TrainERGY project

Case Study

Submission Date:	15-19 May 2017
Place:	Scuola Politecnica e delle Scienze di Base, Università degli Studi di Napoli Federico II Naples, Italy

Sector Analysed:	Window sector
Product Analysed:	Single-chamber aluminium frame window

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1 Introduction

The main objective of the analysis is to assess the total lifecycle carbon emissions, recognize carbon hot-spots and suggest possible interventions to reduce CO_2 emission in the supply chain of an aluminium window.

2 Overview

2.1 Firm description

The company operates in a window sector. It employs more than 700 people in five production plants and trade offices, home and abroad. It also has its own sails chain that consist of few stores (showrooms). The plants occupy an area of more than 26 000 m^2, where on modern processing lines more than 600 000 window and door units are produced ever year. All factories are located in Poland. The company offers a wide portfolio of aluminium windows and doors, PVC windows and doors, aluminium facades, winter gardens, window sills, roller blinds and louvre blinds as well as various accessories. The production is make to order.

2.2 Product description

The manufacturer has more than a million clients from all over Europe, both individual and institutional. This is the greatest distinction, which motivates to further development of innovative solutions in the field of window joinery. The goal of company's activity is Perfection, understood as the source of an endless inspiration in inventing new solutions, as well as the perfection in manufacture of every product.

The analysed supply chain concerns a **single-chamber aluminium frame window**. This product consists of a one chamber, two layers of 4 mm glass and the aluminium frame. The space between the glasses is fulfilled with a mixture of argon and air.

The subject of an analysis is 1m^2 of a single-chamber aluminium frame window (Fig. 1).

Fig. 1. Construction of a single-chamber aluminium frame
http://www.infookno.pl/Izolacja_termiczna_szyb_zespolonych_w_oknach_i_fasadach

2.3 Supply chain of the product

The supply chain of single-chamber aluminium frame window consist of different links located in upstream and downstream. It is an international supply chain with the first, second and third tier suppliers.

Supply chain leader is a described manufacturer of a single-chamber aluminium frame window. One of its plant is located in Lodz. The company cooperates with different suppliers. It purchases a liquid hydrogen and liquid nitrogen from the same supplier, Linde Gaz Polska Sp. z o.o. located in Lodz (Traktorowa 145 street). The soda powder is received form a manufacturer CIECH Soda Polska S.A. (Fabryczna 4 street, Inowrocław). Tomaszowskie Kopalnie Surowców Mineralnych "BIAŁA GÓRA" (Łozińskiego street, Smardzewice) provides all plants with silica sand. The supplier of steel, P.W. OPTIMAX sp. z o.o. is located in Lodz (Wróblewskiego street, Łódź). Tin is transported from Eisenberg (Germany), from VOESTALPINE BÖHLER WELDING FONTARGEN GMBH, whereas KOPALNIA WAPIENIA "MORAWICA" S.A. is a vendor of a limestone. Silica sand, tin and limestone are transported by railway**.**

The plant cooperates with two vendors of aluminium frames. One of them is located in Warsaw and the another - in Lodz. The supplier of a plastic film (Pam-Folie Sp. z o.o.) has a factory in Aleksandrów Łódzki. Finally, the supplier of polyvinylchloride is from in China (Shenzhen). In this case, the company uses maritime transport to Gdynia and then, road transport to Lodz. The supply chain consists of second and third suppliers too (Fig. 2).

