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1. France's nuclear crisis

Problems discovered at Areva's metal forge at Le Creusot have been growing over the past six months and are now even threatening to derail EDF's takeover of Areva's reactor business.

Last spring when Economy Minister Emmanuel Macron visited to tell the workers at Le Creusot that he had every confidence in the nuclear sector, despite the difficulties, 400 files which were being examined for suspected "anomalies" had to be hastily moved out of the meeting room. Now, six months later a crane has been moving prefabricated office buildings into position so that 6,000 records concerning nuclear components – 2.4 million pages – forged at Le Creusot over the last 60 years can be re-examined. Areva has had to accept that the original 400 suspicious files are just the tip of an iceberg and not the only ones containing "irregularities". 50 people are now trawling through the paperwork and as many more are being recruited for a job that will take at least another eighteen months.

EDF's CEO Jean-Bernard Lévy says if Le Creusot's "*problems prove insurmountable, the acquisition will not happen*". (1)

With potentially more than half of France's 58 reactors affected by the "carbon segregation" problem the French nuclear watchdog, the Autorité de Sûreté Nucléaire (ASN) has ordered preventative measures to be taken immediately to ensure public safety. ASN confirmed that, as of late October, 20 reactors were offline and more could be shut down over coming weeks.

Questionable Materials and Documentation

At the heart of France's nuclear crisis are two problems. One concerns the carbon content of the steel used in critical reactor components, steam heat exchangers, and other components manufactured or supplied by AREVA SA, the French state-owned nuclear engineering firm and global producer of nuclear reactors. The second problem concerns forged, falsified, or incomplete quality control reports about the critical components themselves. Excessive levels of carbon in the steel parts could make them more brittle and subject to sudden fracture or tearing under sustained high pressure, which is obviously unacceptable.

Steam generators from 18 reactors have carbon levels that are above the acceptable level. Some of these were forged at Le Creusot, but others were forged in Japan by JCFC, a subcontractor of Areva. Twelve reactors equipped with JCFC steel are still at a standstill and will be in December while inspections are carried out.

The massive outages are draining power from all over Europe. In the event of severe cold weather this winter, there could be blackouts. Worse, new questions continue to swirl about both the safety and integrity of EDF's nuclear fleet, as well as the quality of some French- and Japanese-made components that EDF is using in various high-profile nuclear projects around the world.

In October EDF was forced to reduce its 2016 generation targets from 395–400 TWh to 380–390 TWh, while estimates for nuclear output in 2017 have also been lowered to between 390

TWh and 400 TWh. For perspective, annual nuclear production averaged 417 TWh in the period 2005–2015.

Flamanville

The problem was originally discovered at the Flamanville EPR project in 2014. Since then an internal probe at Le Creusot where many of the components in question were manufactured, has uncovered new anomalies. AREVA is now reported to be reviewing all 9,000 manufacturing records at the forge dating back as far as 1943, including files from more than 6,000 nuclear components.

This autumn there have been almost weekly revelations resulting in plant shutdowns, extended outages, reduced generation, and lots more questions. According to ASN there are now a significant number of reactors offline, with more to be inspected in the next few weeks. "*We are now finding carbon segregation problems from components coming from both Le Creusot and* [the Kitakyushu-based Japan Casting & Forging Corp.] *JCFC plant. As for now, there* [are] *20 EDF reactors offline,*" the official said, noting that the number will fluctuate as inspections take place.

The analyses performed by EDF thus far have found that since 2015 certain channel heads of the steam generators manufactured by Le Creusot and JCFC "*contain a significant carbon concentration zone which could lead to lower than expected mechanical properties,*" according to ASN. *The Japan Times* reports that the JCFC is now also under scrutiny by Japan's Nuclear Regulation Authority.

Shaun Burnie for Greenpeace said "*As a result of substandard manufacturing in Japan, citizens in France have been unknowingly exposed to the risk of catastrophic failure of critical reactor components which could result in a reactor core meltdown. Japanese-supplied steel is now at the centre of France's unprecedented nuclear crisis the scale of which has never been seen in any country. All 12 reactors supplied by JCFC are either in forced shutdown or about to be. It lacks all credibility that the Japanese nuclear industry would claim that there are no implications for the safety of their own nuclear reactors. The steel production records released in France did not reveal the scale of excess carbon, which was only found after physical testing. There are currently no plans for such tests in Japan. That is wholly unacceptable. There are many urgent questions that need to be answered by the industry and the NRA, and with full public disclosure and transparency*." (2)

Energy traders and analysts warn that the French market needs to prepare for longer maintenance periods in coming years given the age of the nuclear fleet and the continuing design flaw revelations. With the average French reactor now more than 30 years old, equipment will need to be replaced more frequently, and increasingly stringent safety requirements will mean that components could be delayed, especially as ASN imposes additional checks. The safety inspections and other reviews "*will lead in particular to extensions of certain planned outages*," EDF said in a press release.

Erring on the Side of Safety?

Despite the outages and findings from the carbon quality investigations, EDF continues to downplay the risk. "*The safety margins are very large and the carbon content does not undermine* *integrity or security, even in the case of an accident*," an EDF spokesperson told *Le Monde* newspaper. But questions about quality control practices at Le Creusot continue to grow. Indeed, the greater the scrutiny, the more problems are being discovered. The number of components affected by irregularities and already installed in operating reactors increased from 33 known issues in April to 83 by the end of September. Startlingly, irregularities affecting just the Flamanville EPR project increased from two to 20 during the same period.

While EDF and AREVA are dealing with costly damage control, ASN and other agencies are erring on the side of caution. Indeed, the ASN representative said, "*We take no risks. That is the rule. If we don't know the dangers of the carbon segregation, then we must take the reactors offline until we know what the situation is and* [can confirm that] *it's not dangerous*."

ASN revealed that AREVA has now identified at least 87 irregularities concerning EDF reactors in operation, including vessels, steam generators, and main primary system piping, plus the 20 issues for parts intended for Flamanville 3, and one more affecting a steam generator planned for installation in Gravelines 5. Inspectors have also found four irregularities affecting transport packaging for radioactive substances. ASN said that whatever the outcome of these investigations, the irregularities "*reveal unacceptable practices*."

