EFFECTS OF HIGH RENEWABLE PENETRATION ON US ENERGY SYSTEM

Neha Patankar, PhD Candidate, Operations Research Department, NC State, 9195237559, nspatank@ncsu.edu
Hadi Eshraghi, PhD Candidate, CCEE department, NC State, 9193486457, heshrag@ncsu.edu
Joseph Decarolis, Associate Professor, CCEE department, NC State, 9196562531, jfdecaro@ncsu.edu

Overview

In response to climate change many policies such as an increase in renewable share, increase in efficiency of existing technologies, etc. are initiated globally to reduce emissions. Even though the US is no more a part of Paris Climate Accord, other countries have continued working towards emissions reduction target. The European Union (EU) has an objective since 2009 to reduce greenhouse gas (GHG) emissions by 80-95% by 2050 relative to 1990 levels. Globally, there is an ambitious effort to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charts a new course in the global climate effort. The presence of policies results in an influence on the energy system for the introduction of renewable and low-carbon technologies. Since the US does not have any emission reductions policies as of now, we rely on the policy implementation in EU where an increase in renewable share has been considered as an effective policy to attain the emission reduction targets. The presence of such policy affects the level of electrification in the heat and transport sectors and can also promote the use of distributed renewables. The scenarios can be used to identify the technologies that contribute to various renewable energy targets to be achieved through 2050. We analyze the degree to which end-use energy services are electrified. Moreover, we generate alternatives using the total system cost required for high renewable penetration as an upper bound to identify the policy scenarios that can lead to higher emission reduction.

Methods

In this work, an open source energy system optimization model, known as Tools for Energy Model Optimization and Analysis (Temoa) (Hunter, et al., 2013), is used in conjunction with a multi-region national US input dataset to assess the effects of varying renewable energy targets in Total Final Energy Consumption (TFEC) on the energy system. Effects of varying renewable penetration level on overall emissions, total system cost, technology mix, and electrification level in various end-use sectors are analyzed. Moreover, because it is not possible to develop a complete mathematical representation of complex energy system, structural uncertainties exist in optimization models (Brill, 1979). As a result, the ideal solution is more likely to be located within the model's inferior region rather than at a single optimal point or along the non-inferior frontier. Hence, we use the Modeling to Generate Alternatives (MGA) technique to find alternative policies for emission reduction which can be achieved at the same total system cost as high renewable penetration policy.

Results

The reference case results show that the total final energy consumption from renewables in 2050 is 9.92%. Hence we systematically increase the percentage of renewable energy in TFEC until the model becomes infeasible due to resource and demand constraints as shown in Figure 1. Results in Figure 2 suggest that higher renewable penetration targets promote electricity sector decarbonization and an increased level of electrification across the energy system. Model results indicate that maximum 44% renewable share can be achieved with 10% increase in total system cost and 54% reduction in CO_2 emissions in 2050 where most of the emission reduction is from the reduced activity of coal power plants. We also identify potential policy measures and barriers to electrification within renewable energy systems. It is surprising to note that 20% renewable penetration can be achieved at 0.5% of total system cost. However, the total system cost increases exponentially as the renewable penetration increases beyond 30%. Alternatives generated by MGA suggests that investment in CCS and nuclear technologies can lead to much higher emission reduction at the same total system cost as 44% renewable penetration in TFEC.

