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Nuclear Power and the „do no significant harm" criteria of the EU Taxonomy

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1 Introduction

The proposal for the taxonomy regulation (EC 2018b; 2021b) goes back to the EU's "Action Plan: Financing Sustainable Growth" (EC 2018a), which called for the creation of a classification system for sustainable activities. The European Commission launched the Technical Expert Group (TEG) on sustainable finance to develop recommendations for technical screening criteria which respond to the framework laid out in the taxonomy regulation. According to (TEG 2020b) the

> *"… TEG mandate has been to focus on economic activities that can make a substantial contribution to climate change mitigation or adaptation, while avoiding significant harm to the other environmental objectives"*

In its final report, the TEG found it impossible to conclude that nuclear energy does not cause significant harm to other environmental objectives on the time scales in question. A robust "do no significant harm" (DNSH) assessment was infeasible to undertake, as no permanent, operational disposal site for high-level waste exists yet, from which long-term empirical data can be drawn in order to evaluate nuclear energy (TEG 2020a, p. 210). Furthermore, the TEG also recommended an in-depth study of the DNSH criteria of nuclear power (TEG 2020a, p. 211).

In the aftermath, the European Commission asked the EU's Joint Research Centre (JRC) to assess whether nuclear meets the criteria to be included in the taxonomy and which technical screening criteria should be used to assess the 'no significant harm' aspects of nuclear energy. This includes environmental risks with respect to the environmental objectives listed in the taxonomy regulation with particular attention to protection of water, waste preventing and recycling (in particular if waste may cause significant and long-term environmental harm), pollution prevention and control, and protection of ecosystems and biodiversity. In March 2021, the JRC published its report and concludes that the analyses did not reveal any science-based evidence that nuclear energy does more harm to human health or to the environment than other electricity production technologies already included in the Taxonomy (JRC 2021).

The objective of this working paper is not to deliver a detailed analysis of the entire report, but a focus on key arguments upon which the report is built and which do not hold at closer look. The focus is on the JRC's assessment of severe accidents (chapter 3.5 Impact of severe accidents) and nuclear proliferation (touched upon in chapters 3.3.5.1.5 and 3.3.5.1.6). A discussion of questions related to nuclear waste management can be found in a corresponding policy paper of the Heinrich-Böll-Stiftung (Böll 2021). For further discussions of the JRC report see for example (Österreichisches Ökologie Institut 2021; BASE 2021; GoE Art. 31 2021; SCHEER 2021).

2 Severe Accidents

In this section we analyse the discussion of severe accidents and their importance by JRC with respect to the “do no significant harm” (DNSH) criteria. A full analysis of the JRC report, its underlying scientific literature as well as the generally available scientific literature on severe accidents is beyond the scope of this paper. But even a coarse analysis of the JRC report shows significant shortcomings, contradictions, and open issues.

2.1 What JRC concludes

In this section we summarize, what JRC has assessed with respect to the potential consequences of severe accidents (chapter 3.5 of the JRC report) and how JRC relates these assessments to the fundamental question of the DNSH criteria.

In its Executive Summary, JRC draws a key conclusion with respect to the DNSH criteria (JRC 2021, p. 7):

> *“The analyses did not reveal any science-based evidence that nuclear energy does more harm to human health or to the environment than other electricity production technologies already included in the Taxonomy as activities supporting climate change mitigation.”*

The assignment given to JRC was to present scientific analysis and evidence whether nuclear energy does significant harm or does no significant harm in the framework of the taxonomy regulation. The task has not been to assess whether nuclear energy does more or less harm than other energy technologies. A finding that nuclear energy does not do more harm than other energy producing technologies is not equivalent to a finding that it does no significant harm as required for a technology to be recommended under the Taxonomy Regulation.

The JRC analysis compares nuclear energy with other energy production technologies for which significant harm occurred in the past decades. Therefore, the finding of the analysis did in fact reveal that nuclear energy does significant harm and that also other electricity production technologies can do significant harm.

The above concluding statement is questionable with regard to the part that such other electricity production technologies ‘*are already included in the Taxonomy as activities supporting climate change mitigation*’. The Taxonomy Regulation does not accept any energy technology as DNSH without further qualifications and criteria. A delegated regulation under the taxonomy regulation act has established specific criteria (e.g. for hydropower plants) resulting in specific limitations, exclusions, benchmarks or criteria specific to those technologies that ensure that no significant harm is done along their life-cycles. Examples of energy technologies used for comparison of harm in the JRC report would not qualify under the Taxonomy Regulation.

JRC does not state in the key conclusions section, whether the assessment of potential consequences of severe accidents are included in its key conclusion, whether the potential consequences of severe accidents have been fully analysed or whether there are remaining open questions for further analysis. In Chapter 4 of the JRC report, which gives a summary of the DNSH assessment for nuclear energy, the same conclusion as above is drawn, but here it is clearly restricted to

> *“The analyses outlined in Chapter 3.2 …”*

of the JRC report (JRC 2021, p. 182). Consequences of severe accidents are not covered by the discussion of human health consequences in Chapter 3.2 but are discussed in Chapter 3.5 of the JRC report (JRC 2021, p. 58):

> *"The results presented here concern normal operation. Human health impacts of accidents are discussed in Chapter 3.5"*

The above conclusion is thus not including consequences of severe accidents and there is no key conclusion with respect to the potential consequences of severe accidents.

In the section on key findings following the key conclusions section, JRC states that (JRC 2021, p. 9)

> *"… the potential impact of severe accidents (see Chapter 3.5 of Part A) have been discussed extensively."*

In fact, Chapter 3.5 of the JRC report – which covers the potential impact of severe accidents – comprises 6 of 397 pages or 1.5% of the whole report.

As indicators to assess the potential consequences of a severe accident, JRC refers to severe accident fatality rates and maximum consequences (fatalities) (JRC 2021, p. 9). No other indicators with respect to the consequences of severe accidents are considered.

Based on the fatality rate, they present the finding that (JRC 2021, p. 10)

> *"… current Western Gen II NPPs have a very low fatality rate (5·10-7 fatalities/GWh). This value is much smaller than that characterizing any form of fossil fuel-based electricity production technology and comparable with hydropower in OECD countries and wind power (only solar power has significantly lower fatality rate)."*

and

> *"… latest technology developments are reflected in the very low fatality rate for Gen III EPR design".*

With respect to maximum consequences (fatalities), JRC finds:

> *"Very conservative estimates of the maximum consequences of a hypothetical severe nuclear accident, in terms of the number of human fatalities, are presented in Chapter 3.5 of Part A and are compared with the maximum consequences of severe accidents for other electricity supply technologies."*

JRC does not summarize or assess these estimates of maximum consequences or their importance to assess the DNSH criteria.

