Bi-objective optimization of biomass supply chains considering carbon pricing policies

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1 Abstract

In all industries There is one main goal for their owners, 'maximizing the total profit'. However, in the past decades due to global warming regarding CO-2 pollutions, governments around the world started limiting carbon emissions by the industries. Clearly industries started to come up with optimized solutions to mitigate their Carbon emissions and also minimizing the total cost.

The article considered a bi-objective model with carbon pricing policies. Also they developed an algorithm to find out a set of Pareto-optimum solutions considering 3 carbon policies. Besides, it determined the effect of different price for carbon and different initial allowances on total cost and total emission. They did it based on a case study that is explained further.

In this paper a case study related to the expansion of a biomass-fed district heating plant at the University of British Columbia (UBC) Canada is described. With the aim of mitigating the carbon emissions from the consumption of natural gas for heat generation, UBC installed a 6 MW biomass-fed district heating plant in 2012.To further mitigate the carbon emissions from the consumption of natural gas, UBC is considering the expansion of the district heating plant to 18 MW capacity. For this purpose, a new 12 MW plant is planned to be installed adjacent to the current 6 MW gasification plant.

2 Data

In this section you can see the data that we used in our bi-objective optimization model.

Table 1: Basic variable

parameter	symbol	value
Maximum storage capacity	S	412
Maximum storage capacity of the silo	Sp	192
Maximum number of truckloads	N	6
Cost of heat produced from natural gas	Cg	37
carbon price per tonne Co2-eq	p	50
Initial emission allowance	InitialAllowance	2000
Emissions compliance target	ComplianceTarget	2000
Maximum heat capacity of the existing system	HCE	518.4
Maximum heat capacity of the new system	HCN	1555.2
Emission ratio for wood	GHGwood	0.094
Emission ratio for natural gas	GHGng	0.056

All of the basic variables and the data used for each of them is shown In Table 1.

Table 2: Biomass parameters

parameter	symbol	woodchips	woodpellets	briquettes
Cost of biomass(dry tonne)	C(b)	20	90	136
gasification existing system	EE(b)	0.735	0.763	0.761
gasification new system	EE(n)	0.768	0.811	0.807
Vehicle capacity	VC(b)	110	110	110

Also biomass parameters for each type of biomass is included in Table 2.

Table 3: Heat Value

	woodchips	woodpellets	briquettes
Heat value	12.5	18	19

Table 4: Moisture Content

	woodchips	woodpellets	briquettes
MC	0.3	0.1	0.12

Table 5: Density

	woodchips	woodpellets	briquettes
Density	0.15	0.75	1.2

It should be noted that numbers in Table 3, Table 4 and Table 5 are considered the same for 365 days.

3 Sensitivity Analysis

In this section we are going to analyse the effect of some of parameters, such as maximum number of truckloads that are allowed to enter the campus of UBC and vehicle capacity, on the total cost and the total emission.

In our model, the total cost decreases with increasing the maximum number of truckloads. If we look closely, we will notice that the model will use more truckloads when the higher number of truckloads is allowed.For example, when we set the maximum number of truckloads to 6, our decision variable nt(b), which we use it to indicate the number of truckload of biomass type b received on a day,will turn out 6. But when we set the maximum to 12, nt(b) will rise to 10 truckloads. Respectful to the lower price of biomass compared to natural gas, the higher amount of biomass we receive in a day, the lower our cost will be. Also we can use the same logic for analysing the total emission with considering that biomass has less emission in same amount of heat than natural gas.Figure 1 and Figure 2 illustrate this.