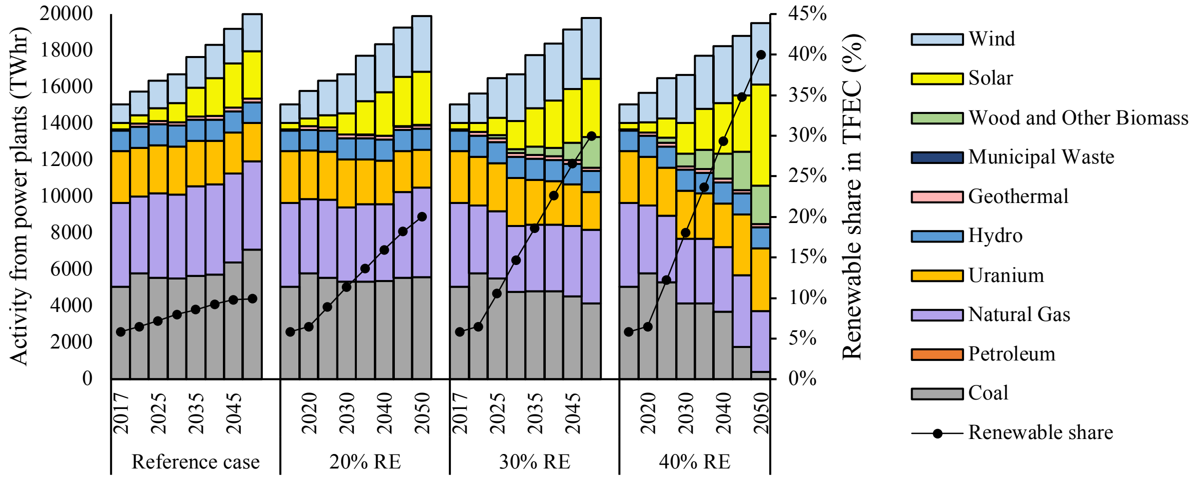

Figure 1: Activity from power plants for increasing renewable penetration in US energy system

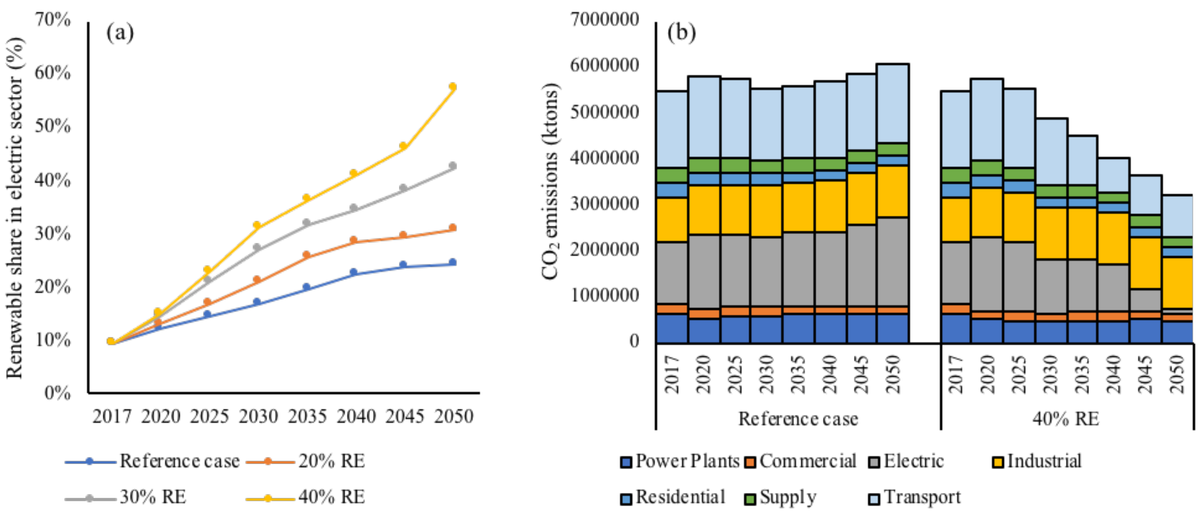

Figure 2: (a) Renewable share in electric sector for renewable penetration scenarios (b) CO_2 emissions by sector for reference case and 40% renewable energy in TFEC scenario

Conclusions

There are a number of extensions that can improve our understanding of limits to renewables penetration. First, the high renewable penetration increases total system cost. As a result, the marginal cost of satisfying end use demand is higher for high renewable penetration. This paper does not consider price sensitivity of end-use demand. Second, the representation of industrial sector is limited due to the level of complexity for US. Moreove, though we analyse the transmission system for incorporating more renewables generation, it is difficult to observe nodal limits to penetration without data about nodal demand. For the future work, we hope to conduct studies beyond this work including the role of energy efficiency and demand flexibility at varying levels of renewable penetration, helping to elucidate a future incorporating unprecedented levels of renewables generation.

References

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