Finally, JRC recognizes:

> *"While the number of human fatalities is an obvious indicator for characterising the maximum severity of accident consequences, nuclear accidents can lead to other serious direct and indirect impacts that might be more difficult to assess. Whereas the public is well aware of the devastating consequences on property and infrastructure, as well as on the natural environment, from historical cases of anthropogenic catastrophes, the disaster and risk aversion might be perceived somehow differently for nuclear related events. Evaluating the effects of such impacts is not in the scope of the present JRC report, although they are important for understanding the broader health implications of an accident."*

Thus, the assessment of the JRC with respect to the fulfilment of the DNSH criteria for severe accident in nuclear power plants is based on the indicator of fatality rates alone (no assessment for maximum consequences is carried out, no other indicators are taken into account). This is clearly insufficient to assess the risk of severe accidents in nuclear power plants, as will be discussed in greater detail in the following. Despite these findings, JRC acknowledges in its key findings that (JRC 2021, p. 10)

> *“Severe accidents with core melt did happen in nuclear power plants …”*

and adds that

> *“Severe accidents are events with extremely low probability but with potentially serious consequences and they cannot be ruled out with 100% certainty.”*

Furthermore, JRC states clearly that

> *“The consequences of a severe accident at a nuclear power plant can be significant both for human health and the environment.”*

To summarize:

- A major risk factor of nuclear energy, the potential consequences of severe accidents, is covered by only 1.5% of the total report what JRC calls “extensive”.
- JRC recognizes that severe accidents did happen and that they can happen.
- JRC finds that severe accidents have significant consequences both for human health and the environment.
- JRC assesses the fatality rates for severe accidents and finds that the consequences of severe accidents – based on this indicator – are comparable to other energy technologies.
- JRC does not draw conclusions on the indicator of maximum fatalities in its key findings, nor does it evaluate further indicators for the potential consequences of severe accidents, despite acknowledging that they exist and are relevant in relation to the taxonomy regulation.
- Still, JRC comes to the overall key conclusion, that nuclear power does not do more harm to human health or to the environment than other electricity production technologies already included in the Taxonomy.

Thus, JRC at one hand recognizes that accidents do happen and that they do have severe consequences. This must be understood as being equivalent to the finding that significant harm has occurred and can occur. At the same time, they conclude that nuclear power does not violate the DNSH criteria.

While it is already evident from this discussion, that the key conclusion of the JRC report is not backed by the actual assessment of the JRC, we will further discuss these aspects in the following section.

2.2 Discussion of the JRC analyses

In this section we discuss what JRC, the literature that JRC cites and the literature that JRC does not cite has to say about severe accidents and their consequences. The JRC analysis of the potential consequences of severe accidents in Chapter 3.5 of (JRC 2021) is based on six references.

Two of those refer to (legally non-binding) recommendations with respect to regulatory requirements of the Western European Nuclear Regulators’ Association (WENRA).

One reference covers the consequences of the severe accident of the Fukushima Daiichi nuclear power plant in 2011 (no reference is given with respect to the consequences of the other severe accidents referenced by JRC, namely Three Mile Island (1979, USA) and Chernobyl (1986, Soviet Union)).

One reference discusses possible consequences of severe accidents (U.S. NRC 2020). JRC refers to an older version of this study (the Revision 1 of 2012). Both versions are based on fundamental work, more fully covered by (U.S. NRC 2012).

Two references are based on the work of Burgherr and Hirschberg (Burgherr und Hirschberg 2014; Hirschberg et al. 2016), who analyse consequences of severe accidents in the energy sector.

In Chapter 4 of the JRC report, one further work by Burgherr and Hirschberg is referenced with respect to severe accidents, namely (PSI 2003), which is not referenced in Chapter 3.5.

No other work on severe accidents is referenced by JRC. Limitations of the literature cited by JRC will be discussed in the following. Still, it is quite evident from this list already, that JRC does not cover the broad spectrum of available literature on severe accidents and thus clearly does not represent different approaches available in scientific literature to assess the possible consequences of severe accidents.

2.2.1 Appropriate risk metric for nuclear accidents

JRC discusses only fatality rates and maximum consequences with respect to severe accidents in nuclear facilities.

Severe nuclear accidents can lead to significant off-site consequences due to the release of large amounts of radioactivity. The release of radioactivity will impact human health by inhalation of airborne radionuclides, ingestion of radionuclides by food or water or by direct radiation due to radionuclides deposited on land. To minimize the consequences to human health, different countermeasures will be taken after a nuclear accident. These countermeasures include sheltering, evacuation, short- or long-term relocation of humans as well as restrictions on land use or drinking water supplies (BfS 2015). While these countermeasures can drastically reduce the impact on human health (and thus the number of fatalities and corresponding fatality rates), they will result in significant consequences concerning other indicators of severe accidents like land loss or costs.

A discussion of severe accidents based only on fatality rates and maximum consequences in terms of fatalities for a severe accident without taking into account the consequences of countermeasures taken to limit these is clearly insufficient.

Indeed, JRC concludes itself (JRC 2021, p. 10):

> *"While the number of human fatalities is an obvious indicator for characterising the maximum severity of accident consequences, nuclear accidents can lead to other serious direct and indirect impacts that might be more difficult to assess. Whereas the public is well aware of the devastating consequences on property and infrastructure, as well as on the natural environment, from historical cases of anthropogenic catastrophes, the disaster and risk aversion might be perceived somehow differently for nuclear related events. Evaluating the effects of such impacts is not in the scope of the present JRC report, although they are important for understanding the broader health implications of an accident."*

Even the literature underlying the JRC analyses makes clear, that (Hirschberg et al. 2016, p. 374)

> *“… decisions may not be solely based on objective and quantitatively measurable risk indicators, but subjective aspects of risk perception and acceptance can play a role too …. Finally, risk assessment is always embedded into the broader context of risk perspectives … and risk concepts …, which can influence the study boundaries and scope, and in turn may affect the choice of risk metrics ….”*

This is also clearly addressed in (Burgherr und Hirschberg 2014):

> *“However, risks of severe accidents are generally not analyzed in a detailed and comprehensive manner, although their impacts can affect the environmental (e.g. land and water contamination), economic (e.g. damage and external costs) and social (e.g. human health and risk aversion) dimensions of sustainability, as well as the availability (e.g. supply disruption), acceptability (e.g. public perception) and accessibility (e.g. import dependency and transit) dimensions of energy security. Furthermore, consideration of accident risks is also important with regard to different time horizons because for example their consequences can be short (e. g. immediate fatalities) or long (e.g. latent fatalities, land and water contamination) term.”*

In fact, even in (PSI 2003), another important risk indicator, land contamination due to the consequences of severe accidents is discussed in the form of interdicted and condemned areas, but no reference is given to this analyses by JRC. Further literature on relevant indicators with respect to severe accidents can be found e.g. in the references of (Burgherr und Hirschberg 2014; Hirschberg et al. 2016).

Thus, already the literature cited by JRC makes clear, that indicators like land and water contamination, damage and external costs as well as human health need to be taken into account to assess the effects of severe accidents with respect to the different dimensions of sustainability. These aspects will be discussed in more detail below.

