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Special Issue: New Nuclear Power Stations and Sea Level Rise

Background

In 2012 an analysis by the UK Government's floods and coastal erosion team found that 12 of the country's 19 nuclear plants would be at risk of erosion or coastal flooding by the 2080s without more protection. Bradwell, Hinkley Point, Hartlepool, Sizewell, Dungeness and Oldbury were considered "high risk." (1)

According to John Vidal a number of recent scientific papers suggest that climate change will impact coastal nuclear plants earlier and harder than the industry, governments or regulatory bodies have expected, and that the safety standards set by national nuclear regulators and the United Nations' nuclear watchdog, the International Atomic Energy Agency (IAEA), are out of date and take insufficient account of the effects of climate change on nuclear power. (2)

Around a quarter of nuclear plants world-wide are in coastal locations; many were built only 10–20 meters (30–70 feet) above sea level at a time when climate change was barely considered a threat. All the sites under consideration for new nuclear plants in the UK are on the coast or estuaries. Some, like Hinkley, Sizewell and Bradwell are already in 'high risk' vulnerable locations

There are 3 flood zones defined by the Environment Agency (EA) based on the likelihood of an area flooding, with flood zone 1 least likely and flood zone 3 more likely to flood. The zones don't always take into account all the rivers in an area, and don't take into account blocked drains or very heavy rainfall etc. so sites in a low risk flood zone 1 for example could still experience flooding. 5 of the 8 new nuclear sites are at least partially in Flood Zone 3. (3)

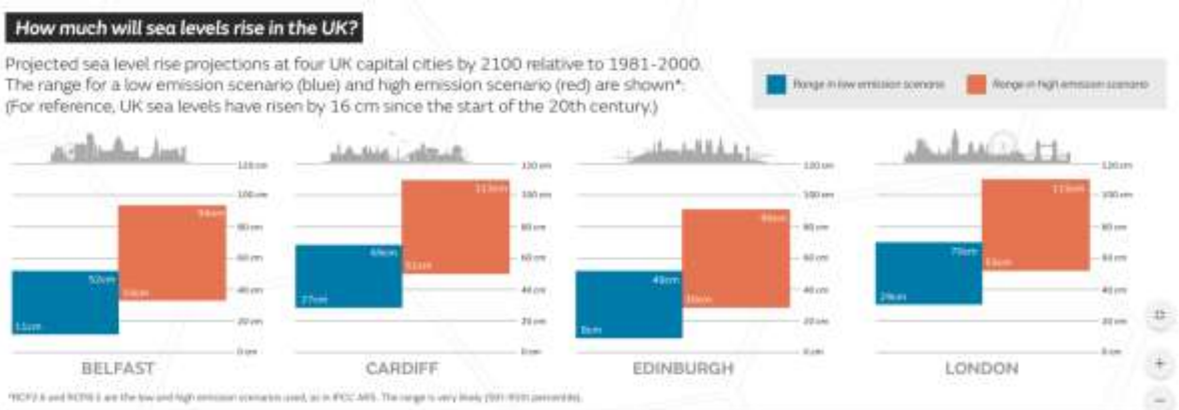
Flooding can be catastrophic to a nuclear power plant because it can knock out its electrical systems, disabling its cooling mechanisms and leading to overheating and possible meltdown and a dangerous release of radioactivity. Flooding at the Fukushima Daiichi plant in Japan as a result of the March 2011 tsunami caused severe damage to several of the plant's reactors and only narrowly avoided a catastrophic release of radioactivity that could have forced the evacuation of 50 million people.

Lisa Martine Jenkins, Robert Alvarez, and Sarah Marie Jordaan point out in a new Energy Policy article that coastal spent fuel storage sites, in the US at least, are particularly vulnerable to sea-level rise. Planning for spent fuel management has consistently received less attention and fewer resources than merited, leaving the system vulnerable to environmental shocks. This vulnerability can lead to unmitigated risks; while the Fukushima disaster impacted the entire power plant, it was the nuclear waste (specifically the waste stored in spent fuel storage pools) that proved to be the greatest liability. (4)

Vidal points out that plans for the Hinkley Point C (HPC) flood defences were drawn up in 2012, before the increasing volume of melting of the Greenland ice cap was properly understood and when most experts thought there was no net melting in the Antarctic. Now estimates of sea level rise in the next 50 years have gone up from less than 30 centimeters to more than a meter, well within the operating lifespan of HPC — let alone in 100 years' time when the reactors are finally decommissioned or the even longer period when spent nuclear fuel is likely to be stored on site.

