Examining the human health and environmental consequences of post-Fukushima energy choices in Japan and Germany

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Near-term national energy pathways remain the largest root source of uncertainty in projections of 21st century global climate change. They depend on many variables including scientific/technological issues (e.g. available energy resources and advances in renewable and nuclear energy) and societal factors (e.g. public and governmental views about different energy sources). After the March 2011 nuclear power plant accident at Fukushima, Japan, nuclear power output experienced a rapid and large decline in that country as well as Germany. Although the specific reasons for this decline differed between the two countries, it is clear that anti-nuclear public attitudes were a major factor. Soon after the accident Germany announced plans to completely phase out its remaining nuclear by 2022.

In our recently published paper (Kharecha and Sato, *Energy Policy*, 2019), we analyze the nature and implications of energy, electricity, and CO_2 emission changes in Japan and Germany after Fukushima. Some of these changes are shown in Figures 1 and 2 below. We also examine some simple hypothetical scenarios in which these countries had reduced coal and natural gas power output after Fukushima by the same amounts as they reduced nuclear. Because life-cycle emissions of fatal air pollutants and CO_2 emissions are orders of magnitude lower for nuclear energy than for fossil fuels, these scenarios allow us to quantify the amounts of emissions and mortalities that could have been avoided if alternative energy choices had been made after the accident. Lastly, we also develop scenarios to analyze the potential effects of complete nuclear phaseout in the near-future (2018-2035) for Germany, the US, and the rest of Western Europe (the world's top two nuclear energy users), where economic factors as well as public policies and sentiment are currently unfavorable toward nuclear power.

From a climate change and air pollution mitigation perspective, our findings include both positive and negative outcomes. Consistent with prior studies, we show that the drastic cuts in nuclear power output in Japan and Germany led to increased CO_2 emissions in the first three years after Fukushima due to higher fossil fuel usage to compensate for the reduced nuclear – a phenomenon that received widespread international media attention. However the good news (which has received less attention) is that since 2013, both countries have achieved an overall reduction in their emissions (Figure 2). This was surprising, as nuclear power was a major non-fossil electricity source for decades in these countries. We assess that this result stems from record-high renewable power increases and lower or steady total energy use (Figure 1). We also note that although Japan's electricity sector emissions remain higher than in 2010, i.e. before Fukushima, the government plans to bring the share of electricity from nuclear back to pre-Fukushima levels and reduce the share from fossil fuels, both of which will help lower emissions.

