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Subject: Nuclear Power Stations and Sea Level Rise

Introduction:

In March 2011, the Japanese nuclear power plant at Fukushima was inundated by a tsunami, with flood waters rendering the plant's cooling systems inoperative, leading to three nuclear meltdowns, three hydrogen explosions and a release of radiation from reactors 1, 2, and 3. The impact is still being felt to this day.

Historically, British nuclear plants have mostly been located on the coast. Most facilities are decommissioned or will be brought out of service by 2028. However, the Johnson Government has recently announced its commitment to 'taking big bets' on new nuclear.

A new large EPR plant is being built on the coast at Hinkley Point C in Somerset; there are plans for two more large plants at coastal sites at Sizewell C in Suffolk and Bradwell in Essex; and there is increasingly earnest talk about a development at Wylfa on the island of Anglesey. Rolls-Royce also has long-term plans for Small Modular Reactors to be built on 16 sites, and the government is about to make a decision on the location of a new experimental fusion reactor; most or all of these facilities will also be on the coast.

Britain's nuclear powered and armed submarines are built or operate from dockyards at Barrow-in-Furness, Coulport, Devonport, and Rosyth.

The Nuclear Free Local Authorities network has becoming increasingly concerned that climate change may lead to many or all of these facilities becoming subject to an increasing risk of flooding as a consequence of steadily rising seas, coastal erosion and the phenomenon known as the storm surge.

In August 2021, the NFLA published 'New Nuclear Monitor 66: Climate change and its impacts on existing UK nuclear and new nuclear facilities', a reproduction by kind permission of research undertaken by Dr Paul Dorfman, a Honorary Senior Research Associate of the UCL Energy Institute at University College London and the founder and Chair of the Nuclear Consulting Group (NCG). Dr Dorfman is the NFLA's representative to the Irish Government's Environment Protection Agency's Radiation Protection Advisory Committee.

The paper can be found at:

https://www.nuclearpolicy.info/briefings/nfla-new-nuclear-monitor-66-climate-change-and-its-impacts-on-existing-uk-nuclear-and-new-nuclear-facilities/

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On 6 April 2022, NFLA Steering Committee Chair, Councillor David Blackburn, hosted a special webinar '*Will the sea have them*?' to examine the viability and safety of these coastal installations will be threatened by climate change." The support of British Pugwash Secretary Andrew Gibson in facilitating this event is gratefully acknowledged.

The webinar had two guest speakers: Dr Sally Brown, who wrote a recent report for British Pugwash on 'Risks of sea-level rise to ports and associated facilities aligning with the Trident programme', and Pete Roche, Director of Edinburgh Energy and Environment Consultancy and a former nuclear campaigner for Greenpeace.

Dr Brown is a geomorphologist and climate change adaptation scientist working at Bournemouth University, whilst Pete also works as a Policy Advisor to the NFLA Scotland Forum.

Dr Brown's report can be found at

https://britishpugwash.org/wp-content/uploads/2021/07/ClimateTrident-report-PDF-British-Pugwash-2021.pdf

Here then is the highly informative paper written by Pete Roche to which the NFLA's thanks are due. This paper underpins his presentation to the webinar.