Indeed, the question of an appropriate risk metric is not new. Already in discussions about the risk of nuclear power taking place in Germany in the 1980s, extensive literature discussed the possible impacts of different electricity production technologies on aspects of sustainability. A critical review of this was performed for example in (Oeko-Institut e.V. 1989, Kap. 3.3) and it is recognized already at that time:

> *“In the common debate, 'risk' is usually defined as 'extent of damage' times 'probability of occurrence'. This definition is based on insurance considerations. A dimension often used to compare risk is 'deaths per year of operation of a plant'. The extent of damage here refers to the type of damage 'fatalities'. Other more commonly used dimensions are 'lost lifetime' or 'lost working days'.*
>
> *However, the results of such comparisons are problematic because the actual effects of each accident always consist of different types of damage, e.g. health damage, financial damage, ecological damage. Each of these types of damage has its own extent of damage in the concrete case, which is different from that of the other types of damage.*
>
> …
>
> *The multidimensionality of the extent of damage also becomes clear when comparing 'Bhopal' and 'Chernobyl'. Although there were significantly more deaths and direct damage to health in 'Bhopal' than in the reactor accident, the extremely far-reaching contamination, the rendering unusable of entire areas of land and housing estates, the other effects on*

> *agriculture and the cost consequences for several national economies made 'Chernobyl' at least as serious an accident.“* [1]

(Oeko-Institut e.V. 1989, Tab. 3.3-1) summarizes different consequences of severe accidents, that would have to be taken into account in a comprehensive discussion of the impact of severe accidents on sustainability, which comprise

- consequences for life and health of humans including direct and indirect deaths, acute and chronic illnesses, genetic damage, psychological damage, fear of further accidents;
- consequences for infrastructure including consequences for drinking water supplies, land contamination, removable and non-removable surface contamination, land loss, loss of neighbouring facilities, loss of further infrastructure;
- consequences for other lifeforms including loss of livestock, loss of wildlife, loss of rare species, loss of biotopes;
- economic costs including cost for civil protection, remediation activities, evacuations, loss of production, damage to image of companies or industries;
- social and political consequences including changes in behaviour of individuals or groups, changes of social or political standards, consequences for international relations and finally
- ecological consequences including impacts on biosphere, ecological resources and natural condition.

A discussion for some of these indicators will take place below.

To summarize:

The JRC assessment of severe accidents using only two indicators clearly represents an insufficient risk metric to fully represent the consequences of severe accidents and does not take into account aspects of risk perception and risk aversion.

In respect of the indicators chosen, the JRC assessment is also not adhering to the Commission’s guidance for the assessment of ‘do no significant harm’ (EC 2021c) and the six environmental objectives covered by the Taxonomy Regulation which clearly include the areas of protection of water and marine resources, pollution prevention, protection of biodiversity. This implies that also the assessment of nuclear accidents has to assess the full range of impacts of accidents and cannot be limited to fatalities.

2.2.2 Maximum number of fatalities

The maximum number of fatalities discussed in the JRC report and shown in Figure 3.5-1 of (JRC 2021), see Figure 2-1 below, are taken from (Hirschberg et al. 2016).

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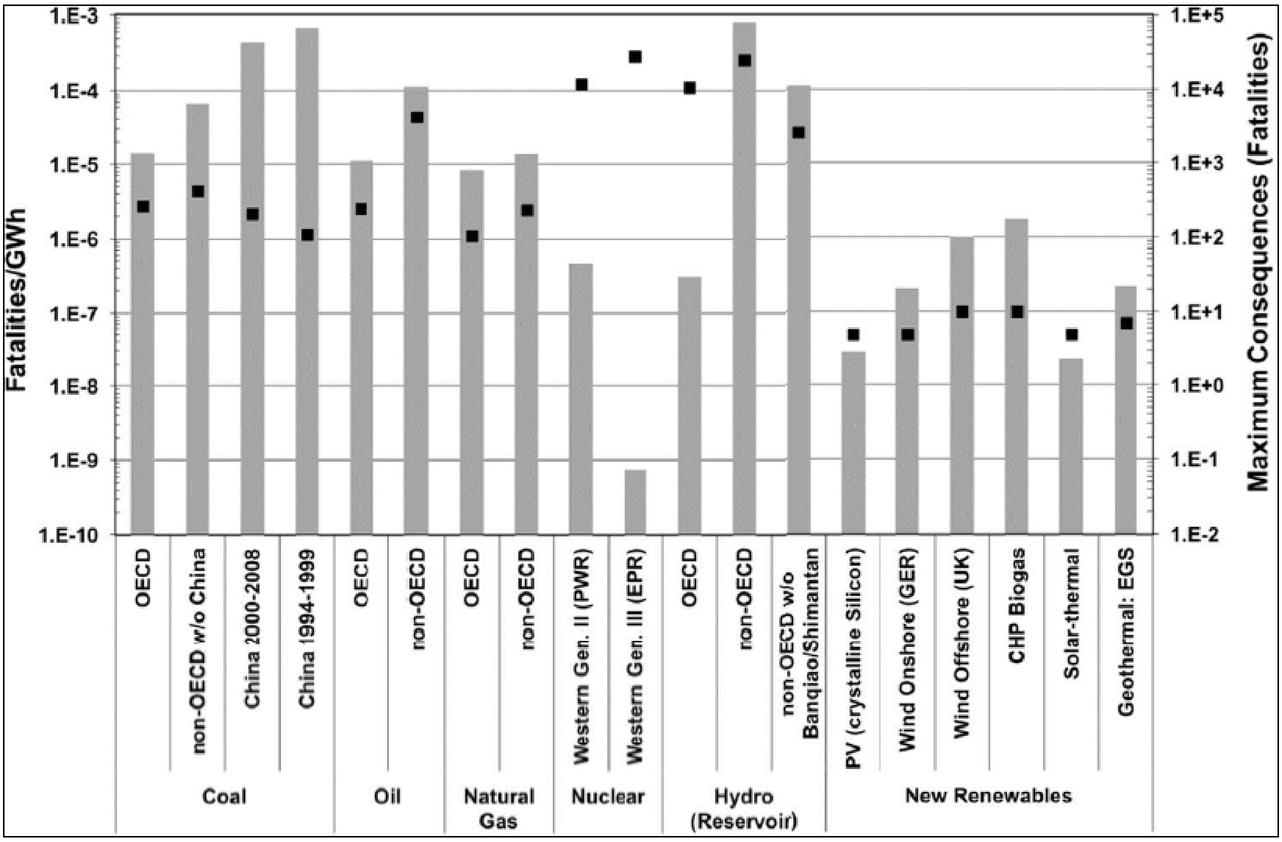
[1] Translation by the authors.

Figure 2-1: Severe accident fatality rates and maximum consequences (black points) assessed for selected electricity supply technologies with the associated energy chains



Source: Figure 3.5-1 in (JRC 2021) referenced from (Hirschberg et al. 2016)

(Hirschberg et al. 2016, p. 376) explicitly refers to a number of exemplary catastrophic accidents in the energy sector, three of them related to oil production and use, two of them to nuclear power (Three Mile Island in 1979 and Fukushima in 2011) and one to hydropower, the Vajon dam failure of 1963 with about 2,000 related deaths. While referenced, the Fukushima accident in 2011 is not included in the evaluation of Hirschberg et al. because it is not in the observation period of their work which covers the years between 1970 and 2008.

With respect to the maximum number of fatalities for non-nuclear electricity production technologies, JRC states (JRC 2021, p. 187)

> *“Note that in Figure 3.5-1 the ‘maximum consequences’ data for the non-nuclear electricity production technologies are real historical data reflecting the officially registered number of casualties (e.g. after a major hydropower-dam accident).”*

Contrary to this statement of JRC, (Hirschberg et al. 2016; Burgherr und Hirschberg 2014) explain with respect to the maximum number of fatalities for hydropower:

> *“The results for fossil options are exclusively based on historical evidence according to ENSAD. The same applies to hydro with the exception of the high value of maximum consequences for OECD (black squarepoint) corresponding to simulated consequences for a specific Swiss dam at a site characterized by relatively high population density downstream from the dam.”*

This is also made clear in the second source cited by JRC, (Burgherr und Hirschberg 2014):

> *"however, in the case of hydropower the analysis is complemented by site-specific consequence modeling."*

Indeed, (Burgherr und Hirschberg 2014) lists actual data with respect to severe accidents in hydropower. According to this, there is one event in the database for OECD countries with a total of 14 fatalities and one event for EU 27 countries with 116 fatalities, 9 events for non-OECD countries (excluding China) with a total of 3,961 fatalities and 12 events in China with a total of 26,108 fatalities. 26,000 fatalities of those were due to the Banqiao/Shimantan dam failures in 1975.