External Parties Push for Answers

After the discovery of anomalies in the composition of steel in certain zones of the vessel closure head and the vessel bottom head of the EPR reactor being built at Flamanville in 2014, an internal audit was carried out and released in April 2015, suggesting the existence of many more anomalies. These were initially downplayed by ASN and AREVA. But in September 2015 an independent evaluation conducted by Large and Associates for Greenpeace France really set the cat amongst the pigeons. "*The nature of the flaw in the steel, an excess of carbon, reduces steel toughness and renders the components vulnerable to fast fracture*," said the report's author, John Large. The Greenpeace report, "*Amplified the questions ASN already had*," said an ASN representative.

12 reactors have been identified by ASN to have carbon problems in replacement steam generators forged by JCFC. In these reactors initial surface tests were followed by more invasive studies. The first reactors to enter scheduled refuelling outages for a more thorough examination were Tricastin 1 and 3. The early nondestructive inspection results for the JCFC bottom channel heads at these reactors revealed an alarming 0.39% level of carbon present, almost 100% greater than the maximum permissible level. That finding, with its associated reduction in material toughness, rendered the component vulnerable to fast fracture, reported Greenpeace in a late October update. ASN decided to order the shutdown of all but one of these reactors and these shutdowns will remain in force until EDF can demonstrate each reactor is safe to re-enter service.

Uncertainty Remains

At a French parliamentary hearing into the situation on October 25, ASN said it would need another year or two to examine the thousands of documents at the Le Creusot foundry and more anomalies and irregularities will probably be discovered. (3)

As of late October 2016 ASN has confirmed the following:

- Six reactors have been granted approval to restart and are operating normally: Blayais 1, Chinon 1 and 2, Dampierre 2 and 4, and Saint-Laurent-des-Eaux B2.
- Seven reactos are in planned outages and have been, or are being, inspected. They are: Bugey 4, Civaux 2, Dampierre 3, Gravelines 2, Saint-Laurent-des-Eaux B1, and Tricastin 1 and 3. (4) *The Times* reports that the re-start of Civaux 2 and Dampierre 3 has been delayed until 31st December. (5)
- Five reactors have been ordered by ASN to be taken offline to conduct checks before 18th January 2017. They are: Civaux 1, Fessenheim 1, Gravelines 4, and Tricastin 2 and 4. (6)
- Three reactors are currently scheduled to remain unavailable throughout the winter months. They are: Bugey 5, Gravelines 5, and Paluel 2.
- One reactor has been ordered by ASN to shut down following the detection of an irregularity in the lower shell of the steam generator. That unit is Fessenheim 2.
- Incidentally, Paluel 2 has been offline since May 2015. Its maintenance period is continuing, following an incident on March 31, 2016, in which a 465-ton steam generator tipped over during removal. (7)

EDF's Debts

EDF faces a seemingly impossible financial equation. It has colossal debt of €37 billion; it must deal with the complex €2.5 billion takeover of Areva; and find the money to extend the life of its 58 reactors at costs estimated between €60 and €100 billion up to 2030. (8)

Meanwhile EDF has been accused by Greenpeace France of grossly underestimating the cost of nuclear electricity. Greenpeace claimed that if EDF disclosed the true cost of running its fleet of reactors in France while financing two new ones in the UK, it would be declared bankrupt.

Greenpeace commissioned an audit by AlphaValue, the equity research company. The French government has agreed to inject €3 billion into the group this year and has renounced dividend payments until next year. Shares in EDF, 85% of which are owned by the French state, have lost almost a third of their value in the past year and the company is no longer listed on the Paris blue-chip index.

The AlphaValue report described EDF as an "*uncompetitive firm - incapable of reacting rapidly and efficiently to the variations in electricity needs and the changes created by the liberalisation of European markets*". It said that EDF's rivals had written down the value of their nuclear plants because of the move to renewable energy and the fall in electricity prices and that EDF had failed to follow suit. Juan Camilo Rodriguez, author of the report, said the company might have to close 17 of its 58 French reactors to meet the government's requirement that nuclear power should provide 50 per cent of the nation's electricity in 2025, down from 75 per cent now.

"*The provisions to safeguard the burden of financing the decommissioning of the French reactors are far from sufficient*. [If 17 are closed], *the group should increase its provisions by more than*

€20 billion." Mr Rodriguez said the cost of handling nuclear waste added at least €33.5 billion to that figure. "*Whatever scenario is retained, an adjustment of the nuclear provisions . . . would lead to the bankruptcy of EDF from an accountancy point of view*," he added. The report said that EDF would need to find a further €165 billion during the next decade to finance projects such as Hinkley Point and the renovation of reactors in France. EDF says it will spend €51 billion renovating its reactors and £12 billion on Hinkley Point. A spokesman for EDF accused AlphaValue of making erroneous calculations that failed to take account of long-term electricity price movements and differences between France and other European markets. (9)

Greenpeace filed a complaint against EDF and its CEO, Jean-Bernard Lévy, for "*stock trading offences*" at the end of November and EDF responded by suing the group for making "false allegations". Greenpeace has asked the public prosecutor "*to open a preliminary investigation or to appoint an investigating judge*", saying that "*shareholders, investors but also French citizens are being misled by EDF and its CEO*". (10)

According to Stéphane L'homme, Directeur de l'Observatoire du nucléaire: "*In summary, the French nuclear fleet is at the end of its course, dilapidated and dotted with deficient parts. At the same time, the finances of EDF are in such a deplorable state that the company could soon join Areva in bankruptcy, and is in any case unable to properly maintain its reactors*."

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2. Renewables – the cheapest way to decarbonise

A new report from a think-tank called E3G, which aims to accelerate the transition to a low-carbon economy, says the Government needs to deliver new low carbon generation capacity as cheaply as possible. The UK will need new capacity capable of producing around 150TWh (terawatt hours = 1,000 million kWh) per year of electricity by 2030 – around half of all current output. All plausible scenarios imply that this can only be achieved by deploying a significantly increased volume of renewable generation – likely to be around 50GW, predominantly from a combination of onshore and offshore wind and solar PV.

The E3G report says there is an increasing body of evidence that the system integration costs of renewable generation are low and that the power system can operate securely and at least cost with more than 50% of electricity demand being met from variable renewable sources. System integration costs are predicted to remain less than £10/MWh which means that not only is it possible to securely operate the power system with high levels of renewable generation, but it also represents the cheapest option. E3G shows that under the current trajectory onshore wind will be at least 22% cheaper than nuclear with offshore wind and solar PV providing savings in excess of 4% and 8% respectively, and savings will probably be even greater as the flexibility of the electricity system improves.

The important conclusion from this E3G study is that **the cheapest way to decarbonise the power system involves large volumes of variable renewable generation even when taking system integration costs into account**. (1)

Renewable costs keep falling

In fact researchers at Citi, a global investment bank, think that paying for energy could soon become a thing of the past. Cheaper storage and smart data analytics may soon make solar and wind energy available to consumers in some parts of the world – completely for free. (2)

Even the government now expects solar and wind power to be cheaper than new nuclear power by the time Hinkley Point C is completed. And Business Secretary, Greg Clark, has admitted that fears that intermittent renewables would jeopardise Britain's ability to keep the lights on have been overblown. (3) An unpublished report by the energy department shows that it expects onshore wind power and large-scale solar to cost around £50-75 per megawatt hour (MWh) of power generated in 2025. New nuclear is anticipated to be around £85-125/MWh, in line with the guaranteed price of £92.50/MWh that the government has offered Hinkley's developer, EDF. On previous forecasts, made in 2010 and 2013, the two renewable technologies were expected to be more expensive than nuclear or around the same cost. This is the first time the government has shown it expects them to be a cheaper option. The figures were revealed in a National Audit Office (NAO) report on nuclear in July. "*The* [energy] *department's forecasts for the levelised cost of electricity of wind and solar in 2025 have decreased since 2010. The cost forecast for gas has not changed, while for nuclear it has increased*," the NAO said. (4)

Onshore Wind Costs

In Europe onshore wind has become one of the most competitive sources of new electricity. Mott MacDonald estimated in 2011 that costs would fall to around £52-55/MWh by 2040 compared with £83-90/MWh in 2011. (5) But according to Bloomberg New Energy Finance (BNEF) new onshore windfarms were the cheapest way for a power company to produce electricity in Britain by 2015 with costs dropping to £55/MWh. (6)

The trade body, Scottish Renewables, has shown that costs could be cut by a further 20% if government, industry and regulators work together to make sure we can use the latest generation of turbines on suitable sites, reduce grid charges, and deploy energy storage technologies. (7)

Solar Power

Sustainability expert, Chris Goodall, author of new book called "*The Switch*" (8), says cheap solar panels and advances in storage technology are about to transform the world. By 2030 or 2040 solar will be the cheapest way to generate electricity, indeed any form of energy EVERYWHERE. At the rate of growth that we are seeing at the moment of 35-45% per year solar will grow from providing 2% of global electricity to at least 50% by 2030. We can see the cost of batteries coming down in price dramatically. Turning surplus solar electricity generating during the summer into something we can put into natural gas networks is what we should be looking at in the UK. Generating hydrogen from water and, using microbes, combining it with carbon dioxide to form methane is the simplest way to do this. The era of fossil fuels is drawing to a close. (9)

Offshore wind

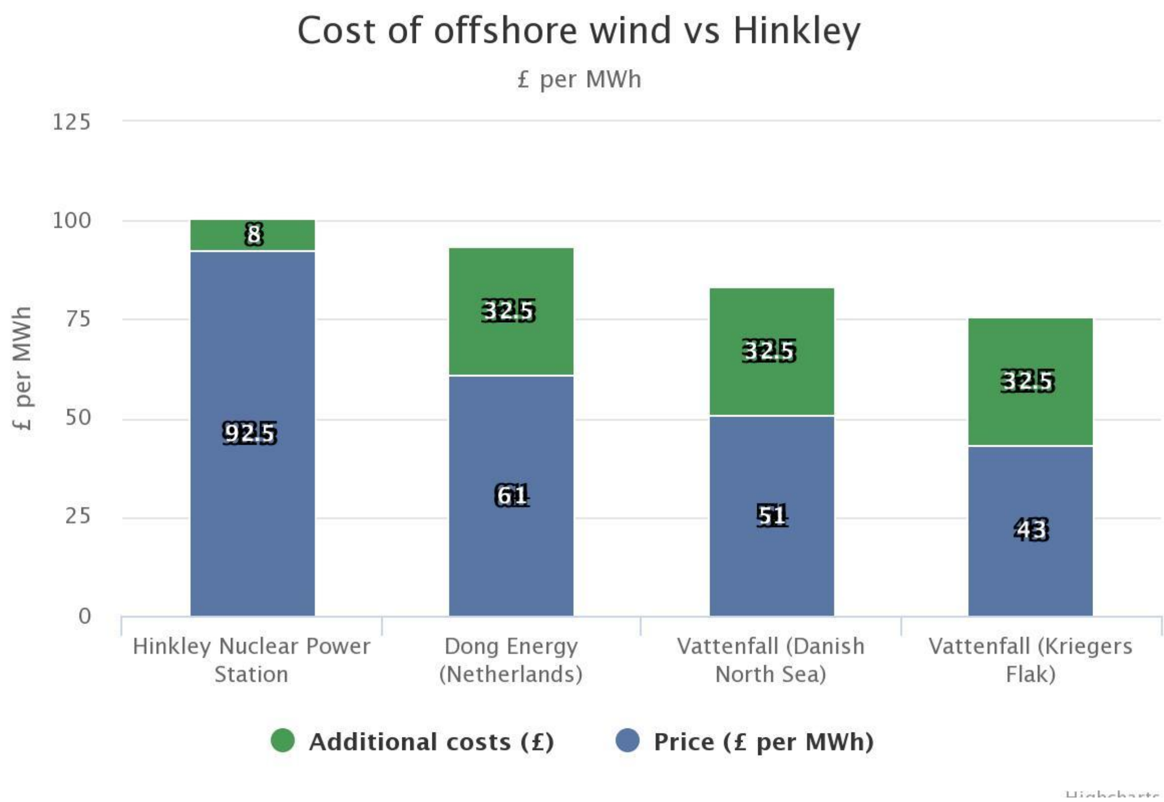
Earlier this year DONG Energy of Denmark, the world's largest offshore wind company, won a bid to build two wind farms 22 kilometres off the Dutch coast. The company says power will be produced for less than any other offshore scheme to date. It is estimated that when the scheme is fully operational, electricity will cost €72.70 per megawatt hour (MWh) and €87 MWh when transmission costs are included. (10)