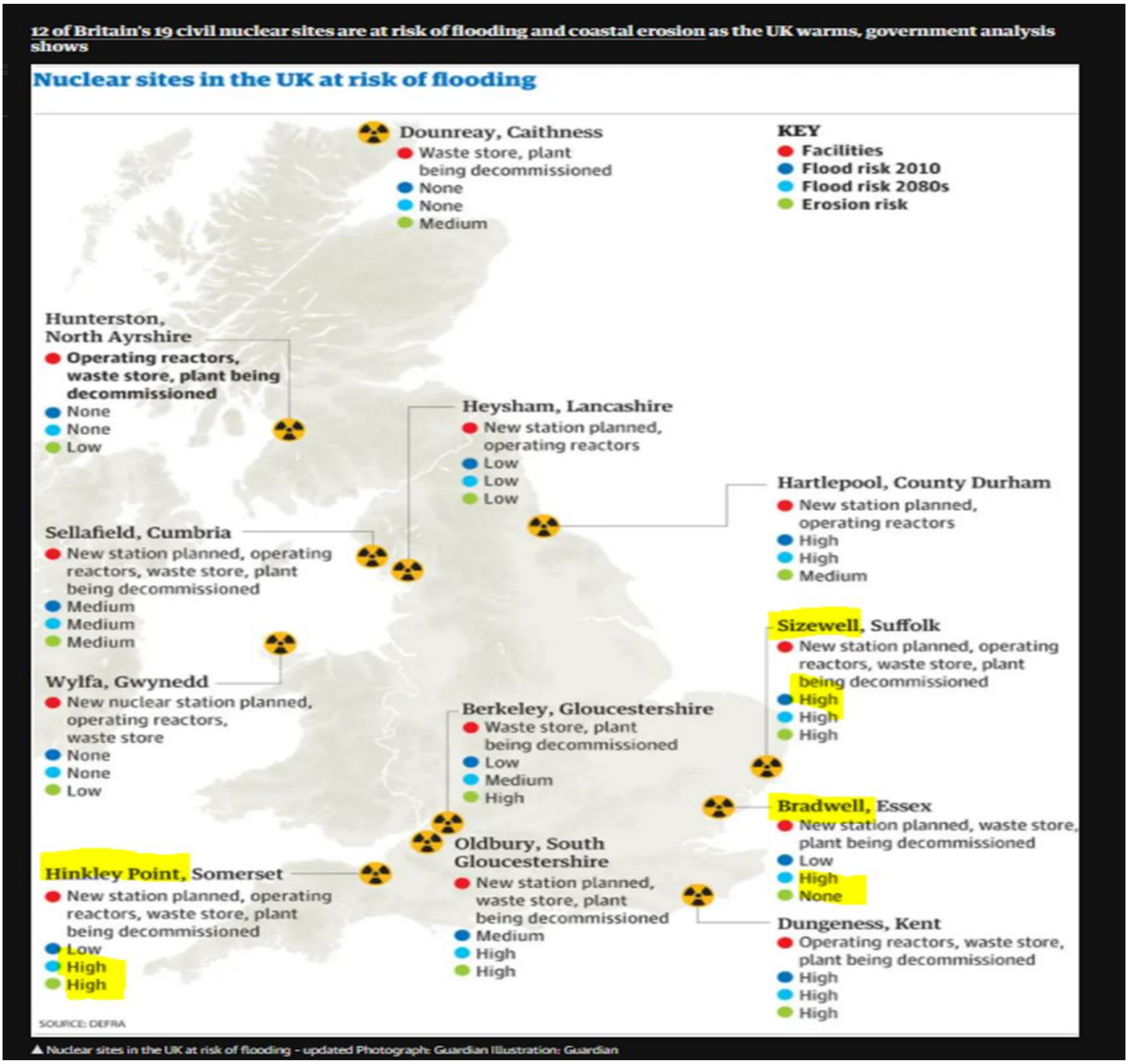
Nuclear Power Stations and Sea Level Rise:

A decade ago, 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 all considered "high risk." (1)

Nuclear power generation, waste and decommissioning sites – Summary of data

Site	New site?	Waste Store?	NDA site?	In IFP?[1]	Elev.[2]	HAT?[3]	Flood Risk 2010	Flood Risk 2020s	Flood Risk 2050s	Flood Risk 2080s	Comment
Berkeley		■	■	Edge	0 to 10	8.6	Yes (low)	Yes	Yes	Yes (medium)	Coast. Sea wall 9.72m AOD
Bradwell	■	■	■	Edge	0 to 5.5	3.0	Yes (low)	Yes	Yes	Yes (high)	Coast. Sea wall 4.6 to 5m AOD
Capenhurst			■	No	High		No	No	No	No	
Chapelcross			■	No	High		No	No	No	No	
Culham			■	No	High		No	No	No	No	
Dounreay		■	■	Small	9 to 15	3.0	No	No	No	No	Coast. Long term erosion risk
Drigg		■		No	High	5.3	No	No	No	No	
Dungeness		■	■	Part	2 to 6	4.2	Yes (high)	Yes	Yes	Yes	Coast. Flood and erosion risk. Relies on defences
Hartlepool	■			Yes		3.3	Yes (high)	Yes	Yes	Yes	Coast
Harwell			■	No	High		No	No	No	No	
Heysham	■			No		5.6	Yes (low)	Yes	Yes	Yes	Coast
Hinkley Point	■	■	■	Edge	10 to 14	6.8	Yes (low)	Yes	Yes	Yes (high)	Coast. Relies on defences. Flood and erosion risk.
Hunterston		■	■	No	5 to 21	2.0	No	No	No	No	Coast. Erosion risk
Oldbury	■	■	■	Edge	4 to 10	8.4	Yes (medium)	Yes	Yes	Yes (high)	Coast. Relies on defences
Sellafield	■	■	■	No	5 to 30	5.3	Yes (medium)	Yes	Yes	Yes (medium)	Coast. Flood and erosion risk to part of the site.
Sizewell	■	■	■	Edge	3 to 10	1.7	Yes (high)	Yes	Yes	Yes	Coast. Flood and erosion risk. Relies on defences
Trawsfynydd			■	No	High		No	No	No	No	
Winfrith		■	■	No	High	1.5	No	No	No	No	
Wylfa	■	■	■	No	9 to 13	3.8	No	No	No	No	Coast

