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Exploring the Investment Cost of Construction of Renewable Power Plant Considering the Effect of Climate Impact

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ABSTRACT

By the end of the century, all countries must reduce carbon dioxide emissions to zero**.** As a result of deep decarbonization and the highest greenhouse gas emissions pathways, this study examines the effects of climate change on our planet. It is necessary to build renewable power plants in order to keep the global temperature well below 2 centigrade degrees. Despite this, building new renewable power plants costs almost twice as much as stranded fossil fuel power plants. Based on different emission reduction targets, this study compares the costs of different mitigation strategies. When comparing mitigation strategies, indirect consequences such as socioeconomic costs and environmental costs should be taken into account.

Keywords: renewable power plants, climate change impacts, integrated assessment, human-earth systems, electricity

1. INTRODUCTION

The Paris Agreement, signed in 2015, aims to keep Earth's average temperature well below 2 degrees Celsius. According to this agreement, carbon dioxide (Co2) emissions on earth must be limited to zero percent by the end of the century. Each country has its own emission targets based on its abilities, including developed, developing, poor, and rich countries.

Representative Concentration Pathways (RCPs) are among the scenarios and trajectories defined for achieving the desired outcome. Study examines the monetary costs of shifting toward renewable power plants due to climate change associated with deep decarbonization and highest greenhouse gas emissions pathways.

2. LITERATURE REVIEW

Turner et al. [1] evaluated the aftereffects of climate change on the investment costs of power plants especially hydropower across the globe. McCollum et al. [2] explored the share of the investment cost for low-fossil-fuel energy system in order to reach the outcome of Paris agreement using six different models. Clarke et al. [3] investigated the operation costs of electricity usage in buildings considering the effect of climate change.

3. METHODOLOGY

Two scenarios are employed in this study in order to carry out the economic evaluation of construction of renewable power plants under the standard pathways for achieving the global temperature well below 2 centigrade degrees. Two other scenarios are used in order to take into account the effect of climate change in addition to reference scenario. Table 1 displays the short description of the scenarios employed.

Table 1- a short description of the scenarios employed.

scenario name	scenario assumptions
Reference	basic
RCP 2.6 - Policy Only [4]	Representative Concentration Pathway for 2.6 Wm^{-2} radiative forcing
RCP 2.6 - Climate Impact [5]	Climate impact related to RCP for 2.6 Wm^{-2} radiative forcing
RCP 8.5 - Policy Only [6]	Representative Concentration Pathway for 8.5 Wm^{-2} radiative forcing
RCP 8.5 - Climate Impact [5]	Climate impact related to RCP for 8.5 Wm^{-2} radiative forcing

The climate impact is seen by the change in the temperature and its effect on the energy demand in the building sector in order to keep up with the desirable temperature. In particular, two variables are related to climate change including heating degree days and cooling degree days. It is assumed that a certain temperature, which is 18 degrees centigrade here [3], is the boundary between the days that require energy for cooling and the days that require energy for heating. As a result, heating (cooling) degree days indicates the number of days over the year that the average temperature is below (above) 18 degrees centigrade and amount of this difference. The estimation of the cost of construction of new renewable power plants as well as the cost of left stranded fossil-fuel power plants is down using a R package called “Plutus” developed by Zhao et al. [7]. The analysis is carried out using the Global Change Analysis Model [8]. GCAM makes use of a model of equilibrium in the market as a tool for investigating the interactions between humans and the planet as a result of changes in technologies, policies, and socioeconomics. Over 32 geopolitical regions, GCAM tracks electricity generation by technology and age.