At the time this was described as the cheapest offshore wind electricity in the world: "*beyond even the most optimistic expectations in the market.*" (11)

Since then Swedish utility Vattenfall has agreed to build a giant offshore wind farm in Denmark that would sell power for €49.50 per MWh. Vattenfall has broken its own previous record of €60 per MWh.

Greenpeace has produced the chart below to show the cost of offshore wind power compared with the cost of Hinkley Point C. The UK's cheapest offshore windfarm will produce power at roughly £120 per MWh, which is far more than the projects being built in Denmark and the Netherlands. Part of the reason for that is that those governments cover transmission costs, so in the name of fairness Greenpeace adds £25 per MWh. And then to address offshore wind's intermittency, you've got to add another £7.6 per MWh — according to the UK government's top climate advisers to cover the cost of the 'balancing'the system. (12)

So we can see that the latest Vattenfall bid is coming in at £75.50/MWh compared with £100.50/MWh for Hinkley Point C. (The £92.50/MWh strike price agreed for Hinkley Point C was index-linked at 2012 prices so £8/MWh has been added to allow for inflation.)



Energy Efficiency

Research out by sustainability expert, Chris Goodall, shows a business and government drive to promote switching of homes, street lights and offices to energy efficient LED light bulbs would see a huge reduction in the UK's electricity demand for lighting - more than two Hinkley nuclear plants' worth of electricity. Lighting is responsible for nearly a third (29%) of total winter peak electricity demand - a complete switch would halve that. Switching entirely to LEDs in homes will save about 2.7 GW of peak winter demand; street lighting 0.5 GW; offices and commercial buildings 4.5 GW.

An expenditure of about £62 in an average house, replacing about 21 of the bulbs in living areas would cut electricity bills by at least £24 per year. This could be done relatively quickly and the total cost of partially upgrading all UK homes to energy-efficient LED lights would be around £1.7 billion. The price of LED light bulbs is falling over time and they cost just £1.60 each at major retailers. Aside from saving money for the householder directly, the government would conservatively save £65 million per year on capacity market payments from this action in houses and more elsewhere in street lighting and commercial sector. (13)

There are good reasons for using investment in energy efficiency as a vehicle to stimulate the economy – the macroeconomic benefits of public energy efficiency programmes have been illustrated by economists time and time again. For instance Verco and Cambridge Econometrics estimate that if delivered as part of a major infrastructure investment programme for £1 invested by government £3.20 is returned through increased GDP resulting in increased employment of up to 108,000 net jobs per annum. A recent study by Frontier Economics calculates that an energy efficiency infrastructure programme could generate £8.7 billion of net-benefits to the economy.

We know from the German KfW loan scheme that public subsidies for energy efficiency are more than offset by the increase in tax revenues and savings in welfare spending due to lower unemployment. Now is the time to do this in the UK, according to Jan Resnow at the Science Policy Research Unit at Sussex University. The economic uncertainty caused by the Brexit vote will prevail for some time until Britain's new status becomes clearer. At the same time, there will be no energy efficiency programme for the able-to-pay sector after 2017 and funds for fuel poverty alleviation are falling short of what is required to achieve the target. The economic evidence is clear – energy efficiency provides a golden opportunity for an economic stimulus in the UK. (14)

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3. New Nukes Make Global Warming Worse

The kind of analysis pioneered by *No2NuclearPower* in 2005 on the contribution nuclear power might make to tackling climate change (1) has been updated by Fairewinds Associates.

The World Nuclear Association industry trade group estimates that an additional 1.1 Gigatonnes of CO_2 would have been created in 2015 if natural gas plants supplied the electricity instead of 438 nuclear stations. That's 1.1 additional Gt out of 36 Gt - only a 3% difference. Put another way, each of the 438 individual nuclear plants contribute less than seven thousandths of one percent to CO_2 reduction. (2)

The World Nuclear Association (WNA) has a plan to build 1,000 new nuclear plants by 2050 (1,000GW) – that means commissioning a new plant on average every 12 days for the next 33 years. It says this is what we need to mitigate global warming. MIT says annual emissions will increase to 64Gt per year by 2050 even if Paris is implemented successfully.

If we build 1,000GW of nuclear capacity we could decrease CO_2 emissions by 6.15%

Constructing these reactor would cost $8,200,000,000,000 = $8.2 trillion

For humanity the $8.2 trillion represents an opportunity cost. Precious time and money wasted.

CO_2 concentrations will grow by 34ppm in the atmosphere by 2050 while we're waiting for those nuclear plants to come on line. The 6.15% offset will never be enough to reduce CO_2 in the atmosphere by 34ppm.

