Atmospheric Chemistry and Physics Discussions
Atmos. Chem. Phys. Discuss., referee comment RC1
https://doi.org/10.5194/acp-2022-91-RC1, 2022
© Author(s) 2022. This work is distributed under
the Creative Commons Attribution 4.0 License.

Comment on acp-2022-91

Anonymous Referee #1

Referee comment on "Climate consequences of hydrogen emissions" by Ilissa B. Ocko and Steven P. Hamburg, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-91-RC1, 2022

The overall quality of the preprint is great. The paper addresses an important emerging issue of hydrogen use in the decarbonation process of the coming decades. The quantification of the climatic consequences in terms of offsetting the benefit of decarb is accounted for in various scenarios and assumption space. The discussion and recommendation for practice is sound.

Major Comments:

- Framing:

Line 46. "how much hydrogen is ultimately deployed to replace fossil fuel systems". There are many places where similar statements are made. e.g., Line 240. "replacing fossil fuel systems with hydrogen applications"

My comment here is that fossil fuel as the primary energy sources are not *replaced* by hydrogen which is secondary sources. Fossil fuel can be replaced by wind, solar and nuclear etc. Hydrogen is more like electricity in the battery as the energy carriers. In that sense, the analysis presented is more akin to the climatic and environmental assessment of future battery use. Maybe some rewording for the context is needed.

Line 67. " The impact of energy transitions". Similar to my comments on Line 46, again in terms of framing of the question, I think the issue here is not energy transition (from fossil fuel to clean energy), but the use of hydrogen as the energy carrier, due to its high energy density, to fulfill the energy demand of some applications that are hard to be electrified. In plain language, there are intense ongoing debate between battery powered EV vs. fuel cell cars. The study here essentially addresses the underreported negative climate effects of the latter.

- The authors need to clarify that in the TWP calculation, by "continuous emission" they had assumed constant emission rate after deployment. This is important because if the short-lived compound emission is backloaded toward the end of time horizon (i.e., with increased emission, a more likely case for hydrogen economy scaling up), the cumulative forcing (and the associated warming) at these longer time scale would be even higher than what TWP implies.

- Line 440. "Fig. 5 shows the anticipated temperature increase in 2050 based". Since the temperature response calculation here is simply a conversation from the instantaneous radiative forcing at a given year, it's assuming temperature equilibrium very quickly which is not the case in the real world (and even in simple climate models). The forcing*climate sensitivity is best known as (geophysical, not socioeconomically) committed warming, which is always larger than the "expected/anticipated" warming at certain point due to the response time of climate system (check e.g., https://www.researchsquare.com/article/rs-969513/v1 or http://www.pnas.org/content/early/2017/09/13/1618481114.abstract)

- Line 269. Why is the 50% estimate here a “conservative” one?

This assumption of “additional” CH_4 fugitive leakage need some more justification. One can argue that nearly all CH_4 usage here for generating H_2 would otherwise be used as gas fuel. I think the author can quantify how much energy supply from 1kg of H_2 (~120 MJ) and calculate how much that can be from CH_4 equivalent (roughly 120/55=2.2 kg). Therefore, there is an additional demand of 3.3-2.2=1.1 kg of CH_4 if the purpose of CH_4 here is to generate H_2 (while losing some energy to the byproduct of CO_2) as opposed to use it as direct fuel.

If the derivation I worked out above make sense, the ratio is more likely to be 1.1/3.3=33%, as opposed to 50%. Of course, I only have spent 10 minutes thinking about this. But I encourage the authors to check my argument and make improvement in the assumption of fugitive CH_4 leakage in the blue hydrogen case.

- The authors accounts for the impact of H_2 leakage on stratospheric water vapor “ when this reaction (in Figure 1) occurs in the stratosphere”, which has a warming effect. Had the authors or previous studies considered the emission of water vapor due to direct combustion of H_2 fuel (e.g., aviation in the stratosphere)? Would that (>90% H_2 not leaked) be more important than the “climate consequences of hydrogen leakage”?

Specific Comments:

I also have some specific comments, in the order of occurrence in the paper, for the authors to consider during the revision phase.

Abstract:

On the first reading, I’m a bit confused by what are the worst-case and best-case rates? Better to specify the numbers (worst is the 10% leakage rate later in Line 25?)