For a hypothetical dam failure in OECD countries with zero pre-warning time, they cite a maximum number of up to 11,000 fatalities. But with a pre-warning time of about 2 hours, this number could be reduced to between 2 to 27.

Contrary to what JRC claims, maximum consequences for hydro plants in OECD countries are thus not based on actual data but on a conservative theoretical calculation for a specific site. Actual maximum consequences for OECD countries and EU 27 countries are 116 fatalities. Even in non-OECD countries, maximum consequences from dam failures are far less than 10,000 fatalities with the exception of a specific Chinese dam accident in the seventies.

With respect to the numbers for nuclear accidents, JRC states (JRC 2021, p. 187)

> *"… Contrary to this, for nuclear energy the 'maximum consequences' values correspond to calculated data which were derived by using highly conservative assumptions (e.g. application of a simplified Level 3 PSA model, dense population in the 100 km region around the plant, no off-site mitigation measures, see Ref. [4-5] for more details)."*

Interestingly, Ref. [4-5] in this quote does not refer the source of Figure 3.5-1 of the JRC report, i.e. (Hirschberg et al. 2016), but to another work of Hirschberg et al., namely (PSI 2003).

With respect to nuclear accidents, (Hirschberg et al. 2016) explains

> *"For nuclear energy a simplified Level III PSA was applied to a specific GEN II plant in Europe and to hypothetical GEN III plant in the same location; the maximum consequences include the dominant latent fatalities."*

In (Burgherr und Hirschberg 2014) they estimate that for the Chernobyl accident

> *"expected latent fatalities range from about 9000 for Ukraine, Russia and Belarus to about 33,000 for the whole northern hemisphere in the next 70 years."*

For maximum fatalities, they give a number of 6,596 for a Swiss Generation II PWR and a number of 46,990 for a Generation III EPR (with the higher number due to a much larger radioactive inventory of the EPR compared to the Generation II PWR analysed).

No estimate for the Fukushima accident is included in the analysis of (Hirschberg et al. 2016),

> *"since a reliable assessment of its consequences is still an open issue."*

(Aliyu et al. 2015) discuss different estimates for human health effects of the Fukushima nuclear accident and estimate the maximum mortality due to all causes at 10,000.

(Hirschberg et al. 2016) conclude with respect to the maximum consequences:

> *"Nuclear and hydro accidents may, however, have very large consequences. … The experience-based maximum consequences of accidents with new renewables are small."*

Interestingly, (Hirschberg et al. 2016) continues with an estimate of the risk of a terrorist attack on energy facilities. In this context, they analyse the possible consequences of an attack on nuclear power plants in the US, Finland, and China as well as on dams

> *“…in China and USA [that] are the largest in the respective countries; the dam in Finland was only planned but never built.”*

Fig. 8 in (Hirschberg et al. 2016) shows frequency-consequence curves for Chinese and Finnish dams and nuclear power plants. From this figure one can draw the conclusion, that for

- the Chinese dam, a maximum number of fatalities of several millions is possible,
- the Finnish dam, the maximum number of fatalities is less than 10,000,
- the Chinese nuclear power plant, the maximum number of fatalities is approx. one million and
- the Finnish nuclear power plant, the maximum number of fatalities is approx. 30,000.

No numbers are given for the corresponding US facilities. Still Fig. 7 in (Hirschberg et al. 2016) gives the corresponding risk of immediate and delayed fatalities per year, showing that the risk for the nuclear power plant in the US is even higher than for the Chinese plant, while the risk for the US dam is two orders of magnitude lower than that for the Finnish dam (which is approx. six orders of magnitude lower than the risk of the Chinese dam).

With respect to the

> *“controversial issue of potential very large consequences of accidents“,*

(Hirschberg et al. 2016, p. 381) clearly refers to their Figs. 4, 5 and 8

> *“with the extent of consequences being clearly visible.”*

To summarize:

- The maximum consequences for nuclear power in Fig. 3.5-1 of the JRC report do not represent absolute maximum consequences, as is evident from the discussion in the underlying literature, citing much higher possible maximum consequences.
- A discussion of maximum consequences for nuclear power has to include mitigative countermeasures (like evacuation, permanent relocation, land use restrictions and others). Without taking the consequences of these countermeasures into account, the “maximum consequences” in terms of fatalities show only a limited picture (see the discussion of other indicators below).
- Still, already given the numbers in Fig. 3.5-1 of the JRC report, the maximum consequences of nuclear power are at least three orders of magnitude higher than for new renewables like photovoltaic, wind, biogas, solar-thermal or geothermal.
- Only for very large hydro plants, and thus a limited number of actual facilities, comparable maximum consequences could be possible. Hydropower plants with such potential fatalities are not be covered by the EU Taxonomy, corresponding technical criteria to exclude them have already been implemented in a Delegated Act under the Taxonomy Regulation (EC 2021a). The comparison made with accidents in some badly designed hydropower dams in China in the seventies or hydropower dams in Finland that were never built is not valid for the purposes of the taxonomy where strict criteria are applied to hydropower excluding the examples taken into account in the JRC study.

Already based on the analyses of possible maximum fatalities of severe accidents in nuclear power plants, it is clear that nuclear energy cannot fulfil any meaningful definition of a “do no significant harm” criterion.

2.2.3 Fatality rates

The fatality rates discussed in the JRC report represent averaged or mean values derived by multiplying the (expected) fatalities with (empirical or calculated) probabilities of an accident. For nuclear power, the probabilities as well as the possible number of fatalities corresponding to a certain accident as used by JRC are not based on actual empirical data (which is sparce) but on theoretically derived values based on so called probabilistic safety assessments (PSA), see the discussion in (Hirschberg et al. 2016). No discussion of uncertainties for fatality rates takes place in the JRC report.

PSA is a very valuable tool to estimate the (theoretical) safety level of a nuclear power plant design. It is used to identify weaknesses in the design and to identify possible safety enhancements (FAK PSA 2005b; 2005a).