[1] Indicative flood plain
[2] Elevation in m Above Ordnance Datum (AOD)
[3] Highest Astronomical Tide



▲ Nuclear sites in the UK at risk of flooding - updated Photograph: Guardian Illustration: Guardian

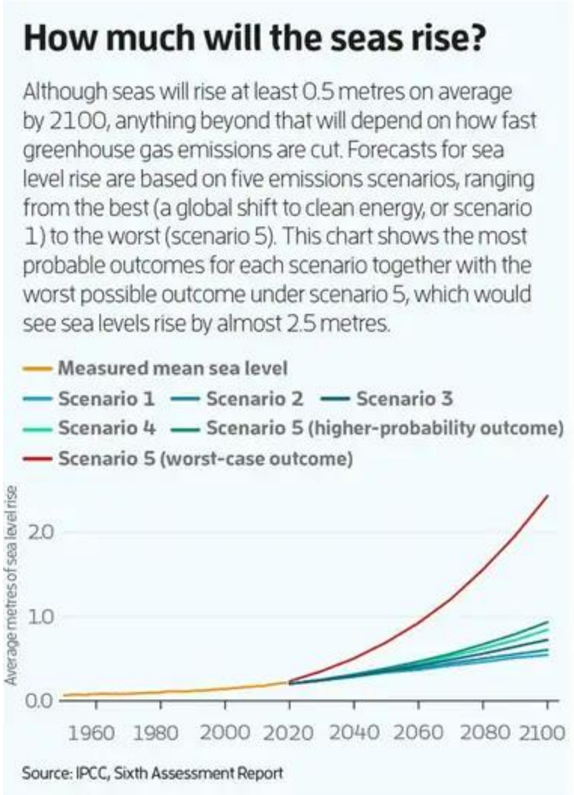
This was followed in 2018 by a NASA study based on 25 years of satellite data which showed that sea level is not only rising but the rate of that rise was getting faster. This acceleration, driven mainly by increased melting in Greenland and Antarctica, has the potential to double the total sea level rise projected by 2100 when compared to projections that assume a constant rate of sea level rise. If this acceleration continues global sea level could be 0.65 meters higher by 2100. The author of the report says this is almost certainly a conservative estimate.

"*Our extrapolation assumes that sea level continues to change in the future as it has over the last 25 years. Given the large changes we are seeing in the ice sheets today, that's not likely*." (2)

The latest IPCC report from August 2021 says "*It is virtually certain that global mean sea level will continue to rise over the 21st century*."

Relative to 1995–2014, the likely global mean sea level rise by 2100 is:

0.28–0.55 m under the very low GHG emissions scenario;
0.32–0.62 m under the low GHG emissions scenario;
0.44–0.76 m under the intermediate GHG emissions scenario;
and 0.63–1.01 m under the very high GHG emissions scenario; (3)