Line 36. Can you add some details of how H2 can perturb the atm chem and lead to increase in other GHGs? Is it true that H2 always leads to increase in other GHGs or are there any second-order compensation effects?

Line 64. I suggest delete “in hydrogen assessments” here.

Line 86. “has a positive forcing on the climate due to stratospheric cooling from water vapor’s absorption of heat”. This is a bit confusing. Can be reworded to explain why it’s a positive forcing (for the surface) f it leads to local cooling in the stratosphere?

The lower-right of Fig 1 says stratospheric warming which contradicts the message here. Please adjust. I think you meant surface warming due to stratospheric effects (Paulot 2021), not stratospheric warming.

Line 134. “Using the GWP formulas”. Can you document the formula for it (and also the TWP) since you used it multiple time for conversation of GWP and radiative efficiency?

Fig 2. How exactly is the solid line of cumulative radiative forcing (Alvarez et al., 2012) defined and calculated? Is that the same as GWP except for the assumption of emission profile (continuous vs. instaneous)? What’s its unit? Is that the same as Tech Warming Potential mentioned in the end of Introduction section.

The paragraphs immediately after Fig 2 seems to be out of place. My understanding is that discuss the caveats of the simple metric approaches (constant radiative efficiency and H2 lifetime etc.). If so, maybe move it to a later place of discussion. (On a second read, maybe move it to be around Line 340).

Line 150. Why 20 times? I thought it's more than that just eyeballing from solid line of Fig 2b.

Line 153. Reword a bit. I guess you cannot call it GWP anymore.

Section 4 title is "Climate implications of hydrogen leakage" which is actually the paper title. Thus, I suggest move 4.1 and 4.2 to be Section 4 (Method) and 5 (Results) instead, and avoid sub-sub-title.

Line 244. I think here Section 4.1.3 should be Section 4.1.1.

Where does the factor of 3 come from in generating H_2 from CH_4? I thought it's more like (12+4)/4=4. It is because of the addition of H_2O in the process to provide more H atoms?

0.111 kg for 3*1.1*3%=0.099 kg?

Line 265. With CO_2 leakage, it's falling into the realm of grey hydrogen.

Table 1. The row for CO_2 should be 11 for all cases.

The row of CH_4 produced does not seem to agree with the add-up of Consumed and Emitted. Please double check if this affects the main results presented later.

Table 2. foot note b seems to duplicate the text right below Table 2.

Here you also need to verify the assumption of energy composition in 2050. Does the 2017 study assume the same fraction of coal/oil/gas as of now or (a more likely) switch from coal to gas? Since coal emits more CO_2 than gas (per unit of energy supply), assuming a constant offset of 11 kg of CO_2 can underestimate the benefits of H_2 because in the near-term the CO_2 offset could be larger than 11.

Line 286. What's "avoided hydrogen emissions from displaced fossil fuel combustion"??

Line 310? What' the assumption of relative magnitude of green vs blue hydrogen evolving from 2020 to 2050.

Line 313. "When considering climate impacts, we only account for emissions from hydrogen leakage for total hydrogen demand "

I'm confused. I thought you also include CH_4 leakage from blue hydrogen?

Line 355 . 0.84 mW m-2 (Tg yr-1)-1) Why is this a different number than the 3.64E-13 in Table 3?

Line 370. Again, is the cumulative radiative forcing the same as the technology warming potential (TWP)? Maybe it's worth showing the equation set.

Line 400. Again, need to justify the 50% assumption.

Line 424. “continuing to use GWP-100 to calculate climate effects will not

only overlook near- and mid-term impacts on the climate,” How about using GWP20 as the authors had previous argued in 2017?

Fig 5. Would you make it a colored graph? Also did you really run the calculation for various levels of assumption of final energy demand (y-axis), or it’s really an extrapolation based on the 20%, 50%, 100% cases shown in Fig 4? If it’s the later, it’s best show those actual data points in markers.

Also, the extrapolation to 0% is problematic; why would the warming be more than zero if there is no hydrogen use after all?

Line 565. “Derwent, R. G.: Hydrogen for Heating: Atmospheric Impacts, Ph.D., Department for Business, Energy & Industrial Strategy,

2018.” Can you specify the citation source?