4. RESULT

4.1 Total final energy consumption in buildings globally

The first result is the total final energy in building sector globally as shown in Figure 1. The sum of heating and cooling energy that end-users consume in buildings are displayed over the century for scenarios RCP8.5 and RCP2.6 on the left hand side and right hand side, respectively. Each plot compares the energy consumption for three scenarios including reference, RCP without climate impact and RCP with climate impact. In general, energy consumption for RCP8.5 is considerably higher than what is consumed in reference probably because of increased demand for cooling in this scenario relative to the reference. Energy consumption for RCP2.6 is slightly lower than what is consumed in reference as it maybe because of decreased demand for cooling in this scenario relative to the reference. On the whole, end-users consume very slightly more energy in scenarios without climate impact, perhaps, that is because of very slightly higher share of heating demands relative to cooling demands worldwide. While energy consumption is increasing over years for RCP2.6 and reaches quite 200 EJ in 2100, the energy consumption is increasing until 2075 and then decreasing for RCP8.5 and reaches almost 300EJ in 2100.

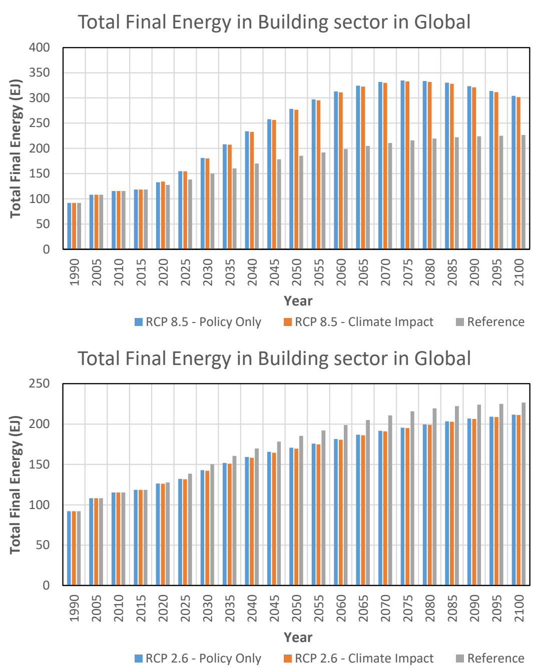


Figure 1. Total final energy in building sector globally

4.2 New power sector investment costs globally

This section shows the result of analysis on how much investment is required in order to build new power plants that follow the trajectories described by each scenario as displayed by Figure 2. The countries across the globe have to invest around $120 trillion altogether at the end of the century in order to follow the deep de-carbonization scenario, while they can spend $75 trillion collectively in order to follow the higher emissions scenario. As a result, the investment costs for RCP 2.6 is almost twice as much as RCP 8.5, moreover, the share of renewable energies such as solar, wind, nuclear, and bioenergy is higher. However, the difference between scenarios with climate impact and without climate impact is insignificant. The investment cost values for reference scenario is nearly the same as RCP2.6 except that the share of fossil fuels such as coal is higher and share of renewable fuels such as bioenergy is lower.