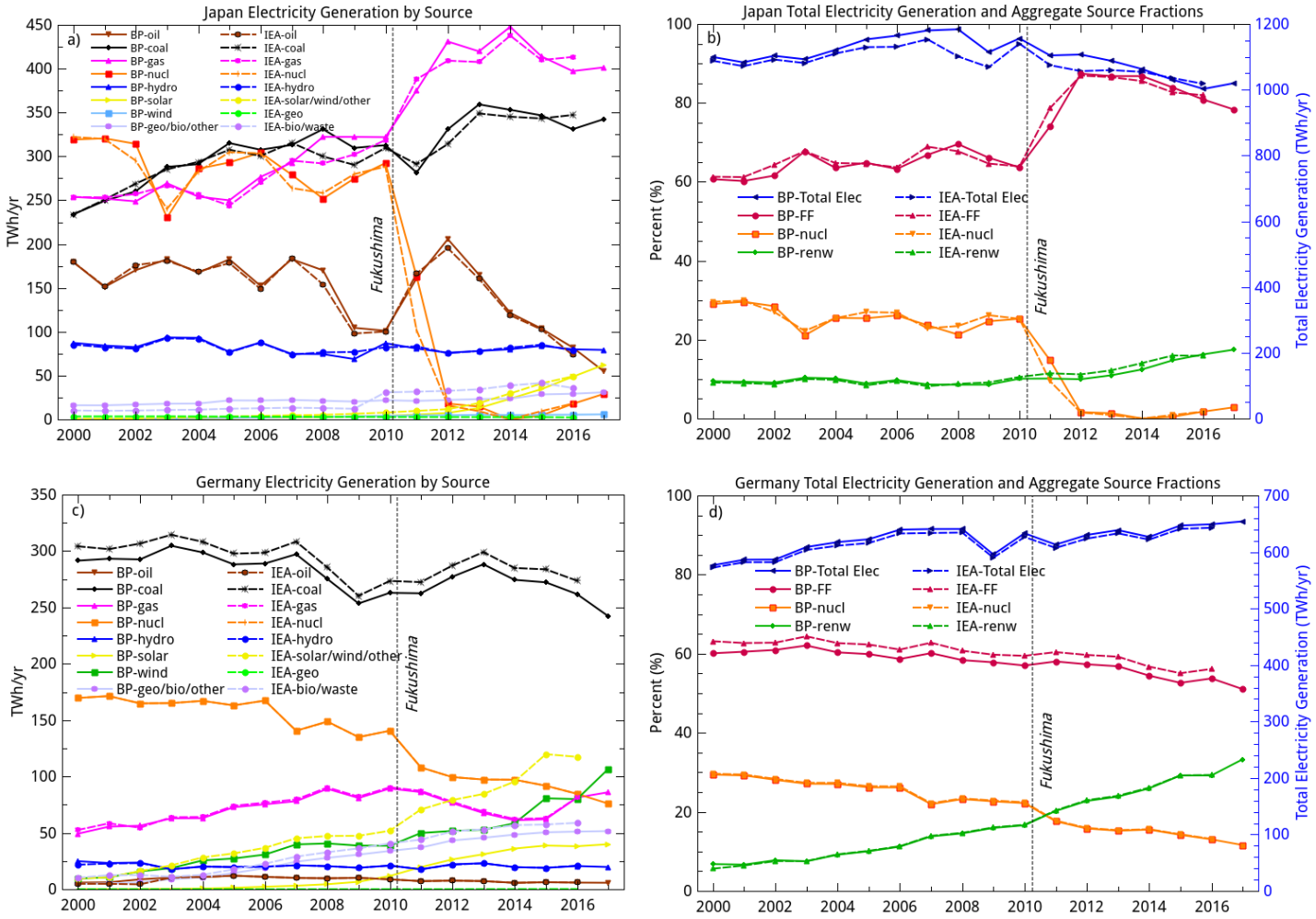

Figure 1. Electricity generation by source (left) and total electricity generation and aggregate source fractions (right) for Japan (top) and Germany (bottom), 2000-2017. See Kharecha and Sato (2019) for data sources. Dashed vertical lines labeled "Fukushima" represent the timing of the accident. All annual values are taken to be end-year values, hence we consider 2011 the first year after the accident. FF = fossil fuels, geo/bio = geothermal + bioenergy, renw = all renewables (hydro + non-hydro).

Now the not-so-positive news: Our hypothetical scenarios show that if Japan and Germany had reduced coal instead of nuclear after Fukushima, they could have together prevented about 28,000 air pollution-induced premature deaths and 2400 megatonnes (Mt) of CO_2 emissions between 2011 and 2017 (Figure 3). Thus, these countries' post-Fukushima energy choices have resulted in major levels of avoidable impacts of the accident.

These lost opportunities will make it even more difficult to achieve national climate change and air pollution mitigation goals, which are already demonstrably inadequate. However, useful lessons can be learned from them -- most notably, the prime importance of targeting fossil fuels for reduction instead of (or at least, before) a major non-fossil source like nuclear. For example, Germany can still avoid up to 16,000 premature deaths and 1100 $MtCO_2$ emissions if it curtails coal power instead of eliminating its remaining nuclear power as planned. Likewise, the US and the rest of Western Europe can each

avoid over 100,000 premature deaths and about 7000 $MtCO_2$ emissions if they too focus on reducing coal rather than nuclear (Figure 3). Our results build on a large body of evidence indicating that major energy users should carefully consider how their energy choices affect their populations' health alongside environmental considerations.

