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rapport

Comments on *"Before the Flood"*

The National Geographic documentary film *"Before the Flood"*, by Academy Award winner Leonardo DiCaprio, is an important collection of information about climate change and the associated threats to humanity. The film deals admirably with several myths and misconceptions about climate change, some of them being actively pursued by climate change deniers. There are, however, some statements in the film that are simplified and deserve further explanation. Furthermore, while the film does not mention nuclear power at all, the related web page contains a number of statements on nuclear power which are incorrect or taken out of context. This report comments on those statements, with the hope that the film makers will change their stance on the issue. Links to the film and the related web page are found in the end of the report, together with references referred to in the comments.

Comments on the film

In the documentary film *"Before the Flood"* [1] there is an interview with the Swedish scientist Johan Rockström, professor and director of Stockholm Resilience Centre, where he makes some statements about renewable energy.

- Rockström: *"We actually have the proof [on high tech clean energy solutions]. You wake up in Germany Saturday morning, you are likely to get 30 percent of the electricity from solar and wind."*
  Comment: Rockström's statement is almost correct. In 2015 German electricity from renewables on average made up 30 percent, out of which 13 percent was from wind power, 8 percent from biomass, 6 percent from solar, and 3 percent from hydro power [2]. At any given moment this may vary, depending on the weather.
  It should be noted that Germany has essentially not reduced its climate emissions from the energy sector since 2009, in spite of a remarkable increase in renewables [3]. The reason is that the use of fossil fuels has not decreased and nuclear power is slowly being phased out, thereby cancelling the positive climate impact from the increased use of renewables [4]. Replacing one low carbon source of power with another is not a good recipe for reducing the climate impact, it would be much better to close down coal and gas before nuclear power.
  Regarding proof for clean energy solutions, Rockström could have looked at his native Sweden where more than 90 percent of the electricity has been low carbon since the mid-1980's. As a comparison, the climate emissions from electricity production in Sweden are about 20 g CO_2-equivalents per kWh, while in Germany they are around 450, see Table 1.

Country	Climate impact g CO_2-eq/kWh	% share of electricity	
		Renewable	Nuclear
Denmark	300	55	-
France	80	16	77
Germany	450	30	14
Sweden	20	64	34
EU average	400	28	26
China	800	24	3
USA	500	14	20
World	500	23	11

Table 1. Approximate climate impact from the electricity production, and percent share of renewable and nuclear electricity, in different countries and regions. Data for climate impact are approximate estimates from different sources, data for renewables and nuclear are from BP Statistical Review of World Energy 2016 [5].

- Rockström: *"Denmark today produces over 100 percent some days of its electricity needs from wind. 100 percent, it's totally renewable."*
  Comment: "Some days" is the keyword here. A national energy system needs to provide power to the consumers all through the year. Wind and solar are two excellent low-carbon energy sources but their production does not necessarily occur when there is demand, but instead when nature allows it. There have been several instances during the last few years when Denmark has produced more electricity from wind power than what the country uses. For instance, 9 July 2015 was a day when wind power supplied up to 140 percent of the Danish electricity needs, with the surplus electricity being exported to neighbouring countries [6]. This is a natural consequence of building large amounts of wind power; some days it will fill all the needs, and other days it will be close to zero, requiring some sort of backup power.

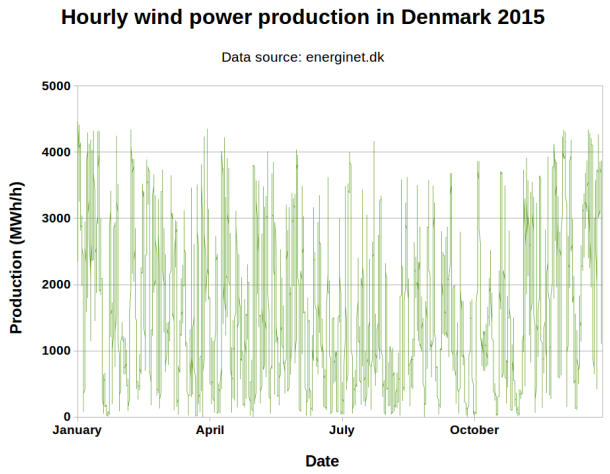

Figure 1. Wind data for Denmark 2015 [8]. As seen the electricity from wind can vary from full potential down to almost nothing.