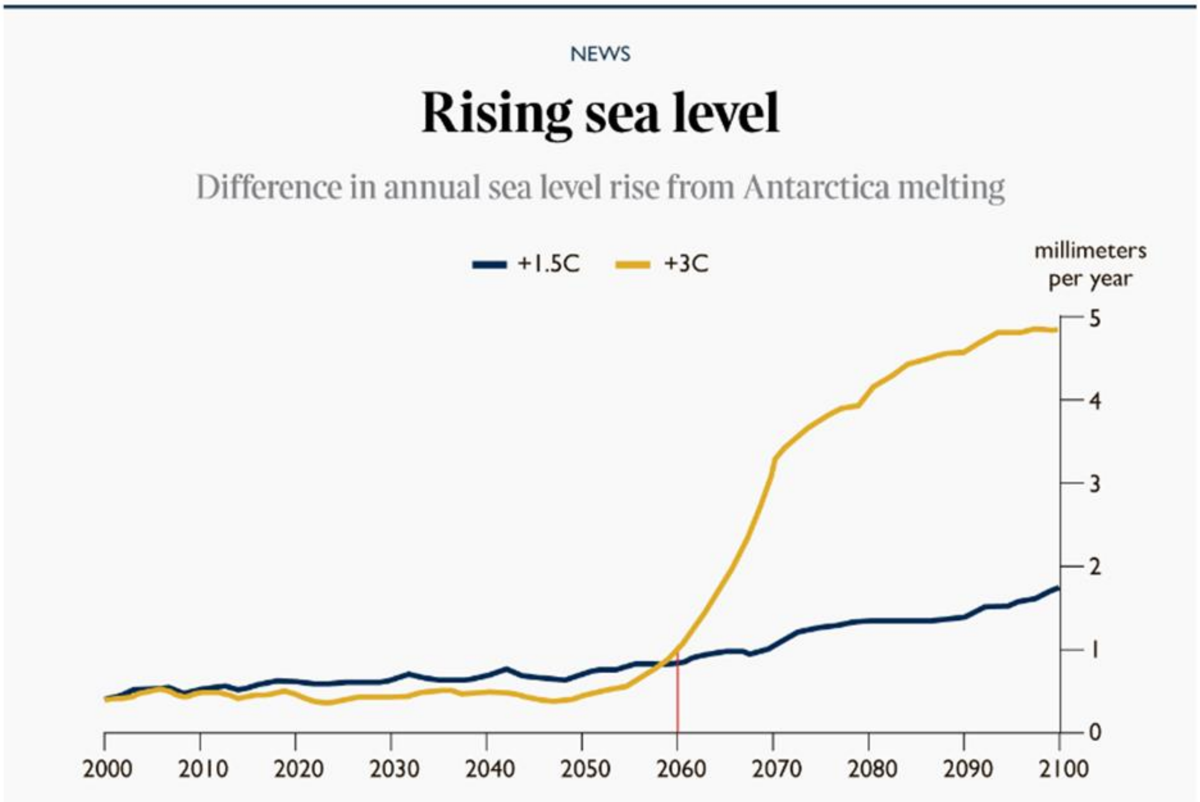
The report goes on to say that global mean sea level rise above the likely range – approaching 2m by 2100 and 5m by 2150 under a very high GHG emissions scenario cannot be ruled out due to deep uncertainty in ice-sheet processes.

Paul Dorfman, in his report on Climate Change and UK Nuclear from June 2021, (4) quotes Aschwanden's figures, which show that the rate of rise has accelerated in recent years and is now estimated at 3 to 4mm per year. (5) But, as we can tell from the title of Aschwanden's paper, "*The worst is yet to come*."

A recent study in Proceedings of the National Academy of Sciences found that scientists may have been underestimating the rate of melting in Greenland. It had been thought that the ice sheet had a net loss of 532 billion tonnes of ice, causing 532 trillion litres of meltwater to enter the ocean in 2019. It is now thought the figure was more like 574.5 trillion litres of water. (6)

At the other end of the globe, we are being warned that the rise in sea level caused by the melting of Antarctic ice will become "*rapid and unstoppable*" unless countries make drastic cuts in emissions. The ice sheet will reach a tipping point by 2060 when the melting rate will sharply increase under the policies being pursued by governments. There could be a tenfold increase in the continent's annual contribution to sea level rise by 2100, from 0.43mm a year now to nearly 5mm a year, according to a study in *Nature*.

Current policies, which put the world on track for a 3ºC increase in average temperature, would result in a sea level increase of 17cm-21cm from Antarctica alone by 2100. Antarctica accounts for only about 15% of the current average annual sea level rise of 3mm but it has so much ice that after 2100 it could be the main factor.



A separate study, also in Nature, found that uncertainties about how Antarctica will respond to rising temperatures mean that the increase by 2100 could turn out to be much higher. (7) There is large uncertainty in the ice sheet community regarding the possible contribution of Antarctica to future sea level rise. Melting of the Antarctic ice sheet will cause sea level rises of about two and a half metres around the world, even if the goals of the Paris agreement are met, according to a paper published in Nature. The melting is likely to take place over a long period, beyond the end of this century, but is almost certain to be irreversible, because of the way in which the ice cap is likely to melt, the new model reveals. Even if temperatures were to fall again after rising by 2ºC (3.6F), the temperature limit set out in the Paris agreement, the ice would not regrow to its initial state. (8)

If the vast Thwaites glacier collapses, we could see some terrifying scenarios. That single glacier contains enough ice to increase global sea levels by 65cm. Worse still it acts like a giant cork holding back a much larger expanse of ice.