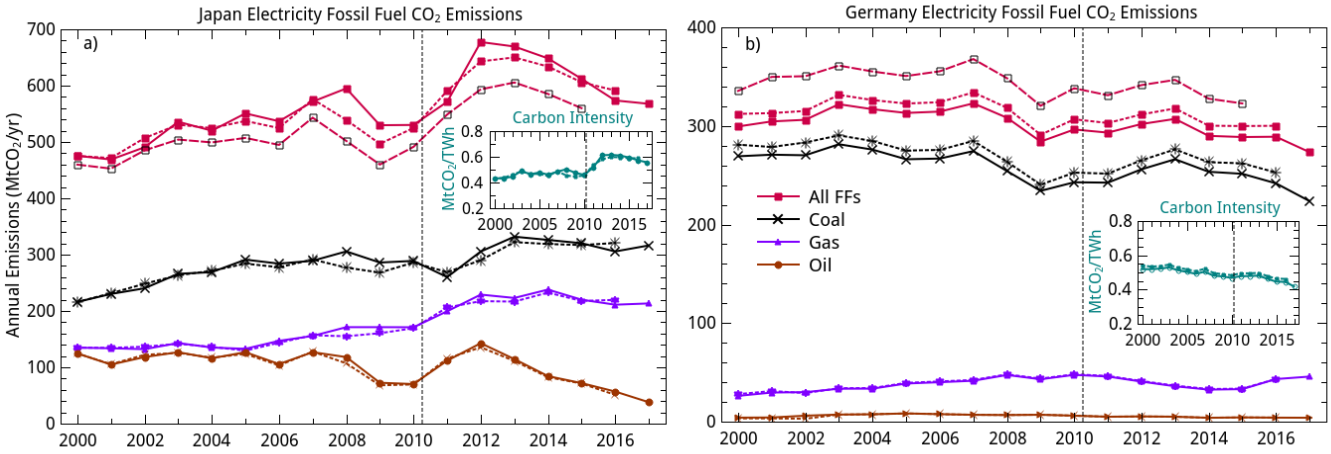

Figure 2. Annual electricity sector fossil CO_2 emissions for a) Japan and b) Germany, 2000-2017. See Kharecha and Sato (2019) for data sources. All FFs = all fossil fuels combined. Inset graphs show carbon intensity of electricity.

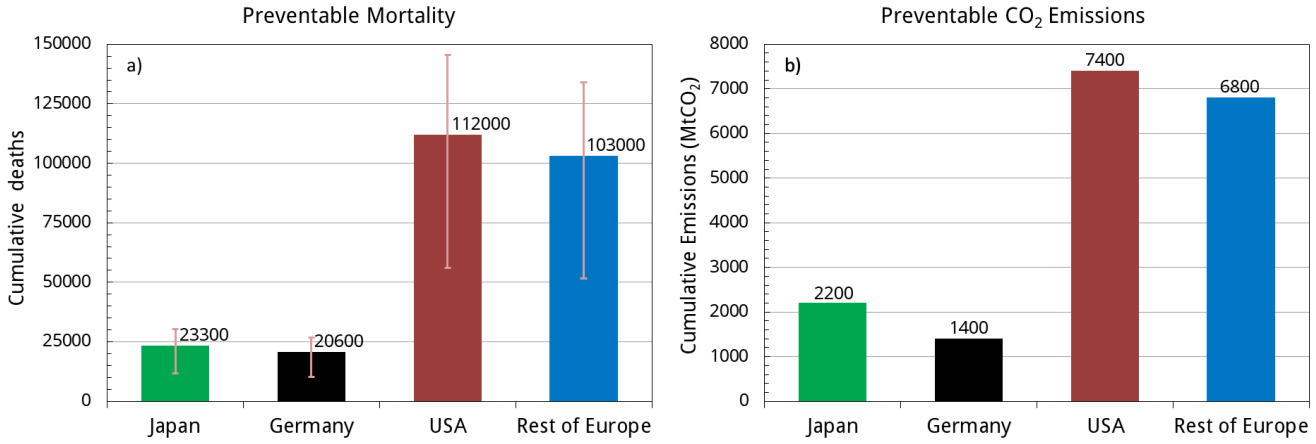

Figure 3. Avoidable impacts caused by reducing nuclear instead of fossil fuels in four major energy using regions. Values are cumulative preventable a) mortality from outdoor air pollution caused by fossil fuel use and b) fossil fuel CO_2 emissions. Error bars denote uncertainty ranges. For Japan we analyze the historical period only (2011-2017) while for the other regions we project to year 2035 in order to simulate complete nuclear phaseout (see our paper for additional details). Values for the US and the rest of Western Europe are particularly high because they are the world's largest nuclear power users.

Reference

Kharecha, P.A., and M. Sato (2019), Implications of energy and CO_2 emission changes in Japan and Germany after the Fukushima accident, *Energy Policy*, **132**, 647-653, doi: 10.1016/j.enpol.2019.05.057