads/2012/03/subsidising_nuclear_26March.pdf

apply for state aid intervention to prevent the company going into liquidation. British Energy was sold to EDF in 2008, after the government had agreed to pick up the tab for its existing spent fuel and waste liabilities.[12]

According to a document just come to light the subsidy bill could reach £20bn, the government has revealed recently. Tom Burke, chairman of environmental think-tank E3G, also said the government estimate of the price guarantee underplayed the sums involved. **His organisation estimates that with annual inflation the actual sum handed over during 35 years will be £45bn (about €61bn).** [13] A 2015 analysis published by Greenpeace Energy eG calculated state aid to reach € 108.6 bn.[14]

The document also reveals that taxpayers would have to **pay up to £22bn compensation to the owners, if the UK government or the European Union would do something that forces the plant to close early (earlier than after 60 years of operation).**

In October 2014, the **EU cleared the UK Government state aid proposal (CfD**), leaving it to finalise the deal with EDF (final agreement has not yet been reached). On 22 January 2015, Austria announced that the government would file a complaint with the European Court of Justice (ECJ) against the Commission decision. In time the Republic of Austria filed the complaint on July 6 2015. In 2014, Austria already has delivered detailed argumentation, that providing permanent state aid for a per se unprofitable technology is in violation with the logic and the system of the precisely defined general state aid rules of the EU.

In March 2015, the renewable energy utilities Greenpeace Energy eG, Germany, and the oekostrom AG, Austria, announced they would lodge a joint legal procedure against the Commission decision with the ECJ. Another energy companies in Austria and Germany have since joined the alliance. Dr Dörte Fouquet, partner at the international law firm Becker Büttner Held, who is representing the Action Alliance, believes the decision to approve the UK state aid to nuclear power **was both wrong in law, and "not in the common interests of the European Union."**

A new study commissioned by the group shows that approval for Hinkley C, together with other proposed nuclear power plant projects in Europe, "could distort prices in Germany's electricity market by up to 12% and thereby massively distort competition." In effect, they say, the heavily subsidised nuclear plants would be forcing prices down and reducing the viability of clean power generation from renewable sources. Again, this effect would increase the costs for the EEG system (Renewable Energy Sources system) and consumers in Germany by some €2.2 billion per year in additional support payments for renewable energy until 2040.[15]

[12] The Guardian, 'Taxpayers £184m to aid private energy firm', 18 July 2005 http://www.theguardian.com/environment/2005/jul/18/energy.business
[13] The Guardian: Hinkley Point C will cost customers at least £4.4bn: 29. Oktober 2015; www.theguardian.com/environment/2015/oct/29/hinkley-point-c-nuclear-power-station-cost-customers-4bn
[14] Energy Brainpool: Höhe der staatlichen Förderung von Hinkley Point C, Kurzanalyse im Auftrag von Greenpeace Energy eG, Berlin, 8. Juni 2015; http://www.no-point.de/wp-content/uploads/2015/06/2015-06-09_GreenpeaceEnergy_Kurzanalyse-HinkleyPoint_F%C3%B6rderkosten_EnergyBrainpool-final.pdf
[15] Ecologist: Austria files Hinkley Point C legal challenge in European Court: 6 August 2015; http://www.theecologist.org/campaigning/2936931/austria_files_hinkley_point_c_legal_challenge_in_european_court.html

2.1.2 Three disastrous EPR projects

In addition to high and long-term state aid the enormous construction delays and problem of the EPR construction projects in other countries raise grounded doubts concerning the Hinkley Point C project.

There are three EPR construction projects around the world:

- Olkiluoto 3 (Finland) was started in 2005 and expected to come online in 2009 at a cost of €3 billion (US$3.6 billion). By 2015, completion was not expected before 2018 at a cost of €8.5 billion (US$9.5 billion). **Costs and construction time almost tripled.**

- Flamanville 3 (France) was started in 2007 and expected to come online in 2012 at a cost of €3.2 billion (US$4.7 billion). By 2015, completion was not expected before 2017 at a cost of €10.5 billion (US$11.8 billion). [16] In a 9 October 2015 letter to the French Energy ministry EDF asked for the official deadline extended to April 11, 2020, another three year delay. **Costs have tripled and the estimated five year construction time has doubled to 14 years.**

- Taishan 1 & 2 (China) units started construction in 2009 and 2010 when they were both due online in 2014. In 2015, completion was expected in 2016 but no reliable cost information has been published. **Due to the recent problems with the reactor pressure vessel, the time of start-up is in doubt.**

A whole range of technical problems caused the delays and cost increases. The Roussely report – a 2010 inquiry into the problems facing the EPR, commissioned by the French government found that: The resulting complexity of the EPR, arising from the choice of design, specifically the level of power, the containment, the core catcher and the redundancy of the safety systems is certainly a handicap for its construction and therefore its cost. [17]

Some of the technical difficulties are outlined in the following section.

For both Olkiluoto and Flamanville, problems emerged on quality control problems particularly with welds, were a recurring problem. For both Flamanville and Olkiluoto meeting requirements for redundancy in the Instrumentation & Control System posed a problem. The latter problem emerged in 2009 when a joint regulatory statement by the Finnish, French and UK (which was carrying out a generic design review) regulators expressed their concerns.[18]

Subsequently the U.S. regulator, which was also carrying out a generic review, also stated its reservations. The generic approval process for EPR in the USA was suspended in 2015 before the U.S. regulator had given approval for the proposed instrumentation & control design. [19]

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[16] World Nuclear News (WNN): Flamanville EPR timetable and costs revised; 3. September 2015; http://www.world-nuclear-news.org/NN-Flamanville-EPR-timetable-and-costs-revised-0309154.html

[17] Schneider et al.: World Nuclear Industry Status Report 2015; July 2015; http://www.worldnuclearreport.org/

[18] 165 HSE's ND (UK), ASN (France) and STUK (Finland), Joint Regulatory Position Statement on the EPR Pressurised Water Reactor—Release No V4 22/10/2009", 2 November 2009, http://www.hse.gov.uk/press/2009/hse221009.htm

[19] World Nuclear Association (WNA): Nuclear Power in the USA, updated October 2015; http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/USA--Nuclear-Power/

More recently it has been reported that leaked documents reveal that France's nuclear safety authorities have also learnt of "multiple" malfunctioning valves in the Flamanville EPR that could cause its meltdown; similar to the 1979 accident at the Three Mile Island nuclear plant in the US.[20]

The most severe problem which emerged with for the EPR has not been completely solved yet:

On 7th April 2015, EDF announced serious faults had been found with the reactor pressure vessel (RPV) bottom and lid at its Flamanville plant in France. [21] This component was jointly manufactured by Japanese companies and Areva at AREVA's Le Creusot plant. This affected the Flamanville and Taishan projects, while the Olkiluoto parts had been supplied by another firm. Three more reactor tops and bottoms were fabricated soon after (for the two UK Hinkley Point reactors and the subsequently abandoned Calvert Cliffs project in the USA) and suffer from the same type of material defect. By mid-2015, investigations were under way to determine what needs to be done.

According to the analysis of the French Nuclear Safety Authority (ASN) and its technical support organisation, the Institute for Radiation Protection and Nuclear Safety (IRSN), Areva therefore chose, contrary to regulatory guidelines, a fabrication process which had not received technical qualification beforehand and which did not use the best available technology. ASN says that it warned Areva on various occasions against the industrial risk that it took when proceeding with fabrication despite those concerns. The programme of studies and tests that Areva proposed about the faults of the RPV parts is expected to deliver its results in the first half of 2016. ASN therefore cannot make its final decision about the acceptability of the RPV before the second half of 2016.[22]

The Chinese regulator announced that no nuclear fuel can be loaded until the situation is resolved.

According to the World Nuclear Industry Status Report 2015, there appeared to be three options: the regulator could rule that the deviation from required specification was acceptable and no further action needed; repairs could be carried out; or the projects could be abandoned because it is no longer feasible to access the parts requiring repair.[23]

The emergence of the pressure vessel issue in April 2015 puts the entire project in doubt. [24] At about the same time the full extent of AREVA's financial difficulties became apparent when it announced annual losses of nearly €5 billion for 2014. AREVA and its Finnish customer TVO were in the midst of a legal battle over who would pay the cost overruns for Olkilouto-3. [25]

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[20] The Telegraph, 'Faulty valves in new-generation EPR nuclear reactor pose meltdown risk, inspectors warn', 9 June 2015; http://www.telegraph.co.uk/news/worldnews/europe/france/11662889/Faulty-valves-in-new-generation-EPR-nuclear-reactor-pose-meltdown-risk-inspectors-warn.html
[21] World Information Service on Energy briefing, 'Fabrication Flaws in EPR Flamanville', 12 April 2015 https://dl.dropboxusercontent.com/u/25762794/20150412Fabrication-Flaws-EPR-Flamanville-v2.pdf
[22] Wise/NIRS: EPR fiasco unravelling in France and the UK: Nuclear Monitor; No. 812; 15 October 2015
[23] Schneider et al.: World Nuclear Industry Status Report 2015; July 2015; http://www.worldnuclearreport.org/
[24] Bloomberg: "Nuclear test risks blowing lid off UK's plans to keep lights on," 16 June 2015 http://www.bloomberg.com/news/articles/2015-06-19/nuclear-test-risks-blowing-lid-off-u-k-s-plan-to-keep-lights-on
[25] Schneider et al.: World Nuclear Industry Status Report 2015; July 2015; http://www.worldnuclearreport.org/

2.2 More new build projects in UK

In addition to the currently planned four EPR, other consortia are planning new nuclear plants in the U.K. The following table gives on overview over the currently planned projects:

The listing shows that the currently planned 13 reactors in the UK amount to almost 18 GW. The following section gives a quick overview over the planned new build projects.

Table 1: Planned NPP new build projects in the UK (as of October 2015)

Proponent	**Site**	**Reactor type**	**Gross output [MW]**	**Start -up**
EDF Energy	Hinkley Point C-1	EPR	1670	2023
EDF Energy	Hinkley Point C-2	EPR	1670	2024
EDF Energy	Sizewell C-1	EPR	1670	?
EDF Energy	Sizewell C-2	EPR	1670	?
Horizon	Wylfa Newydd	ABWR	1380	2025
Horizon	Wylfa Newydd	ABWR	1380	2025
Horizon	Oldbury B-1	ABWR	1380	late 2020s
Horizon	Oldbury B-2	ABWR	1380	late 2020s
NuGeneration	Moorside 1	AP1000	1135	2024
NuGeneration	Moorside 2	AP1000	1135	?
NuGeneration	Moorside 3	AP1000	1135	?
CGN	Bradwell B-1	Hualong One	1150	?
CGN	Bradwell B-2*	Hualong One	1150	?
Total		**13 reactors**	**17905**	

*Both EDF and CGN have not announced yet how many reactors will be built at the Bradwell site. The construction of two reactor is an estimation of the World Nuclear Association (WNA)[26].

[26] World Nuclear Association (WNA): Nuclear Power in the United Kingdom (updated 27 November 2015) http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/United-Kingdom

2.2.1 Four ABWR at Oldbury and Wylfa sites (Horizon)

Horizon Nuclear Power, a wholly owned subsidiary of Hitachi Ltd,[27] planned to build two of the 1380 MWe ABWR units (1380 MW) at both the Oldbury and Wylfa site. In April 2013 it applied to ONR for Generic Design Assessment (GDA), which Hitachi expects to take until the end of 2017. On October 30 2015 the step 3 of four steps of the Generic Design Assessment were finished. [28]

In December 2013 the government signed a cooperation agreement with Hitachi and Horizon with a view to a guarantee by the end of 2016 similar to that for Hinkley Point. If everything went according to plan, the reactor would start up in 2025 at Wylfa and at the end of the 2020 years at Oldbury site.

The Advanced Boiling Water Reactors (ABWR) was developed in Japan. The first two ABWRs (Kashiwazaki-Kariwa-6 and -7) started operation in 1996/97). Since then only two ABWRs started operation. These four Advanced Boiling Water Reactors (ABWRs) have been built in time and budget, however the operation was combined with several troubles. In Japan, two further ABWRs had started construction when the Fukushima crisis happened, so construction has been suspended. Other proposed ABWRs in Japan have been deferred or suspended. The start - up of two ABWRs (construction start 1999) at Lungmen, near Taipei (Taiwan) has been delayed among other because of safety concerns.

2.2.2 Three AP1000 at Moorside site (NuGeneration)

In October 2009 NuGeneration bought a 190 ha site on the north side of Sellafield (*West Cumbria*) from the NDA for £70 million, and announced its intention to build up to 3600 MWe of nuclear plant there, with the site now being called Moorside. NuGen, in June 2014, finalized a new ownership structure with Toshiba/Westinghouse (60 percent) and GDF/Suez (40 percent). **Technology choice is the 1200 MWe Westinghouse AP1000 reactors, and an investment decision is expected by the end of 2018.** In December 2014 NuGen signed a cooperation agreement with the government to receive access to the infrastructure project**. Also it was in discussion regarding terms for the contracts for difference (CfD) for the plant, which need to be agreed before the 2018 investment decision.** The first unit should start operation in 2024. A site licence application is expected early in 2017.

The generic design assessment (GDA) process of the AP1000 reactor is scheduled to be completed in January 2017. [29] In March 2015, the Office for Nuclear Regulation (ONR) have published revised resolution plans in response to 51 outstanding GDA Issues for the AP1000 reactor design. [30]

The first four AP1000 are built, two units at each of the Sanmen and Haiyang sites, in China. Construction of these units started in 2009-10 with completion expected in 2013-15. By 2015, the Chinese plants were running 18 – 36 months late.

[27] But early in 2012 German-based RWE and E.ON announced that they wanted to withdraw from Horizon. In October 2012 Horizon Nuclear was bought by Hitachi from E.ON and RWE for an estimated price of £700 million (US$1.2 billion).