"*The best we can hope for in the next 100 years*", according to oceanographer Stefan Rahmstorf at the University of Potsdam, "*is that the rate of rise remains constant*". Rahmstorf told the *New Scientist* that the IPCC is often accused of underestimating future sea level rise, but he gasped when he read the August 2021 report. Even under the most optimistic scenarios in which global carbon emissions reach net zero by 2050 a further 50cm rise is predicted by 2100. On the other hand, if little action is taken, we might see a rise of nearly 2.5 metres by 2100 and 5 metres by 2150. "*Even a 1-metre rise is quite catastrophic*", says Rahmstorf, "*Five metres on that timescale would basically be an unimaginable disaster*." (9)

Hinkley Point C:

From the point of view of nuclear power stations, why should we worry about a 2.5 metre rise in sea-level or even 5 metres? The primary protection against coastal flooding for HPC is the height of the site platform. At Hinkley Point C the platform is 14m above sea level. (10)

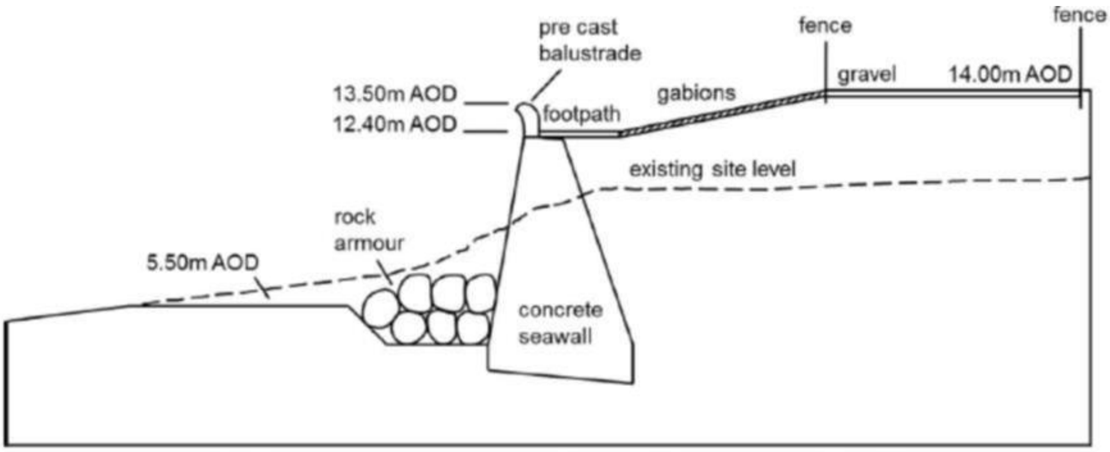


Fig. 17. Section through the proposed seawall at Hinkley C power station.

Storm Surges:

However, the most pressing problem for coastal communities and infrastructure won't be the slow incursion of water but worsening tidal surges, storms and floods that will eventually make coastal areas unbearable to live in. Sea walls and physical defences are expensive and can be unintentionally harmful.

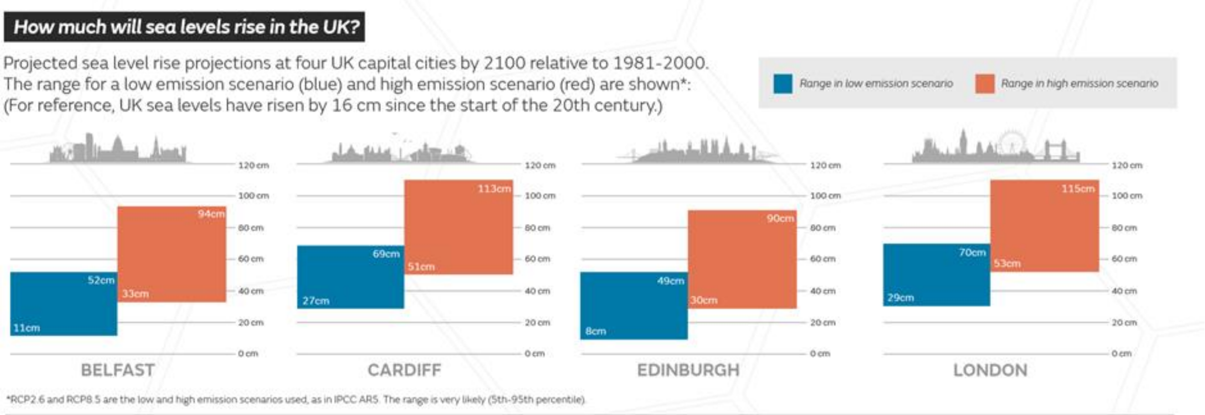
In other words, it's not just the height of the rise in sea level that is important for the protection of nuclear facilities, it's also the likely increase in storm surges. Since 1970, the magnitude and frequency of extreme sea levels (ESLs, a factor of mean sea level, tide and storm-induced increases), 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. (11)