Solar costs have dropped from about 7c/kWh to 3c/kWh since 2013. Electricity from Hinkley Point C will cost about 12c/kWh

Lazard Financial Advisory and Asset Management, with no dog in the fight, says the $8.2 TRILLION could be better spent on less expensive alternatives to get more bang for the buck! Lazard also estimates that solar or wind would be 80% less expensive for the equivalent amount of peak electric output. (3)

1. See Chapter 5 of "Is Nuclear Power a Solution to Climate Change 2005 http://www.no2nuclearpower.org.uk/reports/Nuclear_Power_April_05v2.pdf
2. Fairewinds 19th Oct 2016 http://www.fairewinds.org/demystify//demystifying-nuclear-power-nuclear-powers-carbon-dioxide-co2-smoke-screen
3. The Fairewinds Crew created this special 2-minute animation to show you why building new nukes is a lost opportunity for humankind with precious time and money wasted on the wrong choice. At least $8.2 Trillion would be needed to build the 1,000 atomic reactors the nuclear industry wants – that's 1 reactor every 12-days for 35-years. Watch the animation to see what it means and why. https://vimeo.com/189456305

4. Nuclear Waste Updates

The Department of Business, Energy and Industrial Strategy – BEIS – (formerly called 'DECC') was planning to hold two public consultations, on the draft National Policy Statement for a Geological Disposal Facility and on Working With Communities based on the work of the Community Representation Working Group, this autumn, but the uncertainty caused by recent turbulence in the wider political environment means that these now look likely to be delayed until early 2017.

Energy Minister Baroness Lucy Neville-Rolfe hailed a "*nuclear renaissance*" when she addressed the Office for Nuclear Regulation Industry Conference in Cumbria. She said that as well as Hinkley Point C and proposals for new reactors at Moorside the Government is "*going further, with proposals to develop 18GW of nuclear power across six sites in the UK*."

She said the Government would be launching a new siting process for a Geological Disposal Facility (GDF) in 2017. *The Whitehaven News* reported that the site for the GDF would almost certainly be in West Cumbria, but this was not in the Minister's published speech. (1)

Just to finally knock on the head the idea that most of the nuclear waste is in Cumbria already so we might as well build the GDF there, *nuClear News* has done some number crunching:

Radioactive Waste Management Ltd (RWM) has developed a detailed inventory of radioactive waste for disposal in its proposed GDF which it calls the 'Derived Inventory'. This inventory is subject to uncertainty due to a range of factors such as uncertainty about the life of the AGR reactors and what happens to the UK's plutonium inventory, and, of course proposals for new reactors.

The Derived Inventory is therefore updated periodically to take into account new information. RWM published a new 2013 Derived Inventory in July 2015. This can be compared with the previous 2010 Derived Inventory to obtain further information about the impact of a new reactor programme. The table below is from an RWM report which does just that. (2)

The 2010 inventory showed a derived inventory (2010 DI) which did not include any spent fuel or other waste from new reactors and an upper inventory (2010 UI) - which did include spent fuel and wastes from a 10GW new reactor programme. On the other hand the 2013 Derived Inventory has only one set of figures which includes spent fuel and waste from a 16GW new reactor programme. As mentioned above this could increase in future to take account of the fact that the Government now anticipates the size of the new reactor programme will be 18GW, to allow for the latest additional to the proposed fleet – Bradwell B. Beyond that there are ambitions to build between 7 and 21GW of Small Modular Reactor (SMR) capacity by 2035.

The nuclear industry and government have repeatedly said the <u>volume</u> of nuclear waste produced by new reactors will be small, approximately 10% of the volume of existing wastes; implying this additional waste will not make a significant difference to finding a GDF for the wastes the UK's nuclear industry has already created. However, the use of volume as a measure of the impact of radioactive waste is highly misleading.

A much better measure would be the likely impact of wastes and spent fuel on the size or "footprint" of a GDF. New reactors will use so-called 'high burn-up fuel' which will be much more radioactive than the spent fuel produced by existing reactors. As a result it will generate more heat, so it will need to be allocated more space in the GDF's disposal chambers. So rather than using volume as a yardstick, the amount of radioactivity in the waste – and the space required in a GDF to deal with it - are more appropriate ways of measuring the impact of nuclear waste from new reactors.

The total activity measured in Terabecquerels (TBq) of the 2010 Derived Inventory, (not including any wastes from new reactors) was 4,770,000 TBq. The total activity given in the 2013 Derived Inventory, which includes waste and spent fuel from a 16GW new reactor programme, was 27,300,000 TBq. Not all of this huge increase in activity is down to new reactors. For instance there is a big jump in the activity of legacy spent fuel and 3,700,000 TBq from spent mixed plutonium-uranium oxide (MoX) fuel – a category which does not appear at all in the 2010 inventory. However, 19,793,000 TBq is activity from new reactor wastes and spent fuel. So **the activity of radioactive waste from a new reactor programme would be roughly <u>four times</u> the activity in the total 2010 inventory.**

Of course this figure is for a 16GW new reactor programme. For an 18GW programme the total activity of spent fuel and intermediate level waste would be about 22,267,125 TBq or almost **<u>five times</u>** the activity of existing waste.

Table 5 **Total activities in TBq for each waste and material type at 2200. Data is shown for the 2010 Derived Inventory (2010 DI), 2010 Upper Inventory (2010 UI) and 2013 Derived Inventory (2013 DI)**

Waste category	2010 DI	2010 UI	2013 DI
HLW	1,170,000	2,190,000	1,090,000
Legacy ILW	388,000	580,000	372,000
LLW	6.31	70.7	2.48
Legacy SF	1,920,000	315,000	2,270,000
DNLEU	7,910	9,510	8,370
HEU	3.10	54.4	53.8
Pu	1,280,000	1,840,000	43,700
New build ILW	-	104,000	793,000
New build SF	-	14,100,000	19,000,000
New build DNLEU	-	3,800	-
MOX SF	-	-	3,700,000
Total	4,770,000	19,100,000	27,300,000

These numbers are significant because of the amount of repository space taken up by existing waste mostly located in Cumbria compared with waste stored on reactor sites outwith Cumbria. The NDA has estimated the total repository footprint for a baseline inventory (the total waste expected to be created by the existing programme) of between 5.6 km^2 and 10.3km^2 depending on the rock-type. However, the footprint from a maximum inventory which includes a 16GW new reactor programme would be between 12.3km² and 25km². (3)

	Baseline Inventory	Maximum Inventory
High strength rock	5.6km²	12.3km²
Lower strength rock	10.3km²	25.0km²
Evaportite	8.8km²	24.1km²

Table 3: Repository Footprint for Maximum Inventory which includes a 16GW New Build programme.