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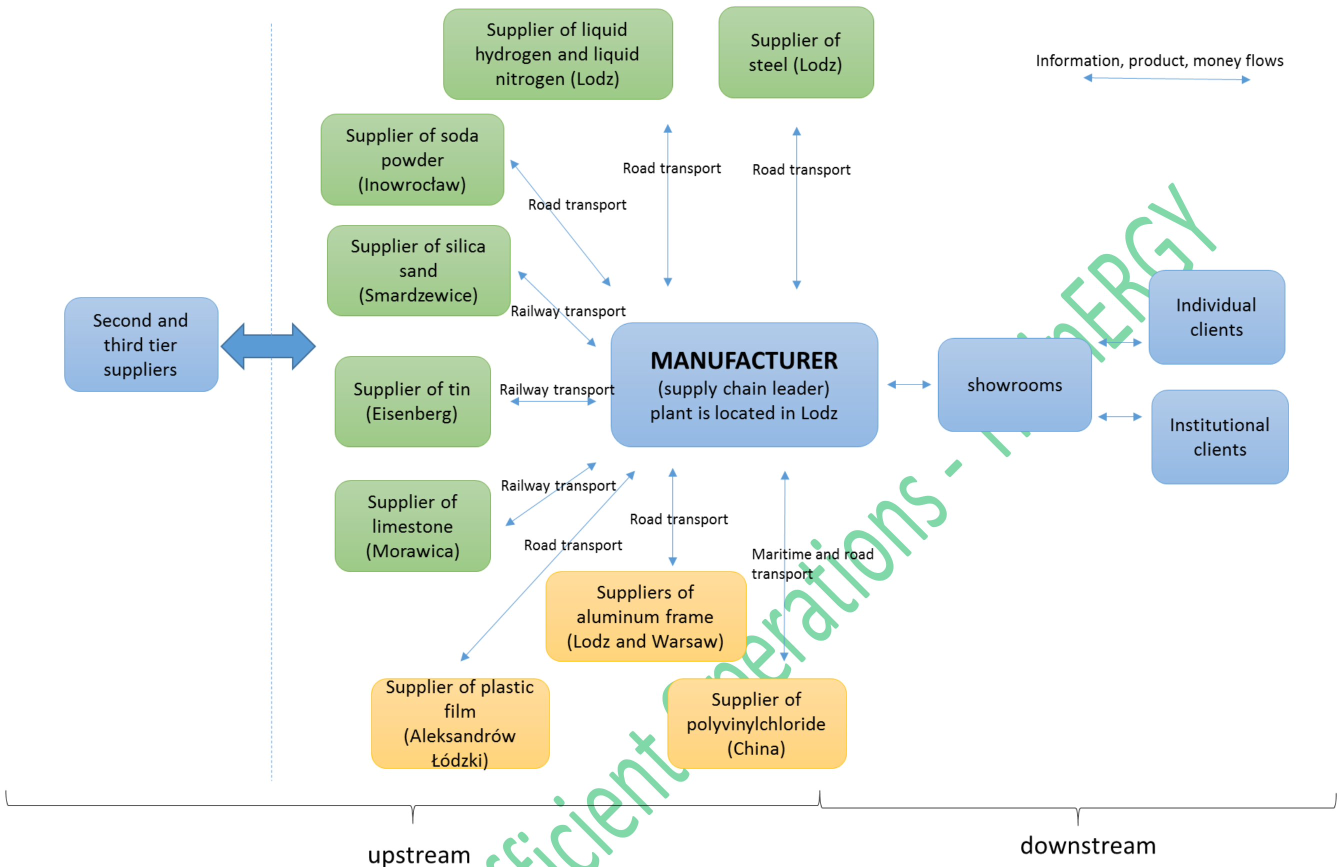

Fig. 2. Supply chain of a single-chamber aluminium frame window

3 Main Analysis

3.1 Process approach

The process of manufacturing a single-chamber aluminium frame window is rather simple. It is divided into two main phases:

1. producing of a glass
2. producing of a window

The first phase requires the following materials:

- Liquid Hydrogen
- Liquid Nitrogen
- Soda Powder
- Silica Sand

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- Steel
- Tin
- Limestone

The output of the first production phase is a glass. The glass is used in the second phase, together with:

- Aluminium frame
- Plastic film
- Polyvinylchloride

The production process of one window requires the two layers of a glass. One layer has 0,83 m^2. The frame is made of an aluminium. During the production process performed in a company's plant, the aluminium frame is covered with a plastic that is made of a polyvinylchloride. Plastic gives a colour and strengthens the frame construction. Finally, the frame is covered with a plastic film that protects window against environmental factors and mechanical damages during logistics and montage processes.