[28] Office of Nuclear Regulation (ONR): UK ABWR progresses to final stage of assessment; 30 October 2015; http://news.onr.org.uk/2015/10/uk-abwr-progresses-to-final-stage-of-assessment/

[29] World Nuclear News (WNN): UK assessment of AP1000 design advances. 12 March 2015; http://www.world-nuclear-news.org/RS-UK-assessment-of-AP1000-design-advances-1203154.html

[30] Office for Nuclear Regulation (ONR): Revised resolution plans for Westinghouse AP1000 design published. 12 March 2015. http://news.onr.org.uk/2015/03/revised-resolution-plans-for-westinghouse-ap1000-design-published/

Four further AP1000s are built in the US. The two Vogtle reactors (Georgia) started construction in 2013 with expected completion in 2016/18. Original estimates for the total price to the utilities buying the power stations were about $14bn (about £9.5bn or €13bn). In February 2015, it was announced the completion date is expected to be June 2019/20. The cost estimates are currently around $18bn (around £12bn or €16.5bn). The two AP1000s being built at Summer in South Carolina are two and three years late (operation start is now also expected for 2019/20), and delays have added $1.2bn to the original $10bn cost estimate. [31]

2.2.3 Two reactors (Hualong One) at the Bradwell site (CGN)

Under the strategic siting assessment process Bradwell in Essex was approved in 2011 as a site for new build, though no firm proposals have so far been brought forward. CGN has expressed interest in it however, and in connection with the Hinkley Point agreement in October 2015, EDF and CGN agreed to form a joint venture company to advance plans **for a new plant at Bradwell and seek regulatory approval - through the Generic Design Assessment (GDA) process - for a UK version of the Chinese-designed Hualong One reactor**. CGN is expected to take a 66.5% share and EDF 33.5% in the Bradwell B project. On the May 7, 2015 the construction of the first Hualong One reactor has officially started on unit 5 of the Fuqing nuclear power plant in China. [32] But it was the CNNC (China National Nuclear Corporation) version of Hualong One. The CGN version of Hualong One, Fangchenggang 3&4, will be the reference plant for the UK's Bradwell B, and unit 3 construction is due to start in December 2015.[33] According media release, if permission is granted, it has been estimated that construction could start on the Bradwell site by 2022 or 2023.[34]

While the Hinkley Point project represents the major focus of public attention, other potential new build sites turn out highly controversial. The Blackwater Against New Nuclear Group that opposes new build at the Bradwell site stated that it had "gathered 10,000 signatures in a face to face petition against new nuclear development at Bradwell." In a rather unusual move, the group has written directly to potential Chinese investors in the site, in order to warn them "about the serious technical, environmental and political difficulties they would face in building on the Blackwater estuary".[35]

2.3 Conclusions

It can be expected, that also during the construction of Hinkley Point C serious technical difficulties will be experienced. In particular the current problems with the defects in the upper lower heads of the reactor pressure vessel and mainly their cause of this, using a non-qualified manufacturing procedure, indicate that further problems are likely to arise.

Look at similar EPR Projects which are up to nine years behind schedule, leads to only one possible conclusion: if you want secure supplies by a given date because you need to avoid a capacity crunch,

[31] World Nuclear Association (WNA): Nuclear Power in the USA. Updated October 2015; http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/USA--Nuclear-Power/
[32] World Nuclear News (WNN): China starts building first Hualong One unit; 7. Mai 2015; http://www.world-nuclear-news.org/NN-China-starts-building-first-Hualong-One-unit-0705154.html
[33] World Nuclear Association (WNA): Nuclear Power in China. Updated December 2015; http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/China--Nuclear-Power/
[34] Essex Chronicle: Construction of new Chines nuclear build at Bradwell could begin by 2022; 9. November 2015; http://www.essexchronicle.co.uk/Construction-new-Chinese-nuclear-build-Bradwell/story-28140802-detail/story.html
[35] Schneider et al.: World Nuclear Industry Status Report 2015; July 2015; http://www.worldnuclearreport.org/

don't order an EPR. The latest estimate for the operation start of Hinkley Point C is 2025 – the contract allows delivery any time before 2033. [36]

New problems which lead to delays and cost increases could occur for Hinkley Point C during the long construction phase due to changes in general and to specific safety requirements. In the UK, e.g. a stronger flood protection for NPP is required in response to the Fukushima accident amongst other measures.

The CfD contract, being good business for EDF, made also other investors in interesting in nuclear newbuild. In total 13 reactors with a gross output of 18 GW are currently planned in UK. It is noteworthy that two other consortia (NuGeneration, Horizon) are already in negotiations with the British government on a Contract for Difference (CfD), which should be comparable to the contract for Hinkley Point C.

Newbuild with the reactor type AP1000, of which three are to be built at the Moorside site, already have caused construction delays and cost overruns in the US. The planned projects with the reactor type ABWR, of which four in total are to be constructed at the Wylfa and Oldbury site, have been stopped mostly. The operation of the four ABWR in Japan has been troubled until now. The reactor type for the newest project, the Chinese reactor type Hualong One, two of which are planned for the Bradwell site, do not come with any experiences, because construction of one of two units will start in China in December 2015 only.

This could lead to the need to keep the old AGR reactors operating to avoid capacity bottlenecks. In 2014 the UK set up the Office for Nuclear Regulation (ONR); an autonomous nuclear inspectorate to avoid the risk of political interference. It remains to be seen, whether the ONR will refuse granting a life extension to the old reactors thereby deciding in favour of the protection of the population.

Whether the introduction of the "Generic Design Assessment" (GDA) before the licensing procedure will shorten the construction phase, remains to be seen. Considering the high number of issues left open from the GDA procedure, this can be doubted. [37]

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[36] The Guardian: Hinkley Point power station makes no sense on so many levels Nils Pratley; 21 October 2015; http://www.theguardian.com/environment/nils-pratley-on-finance/2015/oct/21/hinkley-point-power-station-makes-no-sense-on-so-many-levels

[37] See about EPR for example: Umweltbundesamt: Hinkley Point C, Expert Statement to the EIA; Oda Becker; Report Rep.0413; Wien 2013. http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0413.pdf

3 Accident risks of a nuclear facility

3.1 Accident risk of the planned NPP at Hinkley Point C

A study published by the Institute for Safety and Risk Research at the University of Vienna, concluded that severe accidents for the EPR are not practically eliminated for the planned reactor type EPR for Hinkley Point C either. [38]

The Western European Nuclear Regulators Association (WENRA[39]) has issued a report on the safety of new NPP designs[40] which states that "accidents with core melt which would lead to early or large releases have to be practically eliminated". The report further states that "for accidents with core melt that have not been practically eliminated, design provisions have to be taken so that only limited protective measures in area and time are needed for the public[41] and that sufficient time is available to implement these measures".

WENRA has not undertaken to state quantitatively what they mean by "*practically eliminated*". WENRA cites requirements from the IAEA to the effect that accidents with a large or early release can be considered to have been practically eliminated if it is physically impossible for the accident sequence to occur, or if the accident sequence can be considered with a high degree of assurance to be extremely unlikely to arise.[42]

This situation leads to arguments from project proponents and stakeholders about what "*practically eliminated*" actually means. The result of the use by WENRA and IAEA of practically eliminated as set forth above is that anybody – project proponent, regulator, and stakeholders – is free to argue about what it means. What is a "*high degree of assurance*"? What does "*extremely unlikely to arise*" mean? Is extremely unlikely less than 1×10^{-6} per year, or 1×10^{-7} per year, or 1×10^{-8} per year?

EDF Energy *appear* to be using a frequency of 1×10^{-6} per year to constitute the required high degree of assurance to be extremely unlikely to arise in order that the accidents and accompanying phenomena are practically eliminated. Evaluations of other Generation III and Generation III+ designs use much lower values, ranging from1×10^{-8} per year to 1×10^{-7} per year. However, as noted earlier, all of these values are merely suggestions or arguments from the designers since there is no quantitative guide value for what is meant by "practically eliminated". The only safety target cited in the Pre-Construction Safety Report is a target for core damage frequency of $\leq 1\times10^{-5}$ per year.

At least the probabilistic arguments are used then the probabilistic safety assessment has to be complete to give a basis for the judgement. The PSA for Hinkley Point C is demonstrably incomplete since it has no probabilistic assessment of either seismic hazard or seismic core damage frequency, the mentioned scientists said.

The scientists pointed out, that the EPR containment is not a passive system – it is an active system. It depends on active valves and control circuitry. If the containment is not successfully isolated in a

[38] Institut für Sicherheits- und Risikoforschung Hinkley Point C UK-EPR; Steven Sholly, Univ.-Prof. Wolfgang Renneberg; 1.September 2015
[39] Network of nuclear authorities in Europe
[40] Western European Nuclear Regulators Association (WENRA), Report: Safety of New NPP Designs, Study by the Reactor Harmonisation Working Group (RHWG); March 2013 http://www.wenra.org/media/filer_public/2013/08/23/rhwg_safety_of_new_npp_designs.pdf
[41] no permanent relocation, no need for emergency outside the immediate vicinity of the plant, limited sheltering, no long term restrictions in food consumption
[42] International Atomic Energy Agency (IAEA), Safety of Nuclear Power Plants: Design Specific Safety Requirements, SSR-2/1, February 2012

severe accident, you automatically get a large early release of radioactivity. This is true irrespective of how structurally strong the containment is. In addition, within the EPR design there are still – like current generation plants – accident scenarios in which containment bypass occurs. Containment bypass accidents have nothing to do with how structurally strong the containment may be.

Therefore it does not come as a surprise that the large releases[43] frequency (LRF) is almost 21% of the Core Damage Frequency (CDF), and that large early releases[44] frequency (LERF) is almost 6% of the CDF.

Also the Expert Statement to the EIA procedure of Hinkley point C on behalf of the Austrian Environmental Agency in the framework of the EIA procedure for the planned NPP Hinkley Point C pointed out the little information provided by the PSA value and the existing accident risk. [45] Generally, PSA results should only be taken as rough indicators of risk. All PSA results are beset with considerable uncertainties, and there are factors contributing to NPP hazards which cannot be included in the PSA. Therefore, for rare events, the probability of occurrence as calculated by a PSA should not be taken as an absolute value, but as an indicative number only. In the specific PSA of the UK EPR, many factors are not included, because they are out of scope or not addressed appropriately (for example, Common Cause Failure (CCF)). **The claimed "practical elimination" of a large early release is not sufficiently demonstrated by the UK EPR PSA**. Thus, the study quoted above demanded that **a conservative worst case release scenario for an accident scenario with a possibly high source term should be included in the transboundary EIA.**

According to the PSA 2 study of the EPR Hinkley Point C during a severe accident a Cs-137 release[46] of about 40 PBq are possible which is in about the same size range as the releases from the Fukushima accident (2011). An accident in the spent fuel pool[47] could even result in the Cs-137 release of 1780 PBq, the calculated probability however being very low.

The results of the analysis of transboundary impacts of a potential severe accident at the Hinkley Point NPP site demonstrates that an impact on central European regions cannot be excluded. The results indicate the need for official intervention in Austria. Moreover, the results emphasize the importance of a serious evaluation and discussion of the severe accident scenarios for Hinkley Point C not only in the framework of the transboundary EIA.

3.2 General statistical risk of a nuclear accident

Given that most countries with nuclear power intend to keep their reactors running and new reactors are planned, an important goal is to better understand the nature of risk in the nuclear industry. What, for example, is the likelihood of another Chernobyl in the next few years?

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[43] Large releases: situations that would require protective measures for the public that could not be limited in area or time

[44] Early releases: situations that would require off-site emergency measures but with insufficient time to implement them

[45]Umweltbundesamt: Hinkley Point C, Expert Statement to the EIA; Oda Becker; Report Rep 0413; Wien 2013; http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0413.pdf

[46]In order to simplify the evaluation of the risk potential, one can limit the consideration to potential release of radioactive caesium-137 that, in the case of the Chernobyl disaster, has contributed approximately 75% of the radiological impact.

[47]Each nuclear power plant has a pond for the spent fuel assemblies to cool the spent fuel down for at least one year. The storage building for spent fuel assemblies of EPR reactors is placed in a separate building adjacent to the reactor building.

The work of Spencer Wheatley and Didier Sornette at ETH Zurich in Switzerland and Benjamin Sovacool at Aarhus University in Denmark provide an answer. They have compiled the most comprehensive list of nuclear accidents ever created and used it to calculate the likelihood of other accidents in future. The metric they use in assessing each accident is its total cost in U.S. dollars. And they define an accident as an unintentional incident or event at a nuclear energy facility that led to either one death (or more) or at least $50,000 in property damage. The resulting list ranks 174 accidents between 1946 and 2014.

The most expensive accidents are the Fukushima accident in March 2011, the Chernobyl accident in in April 1986, Sellafield appears five times in the list of the top 15 of most expensive nuclear accidents.

They concluded: There is a 50 per cent chance that a Chernobyl event (or larger) occurs in the next 27 years and a 50 percent chance that a Fukushima event (or larger) occurs in the next 50 years.

Several countries are currently investing in nuclear energy because it produces low-carbon energy. But Wheatley and his colleagues´ work suggests that a severe accident is likely to occur within the working lifetime of the reactors now being built. These risks will have to be carefully weighed against the advantages. The question for engineers, policy makers and the general public alike is whether that risk is worth taking, given what's at stake. [48]

3.3 Terror attacks on nuclear facilities

The public debate tends to concentrate on suicide attacks with a commercial airliner since 9 /11 2001. In fact, the threat is much more diverse and complex. It includes the idea of an attack from the air or a deliberate crash of a helicopter loaded with explosives, or dropping a bomb from helicopter.

Terror attacks can also be performed by terror group on the ground. There are two possibilities: a large amount (over 1 ton) is placed outside buildings or a smaller amount (several kilograms) are detonated at a sensitive spot in the reactor. A large threat for nuclear power is also conducting an attack or support one by insiders. Also a possible: Insiders perform sabotage during repair and maintenance.