Nevertheless, use of PSA results to estimate the actual risk of operating nuclear power plants faces several hurdles. PSA results may be limited to internal events or take into account only selected external events like earthquakes or flooding. For example, (Kumar et al. 2015) discuss the PSA results for the Fukushima Daiichi nuclear power plant which were published before the accident took place. They highlight that:

> *“The Core Damage Frequency (CDF) and Containment Failure Frequency (CFF) for the Fukushima Dai-ichi plants were determined only for internal initiating events. The results obtained by TEPCO … for the CDF of up to 10-7 per year were very low compared to other results for other Boiling Water Reactors (BWR), including those with more backfitting and/or newer designs.”*

Based on today’s knowledge, (Kumar et al. 2015) conclude that

> *“It is recognized today that the determination of the design basis tsunami for the Fukushima Dai-ichi site underestimated both the maximum probable tsunami height as well as the tsunami height for a likelihood of 10^{-4} per year. This led to a false belief in sufficient safety margins even for beyond design tsunamis.”*

Some external hazards are often not (yet) taken into account in PSA, especially with respect to man-made hazards like intentional terrorist attacks on a nuclear facility or possible consequences of military conflicts. Nuclear power plants, but potentially also other facilities of the nuclear supply chain like reprocessing facilities could be targets of terrorist attacks or could be impacted by consequences of military conflicts (be it intentional or by accident). JRC does not discuss the risks of terrorist attacks or military conflicts. This is especially questionable, as the literature cited by JRC does discuss at least the risk of terrorist attacks, although admitting that these analyses are still first-of-its-kind (Hirschberg et al. 2016). Other literature does also discuss at least qualitatively the risks associated with nuclear facilities in crises regions (Oeko-Institut e.V. 2017). According to (Burgherr und Hirschberg 2014, p. 48), 0.5% of the accidents in the energy sector analysed are due to conflicts, making clear that this aspect cannot be ignored with respect to severe accidents in nuclear facilities.

The methodologies for PSA have developed considerably during the past decades (FAK PSA 2016; U.S. NRC 2020). Especially the consideration of human factors as well as common cause failures in PSA has a relevant impact on results. Thus, usually relevant uncertainties have to be taken into account, especially when assessing severe accidents, i.e. extremely rare events. Several limitations of this approach are also recognized by (Hirschberg et al. 2016; Burgherr und Hirschberg 2014).

(Hirschberg et al. 2016) discuss the uncertainties included in their analyses:

> *"Generally, confidence intervals are smallest for fossil chains where large amount of historical accident data is available, intermediate for large hydropower, and highest for new renewables with limited empirical data. For nuclear, where Bayesian approach is employed, PSA-based 95% confidence interval for fatality rates due to severe accidents is typically two orders of magnitude higher than the corresponding 5% confidence interval with mean value being much closer to the 95% value."*

They conclude:

> *"Overall the uncertainties are lowest for severe accidents in the fossil energy chains due to the large number of historical events, moderate for the normal operation, quite large for hydro and PSA-based estimates for nuclear accidents and largest for the terrorist threat."*

A very simplified calculation can illustrate significant uncertainties associated with the use of the theoretically derived fatality rates especially for severe accidents. The annual nuclear electricity production has risen since the 1970s and amounts to about 2,500 TWh today. Assuming an average nuclear electricity production of 2,000 TWh per year during the timeframe 1970 to 2008, which is the evaluation period analysed in (Hirschberg et al. 2016), roughly 75,000 TWh electric energy has been produced. (Burgherr und Hirschberg 2014) estimate the total amount of fatalities for the Chernobyl accident, the only severe accident in the evaluation period, for which they estimate the fatality rates, between 9,000 and 33,000 latent cancer deaths. Assuming just 10,000 fatalities for this accident alone, one would receive an empirical value of approx. 10^{-4}/GWh for the fatality rate of nuclear power. This has to be compared with the theoretically derived number of less than 10^{-6}/GWh for today's Gen II power plants as estimated by (Hirschberg et al. 2016), a difference of more than two orders of magnitude.

An early critic of the probabilistic approach to risk assessment was formulated already in (Hsü 1987). (Wheatley et al. 2016) take up these thoughts and criticise the approach to assess nuclear accident risks based on probabilistic safety analysis, as such techniques are known to poorly predict events and to under-appreciate incidents that cascade into failures. (Wheatley et al. 2016) estimate the rate of severe accidents in nuclear facilities based on a database including 216 nuclear accidents and incidents. They conclude, that for an operational fleet of 388 nuclear reactors, there is a 50% chance that a Fukushima event (or a more costly one) occurs every 60–150 years.

In addition to the limitations of the theoretically derived PSA numbers, further problems with respect to the significance of a purely statistical value like the fatality rate exist. Within the European Research Project ExternE, a methodology to assess external costs of different energy technologies was developed, which is largely also the basis for the work of Hirschberg et al.. With respect to accidents, the ExternE project concludes (IER 2018):

> *"Accidents are rare unwanted events in contrast to normal operation. A distinction can be made between impacts to the public and occupational accident risks. Public risks can in principle be assessed by describing the possible accidents, calculating the damage and by multiplying the damage with the probability of the accidents. An issue not yet accounted for here is the valuation so-called 'Damocles' risks, for which high impacts with low probability are seen as more problematic than vice versa, even if the expected value is the same. A method for addressing this risk type has still to be developed.*

This is also clearly addressed in (UBA 2018):

> *"In principle, the expected value of the damage is to be used for estimating environmental costs. …*

> *However, there are cases where the assessment of risks based on expected values falls short.*
>
> *Firstly, this applies to risks for which there is risk aversion in the population. This means that people are willing to invest more resources to avoid the risk than this is reflected in the amount of the expected value of the damage. Risk aversion is particularly pronounced in the assessment of so-called disaster risks. Disaster risks are characterised by the fact that they occur with a very low probability, but cause very high damage if they do occur (e.g. extreme floods, chemical accidents, risk of a nuclear power accident).*
>
> *Secondly, these include risks about whose probability of occurrence or damage potential there is a very high degree of uncertainty …"*[2]

As (Kumar et al. 2015) conclude on the use of PSA:

> *"PSA results are often narrowed down to very few numbers or even one risk-aggregate figure of merit. … While this certainly simplifies the problem space for the decision maker, this kind of risk aggregation can obfuscate or distort specific PSA results and related plant vulnerabilities. Risk-informed decision making should consider the risk profile of the plants based on sets of PSA risk measures/metrics …, which are understood and presented as uncertainty distributions. These should be accompanied with sensitivity analyses demonstrating the influence of different important sources of uncertainty. Risk-informed decision making should consider always potential long-term consequences of accidental releases. Moreover, the decision making should take into account uncertainty assessments on safety margins, particularly those to known or suspected cliff-edge effects."*

To summarize:

- No discussion of uncertainties for PSA results and especially fatality rates takes place in the JRC report,
- while fatality rates might be a valuable indicator especially for normal operation or for technologies without 'Damocles' risks,
- for nuclear power, fatality rates alone are not a good indicator to assess the risk associated with severe accidents and
- fatality rates are not sufficient to conclude on the DNSH criteria of the EU Taxonomy based on this indicator (alone).

2.2.4 Other indicators

As shown above, even the scientific literature taken into account by JRC makes clear, that indicators like land and water contamination, damage and external costs as well as human health need to be taken into account to fully assess the effects of severe accidents with respect to the different dimensions of sustainability. In this section, a tentative discussion of some of these indicators takes place, which in itself still is by far not comprehensive with respect to a full assessment of severe accidents in nuclear power plants.

Example: Human health aspects (besides fatalities)

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[2] Translation by the authors.

According to (Ashley et al. 2017), following the Chernobyl nuclear accident, a total of 335,000 people have been evacuated from highly contaminated area. Following the Fukushima Daiichi nuclear accident, a total of 160,000 people have been evacuated from the vicinity of the plant. (Ashley et al. 2017) estimate that about 48,000 people who lived in the restricted area have moved outside of the Fukushima prefecture. They further analyse a potential severe accident in a hypothetic U.K. nuclear power plant. The radiologic release of this accident is assumed to be about one order of magnitude lower than the release at Fukushima and two orders of magnitude lower than at Chernobyl (Ashley et al. 2017, Table 9). Based on these assumptions, they estimate a mean number of 44,000 evacuees and a maximum number of 390,000. With respect to the need for permanent relocation, they estimate a maximum number of 41,000 people.