So the activity of existing waste - mostly stored at Sellafield amounts to 4,770,000 TBq. The proposed reactors at Moorside would produce spent fuel and ILW with an activity of around 4,206,012 TBq making a total of 8,976012 TBq stored in Cumbria. However **the activity of spent fuel and ILW stored at new reactor sites outwith Cumbria** would amount to 15,586,988 TBq – **almost twice as much**. And if we assume that the reactors at Bradwell go-ahead it will probably be more than twice as much.

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1. Whitehaven News 3rd Nov 2016 http://www.whitehavennews.co.uk/news/Government-is-committed-to-nuclear-industry-in-West-Cumbria-de408ba6-3d7f-41b8-91f0-f0864a57590d-ds
2. An overview of the differences between the 2013 Derived Inventory and the 2010 Derived Inventory, NDA 22nd July 2015 http://webarchive.nationalarchives.gov.uk/20150817115932/http://www.nda.gov.uk/publication/differences-between-2013-and-2010-derived-inventory/
3. 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 Managing Radioactive Waste Safely Partnership Pete Roche 5th August 2010 http://www.westcumbriamrws.org.uk/documents/94-Inventory_critique_Pete_Roche.pdf

5. Hinkley Point B and Hunterston B Graphite Core Cracking

Radio Four's *Costing the Earth* (1) has been investigating whether it is safe to keep reactors running long past their expected lifespan of about 30 years. Five of Britain's seven AGRs are already older (Torness and Heysham 2 are only 27 years old). Hinkley Point B and Hunterston B are already 40 years old but EDF energy wants them to continue operating for at least another 7 years.

In 2005 the Nuclear Installations Inspectorate (now the Office for Nuclear Regulation -ONR) expressed concern about the structure of the reactor core. The core is made up of 6,000 graphite blocks. Around half of these are 1 metre tall with a bore or channel running through each block. Around 200 of these channels contain rods of nuclear fuel. If anything goes wrong control rods are inserted between the channels to dampen the nuclear reaction and shut down the reactor.

Nuclear Engineering consultant John Large explains that graphite is not elastic, it doesn't bend, and it is not particularly strong. And now the graphite bricks are cracking. The core is an assembly of several thousand bricks, loosely stacked together and the expectation was that the core would never fail, so there was no facility to replace any individual blocks if they did become damaged. But now there are physical changes occurring in the core, in the individual bricks – cracking and fracturing – that must result in some loss of strength – not only of the individual bricks, but of the core as a whole.

The BBC used a Freedom of Information request to obtain a number of documents. One paper from ONR reveals that one third of the channels inspected at Hinkley B and Hunterston B contain what they describe as significant cracks. EDF says the cracks were anticipated at this stage in the reactors' life and it is safe to operate for years to come. It says evidence suggests that its predictions about cracking are accurate.

Brian Cowell, director of nuclear operations, says: "*in fact we are looking to extend life further (than 2023) if we can*." The analysis suggests that we can have more than 1,000 axial cracked bricks and still operate with massive margins of safety. 1,000 cracked bricks would exceed the current safety limit set by ONR, but the regulator is considering changing that limit.

Mark Foy – Deputy Chief Nuclear Inspector says the percentage of cracked bricks ONR is currently happy to accept is 10%, but they are considering increasing that to 20%. Foy says that the original safety case provided by EDF was on the basis of 10% cracking. As experience is gained and analysis and research is undertaken it allows EDF and ONR to gain a more informed and accurate view of what is acceptable and what isn't.

EDF has now provided ONR with a safety case for allowing 20% cracking. This is based on the analysis EDF has undertaken; samples they've taken and the inspections they've undertaken. The focus has been to look at the likelihood of core disruption after an earthquake which could prevent the control rods being inserted. ONR is considering the new safety case.

Keyway Route Cracking

The ONR is also investigating a very specific and more concerning form of cracking. The keyway is a slot that holds each brick to the adjacent brick, the bricks underneath and the bricks on top. These keyways, which are acknowledged to be the limiting factor in the life of these reactors, are beginning to fracture. John Large points out that this will make the graphite blocks a very loose set of bricks.

Prof Paul Bowen of Birmingham University sits on the graphite technical advisory committee for ONR. He says the keyway cracks could potentially prevent the entry of the control rods. If the core distorts too much, it's easy to see how trying to feed anything in could become very difficult.

Seven of the keyways have been discovered to have cracks at Hunterston B. John Large believes the presence of keyway cracks casts doubt on the safety of the reactor in the event of an emergency like an earthquake. We have a cracked and deteriorating core that's lost its residual strength and we don't know by how much. Some of the design case accidents will test the core – one of these would be a seismic shake where the whole core is wobbled. If the core becomes misaligned, and the fuel modules get stuck in the core, the fuel temperature will get raised and could undergo a melt. If the radioactivity gets into the gas stream and the reactor is venting because it's over pressurised then you have a release to the atmosphere and you have dispersion and a contamination problem.

ONR agrees keyway cracks could compromise safety. One of the documents the BBC obtained said the discovery of keyway route cracks at Hunterston invalidates the previous safety case. EDF had to consider what information to present to ONR to satisfy them that the reactor was still safe to operate. EDF brought in articulated control rods and nitrogen injection systems to address the extra risks posed by the keyway route cracking. The new rods are bendy making them easier to insert into a distorted core and an injection of nitrogen could buy several hours of invaluable time in the event of an accident.

However, concern remains because we can't be certain how many keyway route cracks there are. John Large explains that to examine where the cracks are you have to take the fuel out of the reactor and put a camera down to inspect the inside of the bore, but these keyway cracks are on the outside of the bricks so you can't actually see them.