Higher sea levels amplify the impacts of storm surge, high tides, coastal erosion, and wetland loss. Even the relatively small increases in sea level over the last several decades have led to greatly increased frequency of flooding. Prof David Vaughan, the director of science at the British Antarctic Survey, says sea level has a huge effect on the severity of 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. (12)

NOAA says that "*by 2050, the expected relative sea level (RSL) will cause tide and storm surge heights to increase and will lead to a shift in U.S. coastal flood regimes, with major and moderate high tide flood events occurring as frequently as moderate and minor high tide flood events occur today. Without additional risk-reduction measures, U.S. coastal infrastructure, communities, and ecosystems will face significant consequences.*" (13)

Climate Projections:

The UK's most recent Climate Projections were published in 2018 (UKCP18) and were a major upgrade to the range of UK climate projections made in 2009 (UKCP09). It 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 of the UK. (14)



Plans for the Hinkley Point C (HPC) flood defences were drawn up in 2012. EDF Energy's safety case basically relied upon the UK Climate Projection UKCP09 made by the Met Office and 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. EDF says the new projections in UKCP18 are broadly similar to the older ones.

Rather than forcing EDF to go back to the drawing board 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. ONR says 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. (15) 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*." (16)

In February, 2021, the Office for Nuclear Regulation (ONR) told its Expert Panel on Natural Hazards that it was in the process of updating, with the Environment Agency, the Principles for Flood and Coastal Erosion Risk Management to take account of UKCP18 and is continuing to engage with duty-holders on the application of UKCP18 and is seeing UKCP18 being incorporated into safety cases. (17)

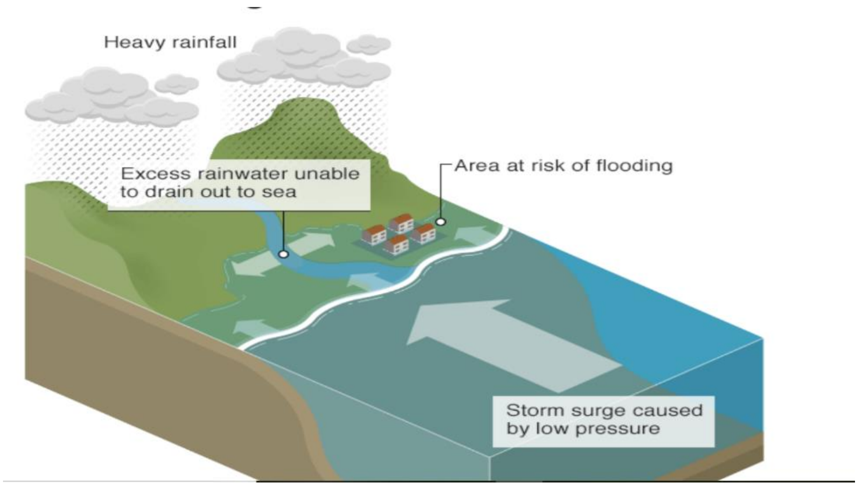
However, the Sub-Panel on Meteorological & Coastal Flood Hazards, submitted a report to ONR in August 2021 which stated that new assessments of future sea-level rise:

"…*have suggested that the [Global Mean Sea Level] GMSL increase will be greater than previously suggested in the IPCC AR5 report* [5th Assessment report 2014] *and UKCP18 …There is a possibility that the rise will be beyond 2 metres by 2100 in the high-emission scenario. This projection lies within the 90% uncertainty for the high-emission bounds. This is more than twice the upper value put forward in IPCC AR5 and UKCP18."* (18)

In 2019, the ONR's Expert Committee talked about "*considerable uncertainty*" with regard to projections for 2100. It said "*small changes to UK storm systems can alter the height of storm surges significantly*" and "...*the loss of a substantial portion of the West Antarctic Ice Sheet may already be committed* [which] *could result in more frequent extreme weather events*." (19)

Compound Flooding:

As well as storm surges, 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 every 6 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. (20)



The Impact on Nuclear Power:

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. (21)

Around a quarter of nuclear plants world-wide are in coastal locations; many were built only 10–20 meters 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.