The whole manufacturing process also requires such sources of energy as:

- Electricity
- Gas
- Fuel Oil

3.1.1 Resources and materials

Table 1. Resources and materials

Process	Input/Element/Material	Quantity (per single unit like kg, km etc.)	Physical Unit	Approximate/Average Cost Unit	Total cost
1 Glass production (1m^2)	Liquid Hydrogen	0,0000045	m3	-	-
	Liquid Nitrogen	0,04	m3	-	-
	Soda Powder	2,29	kg	-	-
	Silica Sand	0,6	kg	-	-
	Steel	0,000137	Kg	-	-
	Tin	0,0000916	kg	-	-
	Limestone	4,05	kg	-	-
2 Window production (1m^2)	Aluminium frame	13,36	kg	-	-
	Plastic film	0,9	kg	-	-
	Polyvinylchloride	0,9	kg	-	-
	Glass	2x0,83	m2	-	-

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3.1.2 Energy usage (per single unit of analysed product)

Table 2. Energy usage

Process	Energy	Quantity (single unit like kg, km etc.)	Physical Unit	Approximate/Average Cost Unit	Total cost
1 Glass production ($1m^2$)	Electricity	1,2	kWh	0,53143	-
	Gas	35,6	MJ	0,0019927	-
	Fuel Oil	0,738	kg	0,45249	-
2 Window production ($1m^2$)	Electricity	12,08	kWh	0,53143	-

3.1.3 Packages (per single unit of analysed product)

Table 3. Packages

Process	Sort of package	Quantity (single unit like kg, km etc.)	Physical Unit	Approximate/Average Cost Unit	Total cost
1 Glass production ($1m^2$)	NA			-	-
2 Window production ($1m^2$)	NA			-	-

3.1.4 Water Usage (per single unit of analysed product)

Table 4. Water Usage

Process	Water	Quantity (per single unit of analysed product)	Physical Unit	Approximate/Average Cost Unit	Total cost
1 Glass production ($1m^2$)	NA			-	-
2 Window				-	-

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production ($1m^2$)					

3.1.5 Means of transport (per single unit of analysed product)

Table 5. Means of transport

Process	Transport	Distance / type of transport	Weight (* converted from m3 to kg)	Tonokilometers (km x the volume transported per month (in tonnes))	Approximate / Average Cost Unit	Total cost
1 Glass production ($1m^2$)	Liquid Hydrogen	14 km / road	0,0000036*	0,0000000504	-	-
	Liquid Nitrogen	14 km / road	0,00495*	0,0000693	-	-
	Soda Powder	190 km / road	2,29	0,4351	-	-
	Silica Sand	60 km / rail	0,6	0,036	-	-
	Steel	5 km / road	0,000137	0,000000685	-	-
	Tin	650 km / rail	0,0000916	0,00005954	-	-
	Limestone	170 km / rail	4,05	0,6885	-	-
2 Window production ($1m^2$)	Aluminium frame	150 km / road	13,36	2,004	-	-
	Plastic film	22,5 km / road	0,9	0,02025	-	-
	Polyvinylchloride	Maritime (Shenzen-Gdynia): 20200 km / sea	0,9	18,18	-	-
		Road (Gdynia-Lodz): 366km / road	0,9	0,3294	-	-

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3.1.6 Waste (per single unit of analysed product)

Table 6. Waste

Process	Waste	Amount	Amount per single unit of analysed product	Approximate/Average Cost Unit	Total cost
1 Glass production (1m^2)	Waste (not specified)	-	0,29 kg	-	-
2 Window production (1m^2)	NA				