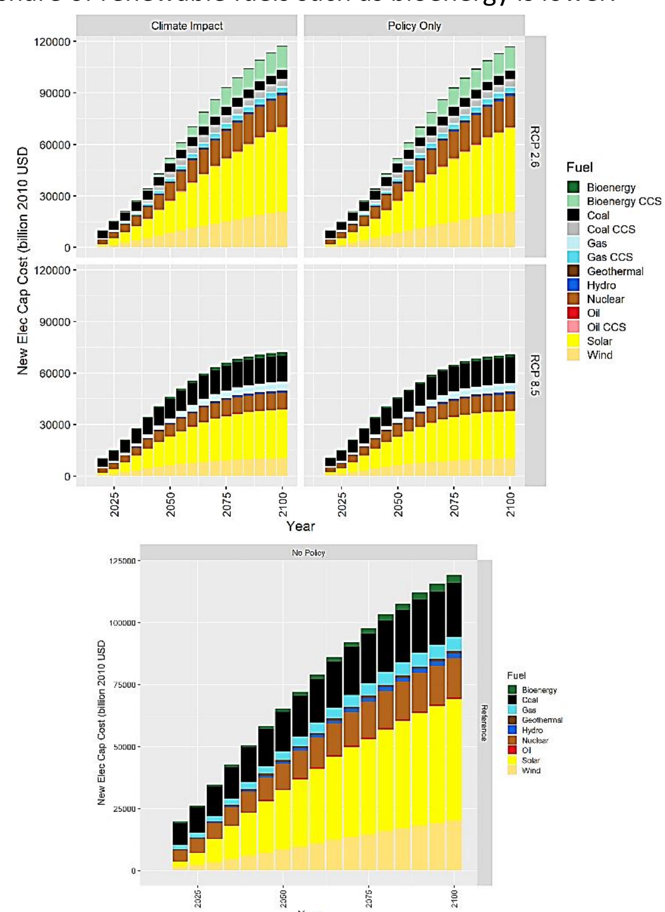


Figure 2. New power sector investment costs globally.

4.3 New power sector investment costs globally

This section shows the result of analysis on how much it costs in order to leave the old power plants that work with fossil fuels before their expected lifetime so that the policy requirement of each scenario is met. As Figure 3 provides, the countries across the globe have to retire around $7 trillion power plants altogether at the end of the century in order to follow the deep de-carbonization scenario, while they only need to retire nearly $200 billion power plants collectively in order to follow the higher emissions scenario.

As a result, the costs of left stranded fossil fuel power plants for RCP 2.6 is almost 35 times as much as RCP 8.5, moreover, the share of left stranded coal power plants is much higher for RCP2.6 than RCP8.5. However, the difference between scenarios with climate impact and without climate impact is insignificant. The cost of left stranded infrastructure for reference scenario is about five percent of deep de-carbonization scenario and 175% of RCP8.5, furthermore, the distribution among fossil fuels is practically even.

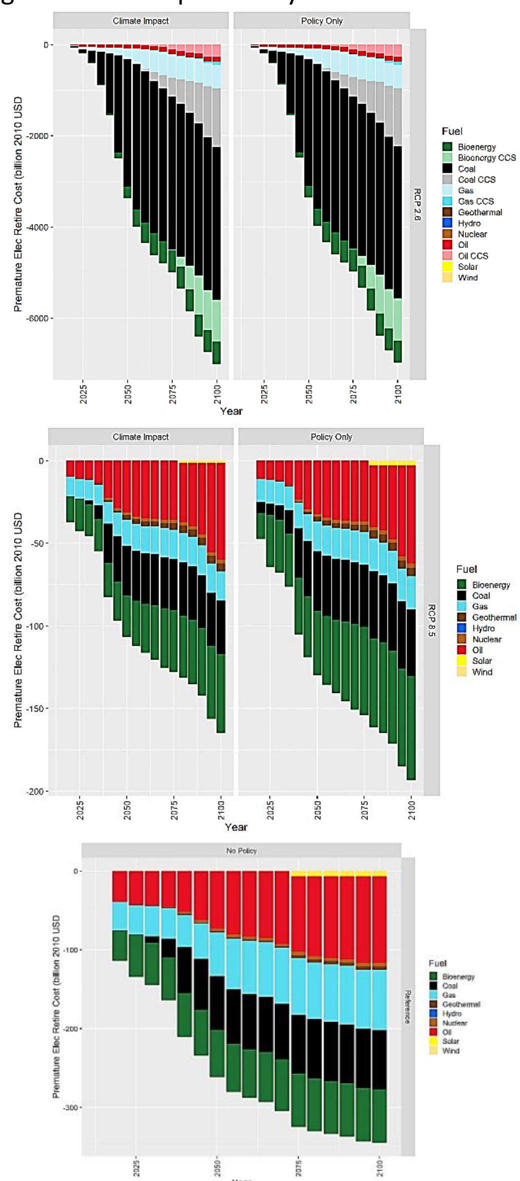


Figure 3. Premature power sector retirements globally.

