

## Response to Comment on “Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power”

Sovacool et al.<sup>1</sup> begin their critique of our recently published paper<sup>2</sup> by claiming that nuclear power is unable to displace greenhouse gas (GHG) emissions as effectively as energy efficiency measures and renewable energy technologies in the near term. However, much of their rationale reflects the common misconception that the electric energy produced by different electricity sources is interchangeable. For near-term mitigation of climate change and air pollution, fossil fuel sources of base load power such as coal and natural gas (i.e., those that can provide essentially continuous power) are most effectively replaced by proven alternative base load sources such as nuclear, hydroelectric, geothermal, and properly (sustainably) designed biomass energy (e.g., see ref 3). This is rooted in the fact that wind and solar photovoltaic energy sources are inherently variable and therefore cannot provide base load power.

These issues are highlighted by the consequences of Germany’s recent decision to phase out its nuclear power production by 2022 following Japan’s Fukushima nuclear accident. Despite a major, laudable expansion of wind and solar power in recent years, Germany’s nuclear phaseout has so far led to an increase in coal burning and an associated increase in national GHG emissions<sup>4,5</sup>—a disappointing outcome, given the government’s stated intentions to reduce GHG emissions. (It has also led to a significant increase in Germany’s electricity rates.<sup>4</sup>) While the emissions increase has been modest so far, it could become substantial in the mid- and long-term, due to the typically multidecadal lifetime of fossil fuel-fired power plants.

Many of Sovacool et al.’s assertions regarding the various costs of nuclear power rely on their Table 1. With the exception of column two, the values in that table are, at best, misleading. For instance, the 0–4.1 gCO<sub>2</sub>/kWh range for nuclear power in column four (sourced from coauthor Jacobson<sup>6</sup>) represents GHG emissions from the incineration of megacities due to hypothetical nuclear war; this purely speculative estimate appears to reflect the common and irrational conflation of nuclear power with nuclear weapons. More importantly, the “opportunity costs” for nuclear power listed in column three (which substantially exceed the life-cycle emissions listed in column two) are based on another set of highly dubious assumptions by Jacobson<sup>6</sup>—namely, that it takes 10–19 years between planning to operation for a nuclear reactor, and, as a result of this delay, continuing fossil fuel GHG emissions from the electricity sector are assigned to nuclear power. This approach, based solely on the U.S. experience, is immediately undermined by simply considering the example of France: in a period of just 10 years (between 1977–1987), nuclear power production in France experienced a ~15-fold increase that led to its share of electricity rising from 8.5% to over 70% (based on ref 7). Thus, under the right conditions it is not inevitable that the international construction of nuclear plants will face long delays.

Other key values given by Sovacool et al. in their Table 1 also lack credibility. Their mean emission factor for nuclear power

in column 6 is much higher than the mean/median emission factors given in more reputable sources such as the review papers we cite<sup>8,9</sup> and Figure 9.8 of the IPCC’s 2011 Special Report on renewables.<sup>10</sup> And for more balanced and meaningful analysis of capital costs and levelized costs of electricity, we refer readers to Table 1.9 of the Global Energy Assessment<sup>11</sup> and Figure 4.27 and Table 4.7 of the most recent IPCC assessment report on mitigation.<sup>12</sup> In essence, peer-reviewed sources that are far more authoritative and credible than Sovacool et al. (and most of their sources) reveal that current as well as projected life-cycle emissions and levelized costs of nuclear power are broadly comparable to those of renewables.

While it is true that our analysis of societal effects of nuclear power focused mainly on mortality and morbidity and not on property damage or evacuations caused by accidents, Sovacool et al. erroneously claim that we ignore the issues of waste disposal and proliferation. To the contrary, we mention these issues in the second paragraph of our Introduction.<sup>2</sup> But because they are not directly relevant to the subject of our paper (e.g., proliferation-related mortality is not meaningfully quantifiable, as we note), we referred readers to a prior peer-reviewed publication of ours in which they are covered in some detail.<sup>3</sup> As we discuss therein, these issues—along with the impacts from continuing uranium mining and enrichment—are largely resolvable by next-generation nuclear reactor designs, some of which have been successfully demonstrated at relatively large scales.

Sovacool et al. next discuss the role of nuclear power in developing countries and imply that small island nations and the least developed countries are ill-equipped to possess nuclear reactors. But nowhere in our current or prior work do we suggest that those countries should construct nuclear plants in order to mitigate global climate change and air pollution. Most developing countries contribute very little to these problems and are not projected to become large-scale nuclear power producers. China and India are another story, however; they are now, respectively, the largest and third-largest emitters of CO<sub>2</sub>, overwhelmingly due to the massive increase in their coal usage over the last few decades (see Figure S3 of our paper<sup>2</sup> and ref 13). Thus it makes great sense for at least these two developing countries to pursue the ambitious nuclear energy agendas they have announced, given the proven ability of nuclear plants to directly displace coal-fired plants. And because they will almost certainly implement next-generation reactor designs, they are very likely to minimize the problems mentioned above.

