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Life Cycle Assessment of the Bio-Mitigation in Steel and Iron Industry Using Chlorella Sp

Ece Polat [1,2], Cemil Koyunoglu [3,4]

[1] Department of Environmental Engineering, Istanbul Technical University, 34469 Maslak, Istanbul, Turkey
[2] Department of Environmental Engineering, Gebze Technical University, 41400 Gebze, Kocaeli, Turkey
[3] Energy Institute, Istanbul Technical University, 34469 Maslak, Istanbul, Turkey
[4] Energy System Engineering Department, Yalova University, 77200, Yalova, Turkey

polatec@itu.edu.tr

Abstract. Pulverized Coal Injection (PCI) used for the first time in 1850 by a French and a Belgian entrepreneur. Because of its increasing use, today, PCI has become the most traditional method decreasing the amount of coke consumption in high ovens. To increase capacity of coal burning process results an increase in ore/coke rate and a decrease in greenhouse gases (CO_2, SO_2, NOx) emissions, in terms of environmental effects, it constitutes significance. Life cycle Assessment (LCA) methodology is preferred in many studies as an evaluation method for economic and environmental effects used in production areas at present. Microalgae are important for the bio-mitigation of carbons/biological sequestration due to their property of under greenhouse gases and under flue gas effectively. Steel and iron industry is known for its high capacity of these kind of gases and microalgae pond integrated to a steel and iron industry can be a good way of struggling the unwanted impacts of these gases. Our project aims to develop a technology to burn Turkish coal and microalgae biomass resources and their mixtures at certain proportions under LCA. The results obtained in this study will be used to create a database on LCA evaluations in energy areas of Turkey.

1. Introduction

Life Cycle Analysis (LCA) is, as a summary, a way of assessing the environmental impacts of products and processes during their lifetime, including the acquisition of raw materials, production, use, final disposal and all shipping phases in between. Comprehensive inventory of all energy, water, and substance inputs and waste and emissions released at these stages are compiled together and the potential environmental impacts of the products are calculated (figure 1). Unlike narrow-ranging environmental impact analyzes, LCA, as a holistic method, prevents environmental problems from being transferred from one life-stage to another by means of the "cradle-to-grave" approach [1-3]. The current standard four-step WBS method is standardized in 1991 by the Environmental Toxicology and Chemistry Organization (SETAC) and its basic principles and framework are firstly standardized by ISO 14040: 1997, ISO 14041: 1999, ISO 14042: 2000 and ISO 14043: 2000 then updated with ISO 14040: 2006 and ISO 14044: 2006 (SETAC, 1991, ISO, 2006a, ISO, 2006b).

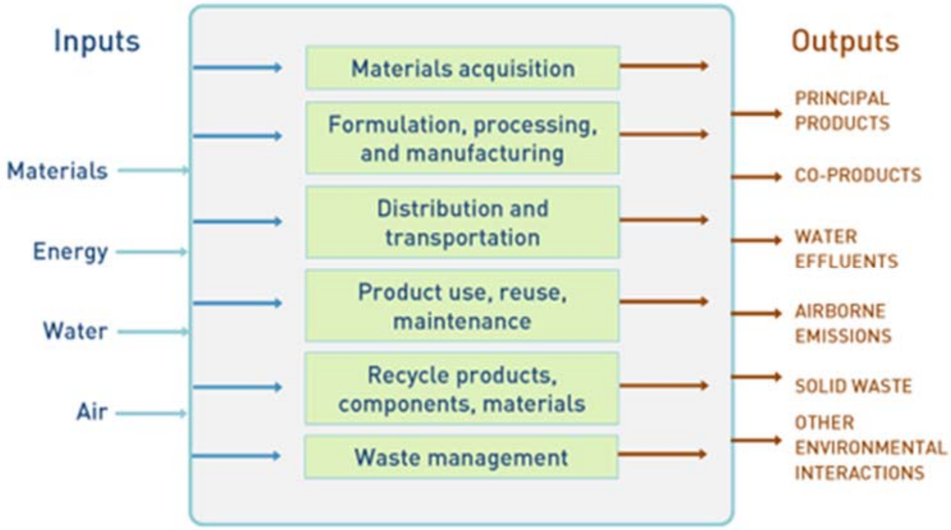

Figure 1. LCA phases [4]

Numerous impact assessment methods, software and databases have been developed to support, improve and make the day-to-day method of development more effective. In addition to the WB, there are Life Cycle Cost Analysis (WBS) and Social Life Cycle Analysis (WBS) methods that assess the economic and social dimensions of product sustainability [5-7].