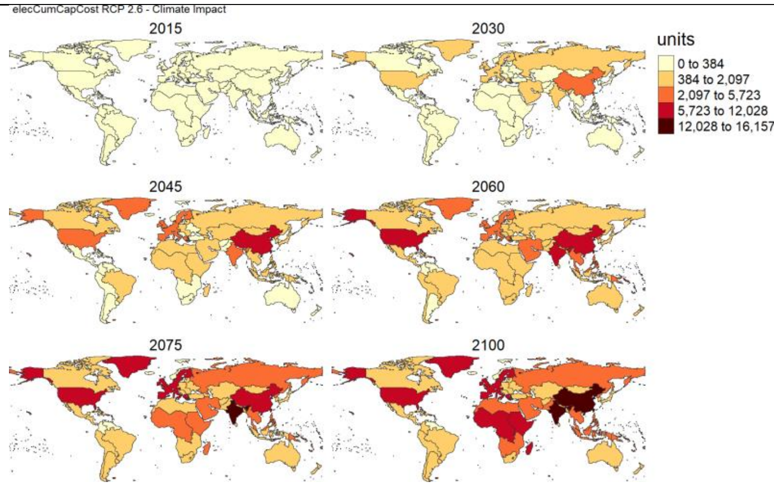
4.4 Map of new power sector investment costs globally

The section demonstrates the map of investment costs that each country has to pay in order to build new power plants that follow the deep de-carbonization scenario. Figure 4 provides the cumulative investment costs for all of the countries worldwide over the century for six years. The plot on top shows the results for the scenario with climate impact and the plot on bottom shows the results for the scenario without climate impact. Investment costs are only aggregated for electricity generated by renewable fuels such as wind, solar, nuclear, bioenergy, bioenergy CCS and geothermal. The units are in billion 2010 USD. As we go from 2015 to 2100, some countries such as China and India have to spend more money, while some countries such as Canada, South Africa and Australia spend less. Thus, two countries of India and Canada are investigated in more detail in the next sections. It is noted that the difference between the scenario with climate impact and the scenario without climate impact is again insignificant.

4.5 Total Final Energy in Building sector in Canada and India

This section provides the detail of total final energy in building sector in two countries of Canada and India as shown in Figure 5. The sum of heating and cooling energy that end-users consume in buildings are displayed over the century for scenarios RCP8.5 and RCP2.6 on the left hand side and right hand side respectively. Each plot compared the energy consumption for two scenarios including RCP without climate impact and RCP with climate impact. Two plots on top, show the results for Canada and two plots on bottom, show the results for India. The pattern of plots for India are similar to the pattern of global plots displayed in section 4.1.

While energy consumption is increasing over years for RCP2.6 and reaches more or less 15 percent of global usage in 2100, the energy consumption is increasing until 2075 and then decreasing for RCP8.5 and reaches almost 12 percent of global usage in 2100. Despite the global plots, end-users consume very slightly more energy in scenarios with climate impact in India compared to scenarios without climate impact. Perhaps, that is because of very slightly higher share of cooling demands relative to heating demands of buildings in India. Indian end-users consume seven and ten times more energy than Canadian in RCP 8.5 and RCP2.6 respectively, at the end of the century.



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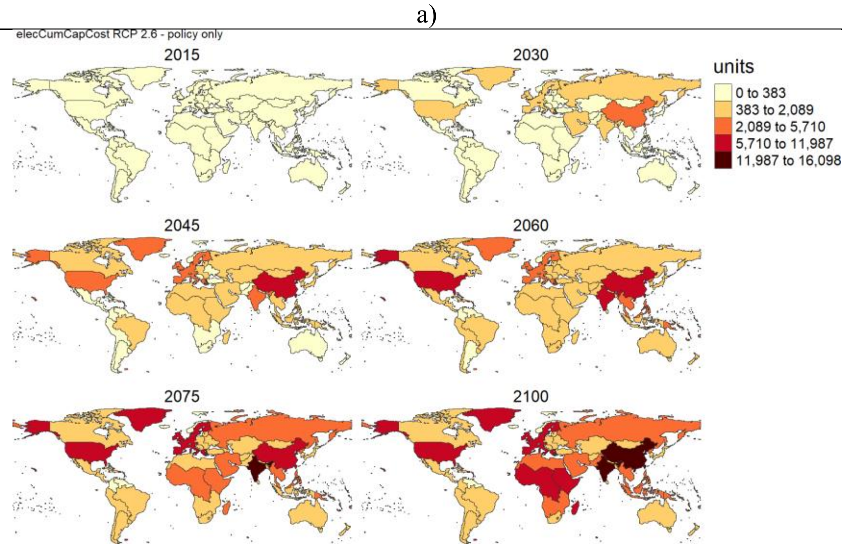