On top of this, every year new possible means for attacks emerge and existing threats are assessed differently. Only a one example of each is listed here:

- Unmanned flying objects, drones, which have flown over French nuclear facilities a number of times in 2014 over 30 times without having found the originators, are also another security threat to nuclear installations. [49] Drones can e.g. – like in military application – be used for the preparation or support of terror attacks.
- In September 2015 a study by the think-tank Chatham House (London) showed the threat to nuclear power plants posed by **cyberattacks**, because the IT safety standards of the facilities are often flawed. [50]

[48] MIT Technology Review: "The Chances of Another Chernobyl Before 2050?", 17 April 2015; http://www.technologyreview.com/view/536886/the-chances-of-another-chernobyl-before-2050-50-say-safety-specialists/
[49] Defense News: "Drone threat to nuclear plants", 30 January 2015 http://www.defensenews.com/story/defense/commentary/2015/01/30/drone-threat-nuclear-plants/22581223/
[50] Chatham House Report : "Cyber Security at Civil Nuclear Facilities – Understanding the Risks"; Baylon, C.; Brunt, R. & Livingstone, D.; September 2015; https://www.chathamhouse.org/publication/cyber-security-civil-nuclear-facilities-understanding-risks

To reduce threats to nuclear installations, a significant increase in civilian and worker surveillance would be necessary; and a corresponding loss of their civil liberties.

Increasingly there are concerns over the vulnerabilities of nuclear facilities in the context of conflict. The continuing tension between Russia and Ukraine, and fighting in the Middle East, has again focussed global attention on these security concerns.

3.4 Accident risk of interim storages for spent fuel in wet storages

Spent fuel is highly radioactive when it is removed from the reactor. All radioactive materials decay in time, however it takes many thousands of years. The high level of radioactivity concentrated within spent fuel results in a significant level of heat being produced. This characteristic makes a period of interim storage necessary during which the level of heat production reduces.

Different storage systems for spent fuel are relatively well known and are utilised internationally by the nuclear industry. Dry storage, although not used by all nuclear companies, is preferable over storage systems which depend on water for coolant.

If a terror attack causes a breach of the concrete walls of a spent fuel pool, the cooling water will pour out. This causes the stored fuel to heat up due to the decay heat. Once the discharged fuel reaches the temperatures of 900 °C, the zirconium cladding of the fuel starts to burn in air. The resulting fire is very hot and cannot be extinguished with water. In the spent fuel the fire could spread to older fuel assemblies, which would not heat up so quickly by themselves. This could make the complete inventory of the spent fuel pond melt. High radioactive releases can be the result, the caesium release rate would be 10 to 100%.[51]

The ignition of zirconium in air is boosted when during a terror attack the fuel assemblies in the pond is destroyed by crashing debris. Small zirconium shavings can ignite already at a temperature of 200°C.

The fuel is kept under several meters of water that constitute an effective radiation barrier. Dose rates in the range of 1 Sv/h are possible up to a distance of 10 m.[52] Unshielded, radiation of spent fuel at short distance would be lethal within a few minutes. Therefore it is very difficult to perform interventions during accidents.

For Hinkley Point C a wet storage is planned as an interim storage for the spent fuel assemblies. When the first spent fuel assemblies will be unloaded from the fuel pond at the NPP Hinkley Point C, the planned final repository will not be operating yet. Therefore the spent fuel assemblies will have to be stored in an interim storage at the site until the repository starts operating. This Interim Spent Fuel Store (ISFS) will have the capability to store for at least one hundred years the spent fuel arising from the operation of the two EPR units. The spent fuel pool of the wet storage facility is semi-embedded into the ground. This design limits the height of the building making it less vulnerable to external hazards. The heat sink will be a mixed passive/active system.[53]

[51] R. Alvarez et al.: Reducing the Hazards from Stored Power-Reactor Fuel in the United States, Science & Global Security, Vol. 11, No. 1 (2003)

[52] In comparison: In Germany, the limit values for interventions to advert a danger from a person or to prevent a significant danger increase are 0,1 Sv per intervention (fire brigades) and 0,1 Sv per year (police). The limit value for the intervention of ambulances to save human lives are in both cases 0,25 Sv and can be exceeded for the fire brigades in very special cases only.

[53] Safety of Long-term Interim Storage Facilities Workshop Proceedings Munich, Germany 21-23 May 2013 Nuclear Safety NEA/CSNI/R(2013)10 January 2014 **www.oecd-nea.org**

As much is known so far, the planned interim storage for Hinkley Point C is supposed to be similar to the wet storage for spent fuel at the Swiss NPP site Goesgen. It uses passive cooling to a very large extent for the fuel pond and is moreover protected against the crash of a commercial airliner.[54] **However, the potential of a large release from the interim storage of the NPP Hinkley Point C persists.** A much better protected wet storage is the subsurface intermediate storage facility CLAB in Sweden.

3.5 Accident risk during transport and storing of spent fuel at dry interim storages

Decentralized storages, which are directly on the NPP site, should be preferred to central storages, because they minimize the necessary transport of radioactive material and the risk entailed. In the UK decentralized interim storages are planned for the new nuclear power plants.

Loss of integrity of one of the spent fuel casks during transport – due to an accident or a terror attack – would lead to massive radiation doses. The possible risk of transport accidents cannot be discussed in the framework of this study. As an example the possible consequences of a relatively simple terror attack will be discussed here, the opening fire with man- portable armour piercing weapons.

For firing at transport and storage cask of the CASTOR type with an armour piercing weapon, a study by the GRS (Gesellschaft fur Anlagen – und Reaktorsicherheit mbH) a radiation exposure of 300 mSv in a distance of 500 m was calculated. [55] For a similar scenario, with additional possible zircaloy fire in a cask, another study concluded, that the evacuation of the population in the area up to 5km distance would be necessary. [56]

Because the site for the spent fuel repository in UK is not known yet, it was not possible to assess the transport risks quantitatively. Taking into account the distances between the new NPP sites on the one hand and the large amounts of spent fuel assemblies on the other hand it is possible to understand now already, that an additional high risk caused by transport will occur, in particular if all planned new build projects will be realized in the UK.

An additional total amount of spent fuel assemblies of 23,000 tHM, which the reactors currently planned at the UK will produce, need to be transported to a final repository site. The mode of transport (by ship, rail or road) is not decided yet, nor the type of transport casks. If it is assumed that a similar type of case will be used as is commonly in use in Germany, the CASTOR V/19, around 2,300 transport casks would be necessary and approx. 100 transports per railroad or numerous heavy load transports with trucks.

[54] AREVA (2003): Separates Brennelement-Nasslager im Kernkraftwerk Gösgen-Däniken. http://www.kkg.ch/upload/cms/user/ArevaNasslagerKKG.pdf
[55] Gesellschaft fur Anlagen und Reaktorsicherheit mbH (2003): Pretzsch, G. und Maier, R.: German Approach to estimate potential radiological consequences following a sabotage attack against nuclear interim storage. Eurosafe 2003
[56] Gruppe Ökologie e.V. und Umweltinstitut München e.V.: Stellungnahme zu Flugzeugabsturz und Einwirkungen Dritter auf das Standort-Zwischenlager Gundremmingen und Berechnung der Strahlenbelastung nach Flugzeugabsturz und Einwirkungen Dritter auf das Standort-Zwischenlager Gundremmingen. Im Auftrag von Forum gemeinsam gegen das Zwischenlager und für eine verantwortungsvolle Energiepolitik e.V., Hannover/München, September 2004

3.6 Conclusions

Accidents are events with a very low probability, but potentially enormous damage. The risk resulting from multiplication of damage and frequency of occurrence is therefore high.

Also for the NPP Hinkley Point C or another new nuclear power plant, severe accidents with very high radioactive releases cannot be excluded. Additionally, accidents with radioactive releases are possible for a long period time during the interim storage operation and the transport of spent fuel assemblies. It is in particular the existing terror threat which was not taken into account for calculating the accident probabilities, which can lead to catastrophic consequences.

Under international law, it is national governments who have to bear the costs for intervention measures after a severe NPP accident. The most recent amendments to the international liability (insurance) regime, although appearing to increase the amounts that would be paid by nuclear companies, also set a financial limit on the companies: which is woefully inadequate to meet the full monetary costs of a major accident.[57]

To calculate the possible consequences of a nuclear disaster in euro, the radiation exposure of millions of people, establishing large nuclear contamination exclusion zones in heavily populated areas and subject this to cost-benefit-calculations, is raising ethical questions. An open debate is needed to see whether society in general is ready to be exposed to such a risk.

A severe accident occurring in a NPP or a nuclear facility anywhere in the world, could make a government close its own NPP at once or in a stepwise manner, as happened in Germany after Fukushima. The consequences of an early closure for Hinkley Point C and/or any other plant constructed via a similar financing mechanism, would lead to immense compensation payments for the owners. The contract for Hinkley Point C earmarked £ 22billion as compensation for EDF in this case.

[57] Greenpeace International, 'Greenpeace condemns the new International Nuclear Liability Convention', 15 April 2015, http://www.greenpeace.org/international/en/press/releases/Greenpeace-condemns-the-new-International-Nuclear-Liability-Convention/

4 Risks posed by normal operation

Handling radioactive material is posing risks, even if the dose limits are fulfilled according to the radiological protection standards, because no threshold is known for the effects of ionizing radiation. The effect mechanism of ionizing radiation are known, which can cause cancer and hereditary damage at any low level dose. This means, that even below the dose limits there is a risk of developing lethal cancer later and the genetical damages. The risk increases with the dose level.

The risk for the population caused by the normal operation of a nuclear facility was assessed by an epidemiological study in Germany from 2007, the so called KiKK study. The extensive investigation proved that – without exceeding the dose limits – an increase in child cancer occurs in the surroundings of NPP: The KiKK study concluded, that an increased risk for leukaemia exists for children under 5 years in the 5 km radius around nuclear power plants. The KiKK study delivered proved about a connection between the distance of the home to the nuclear power plant and the occurrence of child leukaemia. [58]

This finding of the KiKK study cannot be explained with the current knowledge about the impact of ionising radiation on the human organism. However, this does not allow excluding low doses of ionising radiation as a cause for cancer. This is rather a sign, that there are large gaps in knowledge in the field of radiation effects.

A current study proves the general risk for employees in the nuclear industry even for low doses. [59] An international long-term evaluated the exposures of more than 300,000 nuclear workers in France, the United Kingdom, and the USA, who worked with nuclear weapon projects or in research laboratories. The researchers monitored them for 26 years. Then they compared them with the cancer cases in the mortality register of the individual country. They referred to all forms of cancer except leukaemia.

All three countries showed similar results: The comprehensive data proved that even low doses of radioactive radiation can have impacts on the cancer risk. The higher the radiation exposure, the more people died of cancer. The researchers assumed that 209 of 19,064 registered cancer cases are connected with the radiation exposure. Those results could help to improve the safety standards in the nuclear industry. According to the study, the risk of dying of cancer increased for nuclear industry workers by 0.1 percent. The general basic risk of dying of cancer is 25 percent today. [60]

In addition to the negative health impacts caused by NPP operation for the population and the employees, the new study results on low dose could also have economic impacts. Public opinion could change to such an extent, that a government would react to the pressure from the population by shutting down the nuclear power plants. Owners of the NPP Hinkley Point C and of other NPP with similar contracts will demand billions in compensation payment.

At the same time the radiation protection requirements could increase and lead to electricity price increases, what would also be paid by the taxpayer thanks to the contract for difference

[58] Bundesamt für Strahlenschutz (BfS): Epidemiologische Studie zu Kinderkrebs in der Umgebung von Kernkraftwerken (KiKK-Studie); 2007 http://nbn-resolving.de/urn:nbn:de:0221-20100317939

[59] International Agency for Research on Cancer (World Health Organisation): "Even low doses of radiation increase risk of dying from leukaemia in nuclear workers", says IARC. 22 June 2015 http://www.iarc.fr/en/media-centre/pr/2015/pdfs/pr235_E.pdf

[60] Spiegel online: Radioaktive Strahlung: AKW Angestellte sterben häufiger an Krebs; 21.10.2015; www.spiegel.de/gesundheit/diagnose/atomkraftwerk-mehr-krebstote-durch-radioaktive-strahlung-a-1058875.html

(CfD). Also liquidity of the utility might be impacted, when sick employees sue for compensation, which cannot be excluded in the light of the current facts.

5 Situation of radioactive waste in UK

The UK undertook military and civil nuclear activities in the past. **It might also be said the difficulties the UK has in dealing with its radioactive wastes are due to lax management from the early days, the 1950s and 60s, when the nuclear programme was heavily focussed on weapons production**. This is not a topic of this study, however. The study focuses on the interim storages and repositories of spent fuel assemblies, because they constitute the largest share of radioactive material in the radioactive waste.

5.1 Spent nuclear fuel

The following sections will provide a quick overview over existing and expected amounts of spent fuel assemblies and their management.

Until now all spent fuel of the reactors Magnox and AGR are transported to reprocessing to Sellafield. The reprocessing of all Magnox fuel is expected to be complete by 2020. (The last Magnox reactor will stop operating in 2015.)

The current UK Government policy for managing spent fuel is a matter for the commercial judgement of its owners. However, in 2012 the Government made a clear decision to cease reprocessing of the AGR fuel. [61] **The UK has experienced many problems with reprocessing the spent fuel.**[62] However, this is not the topic of this study.

The NDA carried out a comprehensive review and consultation on its oxide fuel strategy, starting in 2010. Subsequently, it declared a 'preferred option' to cease THORP reprocessing operations are scheduled to end in 2018 when the contracts are ; the remaining AGR fuel will then be subject to wet interim storage pending geological disposal. Sellafield Ltd is currently carrying out various activities to support the transition to wet interim storage when reprocessing ceases. The strategy will be reviewed on an annual basis and, as a contingency, research and development will be conducted into dry storage concepts for AGR fuel.

The National Programme for the Management of Spent Fuel explained: In the absence of any proposals from industry (for reprocessing) any new nuclear power stations that might be built in the UK should proceed on the basis that spent fuel would not be reprocessed. If such proposals were to

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[61] Department of Energy & Climate Change (DECC): Lead Document setting out the United Kingdom's National Programme for the Responsible and Safe Management of Spent Fuel and Radioactive Waste, August 2015; https://www.gov.uk/government/publications/the-uks-national-programme-to-the-eu-commission-on-the-responsible-and-safe-management-of-spent-fuel-and-radioactive-waste

[62] The consequences of fuel reprocessing caused radiation exposures for the workers, radioactive discharges ant thus radiation exposures to the public and the environment. Risks of accidents and proliferation. At Sellafield higher contamination of the sea and the beach are noticed which causes high radioactivity in Plants and animals. Scientific publications point to a higher number of cancer case for the children of the Sellafield employees in the surroundings of Sellafield. Fierce debate have been going for years, whether the nuclear installations are the cause for this. A direct causality has not been proven yet, but cannot be excluded either. (Umgang mit radioaktiven Abfällen in der Europäischen Union; Studie für Die Grünen/EFA im Europäischen Parlament, Wolfgang Neumann; intac Hannover, Oktober 2010).

come forward in the future, they would be considered on their merits and consulted upon. [63] Reprocessing of spent fuel assemblies generated at future reactors is not clearly excluded.