Climate Projections

The UK Climate Projections 2018 (UKCP18) - a major upgrade to the range of UK climate projections made in UKCP09 - gives climate change projections out to 2100 in the UK and globally. Sea level is projected to rise somewhere between 27cm and 113cm on the west coast. (5) HPC will have a 900m long seawall. Taking into consideration "wave effects" of 2m there should be a margin of 2.48m, which is deemed to be sufficient. EDF says that natural hazards including all combinations of tides, storm surges, tsunami and possible sea level rise due to climate change have been taken into consideration. (6) So that should be alright then, shouldn't it?



Source: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-infographic-headline-findings-marine.pdf

Well, maybe not. One recent scenario suggests that global warming could rise seven times faster than predicted. This could mean a total sea level rise of 2 metres by 2050 due to thermal expansion alone, and perhaps another half metre due to ice melt, making a total of 2.5 metres. But it could be as much as 4.8 metres in total. (paper available from zencity@environment.org.uk)

In 2007, a report for Greenpeace by the Middlesex Flood Hazard Research Centre took as the basis for its worse-case scenario the collapse of the West Antarctic Ice Sheet (WAIS), which would trigger an abrupt and extreme rise in sea level, estimated at 5-6m. The report pointed out that there are widely divergent opinions on the likelihood of this extreme sea-level rise but one view is that WAIS collapse could begin in the 21st century. Regarding the Hinkley Point C site, the report concluded that "*the site is not a feasible option. Building on a new site, would simply transfer the challenges facing the current station along the shoreline and extend them over a longer time frame.*" (7)

Some researchers say sea levels could rise by as much as six metres or more by 2100, even if the 2 degree Paris target is met, due to substantial reductions of the Greenland and Antarctic ice sheets. (8) Another group of researchers suggest that if global warming continues at its present rate melting in Antarctica alone could lead ultimately to an additional sea level rise of 2.9 metres with rapid melting beginning within the next century. (9)

The Thwaites glacier in Antarctica alone is roughly the size of Britain. It already accounts for 4% of world sea level rise each year - a huge figure for a single glacier - and satellite data show that it is melting increasingly rapidly. There is enough water locked up in it to raise world sea level by more than half a metre. And Thwaites sits like a keystone right in the centre of the West Antarctic Ice Sheet - a vast basin of ice that contains more than 3m of additional potential sea level rise. (10)

The Antarctic ice sheet contains enough ice to raise sea level by approximately 57 metres (187 feet), about half the length of a soccer pitch. (11) While it is unlikely all of this would melt, satellite data suggests that Antarctica is now causing sea levels to rise at a rate of 0.6mm a year – faster now than at any time in the past 25 years. The rate at which ice losses from Antarctica will increase in response to a warming world remains uncertain. (12) But now a massive hole has been discovered in the Thwaites glacier suggesting it may be melting even faster than scientists have long feared. Its melting would destabilise the entire region by exposing it to warmer waters. The void, in total, is about six miles long and 1,000 feet deep — representing the loss of some 14 billion tons of ice. (13)

At the other side of the planet, the Greenland Ice Sheet has the potential to raise sea levels by 7 metres. (14)

What is particularly worrying about some recent research is that the rate ice is melting now seems to be increasing. Greenland's icecap is melting faster than ever. The message for the future is ominous. "*Rather than increasing steadily as climate warms, Greenland will melt increasingly more and more for every degree of warming*," says Dr Trusel, a glaciologist from Rowan University in the US. (15) East Antarctica's glaciers too are melting faster than previously thought. Chris Fogwill, a professor at Keele University says "...*our sea-level projections could be an order of magnitude higher than we're anticipating*." (16)

Storm Surges

But it's not just the height of the rise in sea level that is important for the protection of nuclear facilities, it's also the likely increase in storm surges. Since 1970, the magnitude and frequency of extreme sea levels (ESLs, a factor of mean sea level, tide and storm-induced increases), which can cause catastrophic flooding, have increased throughout the world, according to the Global Extreme Sea Level Analysis project. New satellite studies by the U.S. government's National Oceanic and Atmospheric Administration (NOAA), NASA, and other leading scientific institutions all show mean sea level rising and magnifying the frequency and severity of ESLs. (17)

The Office for Nuclear Regulation's (ONR's) Expert Committee (20th May 2019) says the projections for 2100 contain "*considerable uncertainty*". It points out, for instance that " *small changes to UK storm systems can alter the height of storm surges significantly*". In particular, it continues "...*the loss of a substantial portion of the West Antarctic Ice Sheet may already be committed ... could result in more frequent extreme weather events.*" (18)

