

Geosci. Model Dev. Discuss., referee comment RC1  
<https://doi.org/10.5194/gmd-2021-85-RC1>, 2021  
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## Comment on gmd-2021-85

Anonymous Referee #1

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Referee comment on "REMIND2.1: transformation and innovation dynamics of the energy-economic system within climate and sustainability limits" by Lavinia Baumstark et al., Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2021-85-RC1>, 2021

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**The manuscript presents a detail description of the REMIND model. It is well written the content is mostly very clear. However, there are some comments that must be addressed before the manuscript could be considered for publication. The main concern is that it is not clear what new knowledge about REMIND this manuscript brings to the literature. There are several other research papers that describe several components of REMIND (cited in this manuscript as well) that should be better described here (not just refer the reader to other papers). Additionally, it is not clear what is new in this version of REMIND, compared to previous versions that have been published. The manuscript is not clear about this and does not present a comparison or a section that explicitly presents the improvements. Other minor/detail comments are presented next.**

### Comments Section 1:

Main comment: It is not clear from this section what is new in this version of REMIND to respect the older versions. This needs to be clearly stated. Other minor comments are described next:

- The use of SSPs helps to cover uncertainties regarding technological development for renewable or fossil fuel availability, but also social and behavioral development like population growth, dietary preferences, environmental awareness or international

cooperation.

- It is not clear what is meant by “damages” in the following text: , **the REMIND model represents some damages and can thus be used for cost-benefit analyses or least total cost analyses**
  
- In the next sentence, what is meant by self-consistent? Also, it is understood that the energy sector is modeled, while the economic (macroeconomic) is input. Hence, it seems a bit contradictory the next sentence: REMIND enables the exploration of a wide range of plausible developments and of possible futures of the **energy-economic** system exploring **self-consistent** transformation pathways.
  
- It is mentioned several times (up to page 3) that REMIND is an NLP, however, no description or ideas of the non-linear components are described. What make the model nonlinear? Some initial hints would be beneficial .
  
- “REMIND calculates economic and energy investments”. What is meant by an “economic investment”?
  
- Introduce the concept of Pareto optimum. Pareto is normally use in the context of multi-objective optimization.

- "The optimization is subject to equilibrium constraints, such as energy balances, economic production functions or the budget constraint of the representative household." It is not clear the mathematical structure of the REMIND model. Is it an NLP in the form of an optimization or equilibrium (MPEC) model? (MPEC: Mathematical program with equilibrium constraints).
  
- "REMIND is usually run in a decentralized mode where each model region is optimized separately, and clearing of global trade markets ensured via iterative solutions (see section 2.2)." -> How the model ensures convergence? This needs to be clarified in the corresponding section.
  
- "CH4 emissions from fossil fuel extraction and residential energy use" What about CH4 from the agro-industrial (food, beef-lamb) sectors? If not considered, it must be clarified.
  
- "Historical data for the year 2005 is used to calibrate most of the free variables (e.g. primary 130 energy mixes in 2005, secondary energy mixes in 2005, standing capacities in 2005, trade in all traded goods for 2005)." Why there are not updates to the base calibration year? 2005 seems a bit old to account for new trends.

## **Comments Section 2:**

- "(for more information about the modular structure see Dietrich et al., 2019 - Appendix

A." It would be good to introduce some of this information in this article, since it is such a critical piece of the model structure of REMIND.

- "This paper focuses on realizations which are active in default scenarios. More detail about all modules and their interlinkages can be found in the model documentation". I still believe that this information is relevant and should be somehow described and discussed in this manuscript.
  
- "By default REMIND calculates results for the 12 following world regions:" A table with regions and other important information would be better than just listing countries/regions.
  
- "By parallelizing the calculation of the individual regions in decentralized optimization mode (see section 2.2) the computation time increases only moderately with increasing spatial detail." It would be interesting to have a general idea of the computational complexity of the model (minutes, hours, days?) depending on the type of scenarios.
  
- "Time represents a separate dimension" -> What is meant by this? Not clear at all.
  
- "In essence, the time dimension only increases the number of markets for which the algorithm has to find an equilibrium" I would be extremely careful about the use of the

concept "equilibrium". To this point, the model has been introduced as a NLP optimization problem, with some equilibrium constraints. But there is not clear mathematical structure to really understand what the model does. If it is a pure optimization model, what talk about equilibrium? Why Pareto optimal is mentioned earlier? Please be clear and consistent with the type of solution that is obtained. Also, it was mentioned that CONOPT is used to solve the NLP problem, hence, it is also questionable when authors refer to the "algorithm" use to solve REMIND, since it is in fact a solver who does this process and authors have not developed an algorithm. In the case that an algorithm is indeed implemented, then this has not been clearly stated and differentiated from the NLP-CONOPT process.

- Based on the previous comment, I found then that there is indeed a NASH mode in REMIND. This helps to understand the concept of equilibrium. However, there is still not clarity in terms of what the base structure of REMIND is, how different structures are solve, what type of solution is obtained, solution algorithm, etc. This needs to be further clarified.

### **Comments Section 3:**

- "It is possible to compute the Pareto-optimal global equilibrium including inter-regional trade as the global social optimum using the Negishi method (Negishi, 1972), or the decentralized market solution among regions using the Nash concept (Leimbach et al., 2017)". This is interesting but needs further clarification. In practice, a Nash solution is an equilibrium, that can be categorized in some conditions as Pareto optimal. In fact, it has been studied that Pareto optimal strategies are a subset of Nash Equilibrium strategies (see paper DOI: 1109/ICCCNT45670.2019.8944817)
- "REMIND considers the trade of coal, gas, oil, biomass, uranium, the composite good (aggregated output of the macroeconomic system), and emissions permits (in the case of emissions-trading-system (ETS) based climate policy)". Are ETS global in REMIND? Or can be defined for particular regions? If global, how are allowances distributed?

- "To match 2005 values in the IEA statistics, REMIND adjusts the regional by-production coefficients of combined heat and power (CHP) technologies." This refers to the calibration of REMIND in the Energy Sector? If so, it is still not clear how the full calibration process works since it will also depend on the macroeconomic results and other sectors that may not be linked to CHP plants (transport for instance?).
  
- "represent challenges and options related to the temporal and spatial variability of wind and solar power" Please elaborate on this. If the mode runs with 5 years' time steps, how the temporal variability is considered? It is not inter-annual? Curtailment rates, which are mentioned later, will also depend on the increased levels of demand in future periods as well as the inclusion of other flexibility technologies, such as electrolyzer, which can transform excess electricity into a different energy carrier. Hence, it does not seem correct to consider curtailment rates.