Climate change analysis in energy-mix with non-carbon emission energy incorporated with pandemic society

Tae Ho Woo

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Abstract
The climate energy-mix is analyzed in the aspects of the pandemic as well as global warming where the nuclear and renewable energies are considered the cleaner powers. These factors of the pandemic, global warming, and energy-mix are able to be related to each other in the analysis. The simulations are performed by the modeling which has the quantifications of energy-mix study as mitigations, pandemic, and global-warming. Carbon neutrality is connected to global warming via energy-mix and mitigations. In the case of mitigations, energy-mix case oscillated much higher than the non-energy-mix case. In the case of global warming, the relative impact value is higher in the non-energy-mix case. So, global warming is mitigated when the energy-mix is performed. In figure, the 9.875th year has the biggest difference between the two cases when the energy-mix has the highest effect on the global warming aspect. After this pandemic, the leverage of carbon neutrality could be made.

Keywords Energy-mix · Global warming · Nuclear · Renewable · Pandemic

1 Introduction

The climate energy-mix is analyzed in the aspects of pandemics as well as global warming where the nuclear and renewable energy resources are considered the cleaner powers to meet the demand of the industry (ECMWF, 2020). Three factors of a pandemic, global warming, and energy-mix can be related to each other in the analysis. Electricity-mix is originated from the energy-mix where the electricity generations are from a variety of the power sources such as coal, oil, nuclear, and renewable. Table 1 shows the list of electricity-mix in the USA during the COVID-19 pandemic era (IEA, 2020). When the society is in lockdown, gas and coal decrease in electricity generations. Otherwise, the nuclear and renewable energy consumption increased slightly. However, this trend looks to return after the lockdown softened.
The international mood for supporting the climate change policy has been seeking the solutions including the energy consumption (Davenport, 2020a, 2020b; Eilperin et al., 2020; Guven et al., 2021; McGrath, 2020; Oztig, 2017; Templearchive, 2020; Thompson, 2020). So, it is needed to consider the non-carbon emission energy society with renewable and nuclear energies. As is seen in the case of Table 1, the disease is one of the critical factors for the energy outlook in the future. Due to the pandemic situation, carbon neutrality has been reached to reduce the carbon emission fuels, which means the activities of the summations of carbon consumption and production using planting trees or installing the alternative facilities compensating the fossil fuels. Figure 1 shows the society by climate energy-mix incorporated with the pandemic in which pandemic, climate, and energy-mix create the future society. For the characteristics of climate change, the carbon emissions are controlled by the balancing of the interesting elements in which the leverage is conceptualized as neutrality. Figure 2 is the configuration of balancing for carbon neutrality where the reducing factors are tree planting, non-carbon emission energy, electric cars, and money payments, and the producing factors are fossil fuels, classic cars, and conventional plants (AT&T, 2020). Hence, the right side of the leverage could be regarded as the feedback or resilience from the state of the global warming situation.

Table 1 | List of electricity-mix in USA (IEA, 2020)

| Date   | Gas | Nuclear | Coal | Renewable | Remarks   |
|--------|-----|---------|------|-----------|-----------|
| Jan.   | 40  | 23      | 18   | 19        |           |
| Feb.   | 42  | 22      | 18   | 18        |           |
| Mar. 11| 44  | 21      | 18   | 17        | Lockdown  |
| Apr.   | 42  | 22      | 15   | 21        | ‘’        |
| May    | 39  | 22      | 15   | 23        | ‘’        |
| Jun.   | 41  | 21      | 18   | 20        | Lockdown  |
| Jul.   | 46  | 18      | 22   | 14        | Softened  |
| Aug.   | 45  | 17      | 22   | 16        | ‘’        |
| Sep.   | 44  | 18      | 23   | 15        | ‘’        |
| Oct.   | 46  | 20      | 17   | 17        | ‘’        |
| Nov.   | 40  | 19      | 23   | 18        | ‘’        |

Fig. 1  Society by climate energy-mix incorporated with pandemic
There are some global warming papers that are related to the energy matter without the carbon emissions (Pan & Zhang, 2020; Vural, 2020). Nuclear and renewable energies are significantly important in the aspect of carbon emissions. Although the renewable one has cleaner energy productions, the efficiency is still of limited value. By the way, nuclear stuff could be one of the major non-carbon emission sources of non-fossil fuel.