1.1. Life cycle analysis method and its steps

The standard WBS method described in ISO documents consists of four main stages; purpose and scope description, life cycle inventory analysis, life cycle impact analysis and interpretation of results [8, 9]. The relationship between steps is as shown in figure 2.

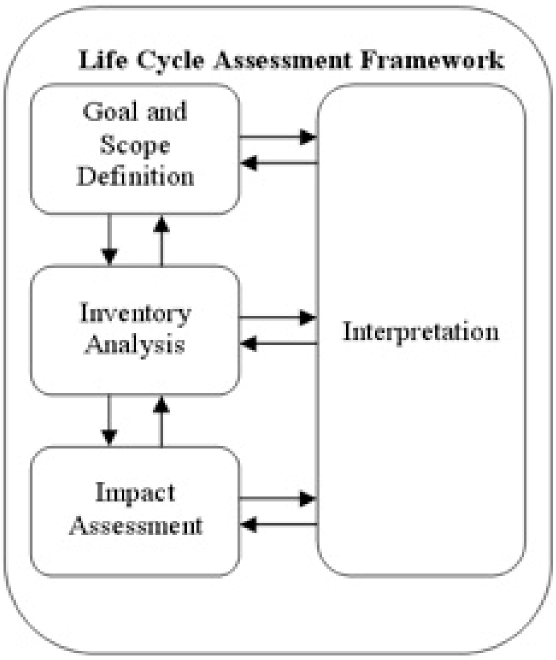

Figure 2. LCA methodology (ISO 14040: 2006) [10]

1.1.1. Purpose and Scope Description
At this stage; objectives, target variables, basic variables, data requirements, constraints and assumptions used are defined. The two most important elements that define the scope and outcome of the work are a) system boundaries and b) functional units. When system boundaries are specified, which phases of the product life cycle and unit processes are included in the analysis, they are excluded and their causes are determined. In addition, the infrastructure information such as the geographical area where the work will be carried out and waste management in the area, transportation and temporary boundaries of work are also defined. The functional unit is the unit function of the examined system, and the basic function of the product or system must be expressed in an open, detailed and reflective manner. For example, the functional unit for the comparison of bioethanol and petrol fuels by the YDA study can be defined as "a medium-sized vehicle traveling at 1 km distance". All inventory input-output and analysis results in the study are expressed in this functional unit [11-13].

1.1.2. Life Cycle Inventory Analysis
At this stage, energy, water, raw material inputs and solid waste, waste water and air emissions are determined within the boundaries of the system under investigation (see figure 3). At the same time, inventory information about all unit processes in the product life cycle is compiled with data collection forms, and deficiencies are completed using literature review and sectoral reports. All collected data are rearranged according to the functional unit and are thus prepared for the calculation of environmental effects. At each stage of this phase, the quality and correctness of the data is very important [8, 14, 15].

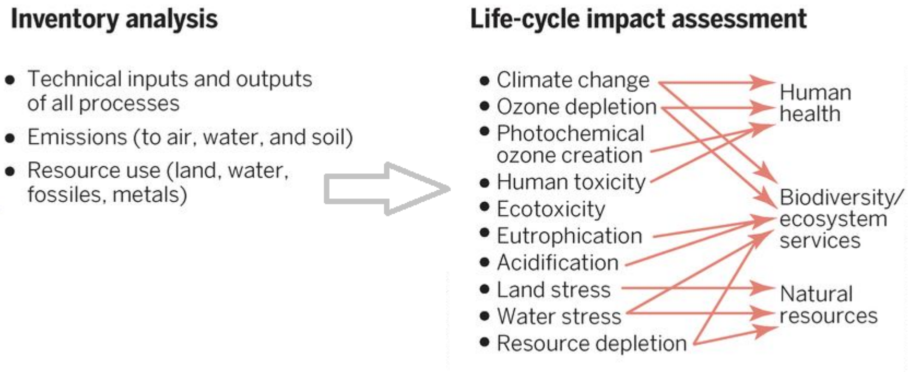

Figure 3. Mid-point to end-point relationship in life cycle impact analysis [16].