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Figure 4. Map of new power sector investment costs globally in scenarios a) RCP 2.6 - climate impact and b) RCP 2.6 – policy only.

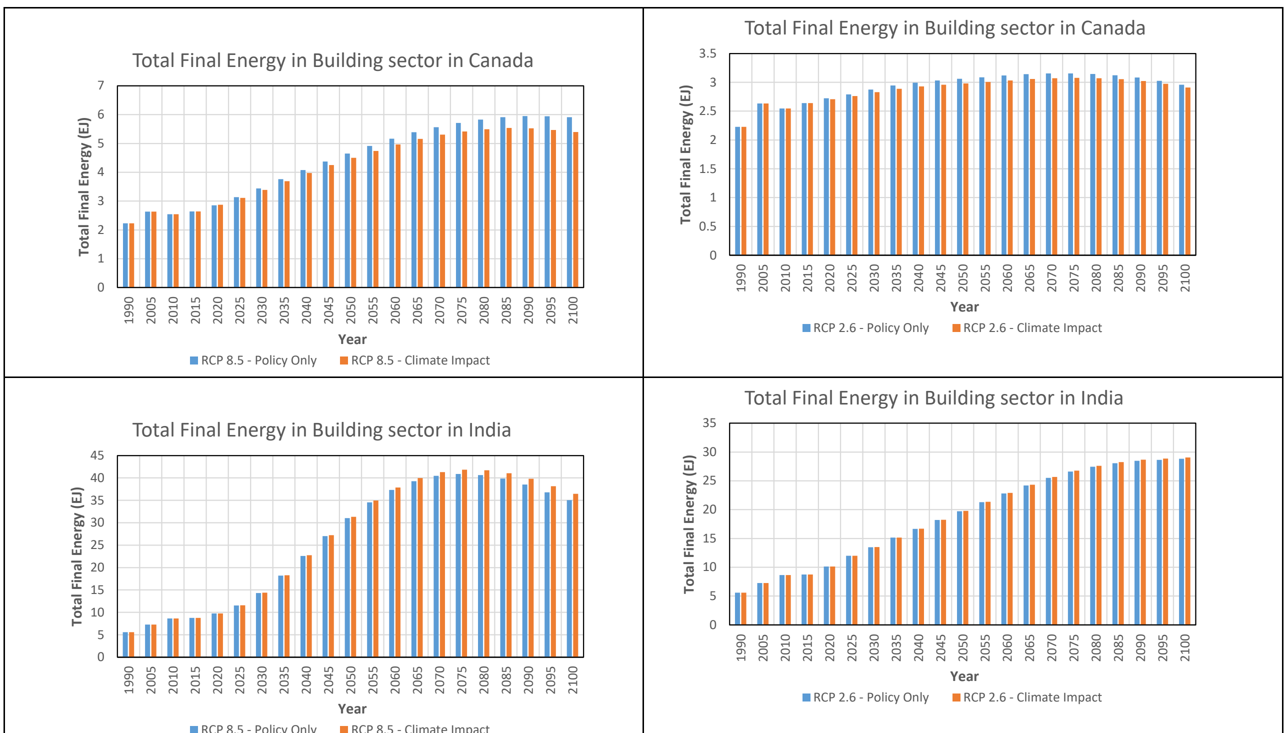
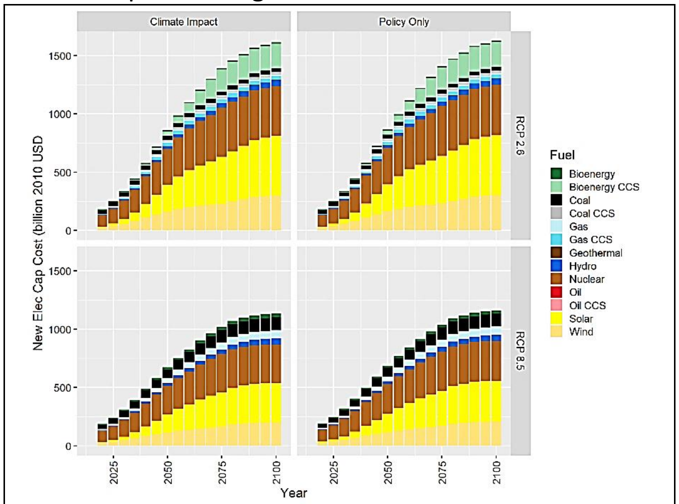