It should be mentioned that in spite of the large supply of renewable electricity that day, the Danish coal power plants were not turned off. Instead they continued providing about 500-800 MW of electricity [7]. So even though Denmark could have been totally renewable during at least parts of that day, it wasn't. The reason for continuing to operate the coal power plants is that they have to operate at a certain power to allow for a fast power increase when nature does not allow for continuous power from wind. Electricity production from wind varies significantly over time as can be seen in Fig. 1 [8].

The average Danish electricity supply for 2015 had a record 42 percent from wind power [9]. This is an impressive accomplishment, but in order to reach the climate goals the use of fossil fuels has to decrease to zero. Wind and solar need to be complemented with other sources that can produce power irrespective of nature. The total national energy system must be turned to a low-carbon system for the entire year, not just "some days".

- Rockström: *"And remember that once you have invested in wind and solar, you actually have free energy forever."*
  Comment: This is not correct. All energy sources have costs, consumption of resources and some sort of environmental impact. Renewable sources such as solar and wind power have the advantage of not needing any fuel as the energy is extracted directly from the blowing wind or from the shining sun. The investments and resources needed, as well as the environmental effects, are mainly from the construction stage. But there are still costs and a need for resources during operation of the plants. Also, the initial financial investments should give a return. Therefore it is not correct to speak of free energy, there is always somebody paying for it. And it is not forever. Every utility for energy extraction has a finite life time and will have to be replaced, requiring new investments and consumption of resources. The operational life time of solar and wind tends to be 2-4 times shorter than for hydro and nuclear.

Comments on the web page

Although the film does not mention nuclear power at all, there is a section on the related web page that does. The page, titled *"Nuclear Power – Not the Answer"* [10] has a text written by Kelly Rigg, director of The Varda Group for Environment and Sustainability. It is remarkable that a film that deals with the myths and misconceptions about climate change, repeatedly referring to the science, has a text about nuclear power that is full of errors and issues taken out of context. Here are comments and corrections of the statements by Rigg.

- Rigg: *"Certain myths and misconceptions simply refuse to die. The myth that nuclear power will help solve the climate crisis is a case in point."*
  Comment: A running nuclear power plant is essentially free from carbon emissions. In a life-cycle perspective, where construction of the plant itself, uranium mining, enrichment, fuel manufacturing, plant decommisioning and handling of spent nuclear fuel are taken into account, nuclear power is still one of the energy sources with lowest climate impact per kWh of electricity, similar to wind and hydro power, and lower than solar PV [11].

  On a global scale nuclear power is at present the second largest low-carbon energy source after hydro power, see Fig. 2. While wind and solar are growing at an impressive rate they still have a long way to go before being larger than nuclear or hydro, and fossil fuels still make up 86 percent of the global energy supply [5]. Nuclear power alone will not solve the climate crisis, but it is also very unlikely that renewables can do it by themselves. The IPCC Fifth Assessment Report says [12]:

  > *"Technology options include a range of energy supply technologies such as nuclear power, solar energy, wind power, and hydroelectric power, as well as bioenergy and fossil resources with carbon dioxide capture and storage."*

  This statement, and reasoning in other parts of the report about costs and risks, gives the conclusion that it is very difficult to stay below 2 degrees increase of the global temperature if some of the options are excluded. So to claim that nuclear power has no role to play is at best a display of ignoring the urgency of the situation.

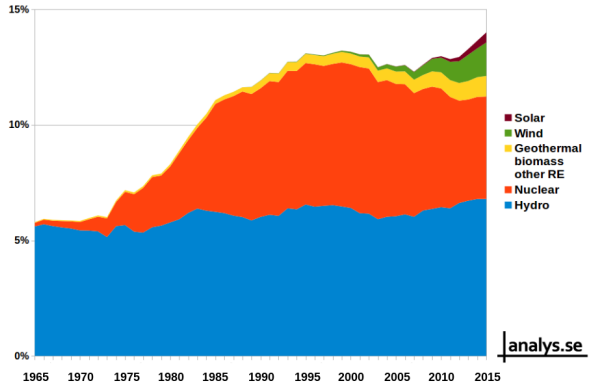

Figure 2. By 2015 the global supply of low-carbon energy sources had reached 14 percent of the world total, the rest is coal, gas and oil. Data from BP Statistical Review of World Energy 2016 [5].