1.1.3. Interpretation of results
The objective of this phase is to present important recommendations and recommendations for the system or product under review, by interpreting the results of both the inventory and the environmental impact analysis stages in line with the purpose and scope of the work. Also in figure 2 we can see the bi-directional arrows between the other stages of the LCA; the necessary changes are made at other stages according to the results obtained at a stage of the study. For example, once the amount and quality of data collected in the inventory analysis has been examined, the scope of the study can be narrowed down or expanded, if appropriate, by passing it back to the public [8, 17, 18].

1.2. Microalgae based energy
Microalgae biomass can be converted into different kinds of products such as biodiesel, bioethanol, biogas, biohydrogen and fertilizers as shown in figure 4.

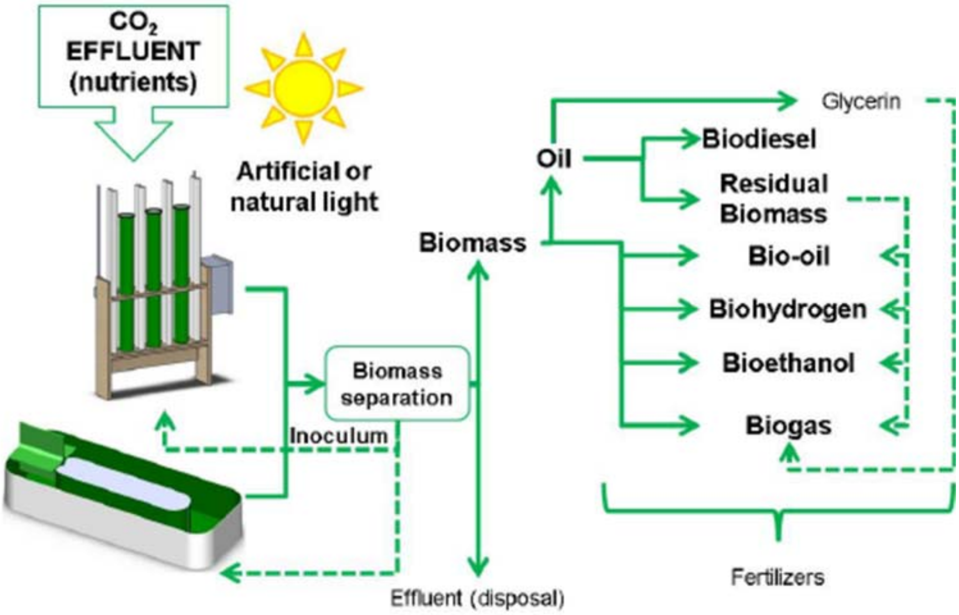

Figure 4. Microalgae based energy [19]

1.3. Using microalgae cake with coal

There are various studies about co-firing facility included coal and microalgae cake in the world. For example, in Germany Niederaussem Thermal Power Plant is operated using with microalgae cake to combine coal to produce less carbon dioxide emissions [20, 21]. In addition, Taştan et.al. [22] studied "A novel coal additive from microalgae produced from thermal power plant flue gas". They proposed for Thermal Power Plant Mihalıççık (Eskişehir, Turkey) using microalgae and coal to generate a novel coal additive called "green coal" [22]. Li et al [23] reviewed subjects on: Utilization of carbon dioxide from coal-fired power plant for the production of value added product. They summarized in their project there are various technologies were explored for minimizing carbon dioxide emissions and they emphasized many different ways to mitigate carbon dioxide in flue gas.

2. Methodology

2.1. Process scenarios

Kardemir Factory number 1 blast furnaces pulverized coal injection process scenarios are presented in figure 5. And scenario 2 examined in detail (figure 6).

2.2. Life Cycle Inventories

The life cycle inputs for Azdavay coal for each process in Scenario 1 are given in table 1. It is known that 50 ton PCI coal burns per 1 day in the blast furnace. For 1-ton liquid iron production, 90 kg PCI coal was used in Kardemir Inc. Blast Furnace Number 4, in 2014. So, for 1-ton liquid iron production 0,0432-hour process work we need. Therefore, the key factor for both scenario 1 and 2 is 1-ton liquid iron production/CO_2 production. Unlike Scenario 1, scenario 2 produces 9000 m3 of flue gas at 1 hour and 20% to 25% CO_2 concentration of biofuel is produced with algae consuming as nutrients, and when the process is burned more efficiently than algal coke with scenario 1, coal if consumption is reduced by 20%, the answer to what happens in the amount of CO_2 production of the PCI coal burned in the iron-steel blast furnace is given in table 2. Burning 20% less coal means that less coal is being transported in the same time, which means less operation, 57.6 kg of coal and 18 kg of algae can be used instead of 90 kg of coal. 1 ton of liquid iron can be produced in 0.0363 seconds.