Figure 5. Total Final Energy in Building sector in Canada and India.

4.6 New power sector investment costs in Canada and India

This section shows the result of analysis on how much investment is required in order to build new power plants that follow the trajectories described by each scenario as displayed by Figure 6. India has to invest around $17.5 trillion at the end of the century in order to follow the deep de-carbonization scenario, while it can spend about $10 trillion in order to follow the higher emissions scenario. As a result, the investment costs for RCP 2.6 is almost 1.75 times as much as RCP 8.5.

Whereas, the population of Canada is nearly three percent of India, it has to invest about ten percent of what India spends at the end of the century in order to follow each of the scenarios. However, the difference between scenarios with climate impact and without climate impact is insignificant for both countries.



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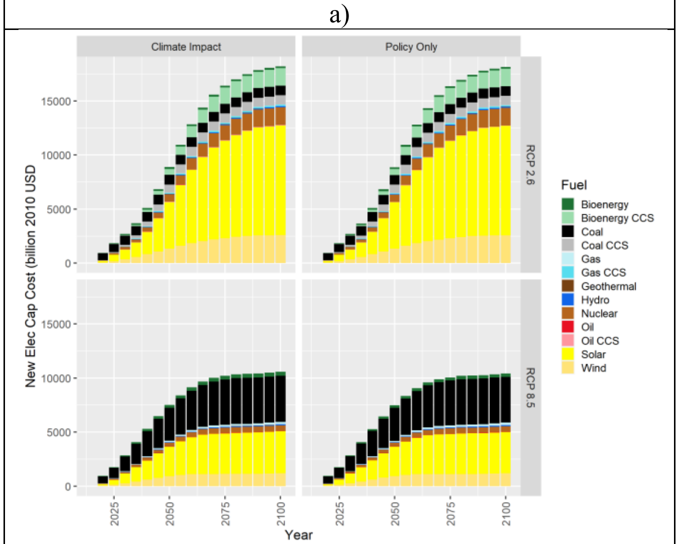

b)

Figure 6. New power sector investment costs in a) Canada and b) India.

4.7 Premature Power Sector Retirements in Canada and India

This section shows the result of analysis on how much it costs in order to leave the old power plants that work with fossil fuels before their expected lifetime so that the policy requirement of each scenario is met. As Figure 7 provides, India has to retire around $1.5 trillion power plants, which forms 20 percent of the global cost, at the end of the century in order to follow the deep de-carbonization scenario, while it only need to retire nearly $45 billion power plants in order to follow the higher emissions scenario. As a result, the costs of left stranded fossil fuel power plants for RCP 2.6 is almost 33 times as much as RCP 8.5, moreover, the share of left stranded coal power plants is much higher for RCP2.6 than RCP8.5.