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. Nuclear waste stores and decommissioned nuclear reactors will all be vulnerable to rising sea levels.

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. (22) Of course, any new nuclear power stations built in the UK are expected to store spent fuel on site for the foreseeable future – probably in spent fuel storage ponds.

According to Institute of Mechanical Engineers (IME) all existing and proposed new UK reactors and their spent nuclear fuel and radioactive waste stores will be increasingly vulnerable to sea-level rise, flooding, storm surge, and 'nuclear islanding'. IME points out that these UK coastal nuclear sites will need considerable investment to protect them against rising sea levels, and even relocation or abandonment. (23)

Sizewell C:

In his submission to the Sizewell C inquiry, Nick Scarr looks at EDF's claim that the Sizewell site will be stable due to the protective nature of the offshore Sizewell-Dunwich banks. (24) These banks have historical provided stability to the Sizewell coastline by reducing the energy of waves before they reach the shore. But the way these banks will react to sea level rise is not known, and there are concerns about their continued stability.

Scarr contends that EDF's Flood Risk Assessment (FRA) modelling is relying on a stable, unchanging offshore geomorphology and bathymetry (the study of underwater depth of ocean floors or lake floors) to the end of Sizewell C's life. His paper shows that the premise of future geomorphological stasis is both implausible and unrepresentative of a significant range of worst-case conditions.

The National Policy Statement on Nuclear Power Generation (EN6), which designated Sizewell and Hinkley Point as suitable sites for a new nuclear power station, predated the 2019 IPCC report and UKCP18 published in November 2018. Extreme sea level events that are rare (once per century) are now projected to occur much more frequently by 2050 in many places. Historical coastal erosion and flooding already experienced by the Suffolk coast is forecast to reach new heights and intensities. The Sizewell C site is surrounded by the low-lying land. For instance much of the Sizewell Belts (1-2 Km to the west of Sizewell) are 2-4m above mean sea level, and the Minsmere levels (1-2Km North of Sizewell) are 1-2m above mean sea level on average.

In his submission to the Sizewell C inquiry (October 2020) Scarr concludes:

"*In my opinion, the National Policy Statement (NPS) that declared Sizewell to be a 'potentially suitable site' for newbuild reactors eleven years ago is adversely impacted by UKCP18 and IPCC reports that it was unable to consider. I consider the claim to current stability of this coast is weak and has a dependency on the offshore Sizewell-Dunwich banks for the security of the Sizewell foreshore. EDF has admitted the potentially insecurity of the offshore morphology; nevertheless, EDF's* [Flood Risk Assessment] *FRA 'worst-case' flood overtopping modelling appears to be relying and dependent upon a best-case … which suggests it fails to meet the current requirements of EN-6's Appraisal of Sustainability*."

Not just operating reactors:

Of course, it is not just operating reactors which we need to be concerned about. Hinkley Point C is expected to operate for 60 years until around 2086. Unlike the spent fuel from Hinkley Point B which is transported by train to Sellafield in Cumbria spent fuel from Hinkley Point C is expected to be stored in wet storage ponds on-site. Because the fuel used at Hinkley will be High Burn-up fuel it will probably require around 100 years of cooling, taking us to 2186. In any case a deep geological disposal facility (GDF) is not expected to be ready to receive waste until around 2050, and existing waste will be emplaced first – this will take around 90 years. So spent fuel from Hinkley is likely to remain on site until at least 2140, but if the search for a site for a GDF doesn't go according to plan, it could remain on site for much longer.