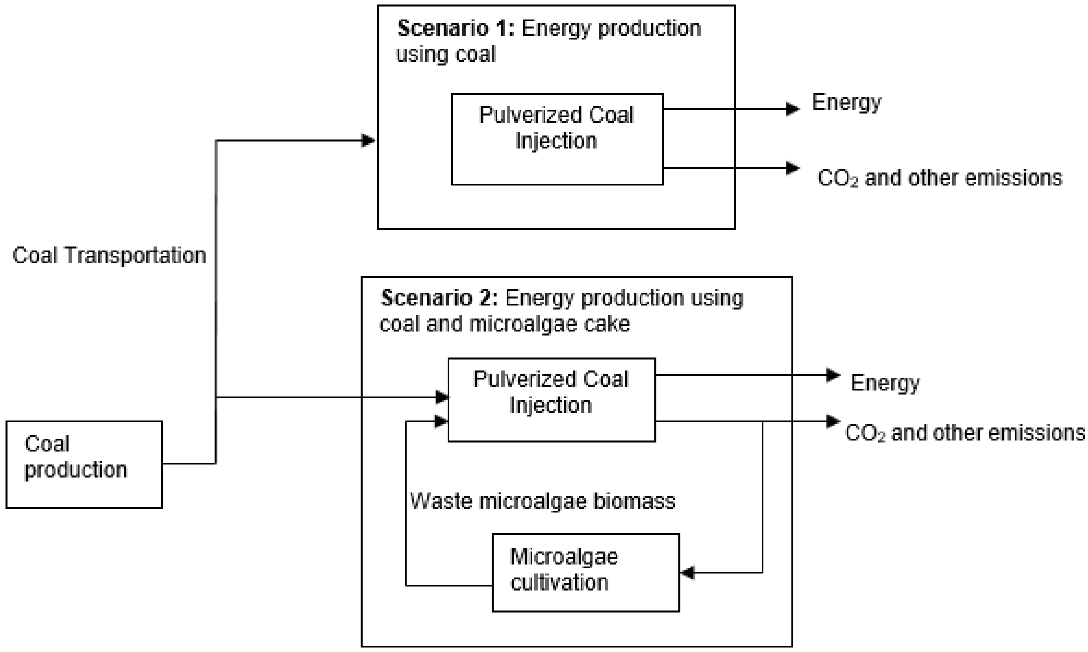

Figure 5. Kardemir's pulverized coal injection plus biofuel production by Chlorella sp.