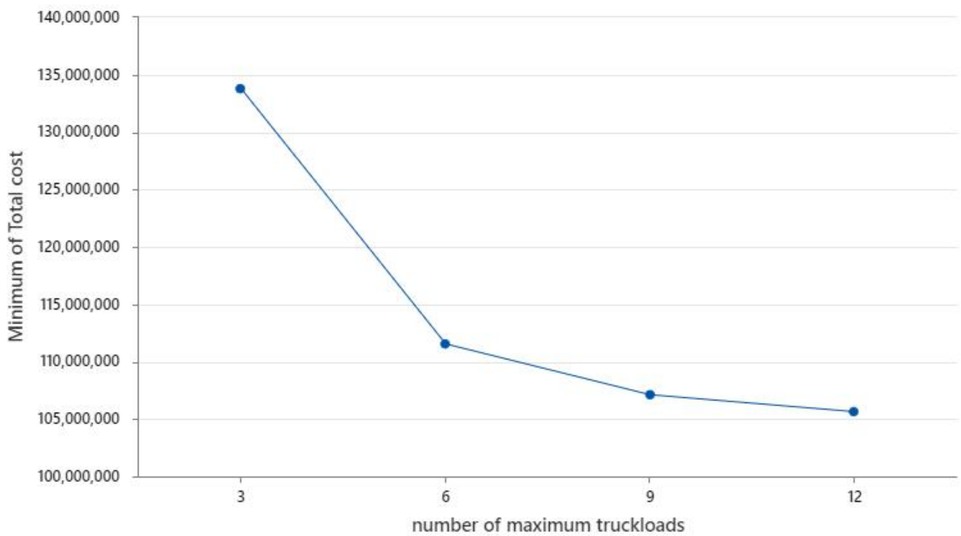

Figure 1: Sensitivity analysis for total cost with varying maximum number of truckloads

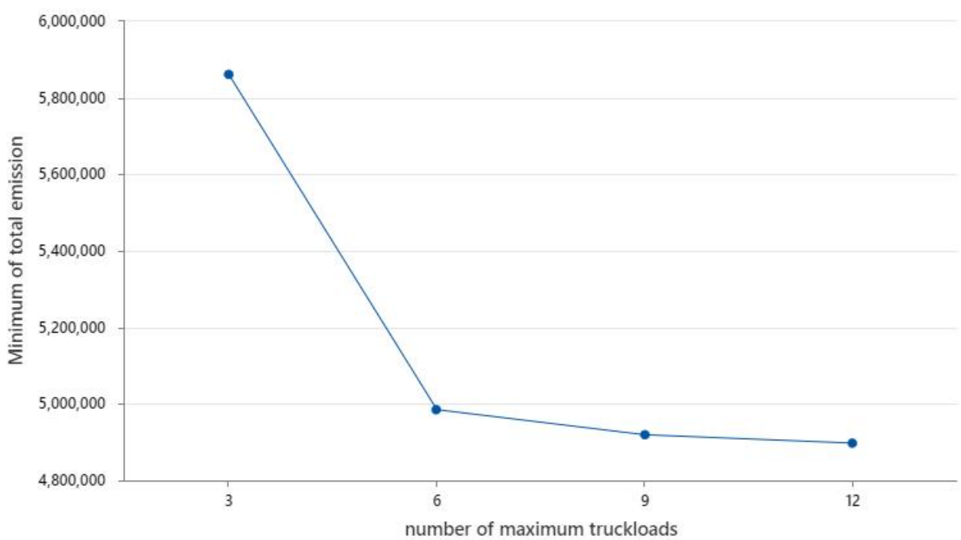

Figure 2: Sensitivity analysis for total emission with varying maximum number of truckloads

For next part of sensitivity analysis we assume that we can upgrade our truckloads so we can have more vehicle capacity. As you can see it is shown in Figure 3 and Figure 4 that with more capacity, we can carry more biomass so in result our total cost and total emission will decrease. But as it is supposed this reduction won't continue this way. It will stop decreasing at 140 cubic meter.After this point, total cost and total emission will rise up. This could be because of crossing the optimal quantity of each biomass.