Crucially, sea level has a huge effect on the severity of storm surges, according to Prof David Vaughan, the director of science at the British Antarctic Survey. An increase in sea level of 50cm would mean the storm that used to come every thousand years will now come every 100 years. If you increase that to a metre then that millennial storm is likely to come once a decade. (19)

ONR's Expert Panel on External Hazards says:

"*The IPCC Fifth Assessment Report [which is the one used for UKCP18] considers that it is very likely that there will be a significant increase in the occurrence of future sea level extremes by 2050 and 2100, with the increase being primarily the result of increases in mean sea level. Storm surge and wave projections for the UK depend on global climate models (ONR, 2018c) producing consistent and accurate simulation of the North Atlantic storm track. At the present time, there is low confidence and as yet no consensus on the future storm surge and wave climate, stemming from diverse projections of future storm track behaviour*." (20)

Researchers says that UK coasts are likely to have more "compound flooding" in future when storm surges combine with heavy rainfall. Devon, Cornwall and the Bristol channel may become "hotspots" with events happening more than once every6 years. Storm surges can be made worse with heavy precipitation but they can also cause trouble by blocking or slowing down the draining of a river into the sea following a period of sustained rainfall. (21)

David Smith Distinguished Research Associate, Oxford University Centre for the Environment Climate Change Risk Management told the ONR Expert Panel in 2014:

"*Rises in GMSL (Global Mean Sea Level) will render the world's coastlines more vulnerable to storm surges and tsunamis, although the pattern and incidence of these events are as yet unclear*." (22)

Nuclear Safety

The primary protection against coastal flooding for HPC is the height of the site platform (14m above sea level).

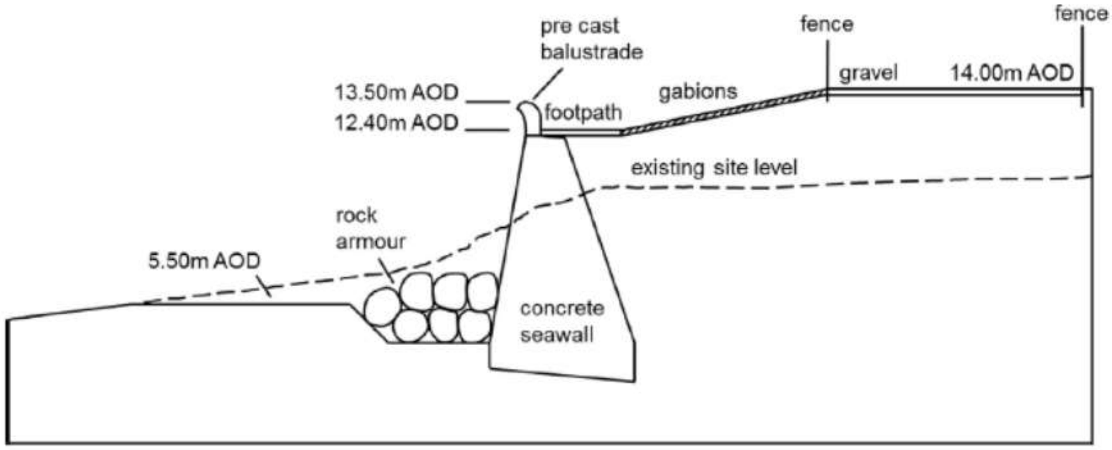


Fig. 17. Section through the proposed seawall at Hinkley C power station.

Source: A. Raby, et.al., Implications of the 2011 Great East Japan Tsunami on sea defence design, International Journal of Disaster Risk Reduction (2015)
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The ONR says detailed studies of the potential for flooding on nuclear licensed sites are carried out by the licensees, and robust engineered flood defences against these hazards are provided as necessary. Flooding hazard studies include an allowance for reasonably foreseeable sea level rise. These claim to have demonstrated that the platform is not vulnerable to a design basis coastal flood. The HPC site licensee (NNB GenCo) will monitor this hazard via Periodic Safety Reviews (including the interim spent fuel store). If necessary, further pre-planned flood protection measures can be put in place. (23) But of course, the first HPC Periodic Safety Review isn't expected to be carried out until the station has been in operation for a decade.