3.2 Scenat analysis

3.2.1 SC Carbon Map

A. Table of SC Carbon Map

	Input	Quantity	Unit	GHG Intensity [kg CO_2eq/unit]	Unit Price [€/Unit]
Glass production - transport	In-bound road	0.722382	tkm	0.16743	
	In-bound rail	1.202769	tkm	0.039603	
Glass production (2 x 0,83 m^2=1,66m^2 is used for a 1m^2 of window)	Liquid Hydrogen	0.00000747	m3	2.0774	
	Liquid Nitrogen	0.0664	m3	0.40767	
	Soda Powder	3.8014	kg	0.4418	
	Silica Sand	0.996	kg	0.044043	
	Steel	0.00022742	Kg	4.8454	
	Tin	0.00015206	kg	21.655	

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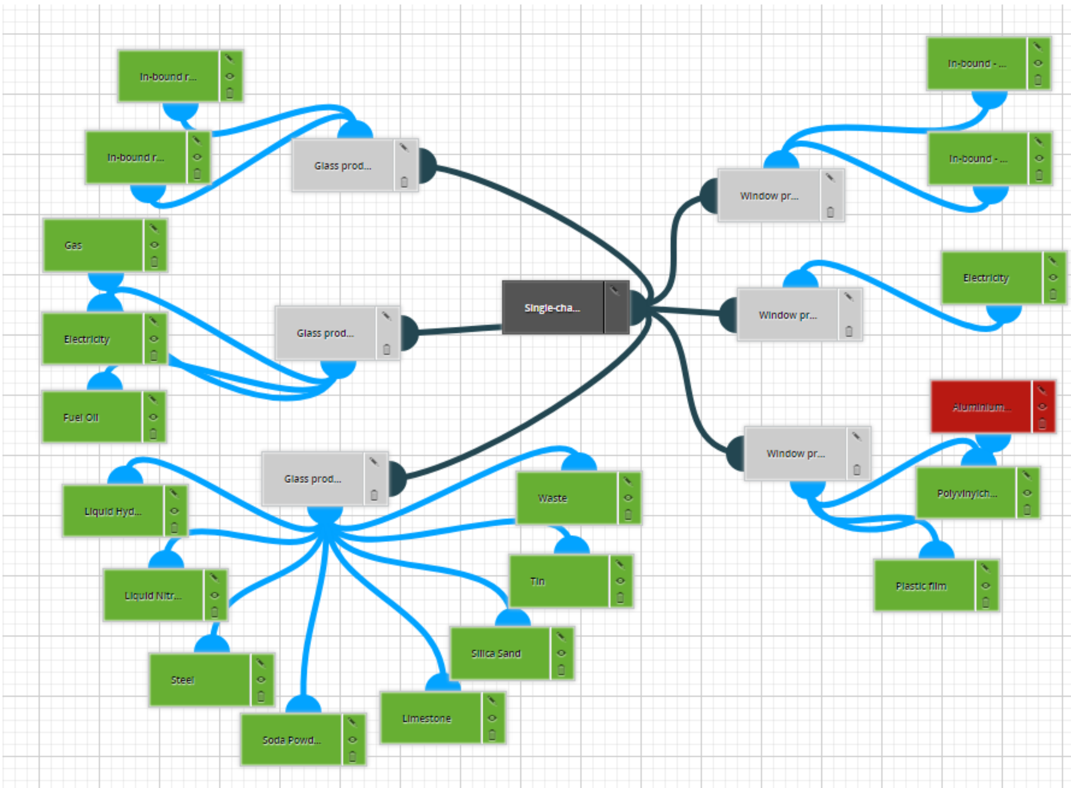
	Limestone	6.723	kg	0.016485	
	Waste	0.29	kg	0.50486	
Glass production - utilities	Electricity Gas Fuel Oil	1.992 59.096 1.22508	kWh MJ kg	1.1625 1.0555 0.097995	
Window production - transport	In-bound - road In-bound - sea	2.35365 18.18	tkm tkm	0.16743 0.011326	
Window production	Aluminium frame Plastic film Polyvinylchloride	13.36 0.9 0.9	kg kg kg	773.83 0.60297 2.1525	
Window production - utilities	Electricity	12.08	kWh	1.1625	

B. Picture from Scenat



3.3 Results

Total emission of assessed product is 10422.48 kg. Only one process is considered as hotspot (red colour) - production of aluminium frame, so it causes the greatest impact on environment. In this process 10338.37 kg of CO2 is emitted, which comprised 99.19 % of its total amount. Rest of the inputs are negligible (green colour) in the first stage of our analysis.