2 Methodology

The relationship between climate and carbon emissions has been analyzed. The energy factor is the most important matter to manage climate-related carbon production. It is studied for the cases of energy-mix modeling which could give a mitigating method for global warming. Nuclear and renewable energies have very smaller carbon emissions in energy production. It is described in the modeling using event connections. However, there are side effects in these energies for mitigating carbon productions, which are analyzed by the modeling in this work such as the random number of generations decided by the expert’s judgments.

2.1 The energy trend

It is focused on the energy-mix of nuclear and renewable energies in this work. These two kinds of energy resources have pros and cons for carbon emissions control. Although renewable energy has been considered the best way to keep carbon neutrality, there is a side effect of carbon production. In the case of photosynthesis, the carbon is transformed into a stable chemical compound (Stile, 2021). However, during the burring, carbons are released into the atmosphere. It is required to manage the side effect of renewable energy, which is described in the modeling.
In addition, nuclear power needs to keep the transmission and distribution of electricity to keep the qualified supply and demand system (NEA, 2012). For the case of load-following power production in nuclear power, it is equipped in the higher power sized plant which is operated recently (NEA, 2012). Hence, it is considered a negative effect on the plant operations, because it is not able to treat the load-following demand due to the neurotic characteristics of the system. Figure 3 shows the simplified modeling for NPP load-following for supply–demand (Rodica et al., 2018) in which the NPP cost, lifetime, budget, and power volume are incorporated. The levelized cost of electricity (LCOE) and net present value (NPV) of NPP are obtained, which shows the economic effects of the load-following operations of the plant.

The investigations between the carbon-induced climate variation and the energy consumption are incorporated with the leverage of carbon neutrality in an unexpected disease pandemic era. As is seen in Table 1 where the list of electricity-mix in the USA during the COVID-19 pandemic era is shown (IEA, 2020), the energy productions are affected by the pandemic state. So, the logical algorithm such as the system dynamics (SD) could be applied to this study where the feedback is used for the quantifications (Woo, 2018, 2019). This tool could give the randomly sampled values are constructed for the designed scenarios where the dynamic and feedback logic is supplied to the analysis.

2.2 System dynamics (SD)

In the modeling, SD is utilized for the disease pandemic as well as the carbon neutrality as the feedback algorithm which was developed at MIT in the 1960s. The program is done by the Vensim 8.1.2 single-precision code system for this work (Vantana, 2015). There are two important algorithms for the SD summations. In manipulating the event feedback, the equation is described as follows (SDS, 2020),

$$\frac{dC}{dt} = INPUT - OUTPUT$$

where $C$ and $INPUT$ are arbitrary data values and the minus $OUTPUT$ shows the feedback event. So, the feedback algorithm is,
In addition, for the coupled equation, it is written as,

\[ C(i + 2) = C(i) - C(i + 1) \]  

(2)

In modeling expression, the double arrow line can make the data addition and subtraction. So, it is shown as,

\[ \frac{dC(i)}{dt} = INPUT(i) - OUTPUT(i) \]  

(3)

\[ \frac{dC(j)}{dt} = INPUT(j) - OUTPUT(j) \]  

(4)

where \( i \) and \( j \) are variables. This can give the accumulations of the event and the consequences by the data calculation as the logical simulations. Using this accumulation property, the stock algorithm can be written as (Barlas, 2009),

\[ EVENTFLOW = \sum (INPUT - OUTPUT) \]  

(5)

\[ EVENTFLOW(k + 1) = EVENTFLOW(k) + \sum (INPUT - OUTPUT) \]  

(6)

So, it could be written as the difference between the previous one and the following one.