The spent fuel of the only **PWR Sizewell B** will be progressively transferred to the dry storage facility and then beginning around 2080, and transported over a 20-year period to a GDF. Construction of the interim storage facility began in 2013, and is expected to become operational in 2016. Although dry storage facilities for used fuel are in use in many locations around the world, the Sizewell B dry storage will be the first such facility in the UK.

According to the national program, the Sizewell B is expected to generate about **1,000tHM spent fuel** over its 40 year operating lifetime. It is anticipated that this fuel will not be reprocessed.[64] Note: The operator is planning a life time extension of 20 years[65], however, the National Waste Management Programme does not mention this.

The total mass of spent fuel from existing reactors was about 9,600 tHM (expressed as tonnes of heavy metal), with estimated future arisings of about 2,200 tHM, the precise amounts will depend on the how long the AGR fleet remains in operation

The vitrified high level waste, products of reprocessing the spent fuel, will be stored in dry storage until the GDF is available. The volume of HLW that will require disposal when packaged for disposal will increase to 1,410m^3.[66]

The reactor core of a UK EPR would typically consist of 241 fuel assemblies. A maximum of 90 spent fuel assemblies would be removed every 18 months of operation from each EPR. With time included for planned outages for maintenance over the anticipated 60 years operation, a total of approximately 3,400 assemblies per EPR are expected to be generated. Through the lifetime of Hinkley Point C (HPC), which would have two EPRs, a total of around 6,800 fuel assemblies would be generated. Each spent fuel assembly has a mass of 527.5 kg of uranium; therefore a total inventory at end of generation would be approximately 3,600 tHM. [67]

EDF gives the amount of intermediate level waste with 1200 m^3 stored in 3660 casks.[68]

If the figures for Hinkley Point C are extrapolated to 13 reactors, the result would be a total of spent fuel assemblies of 23,000 tHM. This more than double of the expected total amount of the currently operating reactors. A more precise estimate is not possible due the different and not yet determined burn-ups, output, fuel cycle etc. of the other nuclear power plants.

5.2 The planned geological disposal facility (GDF)

The UK plans to transfer the spent fuel, the high level waste and the intermediate level waste into a geological disposal facility. It is planned that intermediate level waste can be disposed at the

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[63] DECC 2015: Department of Energy & Climate Change: Lead Document setting out the United Kingdom's National Programme for the Responsible and Safe Management of Spent Fuel and Radioactive Waste, August 2015; https://www.gov.uk/government/publications/the-uks-national-programme-to-the-eu-commission-on-the-responsible-and-safe-management-of-spent-fuel-and-radioactive-waste
[64] DECC 2015, see above
[65] World Nuclear Association (WNA): Nuclear Power in the United Kingdom http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/United-Kingdom/ (updated 30 October 2015)
[66] DECC 2015, see above
[67] Hinkley Point C Pre-Application Consultation Stage 2, Environmental Appraisal Volume 2
[68] There is an additional amount may be generated during the operation of the interim storage facility, however this amount is not calculated yet.

facility from around 2040. Disposal of spent fuel and high level was is expected to commence only around 2075.

Current cost models of this planned £12 billion UK deep geological disposal facility (GDF) for radioactive waste exclude spent fuel from new nuclear reactors. The government is planning to charge electrical utilities for the disposal of this new spent fuel. (see above)

The concept for the geological disposal facility (GDF) is under development, several options are under consideration. The Nuclear Decommissioning Authority (NDA), which oversees the UK government's nuclear decommissioning and radioactive waste disposal programme, have published a Generic Disposal Facility Design document[69] that is intended to provide information on the work undertaken on the development of a number of illustrative designs for a geological disposal facility in the UK.[70] Also the NDA has issued a register of reports about all issues concerning the GDF arising from stakeholders or nuclear authority.[71]

In a document of the Nuclear Waste Advisory Associates (NWAA) the many scientific and technical issues that still need to be researched, let alone signed off on, in order to validate the opinion that spent fuel and other higher activity wastes can be disposed of safely.[72]

For the purpose to give host communities clarity with respect to the wastes that could be disposed in GDF, the 2014 White Paper defines the types of higher activity waste, which would comprise an "inventory for disposal" in a GDF. [73]

- High level waste from the reprocessing of the spent fuel at Sellafield
- Intermediate level waste from nuclear facilities, military, medicine, industry research
- A small amount of low level waste (LLW) not suitable for other disposal facilities because of the specific type of radioactive material it contains
- Spent fuel from existing nuclear power plant and research reactors
- Plutonium from stocks
- Uranium from stocks
- Spent fuel and radioactive waste from the military program
- Spent fuel and intermediate level waste from the new build program

[69] Nuclear Decommissioning Authority (NDA): Geological Disposal – Generic disposal facility designs, December 2010; http://www.nda.gov.uk/publication/geological-disposal-generic-disposal-facility-designs-december-2010/
[70] DECC 2015, see above
[71] Nuclear Decommissioning Authority (NDA): Geological Disposal Facility Issues Register; 2015 http://www.nda.gov.uk/rwm/issues/navigating-your-way-around-the-issues-register/
[72] Nuclear Waste Advisory Associates, 'Outstanding Scientific and Technical Issues Relating to the Production of a Robust Safety Case for the Deep Geological Disposal of Radioactive Waste.' http://www.nuclearwasteadvisory.co.uk/wp-content/uploads/2011/06/NWAA-ISSUES-REGISTER-COMMENTARY.pdf
[73] Department of Energy and Climate Change (DECC): Implementing Geological Disposal. July 2014 www.gov.uk/government/uploads/system/uploads/attachment_data/file/332890/GDF_White_Paper_FINAL.pdf

In the document „Generic Disposal Facility Design“ (2010), **the inventory of the radioactive materials (without new build program) including the reactivity[74] is given**.[75] The following table shows the exact numbers:

	Packaged volume		Radioactivity	
Materials	**Cubic metres**	**(% of total)**	**[TBq]**	**(% of total)**
High level waste (HLW)	1,400	0.3%	36,000,000	41.3%
Intermediate Level Waste (ILW)	364,000	76.3%	2,2000,000	2.5%
Low-level Waste (LLW)	17,000	3.6%	<100	0.0%
Spent nuclear fuel	11,200	2.3%	45,000,000	51.6%
Plutonium	3,300	0.7%	4,000,000	4.6%
Uranium	80,000	16.8%	3,000	0.0%
Total	**475,900**	**100**	**87,200,000**	**100**

This listing shows clearly, that the spent fuel and the high level waste together constitute less than 3 % of the waste volume, but contain around 93% of the total radioactive material.

5.3 Additional inventory from Newbuild Projects

In the beginning the additional radioactive waste from new NPP was portrayed as a small increase of the existing radioactive wastes. Estimates of the Committee on Radioactive Waste Management (CoRWM), an body established by government to provide scrutiny and advice on the UK's management of radioactive waste revealed that the spent fuel from a 10GW programme would contain nearly a three-fold increase in terms of radioactivity - or an additional 265% - over the level of radioactivity contained in all of the UK’s nuclear wastes and nuclear materials produced over the past sixty years. The radioactivity of the newly generated spent fuel will increase compared to the existing spent fuel by 400%.

Those estimates, which were based on 2005 data, are not valid anymore, because meanwhile a 16 GW new build programme is foreseen, most recently even 18 GW of additional capacity are planned. The activity increase of the radioactive wastes and spent fuel assemblies will therefore be even higher.

[74] The unit for radioactivity is Becquerel (Bq).
[75] Nuclear Decommissioning Authority (NDA): Geological Disposal – Generic disposal facility designs, December 2010; http://www.nda.gov.uk/publication/geological-disposal-generic-disposal-facility-designs-december-2010/

In the framework of the West Cumbria partnership program for GDF, the government has been asked for a current list of the expected amount of inventory which should be stored in the GDF. It is not possible to estimate a maximum inventory that could be disposed of in a GDF due to uncertainties in the amount and type of waste that will be present in the future. However, the Government has produced what it calls an '**upper inventory**'. This gives a realistic estimation of a potential inventory should certain scenarios (e.g. new nuclear power stations) lead to higher volumes of waste in the future. This upper inventory is given for both the 10 GW and the 16 GW new build program. The so called '**baseline inventory**' is the amount of different materials currently estimated for geological disposal.

The following table lists the provided data:

	baseline inventory without new build program	**Upper inventory for 10 GW new build program**	**Upper inventory for 16GW new build program**
Materials	[m³]	[m³]	[m³]
High level waste	6,910	12,000	12,000
Intermediate level waste	490,000	786,000	801,000
Low level waste	13,800	150,000	150,000
Plutonium	7,820	10,400	10,400
Uranium	106,000	183,000	216,800
Spent fuel	6,440	22,200	34,400
Total	**630,970**	**1,163,600**	**1,224,600**

The differences between the baseline and upper inventories are based not only on the amount of new nuclear build but also on several assumptions, including: operating lifetimes of existing nuclear power stations; the rate of decommissioning of existing nuclear stations; and direct disposal of non-commercial reactor spent fuel from research reactors. Therefore it is difficult to compare the inventories and the attribute the additional amounts to the possible new nuclear power plants. Mainly the packed volumes say little about the radioactive inventory. Moreover the data on the base inventory does not comply with the previous NDA data (see above). These differences or rather the reasons for the differences cannot be discussed in this study. However, they show how many questions are still open concerning the final disposal of the existing radioactive waste.

It has to keep in mind that according to previous estimates approximately half of the activity of the radioactive materials result from spent fuel assemblies. **The listing shows clearly, that the amount of spent fuel for the disposal and therefore also the activity increase manifold.**

5.4 Impacts of the additional radioactive inventory

The key and much discussed question concerns the impacts of the additional amount of radioactive waste and in particular the spent fuel assemblies of the new build programme. In the final report of the consultation process for the GDF in West Cumbria, it states in the introduction of the chapter inventory: **The types and amounts of radioactive wastes for disposal – the inventory – could affect a GDF in a number of ways, including its design, the size of the underground footprint, the period of operation, the developing safety case and, potentially, the number of required GDFs**.[76]

The fuel used currently and the fuel used in future contain significantly more radioactive material than the existing reactors and generates significantly more decay heat. **The disposal of this waste would impact the underground floor space**:

- Official agencies estimate that a 'legacy waste' only repository in the UK would be approximately 6 km^2 – 9 km^2 (depending on the type of geology of the disposal site).
- They estimated that wastes from a 10 GW programme would add between 9 km^2-20 km^2 (an increase of between 50%-120%; depending on rock type) to a repository footprint;
- They estimated that wastes from a 16 GW programme would add between 11 km^2-23 km^2 to a repository footprint [77]

The government explained some further consequences of the additional inventory:

- The operation time of the GDF will be increase from 100 to around 130 years.
- The changes between the inventories have no significant impact on general safety assessment
- Based on the estimated inventory, it is not possible to say whether or not more than one facility might be required

Pete Roche from Nuclear Waste Advisory Associates (NWAA) described several consequences of the additional inventory generated by new reactors for the envisaged GDF. [78] He was invited to present his findings in the framework of the partnership process in West Cumbria. The most important issue are discussed in the following.

The end of the disposal in the GDF will be moved, because new reactors are likely to use high-burn up fuel which could require up to 100 years of cooling before it can *start* to be disposed of. So assuming new reactors, which starts operation to by 2035 (operation time of 60 years), **disposal could not end before 2200**.

Because there are so many uncertainties involved in waste management in general and deep geological disposal in particular, it should not be planned to create more waste, explained Pete

[76] West Cumbria: MRWS: The Final Report or the West Cumbria Managing Radioactive Waste Safely Partnership' August 2012; http://www.westcumbriamrws.org.uk/images/final-report.pdf
[77] West Cumbria: MRWS consultation, "Geological disposal of radioactive waste in West Cumbria?" November 2011; S. 85; http://www.westcumbriamrws.org.uk/documents/242-Full_Consultation_Document_-_West_Cumbria_MRWS_Partnership_November_2011.pdf
[78] Peter Roche: Higher Level Radioactive Waste: Likely inventory range: the process for altering it; how the community might influence it and understanding the implications of new nuclear build, Presented to West Cumbria Radioactive Wastes Safely Partnership; 5th august 2010; 2nd Version with reactions to NDA responses; http://www.westcumbriamrws.org.uk/documents/94-Inventory_critique_Pete_Roche.pdf

Roche. These uncertainties are illustrated by, for example by the 101 outstanding technical considerations listed in the Nuclear Waste Advisory Associates Issues Register.[79] (see above).

The political and ethical issues raised by the creation of more wastes are quite different from those relating to committed – and therefore unavoidable – wastes. This was stated by Committee on Radioactive Waste Management (CoRWM) in 2006. **The generation of such an amount of additional radioactive waste counteracts the results of the previous participation process for the siting procedure for the potential waste disposal facility.**

NDA only describes the increase of the packed volume of the waste, but more important is the increase of the radioactivity of the additional waste, which increase manifold. This has an impact on the necessary floor space, but also on the risk the GDF poses for the population. According to an assessment by NDA, the disposal of the spent fuel arising from only six new EPR reactors would be to contribute more than the half of the total risk limit which is set by the Environmental Agency (The limit on the risk caused by the burial of radioactive wastes is set to be 10^{-6} per year (i.e. one person in a million per year contracting a fatal cancer, as a result of radiation exposure)).

The realization of the newbuild programme would very likely require a second GDF, the envisaged and necessary operation time extension of the existing reactors increases the probability for second GDF.

5.5 Final disposal search in UK

In its 2008 white paper, the UK government set out a framework for managing higher activity radioactive waste in the long-term through geological disposal. It also invited communities to have discussions, without commitment, with government on the possibility of hosting a geological repository. So far, two areas in Cumbria (Allerdale and Copeland) have expressed interest in hosting the facility.