The costs of left stranded fossil fuel power plants for Canada is about five percent of what India spends at the end of the century in order to follow RCP2.6. While, the difference between RCP2.6 with climate impact and without climate impact is insignificant for both countries, there is no need to have left stranded power plants that work with coal and bioenergy for RCP with climate impact in Canada.

4.8 Conclusions and Future work

In this research, the economic evaluation of constructing renewable power plants is carried out considering the effect of climate change and standard scenarios in order to achieve the global temperature well below 2 centigrade degrees. In particular, scenarios RCP2.6, which is the deep emissions reduction, and RCP8.5, which produces the highest emissions, in addition to their associated climate change are employed. Climate impact is taken into account by required demand for heating and cooling energy in buildings.

It is found that total energy consumption in buildings for RCP2.6 is 67% of what is consumed for RCP8.5 at the end of the century. However, the investment costs for constructing new renewable power plants for RCP 2.6 is almost twice as much as RCP 8.5, in addition to the higher share of renewable fuels such as solar, wind, nuclear, and bioenergy. It is observed that the costs of left stranded fossil fuel power plants for RCP 2.6 is almost 35 times as much as RCP 8.5 in addition to the higher share of left stranded coal power plants. However, the difference between scenarios with climate impact and without climate impact is insignificant. The investment costs and costs of left stranded fossil-fuel power plants is not equally distributed among the countries. As we go from 2015 to 2100, some countries such as China and India have to spend more money, while some countries such as Canada, South Africa and Australia spend less.

It might seem that deep emission reduction scenario is not the right choice because it costs 70 times as much as RCP8.5 and 20 times as much as reference scenario and it is better to adopt adaptation strategies instead of