Example: Land and water contamination

Hirschberg et al. give an estimate on land contamination in (PSI 2003). They distinguish between interdicted area, which can successfully be decontaminated within 20 years and then resettled, and condemned area, which cannot be decontaminated within 20 years. They estimate possible maximum consequences in terms of lost land at 3,500-4,500 km^2 (about twice the size of the state of Luxembourg).

The consequence of a severe accident in German nuclear power plants have been analysed in (BfS 2015). With respect to a high land contamination (of more than 40,000 kBq/m^2) the authors conclude that areas in a distance of up to 65 km and a total area of approx. 312 km^2 could be affected. Permanent relocation of adults results for distances up to 82 km.

(IRSN 2013) estimates the possible sizes of contaminated land for major accidents in a French 900 MW nuclear power plant. Areas of up to 18,800 km^2 may be contaminated in the case of a major accident. 1,300 km^2 of those may be contaminated to a degree that people would have to be relocated from that area.

In Chapter 3.2.3, JRC analyses the impact of nuclear energy with respect to the sustainable use and protection of water and marine resources according to Article 17 of the Taxonomy regulation. With respect to the specific aspect of radiological pollution of water bodies, JRC concludes (JRC 2021, p. 47):

> *“There is no commonly used impact indicator specifically to characterise radiological pollution of water bodies.”*

Thus, JRC does not estimate the possible impact of nuclear energy and especially of severe nuclear accidents on water bodies. Still, the impact of severe accidents on water bodies could be very significant. (Aliyu et al. 2015) discuss the impact of the Fukushima nuclear accident on marine ecosystems and conclude that the impact is still largely unknown. Based on the lessons learned from Fukushima, an analysis of the possible consequences of an severe accident in a swiss nuclear power plant shows a strong impact on drinking water supplies not only in Switzerland but also in Germany, as the lakes under consideration and the flowing waters of the Aare and Rhine would be at high risk in the event of an accident (Oeko-Institut e.V. 2014).

Example: Damage and external costs

To estimate the actual cost of a nuclear accident is by far not straightforward. (OECD; NEA 2000) already discussed relevant methodological aspects, a comparison of different approaches was given in (OECD; NEA 2018). Several authors have performed cost estimates for historic events as well as for different classes of hypothetical accidents.

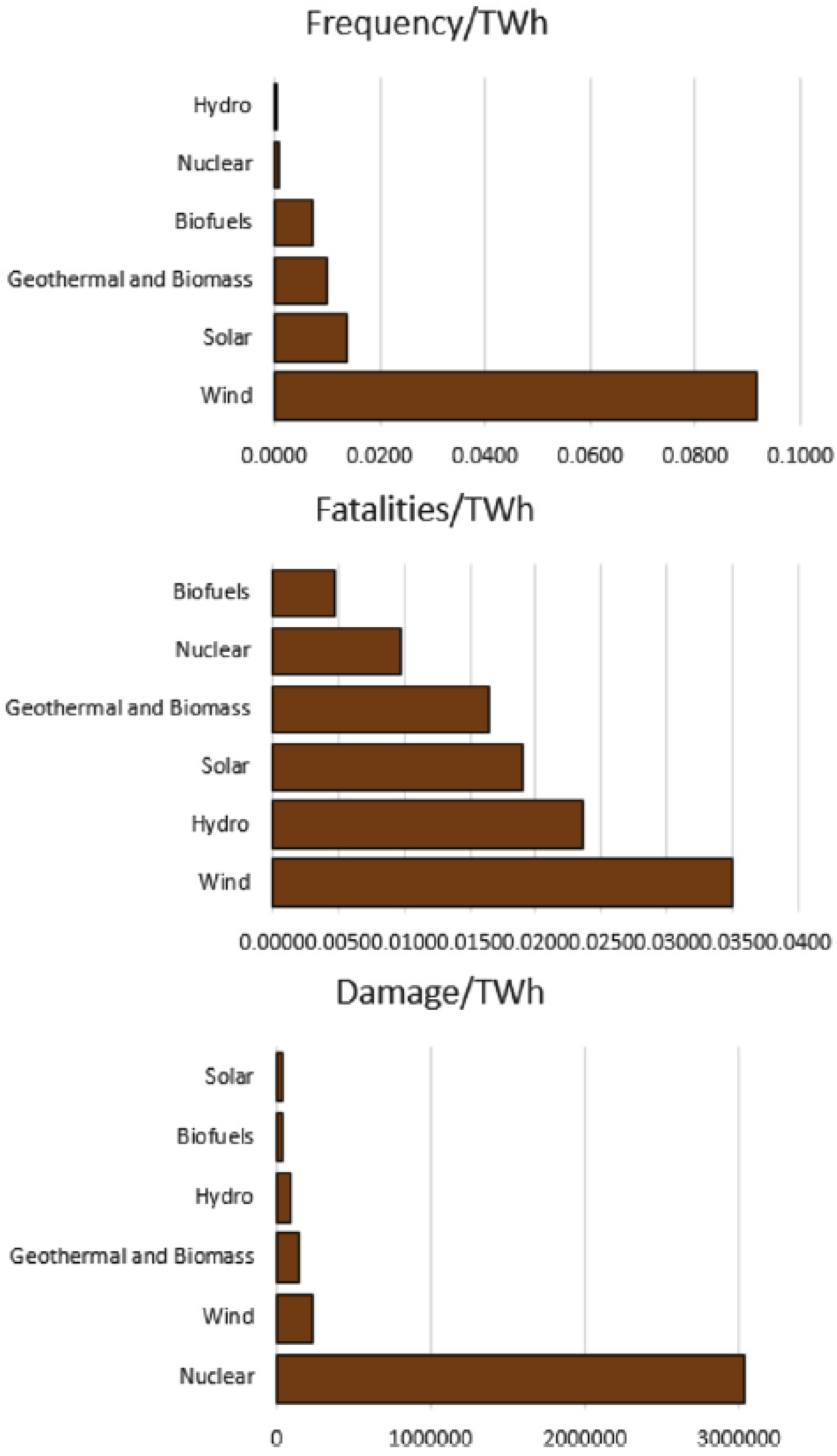
An analysis for an accident in a 900 MW power plant in France is performed by (IRSN 2013). They estimate the total cost and distinguished grave and major accidents. For grave accidents, they estimate an average value of 120 billion Euros with an error margin of 50 to 250 billion Euros. For major accidents, they estimate an average value of 450 billion Euros with an error margin of 200 to 1,000 billion Euros.

(Wheatley et al. 2016) estimate, that the average cost of nuclear energy events per year worldwide is around the cost of the construction of a new plant. They estimate the cost of the Fukushima accident at 166 billion US$.

(Sovacool et al. 2016) assess the risks of energy accidents based on a database of 686 actual accidents over the period 1950-2014. They analyse the frequency, fatality, and scope. By scope they estimate the property damage inflicted by the accidents. An average accident in their database inflicts a mean of 388 million US$ in damage and has 267.2 fatalities.