In January 2013 both communities held votes to proceed into the next phase of the selection procedure (Phase 4: Evaluation of available information for assessing the suitability as a disposal site). The communities voted in favour, but the Cumbria County Council was against it. Because all bodies need to act united, the County Council´s no stopped the site election process.

After this rejection the British government reviewed the site selection procedure. Currently geological conditions are under investigation in England, Wales and Northern Ireland. The host rock has not been determined, salt, granite and clays are under all under consideration. Due to incomplete data on the possible areas, no direct suitability of one of the sites can be predicted. In the first step a data base will be created, to improve the talks with the communities on finding a possible site. The potential site, which could result from a first screening, should be announced in 2016.

Because the idea of the voluntary approach failed in the UK, currently a legal amendment is under consideration, which would enable the British Secretary of State to decide the complex

[79] Nuclear Waste Advisory Associates, 'Outstanding Scientific and Technical Issues Relating to the Production of a Robust Safety Case for the Deep Geological Disposal of Radioactive Waste.' http://www.nuclearwasteadvisory.co.uk/wp-content/uploads/2011/06/NWAA-ISSUES-REGISTER-COMMENTARY.pdf

and politically sensitive decisions concerning the radwaste disposal without votes, e.g. with the councillors. [80]

After years of encouraging West Cumbrian communities to volunteer to host a repository, and working with local and regional government, and others, on whether to progress such proposals, the political atmosphere over volunteering has now changed.

According to the implementation plan of the GDF, **the UK Government continues to reserve the right to explore other approaches in the event that, at some point in the future, such an (voluntary) approach does not look likely to work**.[81] Obviously this points to the possibility **a repository could be forced onto a community**.

Before the siting process stopped one more time, the site selection was expected for 2025, however this might not be possible any more. **The Government cannot guarantee it will find a volunteer community, *with* the right geology, which will take *all* legacy *and* new build wastes**. Note: the geological suitability of the only areas currently under consideration in the MRWS process (Allerdale and Copeland) is being questioned by experts in this field. Indeed, the suitability of the whole Cumbria region as suitable for geological disposal is being challenged.[82]

Prior to 1976 very little thought had been given to the question of how to deal with the nuclear waste. Over the last decades there have been several cases of nuclear waste proposals being abandoned by governments prior to an election.

The Government is now experimenting with more open and transparent consultation techniques, which will include dialogue with 'stakeholders' including members of the public, environment groups and the nuclear industry. It is still too early to predict whether the new approach will be successful in carrying out its remit, but the nuclear waste debate is likely to have implications for the development of democracy in the UK for many years to come. **What is clear, however, is that a vital piece of the public consultation process is missing – the Government has failed to announce an end to the production of more nuclear waste – states an article of „No2NuclearPower".**[83]

There are basically two paths, both expensive, to at least have a chance to conducting a successful site search. Either the state bears high costs for the procedure to involve the population. This carries the risk that the additional costs for the involvement of the people (e.g. increase of safety requirements, abandoning of an investigated site or a second repository) would not be paid by the waste producers. In Germany, e.g. the utilities believe the new repository search is a politically influenced process and refuse to pay for it. [84]

The second possibility consist of the government pushing through a disposal site with force - most likely also expensive. In Germany the costs for the police intervention against the protest during the so

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[80] Endlager: Internationaler Vergleich, Großbritannien. Stand 24.02.2015 http://www.endlagerung.de/language=de/26528/grossbritannien

[81] Department of Energy and Climate Change (DECC): Implementing Geological Disposal. July 2014 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/332890/GDF_White_Paper_FINAL.pdf

[82]Geology: Why the whole of West Cumbria is unsuitable for a nuclear waste repository, David Smythe November 2010; www.davidsmythe.org/nuclear/cumbria%20bgs%20exclusion%20report%20review%20for%20website.pdf

[83] No2NuclearPower: History of nuclear waste disposal in Britain; 20 November 2012; http://www.no2nuclearpower.org.uk/radwaste/history-of-nuclear-waste-disposal-proposals-in-britain/

[84] Mayer-Rüth zur Haftung der Atomkonzerne Knackpunkt Endlagersuche. Stand: 14.10.2015 https://www.tagesschau.de/wirtschaft/atommuell-rueckstellungen-101.html

far last high level waste transport to the highly contested repository site Gorleben reached approx. 33.5 million euro. [85]

Independently of the cost issue there is still the danger that the disposal search might be blocked due to the new build project for decades. The spent fuel assemblies will stay in the surface interim storages and therefore the interim storage will continue posing a significant risk for a long period of time – in the worst case for thousands of years.

6 Costs for the management of radioactive waste and spent fuel

In 2013 the cost for decommissioning and clean-up of the civil and publicly owned nuclear sites are estimated by the responsible authority, the Nuclear Decommission Authority (NDA) to be about £100bn and the majority of this will be paid for by future tax-payers. The biggest part belongs to the, most complex site, Sellafield.[86]

A sound spent fuel and radioactive waste management strategy is a condition for the construction and operation of new NPPs. Such a management strategy also includes adequate financing of all activities and storages.

The Council Directive 2011/70/EURATOM (the 2011 Directive) „ *establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste* " requires European Union (EU) Member States to have National Programmes for the implementation of their management policies for the spent fuel and radioactive waste that falls within the scope of the Directive. The aim is to ensure that Member States provide for appropriate national arrangements for a high level of safety in spent fuel and radioactive waste management to protect workers and the general public against the dangers arising from ionising radiation. This Directive establishes a Community framework for ensuring responsible and safe management of spent fuel and radioactive waste to avoid imposing undue burdens on future generations. The national programmes have to comprise all level of waste management and have to be provided for the first time by August 2015.

According to the EU directive 2011/70/Euratom, the Member States shall ensure that the national framework require that adequate financial resources be available when needed for the implementation of national programmes, especially for the management of spent fuel and radioactive waste, taking due account of the responsibility of spent fuel and radioactive waste generators.

6.1 Financing in the UK

According to chapter 10 (Economic and Financial Considerations) of the national program (according to RL 2011/70/Euratom), the UK Government expects all nuclear operators to take the steps necessary to ensure that their work on decommissioning and radioactive waste management is adequately funded.[87]

In the Energy Act 2008 it is legislated to ensure that operators of new nuclear power stations will have secure financing arrangements in place to meet the full costs of decommissioning and their full share

[85] Hamburger Abendblatt: Niedersachsen rechnet mit 33,5 Millionen Euro für Castor-Transport; 30.11.2011; http://www.abendblatt.de/region/article108186768/Niedersachsen-rechnet-mit-33-5-Millionen-Euro-fuer-Castor-Transport.html
[86] Guardian (23.6.2013): „UK's nuclear clean-up programme to cost billions more than expected", http://www.theguardian.com/environment/2013/jun/23/britain-nuclear-atomic-clean-up-decommissioning
[87] DECC 2015, see above

of waste management and disposal costs. Before construction begins, an operator of a new nuclear power station will have to submit a **Funded Decommissioning Programme (FDP)** for approval by the Secretary of State.

For nuclear new build, the UK Government has issued guidance on the required funding arrangements for decommissioning and waste management. [88]

The Nuclear Liabilities Financing Assurance Board was established to provide impartial scrutiny and advice on the suitability of the FDPs, which advises the Secretary of State on the adequacy of the proposed measures. The fund shall be checked in regular intervals.

Also the Nuclear Decommission Authority (NDA) scrutinises plans for decommissioning and waste and cost estimates by new nuclear power plant developers.

The Government's anticipates that spent fuel and Intermediate level waste (ILW) from new nuclear power plants will be disposed of in the same geological disposal facility (GDF) that the Government intends to construct for the disposal of "legacy" wastes. The Radioactive Waste Management Limited (RWM) is the developer of the GDF. Its plans are used to provide a basis for the assessment of cost by NDA.[89]

6.2 Waste Transfer Contract (WTC) and Waste Transfer Price (WTP)

Alongside approval of an operator's FDP, the UK Government also expects the operator to enter into Waste Transfer Contracts (WTCs) regarding the terms on which the UK Government will take title to and liability for the operator's spent fuel and Intermediate level waste (ILW) for disposal. According to the national program, the WTCs are framed so that operators of new nuclear power stations are charged for waste disposal linked to actual expenditure in all but the most unlikely cases.[90]

The Waste Transfer Contracts (WTCs) will include a pricing methodology which, in particular, will provide for the Waste Transfer Price for the disposal of the spent fuel and intermediate level waste which corresponds to its share of waste management and disposal costs of the geological disposal facility for the legacy waste which will be built by the government.

The Government will also be prepared for the waste transfer to the Government on a specified "Transfer Date" that is earlier than the Assumed Disposal Date. In return the operator will pay the Government a "Lump Sum Payment" to cover all additional costs that the Government will incur in managing the waste prior to its disposal.

It had originally planned to charge a fixed price, this was changed in 2011 to a variable, but **capped, Waste Transfer Price (WTP**). The Waste Transfer Price will be set after a "Deferral Period" to be determined at a specified date during the operational lifetime of the nuclear power plant (upt to 30 years) to provide time for greater certainty in GDF costs. This will be after around 25 years of operation of Hinkley Point C. It is assumed that by 2050 the government will know the true outturn capital cost of siting and constructing the repository and will also have had 10 years' practical operating experience running the repository, which is planned to be fully operational by 2040 (the part for disposal of the intermediate level waste). At this point in time a certain residual insecurity

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[88] Department of Energy and Climate change (DECC): The Energy Act 2008, Funded decommissioning Programme, Guidance for New Nuclear Power Stations, December 2011, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/70214/guidance-funded-decommissioning-programme-consult.pdf

[89] DECC 2015, see above

[90] DECC 2015, see above

about the cost will still remain, thus the operator will pay the UK Government a risk premium for fixing the price ahead of the date of disposal to ensure that the taxpayer is appropriately compensated for taking the financial risk of any subsequent cost escalation.

On the WTP, an attempt has been made to estimate what disposal costs might be like in 100-160 years. A comprehensive document (111 pages) describes the waste transfer pricing methodology, which gives an idea of the complexity of this issue. [91] The consultations process ended in February 2011; the finished methodology was published at the end of 2011.

On October 9 2015 the European Commission announced that it found the pricing methodology (WTP) for waste transfer contracts (WTC) to be concluded between the UK Government and operators of new nuclear power plants compatible with EU state aid rules. The Commission's role is to ensure that when public funds are used to support companies, this is done in line with EU state aid rules, which aim to preserve competition in the Single Market. The media announcement stated: given the uncertainties at this stage concerning the waste transfer price to be paid, the UK government considered it necessary **to set a price cap**, to provide some visibility of future liabilities to secure investors and financing. The Commission was able to conclude that the actual disposal costs are very unlikely to exceed the cap level. Therefore, any potential state aid and distortions of competition due to the cap, if any, would remain very limited.[92]

6.3 Potential additional subsidies via the WTC

According to Greenpeace UK the regulator should have sought more feedback before issuing its decision, because the WTP is a transfer of risk to the taxpayer, which was likely to face a huge long-term bill.[93]

Ian Jackson, author of *Nuclear Engineering International*'s 2008 special publication *Nukenomics*, developed a software model of the economic issues affecting the spent fuel disposal costs for new nuclear reactors (called 'FUPSIM' after the earlier fixed price unit plan), in a research commission for Greenpeace UK. His software FUPSIM[94] simulates waste disposal liabilities for any size of new nuclear power station via 21 adjustable input parameters (such as power station output, generating lifetime, load factor, spent fuel burn-up, storage period, and discount rates) and displays 31 calculation results. It also calculates the any potential funding shortfall that may need to be subsidised by the taxpayer.[95]

In a March 2011 Greenpeace UK report[96], Jackson argues that the cap, £978,000/tU, may be too low to cover the government's costs. Jackson says the government assumes nuclear disposal costs will rise at

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[91] DECC, 'Waste Transfer Pricing Methodology for the disposal of higher activity wastes from new nuclear power stations, ' December 2011 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42629/3798-waste-transfer-pricing-methodology.pdf

[92]European Commission: State aid: Commission approves UK pricing methodology for nuclear waste transfer contracts, - Press release, Brussels, 9 October 2015 http://europa.eu/rapid/press-release_IP-15-5815_en.htm

[93] EU regulators wave through UK nuclear waste clean-up price plan, Reuters, Fri Oct 9, 2015 7:52pm; http://uk.reuters.com/article/2015/10/09/eu-britain-nuclear-idUKL8N1293NN20151009

[94] FUPSIM used UK government generic reactor modelling assumptions based on a 1.35 GWe PWR reactor operating for 40 years lifetime, generation start-up 2020, end of generation 2060, average load factor 90%, with a lifetime generating output of 424,000 GWh over 40 years

[95] Nuclear Engineering International: Estimation the disposal costs of spent fuel; October 2011 http://www.mng.org.uk/gh/private/jackson_nuclear_waste_disposal.pdf

[96] Jackson: Subsidy Assessment of Waste Transfer Pricing for Disposal of Spent Fuel from New Nuclear Power Stations. Research Report, March 2011, http://www.greenpeace.org.uk/sites/files/gpuk/FUP-Subsidy-Report-Mar2011.pdf

only 3.3% per annum above inflation. But past experience shows that nuclear costs typically escalate at between 4.2–4.5% above inflation. Over the past decade the costs of similar major nuclear projects such as NDA liabilities, Yucca Mountain, Olkiluoto-3 und Flamanville-3 have all risen at around this rate. At that rate, spent fuel disposal costs will breach the government price cap much sooner than expected (around 2047). The disposal price paid by the energy utility will not fully cover the NDA's disposal costs, and so the NDA will require a government subsidy to make up the shortfall. The subsidy is around **£1,127 million for a 60 year lifetime of the PWR**. Thus, the report recommends removing the maximum price cap.

In addition, Jackson argues that the government may have underestimated the costs of disposition. Both issues would require a government subsidy to cover costs. His simulation program calculates that the shared spent fuel unit disposal cost for a new 10-reactor PWR fleet is £473,000/tU, which is about £280,000 higher/tU than UK government predictions. Thus, an additional subsidy of about £445 million will be necessary (for a 60 year operation time).

