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Interactive comment on "The influence of constrained fossil fuel emissions scenarios on climate and water resource projections" *by* J. D. Ward et al.

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We thank Ugo Bardi for his positive comments regarding our paper.

In his short comment, Bardi states that "by considering this effect, we are adding a further layer of uncertainty to projections." On the contrary, we would contend that the 40 different – and widely divergent – emissions pathways put forth by the IPCC in the Special Report on Emissions Scenarios (SRES) have already contributed significant uncertainty to the range of future climate scenarios being considered by policy-makers. The four scenarios being put forward in the IPCC's Fifth Assessment Report (AR5)

cover a similarly wide range as the six marker scenarios from SRES.

We argue that by considering the recent advances in scientific understanding of fossil fuel resources and production forecasts, it is possible to refine the future emissions scenarios and produce a much narrower spread of possible pathways. This can only be seen as a reduction in uncertainty when measured against the widely divergent existing suite of emissions scenarios. Notwithstanding this, it must be acknowledged that the field of "peak fossil fuel" modeling is still developing and – like climate science – is subject to ongoing refinements. Moreover, the potential social, economic, technological and environmental impacts of declining global energy production have received little attention in the literature. Hence in this respect, we would agree with Bardi that another layer of uncertainty has been added to the problem once we start to seriously consider fossil fuel depletion.

Bardi draws our attention to the important issue of fugitive methane emissions from the oil and gas industry. In particular, he suggests that as the world seeks to augment declining conventional energy sources with unconventional supplies such as shale gas, the proportion of fugitive emissions is set to rise. As methane is a far more potent greenhouse gas than carbon dioxide, even small percentages of fugitive emissions should be considered explicitly in emissions scenarios. We generally take his point, and this highlights important research that is still to be done in forming more refined future energy/emissions scenarios. As such we agree to his recommendation to add a sentence in the Conclusions section of our paper alluding to this issue and we will recommend future research into non-CO2 emissions that may result from unconventional fossil fuel sources.

As a final point, it should be noted that when we consider the influence of fossil fuel resource constraints on future climate scenarios, we are necessarily talking about a long timeframe. In the shorter term (several decades), climate scenarios are less dominated by emissions; in any case the emissions scenarios do not greatly diverge until after about 2040. As such it is only in the longer term (70 to 100 years) that emissions

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diverge enough to cause significant differences in modeled future climates. This has important implications when considering the enhanced fugitive methane emissions predicted by Howarth et al. (cited by Bardi), as methane is a relatively short-lived greenhouse gas. Over the 70 to 100 year horizon (as is relevant to our resource-constrained emissions scenarios and long-term climate impacts), the relative influence of fugitive methane emissions is shown (by Howarth et al.) to decrease, as the small fraction of methane degrades to CO2 and the combustion component becomes the dominant fraction. While not within the scope of the current paper, it would be very interesting to examine this process within a model of future fuel supply, considering decline in conventional production, the gradual rise in unconventional production, the resultant change in proportion of fugitive methane emissions (based on Howarth et al.), and the ongoing oxidation of methane back into CO2 in the atmosphere.

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