ONR says it's not reasonable to expect licensees to reconsider safety cases every time new academic research is published. It would however expect that where assumptions in the safety case are challenged that the implications for the safety case should be considered by the licensee. ONR may choose to undertake a review of the implications and use appropriate regulatory tools to ensure timely licensee compliance. "*For example, the implications of the revised UK Climate Projections UKCP18 are included on the met office website and will be considered by nuclear site licensees in due course.*" (24)

EDF's Safety Case

EDF Energy's safety case has basically relied upon the UK Climate Projection UKCP09 made by the Met Office. This has now been replaced by UKCP18 published at the end of 2018. But EDF says these new projections are broadly similar to the older ones.

However, the Met Office document which compares UKCP09 with UKCP18 does say:

"Our summary interpretation of the recent evidence is that the H++ [High Plus Plus] scenario of UKCP09 can still be considered a useful plausible but unlikely high-end sea level pathway for decision-making. **It should not be considered a theoretical maximum rate of sea-level rise**. The scientific community will further update the potential for higher sea-level rise scenarios in the coming months but this is likely to be in a different format to the previous scenario, reflecting an emerging need for tailored high-end scenarios for different users. Details will be provided on the UKCP18 website when available." [My emphasis] (25)

Indeed, the ONR's own Expert Panel on Climate Change appears to conclude that the H++ scenario is not necessarily the worst credible maximum scenario for a once in 10,000 years event. (26)

But EDF scenarios are based on the UKCP09 medium emissions scenario – not the high emissions scenario and not the High Plus Plus (H++) scenario. (27)

This is despite the fact that Met Office says "The UKCP18 sea level projections are consistently larger than in the previous set of UK climate projections, UKCP09 for similar emissions scenarios."

"The estimate for low probability, high impact range for sea level rise around the UK to 2100 (H++ scenario from UKCP09) is still a reasonable plausible high-end scenario based on our current interpretation of the evidence. **We recommend that you make use of multiple strands of evidence, including H++ scenarios when assessing vulnerabilities to future extreme water levels**." [Emphasis added] (28)

A 2017 ONR and Environment Agency document on flood and coastal erosion risk management suggests using a maximum credible scenario. It says: "A current example of the credible maximum scenario for sea level rise and storm surge for the period to 2100 is provided by Government's UKCP09, and is termed the H++ scenario." (29)

Uncertainty and Adaptability

Climate change science is fast moving so when ONR receives a safety case for a new nuclear power station it is already two years old, so it is important that it is adaptive to any new science. (30)

ONR's Nuclear Safety Technical Assessment Guide on External Hazards highlights the fact that "*…climate change predictions are associated with substantial uncertainty … Due to the typical operating lifetime of a nuclear site (of the order >100 years); changes to meteorological and coastal flooding hazards as a result of climate change could be significant*." (31)

The way they suggest preparing for higher than predicted sea level rise over the lifetime of the reactors is by setting out an approach for adapting to such unexpected changes.

For instance, the licensee is expected to "*Ensure that all relevant flood and coastal risk management measures are planned, designed and implemented so that they are capable of being* *modified/adapted to maintain adequate safety in light of climate change over the full life-time of the station.*" This would be *"a way of managing the large uncertainties inherent in flood hazard predictions over the life-time of new nuclear reactor sites."* (32)

For the managed adaptive approach to be suitable, according to ONR and EA, it will be necessary to demonstrate that it is made up of:

- Technically feasible and viable options - i.e. that the future cost of the options can be accounted for.
- The lead time between the need for an option being triggered and implemented is achievable.
- The fullest range of risks has been accounted for through the use of the credible maximum scenario.

"*For HPC, NNB GenCo has identified managed adaptive options for protection against coastal flooding by providing the design and space for flood defence barrier in addition to the sea wall. This "set-back wall" would provide an additional 2 metres height flood defence above the platform level. By providing the design and protecting the space for the set-back wall NNB GenCo have demonstrated that the site can respond to sea level rise beyond that currently predicted due to reasonably foreseeable climate change*." (33)