According to Jackson, there are two possible indirect subsidies for the utilities for the disposal costs. The subsidies are indirect, because NDA will provide the shortfall to the utilities but will require an indirect government, i.e. the taxpayer, subsidy to make up the shortfall. For a reactor with a 60 year operating life, the estimated total subsidy was put at £1.572 bn; on top of what the industry was to have paid.[97]

Furthermore Jackson pointed out, that the unit disposal costs (£k/tU) for new PWR spent fuel being about half the cost of AGR spent fuel, because it assumed that legacy AGR spent fuel could be packed so efficient like of new PWR spent fuel. In the opinion of Jackson this assumption is not appropriate. He recommended using the same price per ton for all different reactor types.[98] This issue is not a topic of the study, however, it should serve as an example for those many assumptions the WTP method is based on.

6.4 Assessing the cost sharing for a GDF

The government promised to make sure, that the total costs for the disposal of radioactive waste generated in the new NPP will be covered by the operator. But the energy utilities demand assurance on how much the costs of the final disposal. Therefore the government changed this promise that the operators of new NPP would have to cover the full costs themselves.

As the calculation made by Jackson showed, it is rather unlikely that the paid share of the cost will suffice and rather on the contrary the taxpayers will have to shoulder enormous additional costs. At this point is not possible to predict exact sums, there are too many insecurities about the costs of the final disposal. Looking at facts however makes clear, that the large state aid granted in the frame work of the electricity price guarantees over 35 years for Hinkley Point C are only the tip of an iceberg.

In spite of approved billions of state aid, it is most likely that billions in additional subsidies will be necessary for the disposal of the radioactive waste and spent fuel assemblies.

This hardly meets the criterion of this generation not leaving future generations with the burden of having to deal with radioactive wastes. The reason behind setting a maximum cap which operators can expect to pay is to give certainty to new build investors, whereas no certainty is

[97] For Realisation of the 10GW Newbuild programme
[98] Nuclear Engineering International: Estimation the disposal costs of spent fuel; October 2011 http://www.mng.org.uk/gh/private/jackson_nuclear_waste_disposal.pdf

being provided for the taxpayer that the public purse will not eventually have to pay towards waste and spent fuel management and disposal. The responsibility of the disposal and its costs should remain with the operator and not be removed by the Government which cannot guarantee – regardless of the risk premium various proposed – that the maximum price cap will not be exceeded.

This sharing made the waste deals attractive to EDF, because the per-unit disposal costs of a stand-alone, commercial-waste only repository could be much higher.

The basic inputs used to determine the "waste transfer prices" are not correct anymore, because the method assumed a 10GW new build program and 40 years of reactor operation. Current official planning however talks about 16 GW new build program and operation of 60 years, meanwhile even an installed gross capacity of 18 GW is being planned. This would lead to a 2.4 or 2.7 fold increase in spent fuel assemblies than previously expected.

This also gives rise to the well-grounded notion that due to the new reactors more than one Deep Geological Repository is needed for the additional waste. This would increase the costs substantially.

In the current document "Implementing Geological Disposal (2014) chapter "Communicating the inventory for disposal" it is stated: In event, the 16 GW new build program will be realized, the UK Government would need to discuss and agree the disposal of this additional spent fuel and ILW with any communities participating in the GDF siting process, with a view to either expanding any existing facility development or seeking alternative facilities.[99]

While the government on the one hand does not exclude that another geological repository will be necessary and also says so in the recently published documents, the government on the other hand agrees on a contract with EDF on the disposal costs, which are based on the shared costs of the final disposal. **This makes it very likely, that the price cap on the waste transfer contracts (WTC) will not be sufficient for the payments of EDF and that the state or rather the taxpayers will have to shoulder those additional costs.**

Moreover the site selection procedure for the final disposal has been suspended. It will re-start next year and it is not predictable, whether it will be successful – which is also depending on the expected additional reactor construction. A site for the location of the geological disposal facility has not been selected yet. It is not foreseeable how long the search will take and how expensive it will be.

The disposal costs are difficult to estimate because there is little experience with the cost of disposal of waste. Until now there is no final geology disposal facility for high level waste in operation around the world.

Difficulty in determining costs because of a number of outstanding issues; including there being no final waste form for spent fuel (it might be encased in copper which is the option favoured by Sweden, for example). The type of final disposal is a decisive cost factor. Many issues are still open. Undertaking a cost estimate before many technical question are answered is of course connected to many insecurities.

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[99] Department of Energy and Climate Change (DECC): Implementing Geological Disposal. July 2014 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/332890/GDF_White_Paper_FINAL.pdf

Most relevant also is the limit on the level of radioactivity in the inventory to be disposed of; which is determined by the radiological (dose) limit. The proliferation potential for some materials – and how proliferation resistance configuration of waste disposal would result in stronger security barriers – is another factor. The participating scientists, authorities and people will most likely achieve stronger requirements during the procedure.

Additional to the disposal costs (WTP) a lump sum is to be transferred after decommissioning of the reactor takes place to cover all additional costs that the Government will incur in managing the waste prior to its disposal. However, the waste will emplace at a later, most likely much later point in time. **Therefore the lump sum may be too little, the determination of the lump sum is overly optimistic according to Greenpeace.** Because payment will be made by the operator earlier than the waste will be emplaced, it is necessary to adjust the payment made by the operator to reflect this early payment. This will be done through the application of an appropriate discount rate to the Final Price to reflect the time difference. It is quite possible that the stock market fails to make the returns expected; in this case the taxpayer will take the risk.

It is unacceptable that the agreements concerning disposal costs of spent fuel and intermediate and high level waste (waste transfer contract –WTC), which will have practical and financial implications for over 100 years, will remain closed to the public. Despite publishing some information on the possible costs, the UK Government has decided not to be fully transparent about the actual waste and spent fuel agreements. The government has instead left it to EDF to decide what should be disclosed.[100]

The actual costs for disposing the high level waste are difficult to determine for a state, among other reasons also because the emplacement costs are dependent not only from geological conditions and safety standards, but also the societal acceptance. [101] In the UK, societal acceptance is shrinking more and more because of the planned massive new build programme for NPP.

6.5 Risks connected to the availability of the operators´ reserves

In addition to the question, whether the costs have been calculated in a proper manner, the question whether the agreed WTC sums for the transfer costs and the lump sum and the decommissioning costs for the nuclear installations on the NPP site will be available when needed.

Even under the proposed cost-sharing (WTC) and subsidy scheme (CfD), there might still be a further call on public money if the nuclear operators fail to put aside enough from their incomes or rather the tax payers´ money, which they will be receiving via the guaranteed strike price of the Contract for Difference (CfD).

As a general rule utilities accumulate a certain share from their income as reserves to cover those obligations. On April 2015 the British government declared in a letter, that there is no specific regulation or mechanism to include the costs of decommissioning, waste management and waste disposal costs in the strike price. However, these elements are an operational cost of the plant, and as

[100] Annex III to Greenpeace EU submission to the European Competition Commission 7 April 2014 (paper previously submitted, March 2011, in response to UK Government consultation) http://www.greenpeace.org/eu-unit/Global/eu-unit/reports-briefings/2014/State%20aid%20SA.34947%20%282013C%29%20Greenpeace%20Annex%20III.pdf

[101] Wirtschaftsdienst, Zeitschrift für Wirtschaftspolitik: Kernkraftwerke: Die wahren Kosten der Atomkraft; Sonja Peterson, 91. Jahrgang, 2011, Heft 4 | S. 224; http://www.wirtschaftsdienst.eu/archiv/jahr/2011/4/kernkraftwerke-die-wahren-kosten-der-atomkraft/

such we would anticipate that they would amount to around £2 of the strike price. The letter also points to the fact, that *he Funded Decommissioning Programme would need to be approved by the Secretary of State before construction starts*.[102]

In UK, it is assumed that monies will be accumulated, and companies will remain viable and solvent, over the timescale necessary to see completion of a FDP. However, this cannot be seen as a sure fact. The problems come if the cost has been initially underestimated, the funds are lost, or the company collapses before the plant completes its expected lifetime. All of these problems have been experienced in Britain. [103]

The expected decommissioning cost has gone up several-fold in real terms over the past couple of decades. The focus of the *World Energy Outlook* (WEO)[104] of the International Energy Agency (IEA) 2014 was on the development of nuclear energy. It concluded, that the investment costs for a new nuclear power plants are significantly higher than for any other competing technology. [105] Moreover the paper declared, that the insecurity factors are constantly increasing. **In particular the Decommissioning of nuclear power plants might turn into an incalculable cost risk**. [106] The *World Energy Outlook* also pointed out, that the issue of final disposal still remains unsolved. 60 years after the first nuclear reactor started operating, no state has managed to build a final disposal for the high level waste from nuclear power plants.

Though the final disposal of **high level waste** is a problem worldwide, current estimates on costs of nuclear power seem to consider it being a negligible factor. When taking a decision to build a NPP, the costs associated with of the final disposal of high level waste are given little attention in comparison to other cost factors.

The reason for this lies in the calculation method usually applied for investment decisions. Future costs are estimated with a lower sum, which is calculated with an annual discount. While this seems a reasonable process over periods of a decade or so, you must be very careful with discounting over a long time period.[107] The operators are obliged to accumulate annual reserves for the final disposal, their level being decreased due to discount significantly. **Whether the costs will be covered later, remains unclear. [108] It is possible that that the stock markets are not going to deliver the expected turnover and the reserves will not be sufficient**.

Whether the reserves will be sufficient is also dependent on the economic development over a long period of time. The German minister of economics (Sigmar Gabriel) ordered a stress test for the nuclear utilities to be conducted. The goal was to assess the level of the reserves. The study considered different scenarios, which were based on different assumptions. [109] The necessary level of reserves

[102] Department of Energy and Climate Change (DECC); Letter to Jean Sorley; 1 April 2015
[103] The Economics of Nuclear Power. An update; Steve Thomas; March 2010; Heinrich Böll Stiftung; https://th.boell.org/sites/default/files/thomas_the_economics_of_nuclear_power1.pdf
[104] Leading international publication on global energy security.
[105] To compare: With 5100 USD/kW in Europe net investment costs would be five times higher than for combined cycle power plant (1000 USD/kW).
[106] According to WEO 2014 until 2040 almost 200 reactors will be taken offline (434 were operating at the end of 2013). IEA estimated the decommissioning costs to amount to more than die 100 billion USD worldwide. However, they point out that there is a certain cost insecurity involved; experiences made so far suggest much higher costs for decommissioning.
[107] If the discount of the sum of € 1000 over 100 years is 3% only per year, this would represent a current investment value (capital value) of €52.
[108] Ökologieinstitut: Die wahren Kosten der Kernenergie; Andrea Wallner, Gabriele Mraz; Wien, Juli 2013; http://www.ecology.at/files/berichte/E22.604.pdf
[109]. This assumes the companies´assets cover the NPP decommissioning costs and radioactive waste disposal. Currently the companies accumulated € 38,3 billion. In the Federal Economics Minister´s opinion, the scenarios

needed ranges for Best Case to Worst Case between approx. € 29 to 77 billion. [110] This wide range shows how dependent the level of accumulated reserves is from the economic development at the time when the reserves are needed.

Another accident in a nuclear facility anywhere in the world can force the company EDF, still not re-covered from the Fukushima accident, or some other energy utility with nuclear power into bankruptcy. **A company could attempt to get out of the financial obligations stepwise by restructuring.** In Germany it was necessary to introduce a new liability law to secure the companies´ funds, because some of the responsible companies intended to restructure as a way to outsource the liability claims.

To ensure that taxpayers are not left with the burden of paying for cost, legal measures would have to be implemented to ensure the costs fall wholly on the companies concerned. Checks would need to be made on the financial status of the relevant companies; and regular stress-testing undertaken to determine their long-term economic viability in order to protect taxpayers.

In the UK, a range of control measures has been introduced, however the responsibility and decision about the reserves stays with the operator; transparency is lacking. The main problem is, that controls cannot prevent bankruptcy of the utility, e.g. due to an accident in a nuclear facility.

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with the high reserve values are unlikely, because they assume significant losses in the long term. The co-chair of the Bundestag´s Final Repository Commission believes that the all-clear comes too early, because no one can tell the exact costs until now.

[110] Gutachten: Konzerne können AKW-Rückbau meistern – sagt Gabriel; 13.10.2015 http://www.neueenergie.net/politik/deutschland/konzerne-koennen-akw-rueckbau-meistern-sagt-gabriel

7 More NPP new build projects in Europe

Current conditions make an economic operation of a new nuclear power plants impossible. A nuclear power plant can be operated only with the help of state subsidies, which leads to massive market distortions. **The European new build programs will most likely receive an upward boost from the "Contract for Difference" (CfD) mechanisms, which the British government intends to sign for Hinkley Point C. The long-term guarantee for a strike price makes the reactor new builds profitable for investors.** The following chapter looks into the currently planned projects for new nuclear power plants. However, this is an attempt to assess how likely it is that those projects will be realized.[111] It rather analyses the existing plans for interim storages and final disposal of existing and potentially newly generated spent fuel.

The following table gives an overview over the new build projects under consideration and the additionally generated spent fuel assemblies (in tHM). The data is taken from official documents or based on estimates.

Table 2: Overview over the considered new build projects in Europe and additionally generated spent fuel assemblies

Country	**Site**	**Reactor type**	**Power [MWe]**	**Envisaged Commissioning**	**Additional Spent fuel [tHM]**
Bulgaria	Kozloduy-7	AP1000	1200	2025	1.260*
Poland	Zarnowiec, Choczewo oder Lubiatowo-Kopalino	unknown	max. 3750	2025	4.800
		unknown		2029	
	Unbekannt	unknown	about 3000	about 2035	3.800*
		unknown		about 2035	
Romania	Cernavoda-3	Candu 6	720	2019	11.600*[1]
	Cernavoda-4	Candu 6	720	2020	
Slovakia	Bohunice 3	unknown	max. 1700	2029	2.370*
Slovenia	Krsko II	unknown	1100-1600	?	1.800
Czech Republic	Dukovany 5	unknown	1200*	2035	5.010
	Temelin 3	MIR-1200/AP1000	1200	2035	
	Temelin 4	MIR-1200/AP1000	1200	2040	
Hungary	Paks-5	AES-2006	1200	2025	3.348
	Paks-6	AES-2006	1200	2030	
Total					**33.988**

*Estimate

[1] All reactors with the exception of the Heavy Water Reactors CANDU are Light Water Reactors (LWR); Heavy Water Reactors are loaded with different fuel.