It's very hard to inspect the channels in which the fuel sits. Around 10% are inspected each time the reactor is shutdown. So there may be keyway route cracks that have never been seen at Hunterston and Hinkley. In the absence of a full visual inspection a mathematical model is used to work out the likelihood of cracks in particular parts of the reactor. The trouble is the model has already been shown to be flawed.

Paul Bowen says they haven't been able to get the exact timing of the cracks right. The industry argued that cracks would appear first in layers 4 and 5, but they actually appeared in level 6. John Large says the model relied upon by ONR is not working, so they can't predict the strength of the core. More to the point they can't work out where to put their investigative probes to see where cracking is taking place. So they're in the dark.

If the ONR gives the go-ahead for an increase in the number of cracked bricks from 10 to 20%, it might be difficult for people living near theses reactors to understand why the definition of “safe” seems to be changing.

1. Costing the Earth. Radio 4 BBC 2nd Nov 2016 http://www.bbc.co.uk/programmes/b080t880

6. The AP1000 Reactor Design

NuGen, a consortium of Toshiba and Engie (formerly GDF Suez), is proposing to build three AP1000 reactors at Moorside in Cumbria – a site adjacent to Sellafield. These three reactors together would have a capacity of up to 3.8GW.

The AP1000 reactor is a pressurised water reactor (PWR) designed and sold by Westinghouse Electric Company, now majority owned by Toshiba. But unlike other PWR designs it is what is called an advanced passive design. The idea behind advanced passive design is that it shouldn't require operator actions or electronic feedback in order to shut it down safely in the event of a loss of coolant accident (LOCA). Such reactors rely more on natural processes such as natural convection for cooling and gravity rather than motor-driven pumps to provide a backup water supply. Westinghouse claims that AP1000 plant safety systems are able to automatically establish and maintain cooling of the reactor core and maintain the integrity of the containment which holds in the radioactive contents indefinitely following design-basis accidents.

The nuclear regulators – the Office for Nuclear Regulation (ONR) and Environment Agency – have been carrying out a new process called 'Generic Design Assessment' (GDA), which looks at the safety, security and environmental implications of new reactor designs before an application is made to build that design at a particular site. Initially the GDA for the AP1000 was expected to be completed around spring 2011, when the regulators would have issued a statement about the acceptability of the design. By the end of 2010 it was clear that the ONR would only be able to issue "interim" approvals for the Areva EPR and Westinghouse AP1000 reactor designs at the end of the generic design assessment (GDA) in June 2011. Construction could only occur after any outstanding "GDA issues" had been resolved.

Eventually on 14th December 2011 the Regulators granted interim Design Acceptance Confirmations (iDACs) and interim Statements of Design Acceptability (iSoDAs) for the UK EPR and the AP1000 reactor designs. The Regulators also confirmed that they are satisfied with how EDF and Westinghouse plan to resolve the GDA issues identified during the process.

ONR's interim approval for the AP1000 contained 51 GDA Issues. At this point Westinghouse decided to request a pause in the GDA process for the AP1000 pending customer input to finalizing it. Westinghouse has since become part of the NuGen consortium with its parent company Toshiba taking a 60% stake, the process for AP1000 has resumed, and is scheduled to be completed by March 2017 with issuance of DAC and SODA. By March 2016, the cost of the GDA for the AP1000 had reached £30 million. (5)

The GDA process is being carried out in, what is described as, an open and transparent manner, designed to facilitate the involvement of the public, who are able to view and comment on design information published on the web. Questions and comments can be submitted electronically via the Westinghouse website, or direct to the UK regulators. The deadline for making a comment on the AP1000 plant, as part of the GDA process is 30th November 2016. (6)

Edinburgh Energy and Environment Consultancy was commissioned by Radiation Free Lakeland to write a report on the AP1000 reactor design to submit to this consultation.

(Available here http://www.no2nuclearpower.org.uk/wp/wp-content/uploads/2016/11/AP1000_reactors.pdf)The report came to the following conclusions:

The AP1000 advanced passive nuclear reactor design has a weaker containment, and fewer back-up safety systems than current reactor designs. Conventional reactors rely on defence-in-depth made up of layers of redundancy and diversity – this is where, say, two valves are fitted instead of one (redundancy) or where the function may be achieved by one of two entirely different means (diversity). In contrast advanced passive designs rely much more on natural processes such as natural convection for cooling and gravity rather than motor-driven pumps to provide a backup water supply.

The AP1000 appears to be vulnerable to a very large release of radioactivity following an accident if there were just a small failure in the steel containment vessel, because the gasses would be sucked out the hole in the top of the AP1000 Shield Building due to the *chimney effect.*

Recent experience with existing reactors suggests that containment corrosion, cracking, and leakage is more common than previously thought, and AP1000s are more vulnerable to containment corrosion than conventional reactors.

In addition the AP1000 shield building lacks flexibility and so could crack in the event of an earthquake or aircraft impact.

A thorough review of the AP1000 design in the light of the Japanese accident at Fukushima has shown that:

- Ongoing nuclear fission after a reactor has supposedly been shutdown continues to be the source of significant pressure inside the containment. The AP1000 containment is extraordinarily close to exceeding its peak post accident design pressure which means post accident pressure increases could easily lead to a breach of the containment.

- At least seven ways in which an AP1000 reactor design might lose the ability to cool the reactors in an emergency have been identified. These include damage to the water tank which sits on top of the shield building and some sort of disruption to the air flow around the steel containment.

- The accidents at Fukushima, especially the overheating and the hydrogen explosions in the Unit 4 Spent Fuel Pool showed that the calculations and assumptions about the AP1000 Spent Fuel Pond design were wholly inadequate.

- Fukushima showed that when several reactors share a site an accident at one reactor could damage other reactors. In the AP1000 the water tank on top of the reactor, and the shield building could be vulnerable to damage.

- Westinghouse assumes that there is zero probability of an AP1000 containment breach. But the accidents at Fukushima have shown that there is a high, probability of Containment System failure resulting in significant releases of radioactivity directly into the environment.