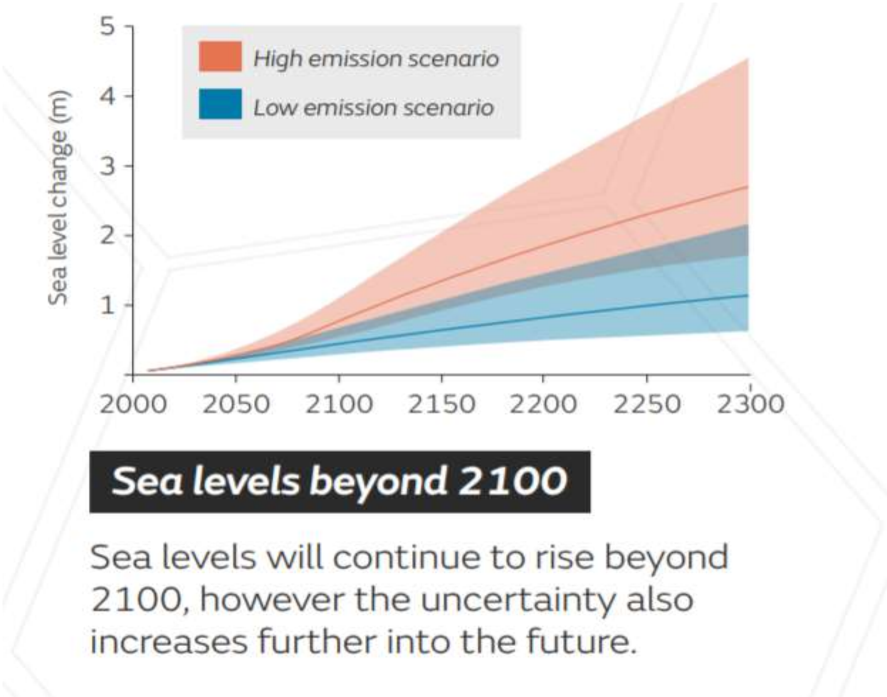
Sea Level Rise Beyond 2100

The Government is hoping that the length of time spent fuel will need to be stored after the end of power station operations can be reduced to 60 years, but that is still 127 years from now – taking us to 2147. (34) This means that sea level rise beyond 2100 will be important too. ONR says its assessment of the HPC Interim Spent Fuel Storage Facility will need to consider the treatment of climate change in the safety case over the lifetime of the facility. As an interim facility it is inherent in the design of the Interim Spent Fuel Store that the fuel can be removed from site. The safety case will have to consider the consequences of site flooding.

UKCP18 has produced some extended projections for sea level rise beyond 2100 – these are referred to as "*exploratory post-2100 sea level rise scenarios*". ONR points out that there is "*a high degree of uncertainty*" in the data beyond 2100, so it "*should be approached with caution, taking into account the managed adaptive approach*."

With regard to uncertainties in the projections for 2100 and beyond ONR's Expert Panel points out that there are three key future research challenges: -

- Improved understanding of dynamic ice processes to better quantify and constrain high-end scenarios.
- Future storm surges and the response of the Atlantic storm track under climate change.
- Translating updated sea level science into resilience planning. (35)



Source: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-infographic-headline-findings-marine.pdf

Conclusions

Polar ice caps appear to be melting faster than expected, and what is particularly worrying is that the rate of melting seems to be increasing. Some researchers say sea levels could rise by as much as six metres or more by 2100, even if the 2 degrees Paris target is met.

But it's not just the height of the rise in sea level that is important for the protection of nuclear facilities, it's also the likely increase in storm surges. An increase in sea level of 50cm would mean the storm that used to come every thousand years will now come every 100 years. If you increase that to a metre then that millennial storm is likely to come once a decade.

The primary protection against coastal flooding for Hinkley Point C is the height of the site platform (14m above sea level). Taking into accounts "wave effects" of 2m there should be a margin of 2.48m above the projected rise in sea level by 2100. But EDF's safety case is based on a medium emissions scenario from the UK Climate Projections of 2009 – not the high emissions scenario and not the High Plus Plus (H++) scenario, or scenarios in the more recent 2018 Climate Projections.

EDF has identified what it calls managed adaptive options for protection against coastal flooding by providing the design and space for a flood defence barrier in addition to the sea wall. This "set-back wall" would provide an additional 2 metres height flood defence above the platform level. They say this demonstrates that the site can respond to sea level rise beyond that currently predicted due to reasonably foreseeable climate change.

The Office for Nuclear Regulation says it's not reasonable to expect licensees to reconsider safety cases every time new academic research is published. But it expects EDF to monitor sea level rise and climate change projections when it is carrying out its Periodic Safety Reviews every ten years. If necessary, the further pre-planned flood protection measures can be put in place.

Bearing in mind that there will probably be nuclear waste on the Hinkley Point C site until at least 2150, the question neither ONR nor EDF seem to be asking is whether these further flood protection measures can be put in place fast enough to deal with unexpected and unpredicted storm surges.

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(If anyone needs any of the references which don’t have a link, feel free to ask rochepete8(at)aol.com)