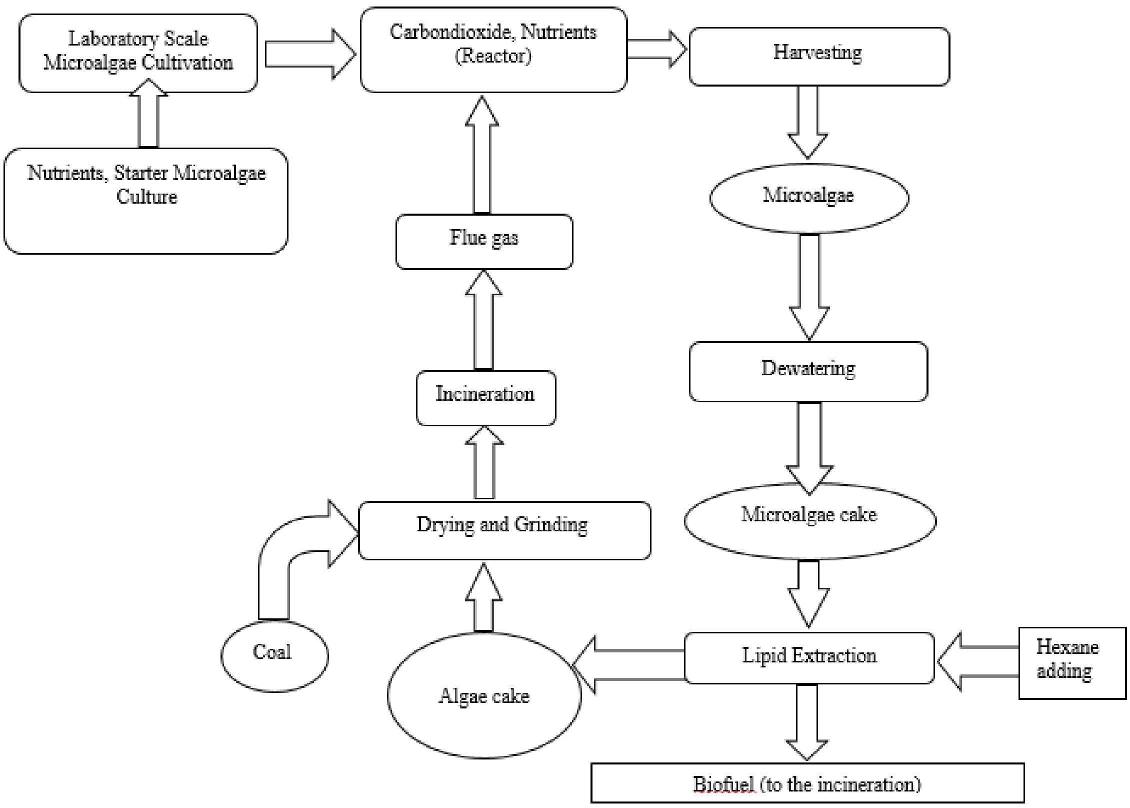

Figure 6. Closer look to Scenario 2.

Table 1. A slightly more complex table with a narrow caption.

Name of Process	Usage of Energy	Time spending (hour)	Source	For Key factor
20% Coal from Azdavay city	Truck (37,5 km)	1	15.36 lt (diesel)	0.663552 lt
80% Coal from Ukrania city	Ship (324,1 km)+Truck (296 km) + Railway (288 km)	48 +8 + 5.8	10 ton (marine diesel oil) + 122.88 lt (diesel) 460.8 kW	9 kg + 0.6636 lt + 3.43 kW
Convey to Silo	Transfer (- km) + open-close (- km)	-	22 kW + 22 kW	0.9504 kW + 0.9504 kW
Silo to bands	horizontal band (-km) + two way band (- km) + close band motor (- km) + digging motor (-km)	-	22 kW + 2.2 kW + 3 kW + 1.1 kW	0.9504 kW + 0.09504 kW + 0.1296 kW + 0.04752 kW
Crushing	Crusher + lubrication motor + sealing fan (15 min.)	-	300 kW + 5.5 kW + 22 kW	12.96 kW + 0.2376 kW + 0.06336 kW
Ventilation	Ventilator		30 kW	1.296 kW
Filtration	Under filter star motor + floor Filter motor (24 pcs.) + Fan	-	1.5 kW+ 0.3 kW + 400 kW	0.0648 kW + 0.31104 kW+ 17.28 kW
Hole Lifter	Mayna viraeldro + Open-close + Vessel + bridge motor + eldro		210 kW + 210 kW + 37 kW + 65 kW + 7.5 kW + 65 kW	9.072 kW + 9.072 kW + 1.5984 kW + 2.808 kW + 0.324 kW + 2.808 kW
To PCI	Drive compressors 2 pcs.) + star compressors (2 pcs.) + Radiator fan (4 pcs.)	-	250 kW + 2.2 kW + 3 kW	21.6 kW + 0.19008 kW + 0.5184 kW

3. Results and discussions

In Scenario 1, 1 kg truck diesel produces;

45.5 MJ energy. 45.5 MJ/kg * 0.832 kg/L * 1.327152 L * 0.001 J/1 MJ = 0.0502 J energy.

According to IPCC 2016 report, 1 MJ diesel produces 74100 kg CO_2 to the atmosphere is equal to 3722.83 kg CO_2.

For 9 kg marine diesel oil;

45.5 MJ/kg * 9 kg * 0.001 J/1 MJ = 0.4095 J and 30343,95 kg CO_2 generates.

For 1 kWh of electricity generation 0.94 kg of CO_2 generates if energy produced from a coal fired plant. For 87.6124 kWh electricity generation 82.3557 kg of CO_2 generates. So the total CO_2 generation for the Scenario 1 is 34149.1357 kg CO_2 for producing 1 ton liquid iron.