- Rigg: *"In the real world, the deployment of renewables is growing rapidly, while nuclear power production (with the exception of China) is shrinking. In 2015, wind and solar PV had another record breaking year, accounting for around 77% of new power installations worldwide. By comparison, nuclear output grew only by 1.3%, and that was solely as a result of growth in China."*

  Comments: In the real world, we need to reduce the use of fossil energy as fast as possible. It is unfortunately a common mistake to make statements about renewables versus nuclear when the immediate discussion need to be about low-carbon vs fossil, and how to meet the double challenge of increased use of energy while simultaneously avoiding potentially disastrous effects from climate change. The rapid increase in renewables should be applauded, but to reject the positive climate impact from existing and future nuclear and claim that it is not needed is to ignore the reality, as shown in Fig. 2.

  Regarding the numbers given by Rigg, installed capacity is not the same as production capacity. For instance the total installed capacity of solar PV in Germany in 2015 was 20 percent while the production of electricity from the same solar PV was 6 percent. For comparison, German nuclear power capacity was 6 percent while supplying 14 percent of the electricity [2, 13]. A failure to understand the need for baseload power supply, and dismissing one viable option because there is too little of it being installed presently, is not helping in solving the climate issue and shows an unfortunate ignorance from those making such statements. The amount of renewables installed each year is impressive and desperately needed, but is not enough in order to stay below 2 degrees global temperature rise [14]. Therefore we need every low carbon option on the table, including nuclear power.

- Rigg: *"In the real world, renewable energy is getting cheaper by the day, while nuclear power plants are outrageously expensive and losing money."*

  Comment: There are indeed some nuclear power projects with cost overruns and delays, just as one may find such examples on solar and wind power projects. Looking closer there are also plenty of examples of reactor constructions that followed the schedule and were within budget. The "outrageous" costs tend to be of the same order as, or slightly higher than, onshore wind, but cheaper than off-shore wind or solar power [15].

- Rigg: *"In Germany, operator E.ON closed one of its reactors six months earlier than required by law."*

  Comment: On 30 May 2011 the German government imposed a ruling to close all nuclear power plants by 2022, the Grafenrheinfeld plant in Bavaria was by this law required to close down no later than December 2015. A tax on nuclear fuel had been imposed in 2010 in an agreement that allowed an 8 year extension of the plant's operation. The 2011 ruling broke this agreement, but without removing the fuel tax which for the Grafenrheinfeld plant amounted to 80 million euro per year. In 2014 E.ON announced that due to this fuel tax, and the fact that the reactor would need to refuel by mid-2015, it would not be financially viable to run the reactor half a cycle before the closure in December. Therefore it was closed down on 28 June 2015 by the end of its fuel cycle [16].

- Rigg: *"In Sweden, early shutdown of at least four units has been confirmed because of lower than expected income from electricity sales and higher investment needs."*

  Comment: While it is true that four Swedish plants will be closed due to financial reasons, the decisive cause for this is a fiscal tax on nuclear that was increased by the red-green coalition government that came into power in 2014. While increasing the tax, subsidies for new renewables were simultaneously increased. In this kind of market set up, no means of electricity production were making profits. Even existing large scale hydro power plants were in trouble, and in spite of heavy subsidies the installation of new solar and wind has stalled. In view of this financial situation, the reactor owners decided to shorten the planned service life for the four oldest reactors in order to reduce the planned maintenance investments. It should be noted that the situation has changed drastically after the Parliamentary energy agreement of 10 June 2016 [17]. Within the framework of this agreement the fiscal tax on nuclear power will be removed, but the political agreement came too late for a reversal of the decision to close the four reactors. The effect of premature

closure of these plants reduces the possibility for Sweden to continue having a low-carbon electricity export that would help reducing the use of fossil fuels in neighbouring countries. An estimate shows that this missing opportunity of reducing emissions equals up to 20 percent of Sweden's total annual emissions [18]. While acknowledging the firm commitment of the red-green government to the climate issue, it should be noted that the increase of the fiscal tax on nuclear power has turned out to be a very bad deal for the climate.

