Anonymous Referee #1

Referee comment on "GCAM-USA v5.3_water_dispatch: integrated modeling of subnational US energy, water, and land systems within a global framework" by Matthew Binsted et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2021-197-RC1, 2021

The manuscript "GCAM-USA v5.3_water_dispatch: Integrated modeling of subnational U.S. energy, water, and land systems within a global framework" presents a new version of the GCAM model, with a focus on the energy, water and land representation of the United States. The model presented is a very welcome contribution of the "systems modelling", and more specifically to the the IAM world, as it contains relevant detail on the regional scale. Furthermore, it expands the capabilities of IAMs to further investigate the "Climate-Land-Energy-Water" nexus. As such, both the manuscript – which largely functions as a qualitative description of the model - are a welcome addition to the literature.

While the manuscript is well written, structured, and clear, I think it could benefit by some improvements before publication. My main comments revolve around a better/clearer and more thorough explanation of some of the critical aspects of the model, as generally the current description is very 'on the surface', and doesn’t allow readers to fully understand how the model structure may affect its results. In this respect, the manuscript could also benefit from a broader discussion of the results. Many of my below comments can be addressed through an appendix with model details (ideally some sort of table with a description of many of the methodological details and assumptions of the model – Table 1 in Bauer et al. (2020) may offer some inspiration, though that focused specifically on bioenergy), as well as an expanded discussion section. More specifically:

On line 81, GCAM is described as "...a partial equilibrium model which captures key interactions between global economic, energy, water, land, and climate systems." Can some more details be given, for instance does it have perfect foresight? Does it optimize some function (I suspect not, given the logit formulation for market shares)?

Concerning the projections for energy demand, on line 399 it states that "final energy demands increase as efficiency improvements are slower than increases in demand for end-use energy services". Some explanation is needed for how the demand in energy services is dealt with. Specifically for buildings in developed regions there is largely a stagnation in energy demand so it is a bit surprising that final energy demand increases faster than efficiency over the entire 21st century.
On line 442 it is stated that agricultural productivity in the US increases between 0% to 0.67% per year between 2015 and 2100. An explanation of what drives this productivity is needed. Is it completely exogenous? Increased irrigation? Economic pressures? Closing of yield gaps? Is it crop or livestock-specific? What exactly is included in agriculture?

Table 1 offers a brief overview of the scenario design, however the explanations are woefully vague, especially for the "Transition" scenario. An appendix with some details of what parameters were changed in the model would be useful when interpreting the results. Judging by fig 2, fossil fuels still play an important (though not dominant role), so it would be good to get a better understanding of what exactly drives this scenario. Is there a carbon price? Ad-hoc assumption? Cost reduction in renewables?

Along the same lines, I recognize that the manuscript presents a new model, and not necessarily a new scenario analysis, but since results are presented, some discussion is needed. Is the transition scenario based completely on improved supply options? If so, there needs to be a discussion as the "socioeconomic drivers" do not cover all "lifestyle aspects" which govern energy demand. Currently it is difficult to derive policy advice or compare the results with other scenario analyses since the projections seem to be little more than tinkering with the model (which is fine, but what was tinkered-with should be clear to the reader). An in-depth explanation and discussion of the scenario design would be helpful.

On line 499 the projected ranges of electrification of building energy services across different states are presented. Can you please explain how the model methodology leads to this result? I guess it has to do with the heating/cooling dichotomy of different locations, but it would be good to point this (or any other relevant dynamic) to the reader. Similarly for line 520 and the transport sector.

Lines 524 to 527 highlight a very interesting calibration problem the authors have faced. This is worth discussing at depth since it likely affects the results significantly. In fact, it would be great if a sensitivity analysis was conducted, where different “consumer preferences” are tested. Alternatively, different “consumer preference” parameterization could be used across the Reference-Transition scenarios, thus expanding the “transition scenario” design.

On lines 597 to 600, the reduction in capacity factors for all technologies is highlighted in the transition scenarios, a very interesting result. Is it appropriate to interpret this as "increased electrification leads to increased redundancy of generating capital", and thus a disproportionate increase in electricity prices? I think this is something worth discussing further especially in connection to the to the model formulation. How does the methodology lead to this result? Is this something directly related to the improved electricity module which, as shown in Figure 1, accounts for load variation at different temporal aggregations?

Related to this, Supplementary Note 2 states that the dispatch of renewables depends on their supply curves, each containing a quantitity of resource available at a specific capacity factor. This detail seems crucial so it would be good to get some insight on how these curves are constructed, and perhaps the curves should be presented as well.

Concerning the projections of agricultural water withdrawals mentioned on lines 267, is it correct to understand that irrigation rates are directly coupled to population and GDP growth (state or national?). Or are the intermediate drivers such as competition for land, food prices, etc.? These methodological choices should be crystal clear to allow the reader the fully appreciate the results.

Similarly, on line 648 it is stated that increased demand for bioenergy crops in the
Transition scenario drives the increased irrigation. Are all bioenergy plantations irrigated by default in the model?

Figure 10 excludes “dedicated energy crops” for the percentage change of cropland. Is there a justification for their exclusion? Does it skew the results? I think this would be an interesting result to show.

Lines 755 onwards give a useful overview of the model calibration. Some more methodological details here would be interesting. Perhaps in an appendix. Are these calibration parameters the “share weights” mentioned on line 780, or are is the forcing simply a model “starting point”? How, is this forcing applied in the projections period? Is there a transition from forced-to-free? Or are the “forcing parameters” maintained?

Concerning the technology costs which enter the logit formulation, is technological learning included. If so, is it endogenous or exogenous?

Lines 864 to 885 list some future improvements for the model. For improvement (1) is this really a priority? While I’m not knowledgeable on the topic, I would expect that there is a lot of inter-state trade for resources and electricity (famously not for Texas though), so I would expect state-level resource endowments (except for land) to provide limited extra insights. I could very well be wrong, in which case a justification for this decision would be very welcome.

Minor Comment:

- Figure 9: I suspect the unit is not supplied to say EJ. If so, that is a very odd unit to use for land use. I would suggest MHa or an other unit of area.
- Lines 749 to 754: question to the editor: Shouldn’t websites be listed in the reference list with date accesses?

References: