**View Reviews**

**Paper ID**

18

**Paper Title**

Deep Reinforcement Learning in Electricity Generation Investment for the Minimization of Long-Term Carbon Emissions and Electricity Costs

**Reviewer #1**

**Questions**

* **1. Submissions are in two tracks: “Papers” and “Proposals.” “Papers” should describe work that is in progress and/or deployed, but not yet published in another peer-reviewed conference or journal. “Proposals” should contain detailed descriptions of ideas for future work. The guidelines for submissions are on the workshop website at https://www.climatechange.ai/events/neurips2020. Please confirm that you have read these guidelines**
  + Agreement accepted
* **2. Does this submission follow submission guidelines? Specifically, is it anonymized and within length limits? NeurIPS format is not required. (Length limits are: 4 pages for the "Papers" track and 3 pages for the "Proposals" track, excluding references; appendices beyond these limits are allowed but reviewers are not required to read them. To find a particular submission's track, go to your main reviewer console, click on the submission ID, and see the authors' response under "Track.") Please note: If a submission violates these guidelines, please proceed with the review nonetheless; however this will be taken into account when making final decisions.**
  + Yes
* **3. Please summarize the objectives and methods of the submission. (approx. 2-5 sentences)**
  + The submission uses reinforcement learning to simulate the investment in a clean energy mix. They authors model the evolution of the technology using Future Technology Transformations for the power sector (FTT:Power) a set of differential equations that describe the transition of one technology into another one.
* **4. Is the problem being solved relevant to climate change (mitigation, adaptation, or climate science)? How important is it to solve this problem (in terms of reducing greenhouse gas emissions or helping society adapt to a changing climate)? (approx. 2-5 sentences)**
  + The optimal investment in energy technologies to achieve a clean energy system is a very relevant problem for climate change.  
    It is clear that we still need to invest more into clean technologies and how to do so optimally will impact our ability to transition faster.
* **5. Are the techniques well-matched to the problem? Is ML necessary, or might simpler (or existing) tools be sufficient? (Feel free to indicate “N/A” if the submission primarily presents a dataset, and does not present specific ML methods.) (approx. 2-5 sentences)**
  + The FFT:Power model is a dynamical model that describes the evolution of different power generating technologies and the transition among them.  
      
    The application of reinforcement learning to simulate dynamical systems defined by differential equations is not new, although the authors seem to be the first to apply it to the FTT:Power model.
* **6. How effective is the submission in addressing the problem at hand? (Please evaluate potential effectiveness if the submission is in the “Proposals” track.) (approx. 2-5 sentences)**
  + The effectiveness of the FTT:Power model is not yet clear with some literature in favor [1] and some against it [2] so it is unclear how realistic this results really are.  
    If the model proves to be a useful representation of technology transition, then the paper can be considered a first good step in increasing our understanding of these models.  
      
    [1] The impacts of the trade liberalization of environmental goods on power system and CO2 emissions  
    [2] Modelling complex systems of heterogeneous agents to better design sustainability transitions policy
* **7. Do the authors properly frame and contextualize their work within the prior work in ML and/or the relevant application domain? (approx. 2-5 sentences)**
  + The authors apply reinforcement learning to simulate a dynamical system defined by differential equations, but do not provide any references in that direction.  
      
    In particular, they mention several times that their results yield "optimal investments" but it is unclear if the selected algorithm has convergence guarantees.
* **8. Do the authors describe the potential impact of the work (including any potential side effects) as well as its pathway to impact? (Please see https://www.climatechange.ai/events/neurips2020#addressing-impact for more discussion on this aspect.) (approx. 2-5 sentences)**
  + The authors describe the impact of their work by stating having found the optimal energy mix for the future, which seems to be a very optimistic claim.   
    Furthermore, they neglect transition times within their model, which likely results in unexpectedly fast changes between technologies. The authors dismiss the importance of this hypothesis even though it seems quite relevant for the real deployment.
* **9. How clear and accessible is the submission overall? Are the goals and methods described with an appropriate level of detail? (approx. 1-3 sentences)**
  + The submission is lacking a better description of the model being solved. In particular, it is unclear how the investment decisions work and if there are any constraints among them.  
    The interpretation of the results is clear, but again, the authors refer to their results as optimal but without proof.
* **10. For submissions in the “Proposals” track, is this a feasible project to be carried out? (N/A if submission is not a proposal)**
  + N/A
* **11. Overall rating of climate change relevance, feasibility, and impact**
  + Medium
* **12. Overall rating of ML relevance and quality (“N/A” if submission presents a new dataset instead of an ML method)**
  + High
* **13. Overall rating of submission clarity and accessibility**
  + Medium
* **14. Please summarize your overall assessment of the submission, referring to the submission guidelines at https://www.climatechange.ai/events/neurips2020. (approx. 2-5 sentences)**
  + The paper uses RL to solve a complex model that describes technology switching among power generating technologies.  
      
    Machine learning has the potential to increase our understanding of such model by solving it in cases where traditional optimization techniques fail.  
      
    In spite of this, the authors use a simplified version of the model and do not explain the convergence properties of their algorithm, which compromises the overall significance of the results obtained.
* **16. Overall rating**
  + Borderline
* **17. Please rate your expertise in the climate change domain area of this submission, picking the closest match.**
  + I have seen talks or skimmed a few papers on this topic, and have not published in this area.
* **18. Please rate your expertise in the ML area of this submission, picking the closest match.**
  + I have closely read papers on this topic, and written papers in the broad area of this submission.
* **19. Please rate your confidence in your evaluation of this paper, picking the closest match.**
  + I tried to check the important points carefully. It is unlikely, though possible, that I missed something that could affect my ratings.

**Reviewer #2**

**Questions**

* **1. Submissions are in two tracks: “Papers” and “Proposals.” “Papers” should describe work that is in progress and/or deployed, but not yet published in another peer-reviewed conference or journal. “Proposals” should contain detailed descriptions of ideas for future work. The guidelines for submissions are on the workshop website at https://www.climatechange.ai/events/neurips2020. Please confirm that you have read these guidelines**
  + Agreement accepted
* **2. Does this submission follow submission guidelines? Specifically, is it anonymized and within length limits? NeurIPS format is not required. (Length limits are: 4 pages for the "Papers" track and 3 pages for the "Proposals" track, excluding references; appendices beyond these limits are allowed but reviewers are not required to read them. To find a particular submission's track, go to your main reviewer console, click on the submission ID, and see the authors' response under "Track.") Please note: If a submission violates these guidelines, please proceed with the review nonetheless; however this will be taken into account when making final decisions.**
  + Yes
* **3. Please summarize the objectives and methods of the submission. (approx. 2-5 sentences)**
  + To mitigate for imperfect information of the future, authors use the deep deterministic policy gradient (DDPG) deep reinforcement learning approach to optimize for a low-cost, low-carbon electricity supply using a modified version of the FTT:Power model. In this work, they model the UK and Ireland electricity markets.
* **4. Is the problem being solved relevant to climate change (mitigation, adaptation, or climate science)? How important is it to solve this problem (in terms of reducing greenhouse gas emissions or helping society adapt to a changing climate)? (approx. 2-5 sentences)**
  + Yes - A change from a high-carbon emitting electricity power system to one based on renewables would aid in the mitigation of climate change. Investments in renewable energy must be made over a long time horizon to maximise return of investment of these long life power generators.
* **5. Are the techniques well-matched to the problem? Is ML necessary, or might simpler (or existing) tools be sufficient? (Feel free to indicate “N/A” if the submission primarily presents a dataset, and does not present specific ML methods.) (approx. 2-5 sentences)**
  + Yes - Through this work, it is possible to assess whether a low cost, low-carbon electricity mix is viable over the long-term using a deep reinforcement learning investment algorithm, as well as finding what this optimum mix should be. This work enables people to closely match the investment behaviour of rational agents, without knowledge of the future, which will be key in moving towards a low-carbon future.
* **6. How effective is the submission in addressing the problem at hand? (Please evaluate potential effectiveness if the submission is in the “Proposals” track.) (approx. 2-5 sentences)**
  + The submission is quite effective in addressing the problem at hand. The authors were able to model a central agent which makes investment decisions in an uncertain environment to find an optimal low-cost, low-carbon electricity mix.
* **7. Do the authors properly frame and contextualize their work within the prior work in ML and/or the relevant application domain? (approx. 2-5 sentences)**
  + Yes, the authors properly frame and contextualize their work by highlighting Oliveira et al.'s work on the capacity expansion problem and Kazempour et al.'s use a mixed-integer linear programming approach to solve the generation investment problem.
* **8. Do the authors describe the potential impact of the work (including any potential side effects) as well as its pathway to impact? (Please see https://www.climatechange.ai/events/neurips2020#addressing-impact for more discussion on this aspect.) (approx. 2-5 sentences)**
  + Yes, the authors describes how an increase in the number of countries modelled would enable them to see a global picture of how different, interdependent regions may evolve in a new climate of a requirement of low-carbon emissions.
* **9. How clear and accessible is the submission overall? Are the goals and methods described with an appropriate level of detail? (approx. 1-3 sentences)**
  + This submission is very clear and accessible. Very well written and organized. The goals and methods are described in an appropriate level of detail that support the results section.
* **10. For submissions in the “Proposals” track, is this a feasible project to be carried out? (N/A if submission is not a proposal)**
  + N/A
* **11. Overall rating of climate change relevance, feasibility, and impact**
  + Medium
* **12. Overall rating of ML relevance and quality (“N/A” if submission presents a new dataset instead of an ML method)**
  + Medium
* **13. Overall rating of submission clarity and accessibility**
  + High
* **14. Please summarize your overall assessment of the submission, referring to the submission guidelines at https://www.climatechange.ai/events/neurips2020. (approx. 2-5 sentences)**
  + Overall, this was a pretty solid paper. It was very clear, accessible, and framed the problem statement from both the climate change and ML technique used perspectives. As mentioned in the paper, the biggest limitation to this work is the investment algorithm does not take into account the technical and timeframe constraints of transitions between technologies, which can have a significant impact on the results. Additionally, modeling a more diverse set of countries would help further validate the robustness of these results going forward.
* **16. Overall rating**
  + Accept (Poster)
* **17. Please rate your expertise in the climate change domain area of this submission, picking the closest match.**
  + I have published one or more papers in the narrow area of this submission.
* **18. Please rate your expertise in the ML area of this submission, picking the closest match.**
  + I have closely read papers on this topic, and written papers in the broad area of this submission.
* **19. Please rate your confidence in your evaluation of this paper, picking the closest match.**
  + I am very confident in my evaluation of the paper. I read the paper very carefully and I am very familiar with related work.

**Reviewer #3**

**Questions**

* **1. Submissions are in two tracks: “Papers” and “Proposals.” “Papers” should describe work that is in progress and/or deployed, but not yet published in another peer-reviewed conference or journal. “Proposals” should contain detailed descriptions of ideas for future work. The guidelines for submissions are on the workshop website at https://www.climatechange.ai/events/neurips2020. Please confirm that you have read these guidelines**
  + Agreement accepted
* **2. Does this submission follow submission guidelines? Specifically, is it anonymized and within length limits? NeurIPS format is not required. (Length limits are: 4 pages for the "Papers" track and 3 pages for the "Proposals" track, excluding references; appendices beyond these limits are allowed but reviewers are not required to read them. To find a particular submission's track, go to your main reviewer console, click on the submission ID, and see the authors' response under "Track.") Please note: If a submission violates these guidelines, please proceed with the review nonetheless; however this will be taken into account when making final decisions.**
  + No
* **3. Please summarize the objectives and methods of the submission. (approx. 2-5 sentences)**
  + The goal of this work is to model the future investments in different types of energy as nations try to slow decarbonize the grid. The work proposes to use a deep RL agent to model investor decisions.
* **4. Is the problem being solved relevant to climate change (mitigation, adaptation, or climate science)? How important is it to solve this problem (in terms of reducing greenhouse gas emissions or helping society adapt to a changing climate)? (approx. 2-5 sentences)**
  + While it's true that decarbonization is necessary and proposes a lot of uncertainties, the paper doesn't mention how exactly modeling these investments better would help tackle climate change. Part of the issue for me as well is it's not entirely clear to me what specifically is being modeled.
* **5. Are the techniques well-matched to the problem? Is ML necessary, or might simpler (or existing) tools be sufficient? (Feel free to indicate “N/A” if the submission primarily presents a dataset, and does not present specific ML methods.) (approx. 2-5 sentences)**
  + It's unclear to me if RL is the right approach here. For one, there is no comparison to non-RL approaches so it's unclear if RL performs better on the reward. Additionally, the authors mention that the RL agent doesn't take some important information into account, resulting in unlikely future predictions.
* **6. How effective is the submission in addressing the problem at hand? (Please evaluate potential effectiveness if the submission is in the “Proposals” track.) (approx. 2-5 sentences)**
  + While I'm not entirely certain, it appears from Figure 3 and mentioned in the discussion that "a rapid change occurs from fossil fuel and nuclear to renewable energy" and that this "transition speed is unrealistic." With that information, it seems to me that the method does not do a great job at simulating the future if these results are intuitively very unrealistic.
* **7. Do the authors properly frame and contextualize their work within the prior work in ML and/or the relevant application domain? (approx. 2-5 sentences)**
  + Yes, the authors mention other works that have tried to solve this problem and how their method differs from these.
* **8. Do the authors describe the potential impact of the work (including any potential side effects) as well as its pathway to impact? (Please see https://www.climatechange.ai/events/neurips2020#addressing-impact for more discussion on this aspect.) (approx. 2-5 sentences)**
  + While the authors do mention that this tool could be used by energy investors, it's not clear to me how these investors making more informed decisions would result in reduced CO2 emissions.
* **9. How clear and accessible is the submission overall? Are the goals and methods described with an appropriate level of detail? (approx. 1-3 sentences)**
  + Overal, I found this paper quite challenging to understand. It's unclear to me what exactly the problem is seeking to model and how that information can be used.
* **10. For submissions in the “Proposals” track, is this a feasible project to be carried out? (N/A if submission is not a proposal)**
  + N/A
* **11. Overall rating of climate change relevance, feasibility, and impact**
  + Medium
* **12. Overall rating of ML relevance and quality (“N/A” if submission presents a new dataset instead of an ML method)**
  + Medium
* **13. Overall rating of submission clarity and accessibility**
  + Low
* **14. Please summarize your overall assessment of the submission, referring to the submission guidelines at https://www.climatechange.ai/events/neurips2020. (approx. 2-5 sentences)**
  + Overall, I found the core idea of this work hard to understand. I feel more clarity and detail in the introduction would help. On top of that, providing some comparison between this method and other methods (for example non-RL methods) would help evaluate the impact of this work.
* **16. Overall rating**
  + Reject
* **17. Please rate your expertise in the climate change domain area of this submission, picking the closest match.**
  + I have little background in the area of this submission.
* **18. Please rate your expertise in the ML area of this submission, picking the closest match.**
  + I have published one or more papers in the narrow area of this submission.
* **19. Please rate your confidence in your evaluation of this paper, picking the closest match.**
  + Not my area, or the paper was hard for me to understand.