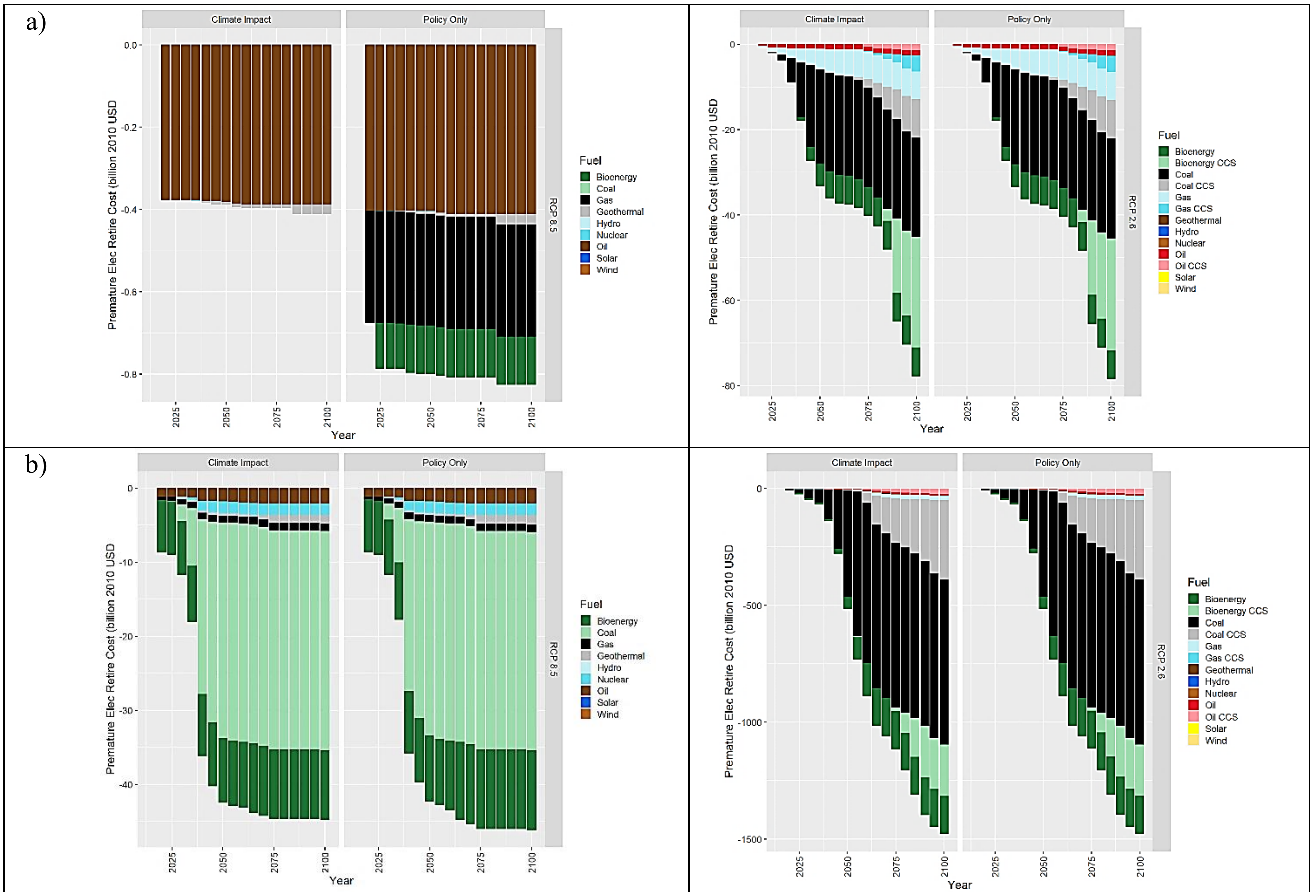

Figure 7. Premature Power Sector Retirements in a) Canada and b) India.

mitigation policies. However, it is worth mentioning that only direct costs of power plants are included in this study. Indirect consequences such as socioeconomic and environmental costs are not taken into account. As a future work, it is recommended to compare the results RCP2.6 and RCP8.5 considering the frequency of extreme events and their consequences, sea level rise, and changing pattern of precipitation. The initial result of this study shows the reduction of energy demands in buildings for RCP2.6, it is recommended to convert these demands into operation costs and add these operation costs to investment costs and costs of left stranded assets, then compare different scenarios.

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REFERENCE

[1] S. W. D. Turner, M. Hejazi, S. H. Kim, L. Clarke, and J. Edmonds, “Climate impacts on hydropower and consequences for global electricity supply investment needs,” *Energy*, vol. 141, pp. 2081–2090, 2017.

[2] D. L. McCollum *et al.*, “Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals,” *Nat. Energy*, vol. 3, no. 7, pp. 589–599, 2018.

[3] L. Clarke *et al.*, “Effects of long-term climate change on global building energy expenditures,” *Energy Econ.*, vol. 72, pp. 667–677, 2018.

[4] D. P. Van Vuuren *et al.*, “RCP2. 6: exploring the possibility to keep global mean temperature increase below 2 C,” *Clim. Change*, vol. 109, no. 1, pp. 95–116, 2011.

[5] N. Nakicenovic *et al.*, “Special report on emissions scenarios,” 2000.

[6] K. Riahi *et al.*, “RCP 8.5—A scenario of comparatively high greenhouse gas emissions,” *Clim. Change*, vol. 109, no. 1, pp. 33–57, 2011.

[7] A. M. Zhao, M. Binsted, T. Wild, Z. Khan, B. Yarlagadda, G. Iyer, C. R. Vernon, P. Patel and S. Silva, “plutus: An R package to calculate electricity investments 1 and stranded assets from the Global Change Analysis 2 Model (GCAM),” *J. Open Source Softw.*, 2021.

[8] K. Calvin *et al.*, “GCAM v5. 1: representing the linkages between energy, water, land, climate, and economic systems,” *Geosci. Model Dev.*, vol. 12, no. 2, pp. 677–698, 2019.