- Rigg: *"Even in developing markets like India, at least two units are candidates for early closure as they are losing money."*
  Comment: The two reactors in India that may be closed are the two oldest ones in Tarapur, both connected to the grid in 1969, so irrespective of ones stance on nuclear it is fair to say that these reactors should be closed down any time soon [19]. Both reactors have a power rating of 150 MW electricity, so closing them is not a very big loss on a national scale. Besides large investments in renewables, India had one 1000 MW nuclear power plant started in 2016. Five more are under construction, and there are plans for twenty more reactors [20, 21].

- Rigg: *"In the real world, renewables account for an increasingly large and diverse share of electricity entering the grid. As a result there is less room for electricity generated by large centralized power plants that need to run all the time."*
  Comment: In the real world, renewables consist mainly of hydro power, see Fig. 2 above. In countries where solar and wind have a larger share of the electricity entering the grid there is still a need for some other source of energy to compensate for fluctuations. If hydro power or other large scale energy storage is not available the remaining options are either nuclear or fossil fuels. Without nuclear power the dependence on continued use of fossil fuels is inevitable. In spite of the high ambitions of the Energiewende this is what we see in Germany. Unfortunately there is no indication of a drastic change in the foreseeable future, and the German government recently announced that it will depend on fossil fuels, in large centralized power plants that need to run all the time, at least until 2050 [22].

- Rigg: *"The problem with nuclear power plants is that they can't be ramped up and down to match demand; they don't come with a dimmer switch."*
  Comment: This is not correct, it is possible to run nuclear power in load following mode. It is done on a regular basis in France and Germany, and other countries such as Sweden have done it earlier. It should be emphasized that there is always a base load to fill, nuclear can do that job while renewables will need some sort of backup system. The dimmer switch is usually not the first option as it makes more sense to run nuclear continuously at full power, but it is there if needed [23].

- Rigg: *"In the real world, the astronomical costs of cleaning up nuclear accidents (of which there are no equivalents for renewable energy) are passed on to the public."*
  Comment: The reactors in Sweden, Finland, Germany and a few other countries have passive containment filtered venting that significantly reduce the release of radioactivity outside of the plant after a severe accident, an example for Switzerland is given in ref. [24]. Had such filters been installed in Fukushima then the external effects and the related costs would have been very limited. Most of the new reactors being built today are designed in such a way as to reduce effects outside of the plant to a minimum.
  It should be noted that although more than 100 000 persons in Fukushima prefecture have been evacuated due to the releases of radioactivity, and where some of them may never be able to return home, there are no discernible radiation-induced health effects, and according to UNSCEAR none will be expected [25].

- Rigg: *"Five years after the Fukushima disaster, taxpayers are out-of-pocket for $40 billion (¥4.2 trillion), with no end in sight. For that amount of money, Japan could have increased its national wind power capacity 8 to 10 times over."*
  Comment: In 2015 Japan produced 5.4 TWh of electricity from wind power, although a lot in absolute term that is only 0.5 percent of the total electricity generation [5]. So a tenfold increase would mean 54 TWh per year of electricity from wind power. This would certainly be welcome as more than 90 percent of Japan's energy consumption comes from fossil fuels. Before 2011, and the closing down of the nuclear power plants, it was around 81 percent. Thus investments in renewable energy, as well as a restart of the nuclear power plants, are urgently needed.
  Regarding the costs for new windpower, $40 billion is approximately the costs of a new nuclear power plant delivering about 50 TWh, based on the projects in Olkiluoto and Plant Vogtle, which have both suffered severe delays and cost overruns.
  It should also be pointed out that weather related damages are increasing globally, partly due to climate change. The German reinsurance company Munich RE estimates that the costs for the first half of 2016 amounts to $70 billion [26]. At that pace the annual

costs will be significantly higher than the estimates for the Fukushima accident.

- Rigg: *"Given that nuclear plant operators can't get insurance – the state has capped liability for operators – taxpayers will foot the bill every time."*
  Comment: Most nuclear power companies have some sort of damage compensation funds which is regulated by national law and international agreements such as the Paris and Vienna conventions [27, 28]. Such funds presently do not cover costs at the level of Fukushima, and it is considered reasonable for goverments to cover such so-called top risks for activities that are of national interest but have an associated small probability of large scale damage. Arguments against the government taking such top risks, which rightfully can be considered a subsidy, also mean that other activities, such as large hydro power dams and petrochemical industries, with potential damage of the same magnitude, can not be considered acceptable, but such discussions are almost never heard. A global risk fund for all nuclear power plants, or regional risk funds for activities with large potential costs, could be a way to achieve a full coverage even for Fukushima-scale accidents. The costs for such funds would be equivalent to a few tenths of a US cent per kWh of electricity [29], but it requires political willingness in order to realize such an arrangement.