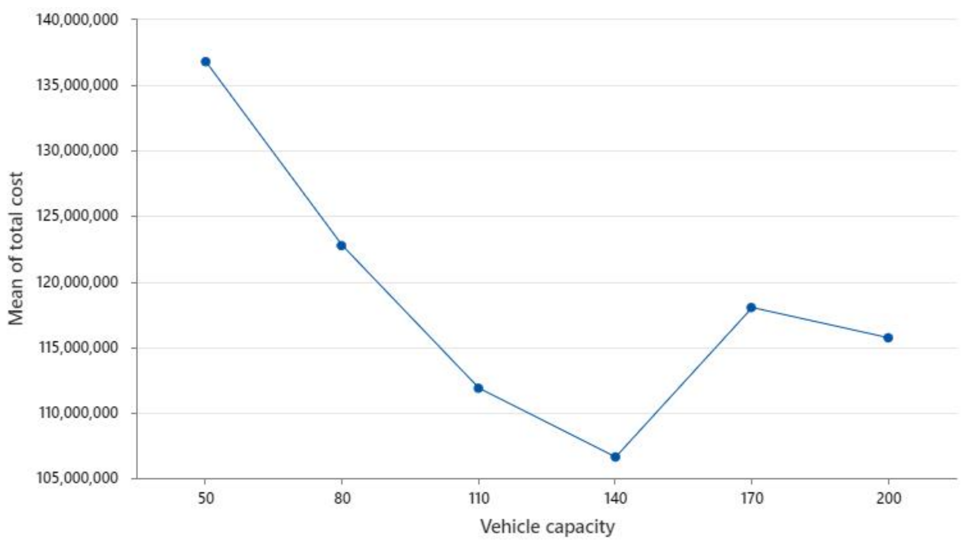

Figure 3: Sensitivity analysis for total cost with varying vehicle capacity

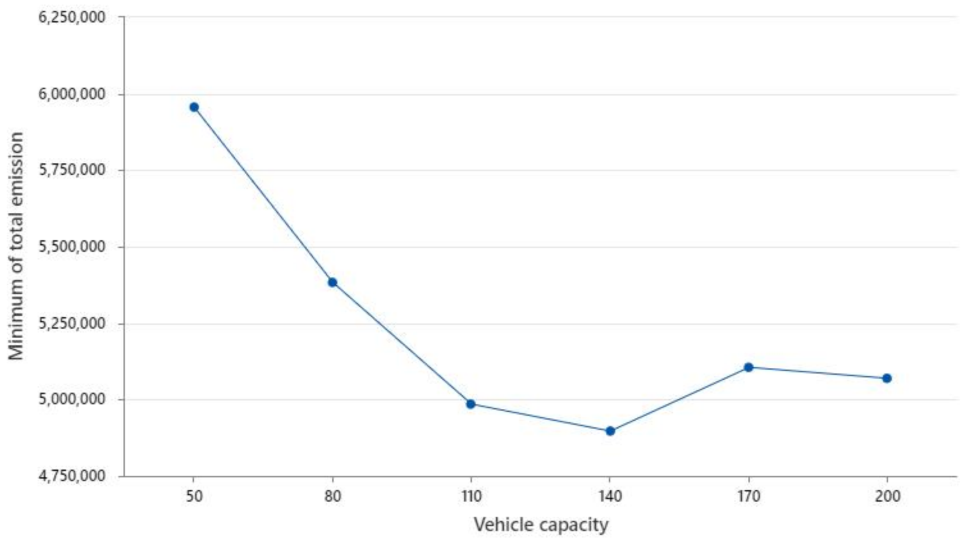

Figure 4: Sensitivity analysis for total emission with varying vehicle capacity

4 Conclusion

In this study, bi-objective optimization model for minimizing total cost and total emission considering 10 different constraint were developed. These constraints refer to space limitation, vehicle limitation, ensuring that heat demand is met and so on. In this level we just solved the model using GAMS in order to get the optimum solution considering we have no limitation in emission. But in the original article or even in reality it is not like this. For instance, the article have mentioned 3 different policies for carbon pricing; Simply referring to that our emission should be limited and based on that planned. These 3 policies include carbon cap-and-trade, carbon tax and carbon offset policy. This study showed that carbon cap-and-trade policy is the most efficient in mitigating emission.

Also with sensitivity analysis here, we conclude that with increasing maximum number of truckloads, it is possible to decrease the total cost and total emission. It should be noted that the original article mentioned that increasing this number any higher than 6 will cause community concern.
Alongside that, we illustrated the impact of any change in each vehicle capacity on the total cost and total emission.