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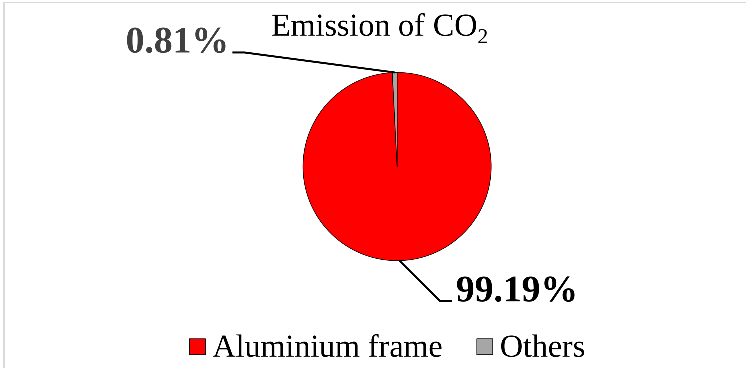

4 Possible improvements

In our scenarios, we didn't take into account the cost of improvements. However, the European Union co-finances projects related to using of renewable energy sources and the implementation of innovative solutions in the production process.

4.1 Scenario 1

4.1.1 SC Carbon Map

Step 1

The first scenario considers replacing aluminium frame with fiberglass frame during window production since this input causes greatest harm to the environment. New material can be delivered from Carbon Centre s.c. company located 10 km away from the window producer. It requires changing in-bound road transport data.

A. Table of SC Carbon Map

	Input	Quantity	Unit	GHG Intensity [kg CO_2eq/unit]	Unit Price [€/Unit]
Glass production - transport	In-bound road	0.722382	tkm	0.16743	
	In-bound rail	1.202769	tkm	0.039603	
Glass	Liquid Hydrogen	0.00000747	m3	2.0774	

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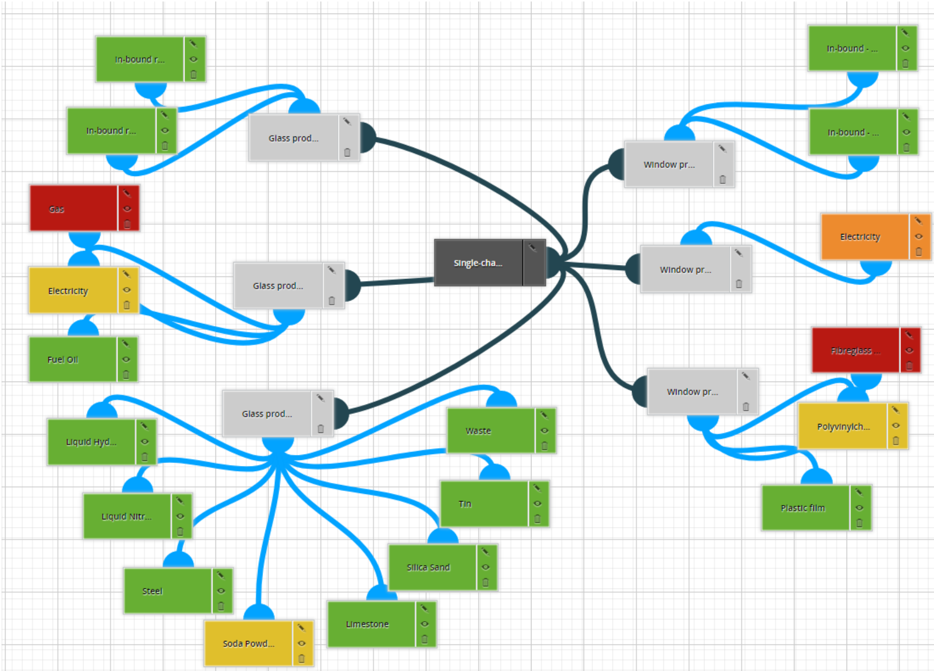
production (2 x 0,83 m^2=1,66m^2 is used for a 1m^2 of window)	Liquid Nitrogen	0.0664	m3	0.40767	
	Soda Powder	3.8014	kg	0.4418	
	Silica Sand	0.996	kg	0.044043	
	Steel	0.00022742	kg	4.8454	
	Tin	0.00015206	kg	21.655	
	Limestone	6.723	kg	0.016485	
	Waste	0.29	kg	0.50486	
Glass production - utilities	Electricity	1.992	kWh	1.1625	
	Gas	59.096	MJ	1.0555	
	Fuel Oil	1.22508	kg	0.097995	
Window production - transport	In-bound - road	0.57492	tkm	0.16743	
	In-bound - sea	18.18	tkm	0.011326	
Window production	Fiberglass frame	31.552	kg	2.2634	
	Plastic film	0.9	kg	0.60297	
	Polyvinylchloride	0.9	kg	2.1525	
Window production - utilities	Electricity	12.08	kWh	1.1625	