3 Modeling

Figure 4 shows the modeling for simulations of energy-mix study in mitigations, carbon neutrality, renewable power factor, and nuclear power factor. Global warming is affected by pandemic feedback as the arrow line in the modeling. Especially, carbon neutrality is that all kinds of greenhouse gas (GHG) emissions should be balanced by carbon sequestration in order to achieve net-zero emissions (European Parliament, 2021). Mitigations are affected by the energy-mix in which nuclear powers are connected to renewable powers. Carbon neutrality is connected in Fig. 4b where there are seven variables of tree planting, non-carbon emission energy, electric cars, and money payments as positive variables and fossil fuels, classic cars, and conventional plants as negative variables. Figure 5 shows the causes tree for modeling for mitigations and energy-mix in which the carbon neutrality is connected to the global warming via energy-mix and mitigations. Table 2 shows the list of variables. Each variable has a quantity. For example, in the case of global warming, the values are obtained by the randomly sampled one in which if the random value is lower than 0.5, it is 1.0. Otherwise, it is 0.0 as the Boolean value. Then, it is subtracted by mitigations and added by pandemic. It is repeated by the designed time step with an initial value of 0. The other cases are similar to the global warming case.

4 Results and discussion

The simulations are performed by the modeling where Fig. 6 shows the simulations of energy-mix study as mitigations, pandemic, and global warming. In the case of mitigations, the values of energy-mix case oscillated much higher than those of the non-energy-mix
Fig. 4 Modeling for simulations of energy-mix study a mitigations, b carbon neutrality, c renewable power factor, and d nuclear power factor
case, which starts in the 0th year as 0.0 of the relative value. In the case of global warming, the relative impact values are higher in the non-energy-mix case. So, global warming is mitigated when the energy-mix is performed. In Fig. 6c, the 9.875th year (= 9th year
and 319th day) has the biggest difference between the two cases when energy-mix has the highest effect on the global warming aspect in Fig. 7. So, it is analyzed that the case of energy-mix has about 1.86 times more impact on the global warming at the time of the highest effect point in this study. However, the results could be different which are based on variables in Table 2. These variables are constructed by the expert’s judgments where the weighting factors could be considered based on the situations of the modeling. The 2nd time happens in the 32.25th year. It means that the energy-mix with non-carbon emission characteristics of nuclear energy shows a better effect on climate change.

5 Conclusions

It is analyzed for the climate change as the carbon neutrality including the disease pandemic situations. The importance of this study is shown as follows,

- The global warming is analyzed with the COVID-19 pandemic.
- Carbon emissions are affected by the electricity-mix method.
- The feedback algorithm could show carbon neutrality.
- The time scale-based simulations show the 50 years of analysis.

The energy productions are related to social matters such as economic and environmental matters. The carbon productions are mitigated by the carbon neutrality factors such as the tree planting or electrical car driving. By the way, the unexpected pandemic situation could reduce the carbon emission energy source of coal and oil. Hence, it is
Fig. 6  Simulations of energy-mix study a mitigations, b pandemic, and c global warming
necessary to keep the ecological integrity associated with clean air, precipitation, and meteorological factors. This is achieved by wise energy usages such as car and plant emission gas controls.

Using the SD simulations, it is possible to examine the best effect in global warming situations by energy-mix. So, the global warming effect can be expected by the designed analysis. However, there is a limitation in the international prospect, because there are many uncertainties in each nation to apply the electricity-mix. Therefore, international corporations are important to keep the integrity of global warming by inducing the temperature of nature. Following the pandemic situation, the leverage of carbon neutrality could be happened without intentional treatment of carbon emissions decreasing.

In addition, if the study period of 50 years could be extended, the multiple pandemic situations could be examined. New kinds of ecological scenarios can give other kinds of implications in the simulations.

Considering complex characteristics of the climate behavior, it requires that the other nonlinear algorithms could be utilized in the energy-related topics. The pandemic situation is an unexpected phenomenon in the atmospheric variations. For example, the fuzzy set theory has the flexible manipulation of the membership function, a main type of theory. So, the interested variables could be weighted easily. Otherwise, the neural networking could be used for the artificial intelligence (AI) algorithms to analyze the weather and its related effects such as fatal viruses, because the expectation ability of a certain situation is higher in the AI contained in the robotics. The combination of technical approaches of complex logic and social-humanity treats could enhance finding the solution to climate troubles and this leads to taking the climate justice for increasing the human welfare.

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Declarations

Conflict of interest The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
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