7.1 Hungary (Paks II)

In Hungary currently four VVER-440/V-213 reactors are operating **at the Paks NPP**, which started operation between 1982 and 1987. An operation time extension of 20 years is envisaged for all four reactors (until 2032-2037), for unit 1 and 2 it was approved already.

[111] The new build projects in Finland (Hanhikivi and Olkiluoto) and in France (Flamanville) are not discussed in this study.

In 2009, the Hungarian Parliament gave preliminary approval to building a new **NPP Paks II**, though some foreign investment would be needed. [112] Out of the above-mentioned five reactor types considered in the first phase of the EIA procedure (the scoping phase), only the VVER-1200 technology has been selected for environmental assessment. In January 2014 the Hungarian Government and the company Rosatom already signed an agreement with the Russian company Rosatom about delivery of the NPP. This decision was taken without conducting a transparent tender process before. Paks II with two VVER-1200 reactors should cost around € 12.5 billion, out of which ten billion will be provided by the Russian partners and the missing € 2.5 billion will be taken out of the Hungarian state budget. The operation of the new units is scheduled for 2025 and 2030, respectively. An operation time of 60 years is envisaged.

In May 2015, the Hungarian authorities notified the European Commission about the plans to invest in the construction of two reactors at the Paks site.

On the 23 November 2015, the European Commission stated that an in-depth state aid investigation into Hungary's plans to provide financing for the construction of two new nuclear reactors in Paks was opened. The Commission will in particular assess whether a private investor would have financed the project on similar terms or whether Hungary's investment constitutes state aid and if whether as planned it would lead to distortions of competition in particular on the Hungarian energy market.

Under the TFEU (Treaty on the Functioning of the European Union) Member States are free to determine their energy mix. The Commission's role is to ensure that when public funds are used to support companies, this is done in line with EU state aid rules, which aim to preserve competition in the Single Market.

The Commission decided to launch an infringement procedure against Hungary as regards the Paks II project, because it has concerns regarding the compatibility of the project with EU public procurement rules. The Hungarian authorities have two months to respond to the arguments put forward by the Commission.[113]

Interim storage and final disposal of spent fuel

Hungary has not published the national program according to Council Directive 2011/70/Euratom yet (as of November 2015). According to the fifth *Hungarian National Report Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* (2014), the number of spent nuclear fuel assemblies that will have been generated by the end of the life-time of the nuclear power plant (2037) and may remain in Hungary will be about 17,728, with approximately 2,100 tHM content[114].[115]

According to the EIA-Report, the spent fuel that will be generated during the operation of Paks II after 60 years of operation will account for 3,348 tHM. It is not clear yet, that the spent fuel after unloading

[112] World Nuclear Association (WNA): Nuclear Power in Hungary (Updated April 2015): http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Hungary/

[113] European Commission State Aid: Commission opens in-depth investigation into Hungarian investment support for Paks II nuclear power plant; Press release Brussels, 23 November 2015; http://europa.eu/rapid/press-release_IP-15-6140_en.htm

[114] Previously, between 1989 and 1998, altogether 2331 spent fuel assemblies with 273 t heavy metal content were shipped back to the Soviet Union (later to Russia).

[115] The Hungary National Report prepared within the framework of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management; Fifth Report; 2014; http://www.oah.hu/web/v3/HAEAportal.nsf/F9E0B8119D23045DC1257E59003C7850/$FILE/5th_nat_rep_JC_0818_ENG_v2.pdf

from the reactor pond will be stored at the site (most likely in a dry interim storage) or transported to Russia.

For final disposal of HLW, long-lived LILW and SF a deep geological repository will have to be established in Hungary. It is stated, for choosing the location, studies were conducted in the area of the Western Mecsek hills; a deep geological laboratory is planned in the clay soil to be built until 2030.

However, no decision has yet been taken on the back-end of the fuel cycle. The EIA report explains three option for the management for spent fuel of Paks II. The first one is the direct disposal of spent fuel into a deep geological repository. The second approach is reprocessing. The third scenario is the so called approach *“Do and See” (previously “Wait and See”)*. This means that the program could consist of several consecutive phases and switching between these phases is possible. At certain points the next steps will be decided made concerning the program according to the appropriate deliberations.

Conclusions: Hungary does not have any concrete plans for the disposal of spent fuel assemblies; therefore a key precondition of the construction of another NPP – Paks II – is lacking. The agreements made with Russia concerning Paks II are also highly problematic. The European Commission shares this view and initiated investigations in those issues.

7.2 Czech Republic (Dukovany 5 and Temelín 3&4)

In the Czech Republic two nuclear power plants are operation, the NPP Dukovany and the NPP Temelín. The licence holder and operator is ČEZ, a.s. which is 70% owned by the government.

The four reactors operating at the **NPP Dukovany (**Type VVER-440/V213) end between 2015 and 2017.The envisaged operation time extension for 10 or even 30 years are in question because of safety relevant issues.

The construction of the **NPP Temelín (Temelín 3& 4)** started in 1987 but was put to a halt, construction resumed later and Temelín 1& 2 (VVER-1000/V320) was put into operation in 2000 and 2002 resp.

In July 2008, CEZ announced a plan to build two more reactors at Temelín, with construction start in 2013 and commissioning of the first unit in 2020. In January 2013 the government gave environmental approval for the two units. Additionally a feasibility study for a new reactor at Dukovany (**Dukovany 5**) is in progress.

In 2013 CEZ announced all decision deferred for about 1 or 2 years. The previous government was planning to legislate for a cost-difference guarantee for electricity from Temelín 3&4 comparable to the Contract of Difference in UK for Hinkley Point C).[116]

On June 2015 the Czech cabinet has approved an action plan on nuclear energy, providing for future construction of 1 or 2 reactors at both the Temelín and Dukovany nuclear sites. Dukovany 5 has priority over Temelín. [117] Start-up for Dukovany 5 and Temelín 3 are scheduled for 2035 and for Temelín 4 in 2040.

[116] World Nuclear Association (WNA): Nuclear Power in Czech Republic (updated October 2015); http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Czech-Republic/
[117] World Nuclear News (WNN): Cabinet approval for Czech strategy; 04 June 2015; http://www .world-nuclear-news.org/NP-Cabinet-approval-for-Czech-strategy-0406158.html

Interim storage and final disposal of spent fuel

At Dukovany, two dry interim storage facility are in operation. The storage capacity is sufficient to cover all spent fuel production of NPP Dukovany with the anticipated operation of the units at least until 2035.

The storage capacity of spent fuel storage facility Temelín (in operation since 2010) is sufficient to cover all spent fuel of the two NPP Temelín units for 30 years of its operation and it may be expanded on as needed basis by building of additional storage halls.

The program of a deep geological repository (DGR) development started back in 1992. The works were suspended in 2005 due to public resistance. The next period was used for intensive negotiations with the affected municipalities and with the general public. A Working Group for Dialogue about the deep geological repository was established in late 2010 with the objective to improve transparency of the process to select the future DGR location. Following the discussion with public, SURAO expects starting the geological works at several sites in 2016. During 2015 all seven potential sites obtained an approval for the first phase of geological works using surface techniques. However, at all sites the people and the communities organized a strong resistance to those investigations and the final disposal.

The government expects selection of a candidate and a reserve site by 2025, with construction start after 2050, and operation beginning in 2065. The cost of building and operating the deep repository is estimated at CZK 111.4 billion (€4.0 billion).

The national report provided the amounts of spent fuel for different scenarios (see table above).[118] Three new reactors will generate significantly more spent fuel assemblies (per tHM) than the 40 year operation of all six existing reactors, and even a little more than during their 60 years of operation.

	Amount of spent fuel [tHM]			
Operation time	Dukovany 1-4	Temelín 1&2	Temelín 3&4, Dukovany 5	Total
40 years	1740	1750		3490
60 years	2430	2470		4900
60 years	2430	2470	5010	9910

Conclusions: The enormous problems surrounding the final disposal site for spent fuel from the existing reactors make it very irresponsible to intend producing the same additional amount in new reactors.

7.3 Romania (Cernavoda 3&4)

In Romania two CANDU reactors are operating at the Cernavoda site, **Cernavoda 1 & 2**. The previous plan in the 1970ies included 5 reactors at Cernavoda. In 1991 the construction of units 2-5

[118] *Czech Republic: National Report under the Article 14.1 of Council Directive 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste, Revision 1.1;* June 2015; https://www.sujb.cz/fileadmin/sujb/docs/zpravy/narodni_zpravy/EuroNZ_VP_RAO_1_1a.pdf

was halted to focus on unit1, which went into operation in 1996. In 2000 only construction at Cernavoda 2 was resumed and the unit went into operation in 2007.

Now **Cernavoda 3 and 4** are to be completed; an environmental mental assessment (EIA) was conducted in 2007. In October 2014 Nuclearelectrica (SNN) designated China General Nuclear Power Group (CGN) as the "selected investor" for the project. The units will be updated versions of the Candu 6 (reactor type of Cernavoda 1&2), but not the full EC6 version, since the concrete structures are already built. Unit 3 is reported to be 53% complete and unit 4 is 30%.[119] They will have an operating life of 30 years with the possibility of 25-year extension. Start of operation is still scheduled for 2019 and 2020 resp. angegeben.[120]

In November 2015, Romania's state owned electricity producer Nuclearelectrica and Chinese group China General Nuclear Power signed the memorandum of understanding for the Units 3 and 4 of the Cernavoda. However, in order for the project to move on, the Chinese want the Romanian state to guarantee a minimum selling price for the electricity that the new reactors will produce.[121]

Interim storage and final disposal of spent fuel

Spent fuel of Cernavoda 1 and 2 is transferred to a dry storage facility at Cernavoda based on the Macstor system designed by AECL. The storage capacity will be expanded gradually, assuring storage of spent fuel resulted from operation of two reactors for the 30 years each one. The first module was commissioned in 2003.

In the EIA report about the construction of Cernavoda 3&4 it is stated that existing storage facilities for spent fuel will be extended in order to handle the radioactive waste and spent fuel from the new units. It is also stated that a national final disposal facility for spent fuel are planned. Further information is not presented.[122] Both new units are estimated to produce around 11,600 tHM of spent fuel.

Until now no dedicated efforts to find a site and to construct a final disposal for spent fuel and high and medium level waste are noticable.

The National Waste Management Program (in line with directive 2011/70/Euratom) has not been published yet (as of November 2015).

According to the fifth report of *Joint convention on the safety of spent fuel management and on the safety of radioactive waste management (2014),* ANDR (*Nuclear Agency for Radioactive Waste)* is setting up a knowledge database for siting, by gathering existing information on geological, hydrogeological and seismic characteristics of the preferred investigation areas. In order to keep all the

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[119] World Nuclear Association (WNA): Nuclear Power in Romania (updated in November 2015); http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Romania/

[120] World Nuclear Association (WNA): Nuclear Power Plants in Romania; (Updated November 2015); http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Romania/

[121] Chinese demand fixed energy price for investment in Romanian nuclear plant; 12 November 2015; http://www.romania-insider.com/chinese-demand-fixed-energy-price-investment-romanian-nuclear-plant/159665/

[122] Construction of NPP Cernavoda unit 3&4; Environmental Impact Assessment; Experts Statement, A. Wenisch, R. Kromp, G. Mraz, P. Seibert: Ordered by the Federal Ministry for Agriculture, Forestry, Environment and Water Management; REPORT; REP-0126; Wien, 2007; http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0126.pdf

options open for future, studies are planned to assess the possibility of recycling the spent nuclear fuel generated by the CANDU Units of Cernavoda NPP.[123]

Conclusions: It is irresponsible to generate additional radioactive waste and spent fuel assemblies, because Romania has no strategy for the disposal of spent fuel assemblies.

7.4 Slovakia (Bohunice 3)

In Slovakia there are **four units with reactors of VVER-440 type in operation**, two at the Jaslovské Bohunice site (**Bohunice V2**) and two at the Mochovce site (**Mochovce 1&2**). For Bohunice V2, an operation time extension to 2045 (operation time of 60 years) is envisaged.

At the Mochovce NPP site two units (**Mochovce 3& 4**) are under construction. The construction started in 1986. Construction of Mochovce 3 and 4 resumed in 2008. The two additional units had been expected to start up in 2013. Due to construction delays, start-up of Mochovce 3 and 4 is currently expected in 2017 and the estimated cost of completing the project has risen from €2.8 billion in 2007 to €4.6 billion.

The plans for a new reactor (**Bohunice 3**) at Bohunice nuclear power plant site were announced in 2008. For the NPP Bohunice 3, it is planned to construct a new Pressurized Water Reactor of Generation III+ with a power up to 1700 MWe and an operation time of 60 years. In the current EIA procedure it is not explained which reactor type[124] will be chosen. It is explained that the supplier and reactor type respectively will be chosen after finishing the EIA procedure. The envisaged start of operation time is now 2029. [125]

Interim storage and final disposal of spent fuel

3,180 spent fuel assemblies are expected from 60 years operation of Bohunice 3. The spent fuel will be transported to an interim storage facility. [126]

An interim storage facility is in operation at the Bohunice NPP site, the capacity of this old wet storage facility is to be increased. The EIA- process for this enlargement is ongoing. The EIA procedure identified a modular dry storage facility (block storage) as the optimal solution. (The reasons for this decision are however economy and not safety driven.) The assemblies will be first stored in the wet storages and then transferred step by step. The design of the wet storage facility does not fulfil current safety standards on the protection against external impacts and the use of passive cooling systems.