For accidents in nuclear energy, they evaluate a mean value of 1.4 billion US$ in property damage, approx. twice the value for hydro and more than fifty times the value for other renewables (wind, solar, hydrogen, biofuels, biomass, geothermal). Even the normalised risk in terms of damage per TWh amounts to 3 million US$ for nuclear, compared to between 35,500-235,400 US$ for the other technologies. Thus, the authors conclude that nuclear accidents are the most expensive, inflicting a total of 265.1 billion US$ (or 90.8 percent of the total damage of energy accidents), see Figure 2-2. For the Fukushima accident, they assume property damage of 162.7 billion US$, the Chernobyl accident is listed with a total property damage of only 7.7 billion US$ and the Three Miles Island accident accounts for 2.7 billion US$.

Figure 2-2: Low-carbon energy accident frequency, fatalities, and damage normalized to TWh, 1990–2013.



Source: (Sovacool et al. 2016, Fig. 5)

(Ashley et al. 2017) summarize costs of the nuclear accidents in Fukushima, Chernobyl and Three Mile Island. For the Fukushima nuclear accident, they cite an amount of 38.9 billion US$ in compensations payed by TEPCO up to 2015 and an estimate for further costs for decontamination and renovation of 65.9 billion US$. For Three Mile Island, the costs of compensations were at around 71 million US$ with additional clean-up costs of around 975 million US$. For the Chernobyl accident, they cite estimates of losses of up to hundreds of billions of dollars.

(JCER 2019) estimates the clean-up costs after the Fukushima accident to 35-80 Trillion Yen (around 270-617 billion Euros).

(Silva und Vechgama 2021) estimate the costs of a hypothetical power plant located 50 km northeast of Bangkok. For the base case they estimate total costs of 1.8E7 MTHB (approx. 580 billion US$), under worse assumption costs of up to 1.1E8 MTHB (approx. 3,500 billion US$) could be possible.

To summarize:

- There are other indicators with respect to severe accidents – like the number of people evacuated or relocated, the area of land contaminated for decades or even centuries or the economic consequences of a severe accident – that are relevant to assess the consequences of severe accidents,
- there exists scientific literature making clear that these indicators have to be taken into account and
- that severe accidents in nuclear power plants have significant consequences besides fatalities.

2.3 Summary on severe accidents

For its assessment of the potential consequences of severe accidents, JRC

- refers to a very limited amount of scientific literature, which does not provide a comprehensive assessment of different consequences of severe accidents,
- discusses only two indicators with respect to severe accidents – maximum number of fatalities and fatality rates –, that are clearly an insufficient risk metric to fully represent the consequences of severe accidents,
- relies on theoretical analyses to assess these indicators without discussing the underlying uncertainties and methodological limitations of such an approach,
- does not discuss other indicators with respect to severe accidents – like the number of people evacuated or relocated, the area of land contaminated for decades or even centuries nor the economic consequences of a severe accident – although they are relevant and there exists scientific literature making clear that these indicators have to be taken into account,
- finds that severe accidents in nuclear power plants have significant consequences both for human health and the environment.

Therefore, we conclude, that the JRC report is clearly not sufficient to draw a meaningful and comprehensible conclusion with respect to the DNSH criteria for nuclear power.

Severe accidents in nuclear power plants can happen and they do have significant consequences for human health and the environment.

Thus, taking into account all consequences of severe accidents, nuclear power clearly violates any possible meaningful definition of a “do no significant harm” criterion.

3 Nuclear Proliferation

Nuclear technology can be used for peaceful energy production and for military purposes such as nuclear deterrence and ultimately to wage nuclear war. Nuclear proliferation is the spread of nuclear weapons, nuclear weapons technology, fissile materials and fissile material production technologies, and of other materials or know-how relevant to the use and fabrication of nuclear weapons. Any discussion of a “do no significant harm” (DNSH) criterion for nuclear energy needs to address the inherent dual-use characteristic of nuclear technologies and the danger of nuclear weapons for human wellbeing.

3.1 What the JRC concludes

The JRC report addresses proliferation risks only in chapter 3.3.5.1.5 and 3.3.5.1.6 on reprocessing and in a brief section on the European safeguards system in Annex 1. The authors acknowledge the military history of plutonium production and reprocessing and the proliferation implications of plutonium separation. However, they focus on the civilian use (JRC 2021, p. 312):

> *“As this report focuses on the effects originating from the authorized use of radioactive materials in the nuclear fuel cycle, the nuclear safeguards’ legal framework is only briefly described here.”*

It is implied, that the current system of control with international treaties, safeguards and physical protection measures is sufficient to separate civilian from any military use of nuclear technologies. The report also addresses a potential benefit of a closed fuel cycle for long term proliferation risks, if all fissile material will eventually be consumed in such a closed fuel cycle (JRC 2021, p. 109).

3.2 Discussion of the JRC analysis

3.2.1 Humanitarian impact of nuclear weapons and proliferation

Any use of a nuclear weapon would have catastrophic impact on human health and the environment. The conferences on humanitarian impact of nuclear weapons in Vienna, Nayarit and Oslo 2013-2014 summarized the evidence of the immediate and longer-term impacts of the use and testing of nuclear weapons. The last conference was attended by 157 states. The humanitarian impact of nuclear weapons is also the background against which the Treaty on the Prohibition of Nuclear Weapons was negotiated and entered into force in January 2021 (UN 2017).

The unimaginable destructiveness of nuclear weapons was shown at the attacks on Hiroshima and Nagasaki. This led to the doctrine of nuclear deterrence that frames the international security environment to this day. Due to sheer luck, nuclear war was avoided - so far. In the nuclear arms race tens of thousands nuclear weapons were fabricated, and more than 2,000 tested in the atmosphere, in the oceans and underground. The environmental legacy of highly radioactive waste to produce fissile materials and from nuclear testing will impact generations to come.

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is the cornerstone treaty to curb proliferation (UN 1970). Nuclear disarmament efforts as enshrined in Article VI did not make much progress. Instead today the world faces renewed interest in nuclear weapons with nuclear weapon states modernizing their arsenals and emerging new nuclear weapon states. According to article IV of the NPT, all states have an inalienable right to the peaceful use of all nuclear technologies and parties to the treaty should also facilitate the development and distribution of peaceful technologies. This includes sensitive technologies such as reprocessing and enrichment (see below). The International Atomic Energy Agency (IAEA) is the international body that implements safeguards to control the boundary between peaceful and military use according to article III, and also to encourage international cooperation to further develop and distribute nuclear technology for peaceful purposes. Every party to the treaty can withdraw from the NPT with a three-month notice period, as was the case with North Korea 2003.

The risk of nuclear proliferation is also acknowledged by the Intergovernmental Panel on Climate Change (IPCC) in its 2018 report (IPCC 2018, p. 461). They argue that increasing the share of nuclear energy to reach the goal of only a 1,5°C global temperature increase,

> *"can increase the risks of proliferation (SDG 16)".*

The IPCC refers to the Sustainable Development Goals (SDG) that the United Nations laid out in its "2030 agenda for sustainable development" (UN 2015). Central for nuclear proliferation in this set of goals is the SDG 16 (peace, justice and strong institutions). But literally all other SDGs would be impacted by nuclear testing, nuclear war, or an inadvertent use of nuclear weapons. Also, the IAEA acknowledges unique challenges of nuclear power – among which is nuclear proliferation – for sustainable development (IAEA 2017, p. 7).