Lastly, Sovacool et al. assert that our conclusions are undermined by (a) our citing of the 2008 UNSCEAR report<sup>14</sup> for Chernobyl mortality estimates and (b) our alleged nonuse of the linear no-threshold (LNT) model in our mortality calculations. They argue that we thereby contravene the

Published: May 22, 2013

“prevailing scientific consensus”. In fact, while we and many others question the LNT model, our mortality calculations *do* employ it, as explicitly stated in the fourth paragraph of our Results and Discussion section (“...the ‘linear no-threshold’ model used to derive the nuclear mortality factor in Table 1...”<sup>2</sup>).<sup>2</sup> As we also clearly state in the caption to our Table 1 and in the Methods section, our mortality and emission factors are based on analysis of the entire fuel cycle for each energy source. Furthermore, Sovacool et al. provide no references for the “prevailing scientific consensus” they allude to regarding Chernobyl deaths. The only relevant source they cite is a single-authored web posting from the Union of Concerned Scientists, an organization that is well-known for its long-held opposition to nuclear power. By contrast, the 2008 UNSCEAR report that we cite<sup>14</sup> represents a rigorous scientific assessment performed by expert scientists from 27 countries (including the countries most affected by the accident).

On a broader note, essentially all credible energy projections from authoritative sources (e.g., refs 10, 12, 15) indicate that in order to achieve near-term climate change mitigation targets, nuclear power will need to make a substantial contribution to the near-term energy mix—even after factoring in large-scale energy efficiency improvements and renewable energy deployment. The objections to nuclear power raised by Sovacool et al. can readily be resolved by next-generation reactors, as we described in ref 3. We fully acknowledge that renewables and energy efficiency must play an important role, but relying solely on them to provide all the required GHG emissions reductions would seriously threaten our chances of success.

Much as Sovacool et al. would prefer to live in a world in which near-term mitigation targets can be fully realized without nuclear, in the real world the urgency and scale of the climate crisis require that we retain and expand *all* nonfossil electricity sources, especially those that can directly displace base load coal plants. The propagation of biased and misleading arguments against nuclear power by Sovacool et al. and others does a great disservice to the all-important goal of avoiding dangerous anthropogenic climate change.

**Pushker A. Kharecha\***

**James E. Hansen**

NASA Goddard Institute for Space Studies and Columbia University Earth Institute, 2880 Broadway, New York, New York 10025, United States

## AUTHOR INFORMATION

### Corresponding Author

\*Phone: (212) 678-5536; fax: (212) 678-5552; e-mail: pushker@giss.nasa.gov.

### Notes

The authors declare no competing financial interest.

## ACKNOWLEDGMENTS

We thank George Stanford for helpful comments about this rebuttal.

## REFERENCES

- (1) Sovacool, B.; Parenteau, P.; Jacobson, M.; Ramana, M. V.; Diesendorf, M.; Delucchi, M. Comment on “Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power”. *Environ. Sci. Technol.* **2013**, DOI: 10.1021/es401667h.
- (2) Kharecha, P. A.; Hansen, J. E. Prevented mortality and greenhouse gas emissions from historical and projected nuclear power. *Environ. Sci. Technol.* **2013**, *47*, 4889–4895.

- (3) Kharecha, P. A.; Kutscher, C. F.; Hansen, J. E.; Mazria, E. Options for near-term phaseout of CO<sub>2</sub> emissions from coal use in the United States. *Environ. Sci. Technol.* **2010**, *44*, 4050–4062.

- (4) Schiermeier, Q. Renewable power: Germany’s energy gamble. *Nature* **2013**, *496*, 156–158, <http://www.nature.com/news/renewable-power-germany-s-energy-gamble-1.12755>.

- (5) U.S. Energy Information Administration. Germany: overview data. <http://www.eia.gov/countries/country-data.cfm?fips=gm> (accessed May 2013).

- (6) Jacobson, M. Z. Review of solutions to global warming. *Energy Environ. Sci.* **2009**, *2*, 148–173.

- (7) IEA World Energy Statistics and Balances, database; International Energy Agency: Paris, France, 2012; DOI: 10.1787/data-00512-en.

- (8) Lenzen, M. Life cycle energy and greenhouse gas emissions of nuclear energy: A review. *Energy Convers. Manage.* **2008**, *49*, 2178–2199.

- (9) Lenzen, M. Current state of development of electricity generating technologies: A literature review. *Energies* **2010**, *3*, 462–591.

- (10) *Special Report on Renewable Energy Sources and Climate Change Mitigation*, Prepared by Working Group III of the Intergovernmental Panel on Climate Change (IPCC); Edenhofer, O.; Pichs-Madruga, R.; Sokona, Y.; Seyboth, K.; Matschoss, P.; Kadner, S.; Zwickel, T.; Eickemeier, P.; Hansen, G.; Schlömer, S.; von Stechow, C., Eds.; Cambridge University Press: New York, 2011.

- (11) International Institute for Applied Systems Analysis. *Global Energy Assessment – Toward a Sustainable Future*. <http://www.globalenergyassessment.org> (accessed June 2012).

- (12) *Climate Change 2007: Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC); Metz, B.; Davidson, O. R.; Bosch, P. R.; Dave, R.; Meyer, L. A., Eds.; Cambridge University Press: Cambridge, U.K., 2007.

- (13) Boden, T. A.; Marland, G.; Andres, R. J. *Global, Regional, and National Fossil-Fuel CO<sub>2</sub> Emissions*, Carbon Dioxide Information Analysis Center; Oak Ridge National Laboratory, U.S. Department of Energy: Oak Ridge, TN, 2012; DOI: 10.3334/CDIAC/00001\_V2012.

- (14) United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation. Annex D: Health Effects due to Radiation from the Chernobyl Accident, 2008. [http://www.unscear.org/docs/reports/2008/11-80076\\_Report\\_2008\\_Annex\\_D.pdf](http://www.unscear.org/docs/reports/2008/11-80076_Report_2008_Annex_D.pdf) (accessed August 2011).

- (15) *World Energy Outlook 2012*; OECD/International Energy Agency: Paris, France, 2012.