The spent fuel which might be produced by the currently planned nuclear power plant Bohunice 3 is not taken into account for the capacity enlargement, but the interim storage can be enlarged at a later

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[123] Romania Joint convention on the safety of spent fuel management and on the safety of radioactive waste management Romanian fifth National Report; 2014 http://www.cncan.ro/assets/Deseuri-radioactive-si-dezafectare/Conventie-de-deseuri/RomaniaJC5thNational-Report.pdf

[124] Six reactor types and suppliers are considered: Westinghouse AP1000, Atmea 1100, Mitsubishi APWR 1700, Atomstroyexport MIR 1200, KHNP APR 1400 and Areva EPR 1600

[125] JESS 2015: Neue Kernanlage in der Lokalität Jaslovké Bohunice. Bericht über die Umweltverträglichkeitsprüfung der projektierten Tätigkeit. August 2015. http://www.umweltbundesamt.at/fileadmin/site/umweltthemen/umweltpolitische/ESPOOverfahren/UVP-EBO3/uve/JESS_UVP_Bericht_NJZ.pdf

[126] Report of the Slovak Republic compiled in terms ARTICLE 14 par.1 COUNCIL DIRECTIVE 2011/70/EURATOM; 2015 http://www.ujd.gov.sk/ujd/WebStore.nsf/viewKey/Smernica_Euratom/$FILE/Report%20of%20the%20SR%20-%20Art%20%2014%201%20CD_2011_70_EURATOM%20-%20EN_FINAL.pdf

point in time if necessary. In the National Program according to directive 2011/70/Euratom the spent fuel of Bohunice 3 is not considered.

A final disposal of the spent fuel in a deep geological repository is planned: The present document established for disposal of spent fuel the National Repository uses a double path: Disposal in a deep geological repository in Slovakia (scheduled start of operation in 2065) or participating in an international repository.

Conclusions: Taking into consideration the threat posed by surface storages of spent fuel assemblies it is utterly irresponsible that the planning of the new reactor Bohunice 3 is lacking concrete plans for the interim storage and the final disposal.

7.5 Slovenia (Krško II)

Slovenia has one nuclear power plant in operation, the NPP Krško, which is jointly owned with Croatia. Its operational life was designed to be 40 years (end by 2023), but a 20-year extension to 2043 is envisaged.

An application towards a second reactor at the Krško nuclear power plant site was submitted by GEN Energija in January 2010. The reactor **Krško II** (1100 to 1600 MWe) should be in operation between 2020 and 2025. The cost is estimated at up to €5 billion, and it would be fully owned by Slovenia.[127]

The decision has not been taken yet. In 2014 a seismic study by the French Institute for Radiation Protection and Nuclear Safety (IRSN) proved, that the area is inapt for the construction of NPP.[128]

Interim storage and final disposal of spent fuel

In the First Slovenian Report under Council Directive 2011/70/Euratom it is stated: In the light of new knowledge in SF management in general and the SNSA decision issued in 2011 regarding the prevention of severe accidents and mitigation of their consequences, Krško NPP assessed the options to reduce risk associated with SF. Since the current wet storage capacity is not adequate, from both safety and operational capacity points of view, for the plant's operational lifetime (to 2023), let alone lifetime extension until 2043, a dry storage option was proposed, a dry cask storage facility should be operational in 2018.

For long-term spent fuel management, a dual-track strategy has been adopted. The basic reference scenario for national geological disposal has been developed, assuming the disposal of spent fuel in 2065. The option of multinational disposal is kept open.

It is planned to identify sites for the geological repository by 2035 and to propose the site by 2055. The operational phase of the spent fuel repository will end in 2070 and the repository should be closed in 2075. In the event of an export option, the removal of spent fuel from dry storage is planned for between 2066 and 2070.

[127] World Nuclear Association (WNA): Nuclear Power in Slovenia (Updated July 2015); http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Slovenia/
[128] Oekonews: Slowenien: Schwierigkeiten bei den Vorbereitungen zum Bau eines zweiten Atomreaktors; 03.02.2014; http://www.oekonews.at/index.php?mdoc_id=1087262

Until 2040 the operated reactor in Krško would have generated an amount of spent fuel amounting of 840 tHM. The new reactor Krško II would generate an amount of spent fuel of around 1800 tHM. [129] This is more than double of the already existing amount.

Conclusions: It is not acceptable, that the (time) plans for the GDF do not take into account the spent fuel generated at the possible new Krško II NPP.

7.6 Bulgaria (Kozloduy 7)

In Bulgaria, there two reactors in operation at the Kozloduy site. **Kozloduy 5 and 6** are currently licensed to 2017 and 2019, but there are plans to extend their operating lifetimes beyond the current 30 years to 50 years.

In April 2012 the Council of Ministers approved in principle the construction of new capacity (**Kozloduy 7**) at Kozloduy. The Minister for Finance announced that it will without government money or state guarantees, an investor is being sought for the project.

In 2012 a transboundary EIA was started, taking into account several options for the reactor type. Currently however the government is negotiating exclusively with Westinghouse about the construction of an AP1000. Construction should start in 2016. Westinghouse has quoted $7.7 billion for the plant, with estimated completion in 2025.

On 1 August 2014, Westinghouse signed an agreement to take 30% equity in the new plant through Kozloduy NPP-New Build plc., government-owned Kozloduy NPP plc will hold 70%. The agreement also formalizes the selection of an AP1000 design reactor. In 2015, progress of the project was delayed by lack of finance and low electricity demand. In April 2015 Westinghouse announced that while the shareholder agreement for Kozloduy 7 had expired, discussions were continuing on a new structure and timeline.[130]

Interim storage and final disposal of spent fuel

A new dry storage facility for spent fuel has been built at Kozloduy, with finance from the Kozloduy International Decommissioning Support Fund administered by the European Bank for Reconstruction and Development (EBRD). This Dry Spent Fuel Storage Facility (DSFSF) was being constructed by a joint venture partnership between Nukem Technologies and GNS. Later expansion to accommodate 8000 VVER-440 and 2500 VVER-1000 assemblies is envisaged. The facility, was officially opened in May 2011. It will accommodate used fuel from Kozloduy's four closed VVER-440 units, currently in pool storage, and will be subsequently enlarged to receive casks with fuel from VVER-1000 units 5 and 6.[131]

A part of the spent nuclear fuel of the existing reactors was transported to Russia for reprocessing. Vitrified HLW will be returned to Bulgaria.

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[129] Republic of Slovenia; Ministry of the environment and spatial planning, Slovenian Nuclear Safety Administration: The First Slovenian Report under Council Directive 2011/70/Euratom on safe management of spent fuel and radioactive waste; July 2015; http://www.ursjv.gov.si/fileadmin/ujv.gov.si/pageuploads/si/Porocila/PorocilaEU/WD_porocilo_master.pdf

[130] World nuclear news (WNN): Westinghouse continues talks with Bulgaria on Kozloduy 7; 07 April 2015; http://www.world-nuclear-news.org/NN-Westinghouse-continues-talks-with-Bulgaria-on-Kozloduy-7-07041501.html

[131] World Nuclear Association (WNA): Nuclear Power in Bulgaria (Updated May 2015): http://www .world-nuclear.org/info/Country-Profiles/Countries-A-F/Bulgaria/ http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Bulgaria/

For the new nuclear unit a new spent fuel storage facility will be constructed. According to the EIA-Report for Kozloduy 7 approx. 2330 spent fuel assemblies will be generated by the new reactor.[132] More detailed data on the expected amount of spent fuel assemblies and high level waste from operating reactors and from Kozloduy 7 are not available. The amount of spent fuel is expected to be around 1,260 tons of heavy metal (tHM).

According to the National Strategy for spent nuclear fuel and radioactive waste management, it is recommended to use an open cycle (direct disposal) with priority to the use of dry spent fuel storage method.[133]

No information is known about any serious efforts to construct a final disposal for high active waste and spent fuel in Bulgaria.

Both the National Plan about Radioactive waste Management according to directive 2011/70/Euratom and the 5th Report to the Joint Convention (2014) have not been published yet.

Conclusions: It is unacceptable that Bulgaria is planning the construction of a new reactor, because the funds are not available for this NPP, nor are they available for the long-term disposal of the additionally generated spent fuel assemblies. Until now there are not even concrete plans for the final disposal of spent fuel and high level waste.

7.7 Poland (Zarnowiec, Choczewo oder Lubiatowo-Kopalino and?)

In Poland no NPP are in operation. In 1990 the construction of the NPP Zarnowiec was stopped after protests in reaction to the Chernobyl accident.

Poland is generating over 90% of electricity from coal. To decrease the dependency on coal, Poland changed the energy policy dramatically and decided to build nuclear power plants.

PGE (Polska Grupa Energetyczna), as Poland's largest power group by generating capacity, announced in January 2009 plans to build two nuclear power plants, each with a capacity of 3,000 MWe.

In 2010, the entity PGE EJ1 is set up to build the first plant and it will be future operator and licensee. PGE aims to have one main contractor. It will also need to offer some financing. In April 2015 there was a further announcement that the three companies had acquired the 30% equity in PGE EJ1, with PGE retaining 70%.

According to the EIA report[134], three potential sites are being assessed to serve as the site for the first NPP: **Zarnowiec, Choczewo oder Lubiatowo-Kopalino**. PGE expects to make a final investment decision on the two plants by 2018, including site and technology. The first unit is now expected to be operational in 2024, the second in 2029. The second power plant is scheduled for operation in 2035.

It is not clear whether Poland will be able to find the necessary funds for the NPP programme. Early in 2015 PGE said that “having described and justified a catalogue of potential support mechanisms, it

[132] Consortium Dicon – Acciona Ing (2013): Environmental Impact Assessment Report for Investment Proposal: Building a new nuclear power unit of the latest Generation at the Kozloduy NPP site.
[133] Consortium Dicon – Acciona Ing (2014): Replies to Austrian Expert Statement to the EIA Report of investment proposal: Building a new nuclear power unit of the latest Generation at the Kozloduy NPP site. Received during the EIA Procedure in a transboundary context (ESPOO-Convention) by Austrian Environment Agency, commissioned by the Austria Federal ministry of Agriculture, Forestry, Environment and Water.
[134] PGE EJ 1: The First Polish Nuclear Power Plant, Environmental Scoping Report; September 2015

had singled out contracts for difference (CfD) as the mechanism that should be dedicated to nuclear energy." "It is assumed that this type of mechanism should apply market tools in a manner similar to the contracts for difference mechanism used in the United Kingdom."[135]

According to PGE five power giants have expressed interest in building Poland's first nuclear plant: French EDF/Areva, US firm Westinghouse, Canada's SNC-Lavalin Nuclear, South Korea's KEPCO and US-Japanese GE Hitachi.[136]

Interim storage and final disposal of spent fuel

Until now Poland has produced only small amounts of spent fuel assemblies in research reactors, which are currently in interim storages. In year 2014 studies on possible sites for deep geological disposal have begun. It is intended to continue research and development on deep geological repository undertaken in Poland in the late 1990s. Poland also decided to participate in international project connected with final spent nuclear fuel disposal (ERDO[137]). By this time, spent nuclear fuel will be stored on-site the NPP or in an interim storage facility located in a different place.[138] According to the EIA report, a modern NPP with a maximum output of 3750 MWe generates approx. 80 tHM per year[139], i.e. 4800 tHM in 60 years.

Conclusions: Because Poland lacks the funds for the construction of the planned reactors, it has to be assumed that there will be no funds available for the necessary interim storage and final disposal for the spent fuel either.

7.8 Conclusions

The analysed European countries all face enormous difficulties to find investors for new build reactors with providing subsidies. Therefore the plans for new reactors are in very early stages, even if they have been announced long ago, have positive decisions in principle and completed EIA procedures.

Only in Hungary the plans to build Paks II are in more advanced stage, because they already have signed a contract with Russia or rather the company Rosatom. If the European Commission actually stops the preparations because of illegal state aid, this will most likely keep any new NPP project from getting started. However, for Hinkley Point C the EU Commission in the beginning also seemed critical, but later agreed to the Contract for Difference (CfD) and later to the Waste Transfer Contract (WTC) on the waste and fuel disposal costs.

If the Waste Transfer Contract (WTC), that the NPP operator is responsible only for a certain capped maximum price for the disposal of waste, agreed in advance, will be copied by other countries with new build plans, those plans could become more attractive to investors, but increase the costs and the granting period for state subsidies.

All investigated countries have only preliminary plans or not very detailed plans for the long term disposal of spent fuel. Experience shows that the costs have usually been underestimated. After end of

[135] World Nuclear Association (WNA): Nuclear Power Plants in Poland; (Updated May 2015); http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Poland/
[136] Foreign groups seek to build Poland's first nuclear plant; November 30, 2015; http://www.globalpost.com/article/6696662/2015/11/30/foreign-groups-seek-build-polands-first-nuclear-plant
[137] European Repository Development Organisation
[138] National report of Republic of Poland on compliance with obligations of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management; July 2014; http://www-ns.iaea.org/conventions/results-meetings.asp?s=6&l=40
[139] PGE EJ 1: Erstes polnisches Kernkraftwerk, Informationsblatt des Vorhabens; September 2015

commercial operation of NPP, enormous funds are needed for the management of radioactive waste and spent fuel, in particular for the final disposal.

As the case Hinkley Point C showed clearly, it is exactly the “sharing” that makes large additional subsidies from the state or the taxpayer necessary.

A serious problem of storage outside of final disposal facilities is the threat of large releases during accident from the existing high level waste and spent fuel during surface storage. Moreover it can be assumed that the population will only participate in the siting of a final disposal once no new reactors are planned any more. It seems very likely, that even after shut-down of reactors the next generations will be subject to the risks posed by the use of nuclear power.

According to the EU Directive 2011/70/Euratom member states need to set up national programmes on the management of spent fuel and radioactive waste. The programmes needed to be delivered for the first time in August 2015. The goal is the safe and responsible disposal and protection of employees and population from ionizing radiation. Future generations are not to be burdened in an inappropriate manner. Out of the seven countries with plans for new build, only three (status November 2015), which were Slovakia, Slovenia and the Czech Republic, presented the required report; the Slovak report however did not take into account the additional amounts. The European Commission has not responded to this situation yet.

Moreover it has to be kept in mind, that not only the reactors in operation, but also the new Generation III+ reactors pose the risk of accidents with severe impacts. Such an accident would not only impact hundreds of thousands of people, but also the nuclear industry, which will transfer this enormous burden on the tax payers, as this study pointed out.