3.2.2 Nuclear Proliferation and the "Do No Significant Harm" Criteria

The JRC report only focuses on authorized use of nuclear technologies. It implicitly argues, that since large institutional arrangements of engineered safeguards designed to reduce the risks of nuclear proliferation are applied, the risks will be mitigated. The assumption is that the current system of control is capable of discovering actors that intend to acquire nuclear weapons early enough and that there are effective means available to stop them.

Contrary to this, the EC guidance on the use of the DNSH criteria makes clear that (EC 2021c):

> *"Complying with the applicable EU and national environmental law is a separate obligation and does not waive the need for a DNSH assessment. All measures proposed in the RRPs must comply with the relevant EU legislation, including the relevant EU environmental legislation. Although compliance with the existing EU legislation provides a strong indication that the measure does not entail environmental harm, it does not automatically imply that a measure complies with DNSH, in particular as some of the objectives covered by Article 17 are not yet fully reflected in the EU environmental legislation."*

The Taxonomy regulation is about economic activities to be considered as 'green investments' globally, thus the approach should not be limited to sites within Europe or OECD countries, but should be valid globally. An appropriate assessment has to take into account the risks of nuclear proliferation in non-European countries because the criteria aim at a global not only a European context.

The JRC may not have been mandated to use criteria in its report beyond those related to environmental goals. We, however, argue that a broader set of criteria needs to be taken into account to review the sustainability of nuclear power. And that includes an in-depth discussion of the consequences of nuclear proliferation.

Also, the Technical Expert Group on Sustainable Finance (TEG) did not restrict exclusion criteria only to detrimental effects for the environment (BASE 2021). The technical screening criteria process of the TEG explicitly points out for sectoral activities with high mitigation potential that other (TEG 2020a, p. 33)

> *"material issues whereby an activity is considered unsuitable for inclusion in the Taxonomy may include but are not limited to […] intergenerational risks."*

As with severe nuclear accidents the DNSH criteria have to account for low probability, high risk events. The vast infrastructure of international and European safeguards and physical protection measures is a certain protection against the risk of nuclear proliferation. Also, the system of international security is set up to disincentivize the acquisition and use of nuclear weapons. But these systems are not failproof. States can have incentives to build nuclear weapons (Sagan 1996) and use the dual-use characteristic of nuclear technologies to their advantage, but also terrorists could acquire fissile materials (nuclear terrorism) (Belfer Center 2016).

If the protective systems fail, there could be catastrophic effects. Even a very localized nuclear war, would have global climatic effects as (Robock et al. 2007) showed. The consequence of nuclear weapons use is not in any meaningful sense comparable to risks by other technologies in terms of casualties and harm done. Effects would not only effect humanity and the environment today, but future generations as well. Ultimately, an all-out nuclear war is still possible and could literally destroy human civilization within one hour. Consequently the world-renowned Doomsday Clock (Bulletin of the Atomic Scientist 2021), first started in 1947, is currently set to 100 seconds to midnight, closer to midnight than ever.

We argue therefore, that for an assessment of the sustainability of nuclear power the risk of nuclear proliferation and nuclear weapons use needs to be treated as seriously as global warming. Such a treatment is lacking in the JRC report.

3.2.3 Proliferation and Dual-Use

Historically, the dual-use characteristic of nuclear technology is an integral part of nuclear weapons programs. Of course, not every country with a civilian nuclear program will develop a nuclear weapons program. Although historically, an astonishing number of countries with nuclear infrastructure explored at some point in time to do so (Sagan 2011) and exploited the dual-use characteristics of nuclear technologies. Almost all these states used synergies between their military exploration and civilian nuclear programs.

The JRC report neglects this important dimension of dual use and therefore does not address e.g. the problem of technology transfer. Historically, some states had an incentive to provide sensitive nuclear assistance under certain strategic conditions by transfer of dual-use materials and technology (Kroenig 2010). Such transfer for peaceful use is even mandated by the NPT under article IV (see above). The taxonomy decision will also have economic impact on nuclear related economies outside of the European Union, thus possibly strengthening nuclear countries that purposefully walk the dual-use path to establish a nuclear infrastructure.

Finally, it is fair to say, that a civilian nuclear energy program gives a country a technological potential, a latent nuclear weapons option. A state may even acquire dual-use technology with only peaceful intent, but only later give in to the temptation to initiate weapons research depending on the international security environment (Fuhrmann 2009). The former IAEA director general El Baradei coined the phrase "virtual nuclear weapon states" for such countries with certain nuclear capabilities. The international concern about the civilian nuclear energy program in Iran exemplifies this today. The inherent dual-use characteristic of nuclear technologies therefore turns any transfer or financial assistance for these technologies into a bet on the future, that no circumstances will arise that lead states to use a nuclear infrastructure for military instead of peaceful purposes.

3.2.4 Proliferation prone nuclear technologies

The development of a civilian nuclear energy program establishes a nuclear infrastructure with corresponding facilities, know-how, materials, and manufacturing processes. This latent potential (latent proliferation) is henceforth available for use in a parallel or subsequently pursued military nuclear weapons program. Furthermore the technology itself can proliferate (Braun und Chyba 2004) to state and non-state actors (nuclear terrorism).

This connection is most obvious for fissile materials and fissile material production. Of course, not all technologies and fissile materials are equally suitable for military use (proliferation resistance). Especially the technologies to enrich uranium and separate plutonium from spent nuclear fuel are considered sensitive.

The JRC report does not mention the proliferation risks of uranium enrichment in the life cycle analysis of uranium enrichment. Historically e.g., the Pakistani nuclear weapons program started by a theft of blueprints for uranium enrichment technologies from the European enrichment company URENCO in the 1970s. Pakistan tested its first nuclear weapon 1998 and sold the technology globally to countries like North Korea, Lybia, Iran and Irak and thereby shaped the current international security environment (Braun und Chyba 2004).

The JRC report addresses the proliferation risks of reprocessing technologies to separate plutonium. It also acknowledges that plutonium from spent fuel is less attractive to fuel a nuclear weapon, although it is still usable for a nuclear weapon, depending on the technical skills of an actor. What the report does not discuss is that the “quality” of the plutonium produced in a reactor depends mostly on the time that a fuel element producing plutonium is being used in the reactor. The longer it is being used the less attractive the plutonium contained is for weapon use. Under normal circumstances, nuclear fuel will be used as long as possible in a reactor due to economic reasons. However, the fuel could also be taken out of the reactor earlier than planned. If the irradiation time is short enough it would contain weapon grade plutonium (NPEC 2004). Therefore, all nuclear reactors, also light water reactors which make up the current fleet of reactors, could be used for weapons plutonium production.

The JRC report also mentions the – still theoretical – closed fuel cycle (reusing plutonium and other fissile elements) and even discusses the closed fuel cycle as a benefit for long term proliferation risk, if eventually all plutonium would be consumed after many decades or centuries of operating such a closed fuel cycle. But such a closed fuel cycles involves the operation of reprocessing plants and the handling of separated plutonium as well as the use of breeder reactors during the whole operation time, implying significant proliferation risks.

3.3 Summary on nuclear proliferation

The JRC report does not assess the risks of nuclear proliferation when assessing the DNSH criteria for nuclear energy production. Any use of nuclear weapons would have catastrophic impacts on human health and the environment.

The JRC reports evades the complex history and an in-depth discussion of the use of nuclear energy and nuclear proliferation. But the simple fact is, that all nuclear technologies have a dual-use characteristic and therefore carry a potential for misuse. Any discussion of a DNSH criteria not covering nuclear proliferation is thus incomplete.

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