- Rigg: *"In the real world, the devastating impacts of climate change remind us daily that decarbonizing our economy is a matter of the gravest urgency. New nuclear power plant construction is characterized by lengthy delays and massive cost overruns – often by years, in a number of cases by decades. The fact is, increasing energy efficiency and rapidly scaling up the deployment of renewables are the only way to bring down emissions quickly enough to stave off a full-blown climate catastrophe."*
  Comment: Kelly Rigg is correct, the need for a fossil free society is urgent in view of the climate issue. Unfortunately we are not even close to building renewables fast enough yet. But France, Sweden and a few other countries managed to build their nuclear fleets at the pace that would be necessary in order to decarbonize the electricity supply globally [14, 30]. This does not mean that we should do it with nuclear only, rather that we need to speed up the construction of both renewables and nuclear. Energy efficiency and solutions such as carbon capture may also be necessary. And even more important, those who care about the climate issue should work actively against premature closure of fully functioning nuclear plants, especially as there is no benefit for the climate to replace them with renewables. In the US, the recent closure of four nuclear plants means a loss of low carbon electricity equivalent to the entire US addition of solar power, and within the states where they have closed down the use of fossil fuels has increased [31].

- Rigg: *"But let's get one thing straight – nuclear power is a false solution. Nuclear is dangerous, slow and expensive."*
  Comment: Let's get one thing straight – nuclear power is a safe existing solution, together with renewables and other means of combatting global warming. It is very dangerous to exclude it if we are to avoid devastating consequences caused by a too slow transition away from fossil fuels. And according to the IPCC it will also be more expensive.

- Rigg: *"Who knows, maybe one day in the future we'll get a safe, clean, cheap version of nuclear power, …"*
  Comment: We have some good news for Kelly Rigg, there are several reactor designs that address the percieved issues of safety and waste problems. These reactors have passive safety systems, reuse of the existing spent nuclear fuel, and less waste to handle for long time spans. The reuse of nuclear fuel enables a source of energy for several centuries. Some of these reactor concepts have not materialized yet, others have been available for a long time but were stopped from further development due to political decisions based on unfounded fear (Superphenix in France, and the Integral Fast Reactor in the USA are notable examples). In order to address these issues there is also a need for a complete system handling the fuel (the so called Generation-IV concept), and there are some technical challenges to solve in order to make the system economically feasible. But it is remarkable that people who do not believe in the possibility of further technical development of nuclear power often display an unlimited optimism for overcoming the challenges with a 100 percent renewable energy system.

- Rigg: *"…or maybe even "dilithium crystals" that can power space travel."*
  Comment: It may come as a surprise to Kelly Rigg, but exploration of the outer parts of the Solar system relies on nuclear power in the form of plutonium batteries, as there is not enough sunlight available for using solar cells [32]. There are also several space rocket designs proposed that use nuclear fission that heats hydrogen gas for the propulsion. We do not need dilithium crystals, space travel is already possible with the help of nuclear technology.

- Rigg: *"Unlike nuclear, which requires the mining of uranium, renewable technologies simply harness what is freely available."*

Comment: Renewable energy also requires the use of finite resources, including mining of metals and other materials that give a large environmental impact. Furthermore, large scale deployment of renewables may lead to bottlenecks in the supply of certain resources [33]. While the wind and the sunshine is free, the technologies to harness them come with a cost. In the real world somebody needs to pay that cost.

- Rigg: *"And in the time it takes to build a single new nuclear plant we could build thousands of new solar and wind plants."*
  Comment: We can build nuclear as fast, or faster, than we can build the equivalent amount solar and wind plants. But we need to do both, and we need everything available if we are to take the climate issue seriously. In China the use of coal seems to have reached the peak level. This is very welcome news, but the challenge remains to bring the use of fossil fuels to zero. The arguments given by Kelly Rigg show a willingness to prefer nuclear phaseout before solving the climate issue. This is indeed a very dangerous game to play for anybody who claims that decarbonization is a matter of the gravest urgency.

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References and links

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