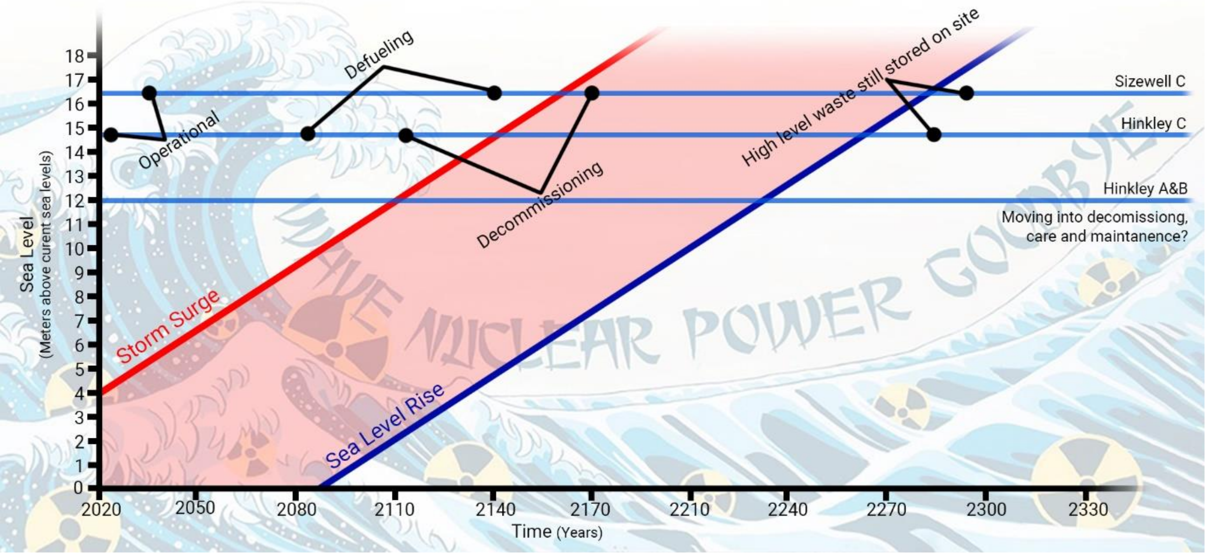
All Magnox sites, including Hinkley Point A and Sizewell A are now spent fuel free, but there is still Intermediate Level Waste on the sites which needs to be retrieved and packaged. The Nuclear Decommissioning Authority says only 15% of the total packaged Intermediate Level Waste (ILW) it expects to be produced over the lifetime of the NDA group is currently in safe storage. At Hunterston A, for example, waste will continue to be retrieved and packaged and placed in the ILW store until 2030. Then in 2035 reactor dismantling is expected to start. This could take 25 years – taking us to 2060.

Hunterston B, which has recently closed, will start the process of defuelling soon. This could take 3 or 4 years up to 2026. The reactors will then be prepared for a period of care and maintenance and could then be left for up to 60 years before final dismantling in the 2080s and 90s.

The Stop Hinkley Campaign has produced the following chart to help provoke discussions with ONR. It has also been debating with Head of Environment at HPC about how long Spent Fuel, (basically High-Level Waste) will be stored on site at HPC. He says it's not 200 years but it is still not known how it will be stored and when it will be cool enough to move.

When Climate Change Meets Nuclear

The straight diagonal black blue represents sea level rise based on average forecasted trends over next 300 years.
This forecast does not include storm surges plus tide and wave action.
We have taken an average of the highest storm surges over last 400 years
(1607-7.5m Severn Estuary, 1899-13.5m Australia, 2005-8.5m New Orleans).
This is shown as an average of 10m with a red line.
The horizontal lines show the height of sea defences of individual Nuclear Power Stations and their significant lifetime events.
Scientist are predicting that extreme weather events that used to happen every 100 years will start to happen every 10 years.



The chart illustrates how storm surges and sea level rise could begin to impact both Hinkley Point C and Sizewell C and spent fuel stores before the reactors have been decommissioned and spent fuel moved off site.

Conclusions:

- Sea levels are not only rising but the rate of that rise is getting faster.
- There is "*considerable uncertainty*" with regard to projections for 2100, but the increase will be greater than previously suggested in the UK's latest climate projections (UKCP18).
- Plans for the Hinkley Point C (HPC) flood defences were drawn up in 2012 and relied upon the UK's earlier climate projection: UKCP09.
- Although the ONR expects EDF to take into account new studies of the potential for flooding on nuclear licensed sites, but it is not expected to take any further action until after Hinkley Point C's first Periodic Safety Review.
- EDF's Flood Risk Assessment (FRA) modelling for Sizewell C relies on a stable, unchanging offshore sand bank. It has been suggested that this future geomorphological stasis is both implausible and unrepresentative of a significant range of worst-case conditions.
- 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 a metre would mean that storms which happen once every thousand years are now likely once a decade.
- 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.
- It's not just operating reactors that we need to be concerned about, but also waste stores and decommissioned reactors.
- At Fukushima it was the nuclear waste (specifically the waste stored in spent fuel storage pools) that proved to be the greatest liability.

Paul Dorfman concludes:

"*The unfortunate reality is that nuclear, far from helping with our shared climate problem, will add to it. In other words, review of recent peer-reviewed published climate impact data implies a substantive reassessment of nuclear's role in net-zero*."

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