In Scenario 2, 1 kg truck diesel produces

45.5 MJ energy. 45.5 MJ/kg * 0.832 kg/L * 1.99181 L * 0,001 J/1 MJ = 0.0754 J energy.

According to IPCC 2016 report, 1 MJ diesel produces 74100 kg CO_2 to the atmosphere is equal to 5587.29 kg CO_2.

For 7.5625 kg marine diesel oil 45.5 MJ/kg * 7.5625 kg * 0.001 J/1 MJ = 0.3441 J and 25497.35 kg CO_2 generates for 1 kWh of electricity generation 0.94 kg of CO_2 generates if energy produced from a coal fired plant. For 78.52 kWh electricity generation 73.87 kg of CO_2 generates. So the total CO_2 generation for the Scenario 2 is 31158.51 kg CO_2 for producing 1-ton liquid iron

Table 2. Scenario 2 inputs

Name of Process	Usage of Energy	Time spending (hour)	Source	For Key factor
20% Coal from Azdavay city	Truck (37,5 km)	1	15.36 lt. (diesel)	0.557568 lt
%80 Coal from Ukrania city	Ship (324,1 km)+Truck (296 km) + Railway (288 km)	48 +8 + 5.8	10 ton (marine diesel oil) + 122.88 lt (diesel) 460.8 kW	7.5625 kg + 0.5575 lt + 2.884 kW
Convey to Silo	Transfer (- km) + open-close (- km)	-	22 kW + 22 kW	0.7986 kW + 0.7986 kW
Silo to bands	horizontal band (-km) + two way band (- km) + close band motor (- km) + digging motor (-km)	-	22 kW + 2.2 kW + 3 kW + 1.1 kW	0.7986 kW + 0.07986 kW + 0.1089 kW + 0.03993 kW
Crushing	Crusher + lubrication motor + sealing fan (15 min.)	-	300 kW + 5.5 kW + 22 kW	10.89 kW + 0.19965 kW + 0.05324 kW
Ventilation	Ventilator		30 kW	1.089 kW
Filtration	Under filter star motor + floor Filter motor (24 pcs.) + Fan	-	1.5 kW+ 0.3 kW + 400 kW	0.05445 kW + 0.26136 kW+ 14.52 kW
Hole Lifter	Mayna viraeldro + Open-close + Vessel + bridge motor + eldro		210 kW + 210 kW + 37 kW + 65 kW + 7.5 kW + 65 kW	7.623 kW + 7.623 kW + 1.3431 kW + 2.3595 kW + 0.27225 kW + 2.3595 kW
To PCI	Drive compressors 2 pcs.) + star compressors (2 pcs.) + Radiator fan (4 pcs.)	-	250 kW + 2.2 kW + 3 kW	18.15 kW + 0.15972 kW + 0.4356 kW
From Flue gas to Raceway ponds	electrostatic precipitator + selective catalytic reduction + air heater + wet limestone gypsum process of scrubber + hydro cyclones + slurry pump + centrifuge + programmable logic controller [24-29]	24	40 kW + 560 kW + 97 kW + 1202 kW + 24 kW + 7.5 kW + 1234 kW + 55 kW + 15 kW	0.0605 kW + 0.847 kW + 0.14671 kW + 1.818025 kW + 0.0363 kW + 0.011344 kW + 1.86425 kW + 0.08318 kW + 0.02269 kW
Algae cake from ITU to Kardemir Inc.	Truck (404 km)	7	162.2016 lt	0.84113 lt
Pond process	Wheel + Control panel	24 + 24	37 kW + 12 kW	0.0559625 kW + 0.01815 kW
From p ond to Filter press	Pomp [30]	4	66 kW	0.59895 kW
Filter press process	Filter press [30]	24	33 kW	0.0499125 kW
Alg Cake production	Rotary evaporator [31]	4	0,186 kW	0,00168795 kW

4. Conclusions

In conclusion, if we construct a raceway (5000 m^2 area) using blast furnace PCI system flue gas we will reduce 34149.14 (Scenario 1) – 31158.51 (Scenario 2) = 2990.63 kg of CO_2 due to the 1-ton liquid iron production which means for 0.0363 hour. So, for 1-day reducing CO_2 consumption will be 1997275.64 kg (=1997 ton), for 1 month reducing CO_2 consumption will be 59318269.1 kg (=59318.3 ton) and for 1 year reducing CO_2 consumption will be 1423638458.2 kg (=1423638.4 ton). Using microalgae as a carbon mitigation source can be important for decreasing the carbon footprint of steel and iron industry.

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