The AP1000 reactor design is not fit for purpose and so should be refused a Design Acceptance Confirmation (DAC) and Statement of Design Acceptability (SDA).

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1. http://www.nugeneration.com/about_nugen.html
2. See also Time for Engie to get the hell out of nuclear, CORE 30th August 2016 http://corecumbria.co.uk/news/time-for-nugens-engie-to-get-the-hell-out-of-nuclear/
3. Telegraph 5th Nov 2016 http://www.telegraph.co.uk/business/2016/11/05/government-could-part-fund-new-uk-nuclear-plants-nugen-suggests/
4. See http://www.onr.org.uk/new-reactors/index.htm
5. World Nuclear Association, Nuclear Power in the United Kingdom (accessed 3rd Nov 2016) http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/united-kingdom.aspx
6. See http://www.westinghousenuclear.com/uknuclear/Make-A-Comment

7. New Reactor Notes

- The Environment Agency is planning to launch a consultation on its preliminary conclusions on the Advanced Boiling Water Reactor design which Horizon Nuclear is proposing to build at Wylfa on Anglesey and Oldbury in Gloucestershire. The consultation will run between 12 December 2016 and 3 March 2017. (1) EA will hold a consultation meeting on 24th January 2017 at the Botanical Gardens, Birmingham. This should give participants an introductory understanding of the reactor design currently being assessed through the GDA. (1)

- The second stage of a public consultation into the two EPR reactors planned for Sizewell in Suffolk has been launched. EDF Energy and its Chinese partners want to build two new reactors on the site. The updated designs for Sizewell C will go on display at 23 public exhibitions around the county. The consultation runs until February. (2)

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1. See https://www.gov.uk/government/consultations/gda-of-hitachi-ge-nuclear-energy-ltds-uk-advanced-boiling-water-reactor/gda-of-hitachi-ge-nuclear-energy-ltds-uk-advanced-boiling-water-reactor
2. EDF Energy 23rd November 2016 http://media.edfenergy.com/r/1177/sizewell_c_stage_2_consultation_launches_today

8. Hinkley Notes

- The chief executive of EDF Energy has vowed that Hinkley Point C will be built by 2025 on budget. In evidence to the House of Lords economic affairs select committee, Vincent de Rivaz dismissed parallels with Flamanville and Olkiluoto, which have both suffered delays and cost overruns. He insisted that UK taxpayers would not have to pay for any unforeseen cost increases. He said planning of the two earlier projects had been "flawed" and there had been "*underestimation*" of their costs but insisted EDF had learned lessons from these setbacks. De Rivaz was asked by the committee about EDF's prediction in 2008 that Hinkley would deliver electricity at just £45/MWh. He admitted the figure had been a mistake. "*At that time there were flawed assumptions based on the cost of Flamanville.*" (1)

- Patrick Merliaud, CFDT Secretary of the Works Council at Areva's Le Creusot forge is worried about how to prepare to carry out the order for the two Hinkley Point EPRs. The group plans to make a test piece (a large metal tube) at the end of the year. "*We must make several practice pieces to test out. The problem is, many people have gone into retirement with Creusot's voluntary separation plan. Forty employees out of the workforce of 270 people. The conditions were good to leave and not good to stay.*" Areva had also launched a programme with its historic supplier and neighbour Industeel (ArcelorMittal) to develop a new type of steel "ingot". But it will not be available until 2018, when we hope to make the cap and bottom of the second Pressure Vessel for Hinkley Point. At present, the EDF customer is not committing itself to when. Meanwhile, the parts for Hinkley's first EPR will be outsourced to the Japanese JSW. (2)

- Leigh Fisher, a management consultancy, which worked as an adviser to the Department of Energy and Climate Change (DECC) on the deal to pay EDF £92.50/MWh index linked for the power produced by Hinkley for 35 years was paid £1.2 million for its advice. Now the UK arm of Jacobs Engineering Group, a US firm which also owns Leigh Fisher, is supporting EDF on the Hinkley project. Tender documents obtained by *The Times* under the Freedom of Information Act show Leigh Fisher disclosed a number of potential conflicts of interest, including that Jacobs was providing engineering services and project and construction management resources for EDF and had seconded staff. Iain Wright, the Labour MP and chairman of the business, energy and industrial strategy committee, said there were questions over whether the advice given by Leigh Fisher was impartial and he would investigate further. (3)

- The UK government spent about £20m on consultants to help negotiate aspects of the Hinkley deal, according to the BBC. This includes more than £12m to employ law firm Slaughter and May. The Stop Hinkley campaign group said it was "shocking, but not surprising". Figures released by the Department for Business, Energy and Industrial Strategy show that four firms paid to advise the government between 2011 and 2016 were: KPMG (accountancy) – £4,363,767; Slaughter and May (legal) – £12,038,989; Lazards (finance advice and asset management) – £2,583,131; Leigh Fisher (planning and technical advice) – £1,247,630. Stop Hinkley spokesman Roy Pumfrey said: "*I knew* *years ago we were racking up bills for lawyers for Hinkley C. It seems to me absolutely outrageous that this bill has mushroomed, that we have got to more than £20m of public money spent on this."* In a statement, the department said the consultants had provided *"legal, technical, financial skills and knowledge that were vital to support the department in its negotiations with EDF*". (4)

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1. Guardian 1st Nov 2016 https://www.theguardian.com/uk-news/2016/nov/01/hinkley-point-c-will-not-cost-taxpayers-extra-says-edf-energy-boss
2. LesEchoes 22nd Nov 2016 http://www.lesechos.fr/industrie-services/energie-environnement/0211517137928-areva-au-creusot-les-failles-du-forgeron-2044714.php
3. Times 21st Nov 2016 http://www.thetimes.co.uk/edition/business/hinkley-firm-in-conflict-row-over-links-to-french-m8mzv0cxt
4. BBC 21st Nov 2016 http://www.bbc.co.uk/news/uk-england-somerset-38031448