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Targeting Reduction in Carbon Emission of PowerPlants by Regulating Supply of Biomass

Pratham Sudhakar[1], Aman Yadav [2], Dr. J.P. Kesari[3]

Delhi Technological University (Bawana Rd, Shahbad Daulatpur Village, Rohini,New Delhi, Delhi-110042

ABSTRACT

Due to high implementation costs and a lack of instruments for quantitative planning, the biomass energy sector is not well established in the majority of developing nations. In order to plan and optimize biomass supply chains based on carbon reduction targets, a quantitative planning tool is presented in this study as a solution to the problem. The Carbon Emission Pinch Analysis (CEPA), mathematical optimization, and multi- stakeholder analysis are the three key phases that the methodology suggested in this work centers on. The bare minimum amount of biomass needed to reduce carbon emissions is calculated using CEPA. The biomass supply chain isthen optimized using mathematics in accordance with the carbon reduction goal. New biomass power plants and co-firingof existing power plants are two factors taken into account during the optimization stage.

Introduction

Carbon dioxide (CO2) levels in the air are at their highest in 650,000 years, according to the NASA Climate Change and Global Warming Database. In some cases, CO2 emissions takes place from the energy sector. The number of people indeveloping nations alone is at an alarming 244.5 million.
Since 2018, tonnes have been produced. CO2 contributes toglobal warming since it is a greenhouse gas. Primarily as a result of global warming, land and ocean temperatures haverisen at a 0.07 degree Celsius each decade on average. Since1880. To solve the aforementioned concerns, the Malaysia's government has committed to a climate action plan to cut emissions. In 2015, the goal was to reduce greenhouse gas emissions by 45 percent by 2030. The United Nations is hosting the 21st Conference of Parties.

Literature review

One of the tools that can be used for quantitative planning in the energy sector is carbon emission pinch analysis (CEPA).CEPA is based on a well-established graphical tool introducedby Linnhoff and Flower known as Pinch Analysis. CEPA can beused to obtain the minimum amount of clean energy resource (e.g., biomass) based on carbon
reduction targets. However, CEPA assumes clean energy resources have zero impact on carbon emissions. Instead of assuming zero carbon emissions, Lee et al. proposed a modified CEPA, which factored in minimal carbon emission from biomass. Aside from this, the inaugural CEPA proposedby Tan and Foo is graphical. The graphical nature behind CEPA makes it simple to use but can lead to challenges in producing accurate plots. With this in mind, Sahu et al introduced an algebraic method as a targeting technique forbiomass energy planning. Apart from Sahu et al, there are many other variations and applications of CEPA based on different geographic contexts and scales.

Methodology

The suggested technique is divided into three steps, as shown in Fig. 1 by the dotted outlines. The Carbon Emission Pinch Analysis is the initial stage (CEPA). The amount of biomass necessary to meet a carbon reduction objective is calculated in CEPA. Section 3.1 goes through the specifics ofthis stage. Following that, biomass supply chain optimizationcalculates the best supply chain for achieving the minimum biomass set by CEPA.
The multi-stakeholder analysis is the next step in this process.The Shapley-Shubik power index is used to determine the relevance of each power plant in the ideal supply chain. It is considered acceptable if the cost of the biomass supply chain is affordable or accepted by decision-makers. If it is not, the first task of the methodology is revisited to allow some flexibility in data collection. For instance, some leniency can be given to the constraints such as the fossil fuel input, maximum and minimum capacity of conversion technologies. However, if the generated supply chain is considered acceptable, then it can be recommended for implementation.

Casestudy

Unfortunately, Selangor's power plants are heavily on fossil fuels. The state's significant reliance on fossil fuels contributed to an increase in carbon emissions. As a result, the initial goal of this case study is to establish the lowest quantity of biomass necessary in one of Selangor's provinces to accomplish carbon emission reductions while meeting the same level of electricity demand. Second, depending on the carbon emission reduction objective, an ideal biomass supplychain will be established.
A power purchase agreement must be followed by the powerplants in the optimum biomass supply chain (PPA). Power plants are frequently required to commit to a minimum of 70% of the total power that may be delivered under PPAs with local electrical utility companies.

Limiting individual power plant outputs

The power plant that will be added in PPA is a power plant that is already operational. It ran on natural gas, meaning that there was no co-firing at this power station. As a result, this power station will not contribute to carbon emission reduction. Because natural gas is less expensive than carrying biomass to PP4, it was used in PP4. Aside from that, comparable outcomes were seen. The model, for example, chose the shortest distances. Furthermore, because of its cheaper capital expense, biomass flow was concentrated on PP2. In addition, new power plants have chosen the boiler-steam turbine combination. The 5 tonnage trucks were picked for this complete supply chain. This confirms the result reached in Scenario 1, namely that recruiting costs have a greater influence on overall transportation costs.

Discussion overview

For starters, Scenario 1 had the lowest cost of carryingbiomass due to the use of shorter routes.As a result, newer plants were more likely to be chosen. Although this scenario resulted in greater annualized capital and operating expenditure, the cost of transporting biomassto these new plants was far lower, lowering total expenses.The power output restriction of 15 MW for new plants in Scenario 2 allowed annualized capital and operational expense to be reduced. This meant that a greater number ofnew and existing power plants would be required to meet the required 100 MW threshold. Some of these plants were placed considerably further away from the biomass source.

Mandatory selection of newpower plants

The results of this scenario show that biomass flow patternsare comparable (into PP2). Here, too, the shortest distanceswere picked. The only change in this scenario is that NPP3 was chosen as an extra power plant. Boiler-steam turbine systems were also used in new power plants. Because of thelower rental costs, the 5 tonnes trucks were chosen for this supply chain design.
In addition, the power plants in this supply chain were subjected to a multi-stakeholder examination. Using the plants' respective power outputs estimated in the optimum supply chain, the Shapley-Shubik power index was calculated.Table 14 shows the various power outputs.

The power indices were more evenly distributed among PP2, NPP1, and NPP2 in all three quotas. This is because, in comparison to Scenario 2, the power outputs of these three power plants are more evenly spread. In this supply chain system, PP2 was not a dictator in any of the quotas.
However, when compared to the other two power plants,PP2 still has the most power.

Conclusion

This work presented a three-stage integrated methodology to optimize and plan biomass supply chains. The first stage involved carbon emission pinch analysis (CEPA), where the minimum amount of biomass energy resource was determined to achieve carbon emission reductions. This amount of biomass was then added as a target into a biomass supply chain optimization model, where the optimal biomass supply chain was determined. The optimization model considered options for new biomass power plants or fossil fuel power plants co-fired with biomass in this stage. Inthe last stage, the optimal supply chain results were analyzed via a multi-stakeholder analysis known as the Shapley Shubik power index. This was done to identify the importance of each stakeholder in the supply chain. Unlike previous works, this work addressed aspects such as carbon-constrained energy sector planning, biomass supply chain optimization,co-firing, and multistakeholder analysis in an integrated manner. The methodology presented can be extended to other cases which require the planning of supply chains for carbon reductions. For demonstration, the methodology wasused for a case study in Malaysia consisting of palm oil mills (i.e., biomass source), existing fossil fuel power plants and potentially new biomass power plants.

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