B. Picture from Scenat



Results

After the first improvement, we observed that CO_2 emission dropped significantly from 10 422.48 kg to 155.23 kg and another factors became noticeable, but the fiberglass frame is still marked as a hotspot. First of all, gas during glass production process is marked as a hotspot. Secondly, electricity in both glass production and window production appear to be vastly influential when it comes to the harmful emissions.

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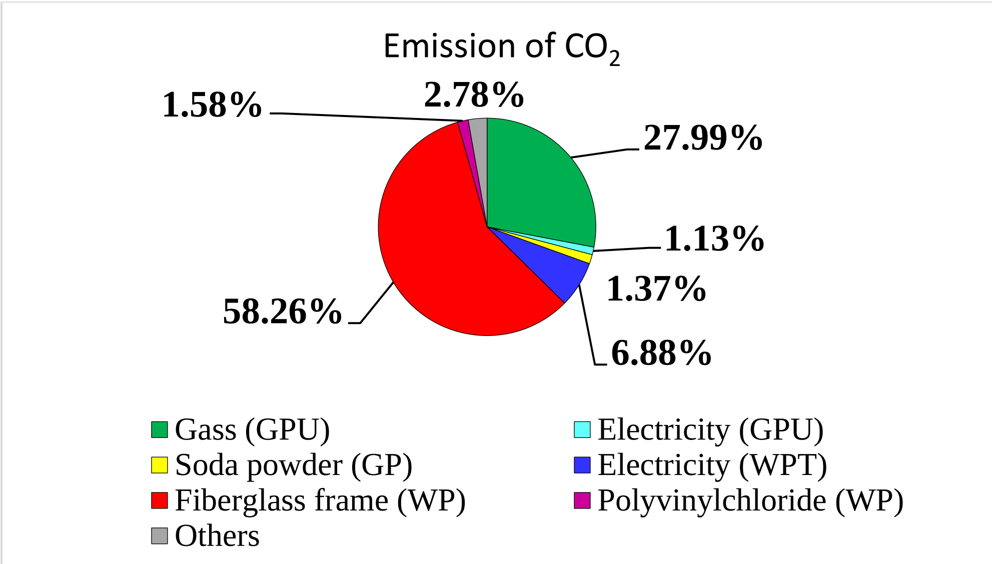


GP – Glass production, GPT – Glass production transport, GPU – Glass production utilities, WP – Window production, WPT – Window production transport, WPU – Window production utilities

4.1.2 SC Carbon Map

Step 2

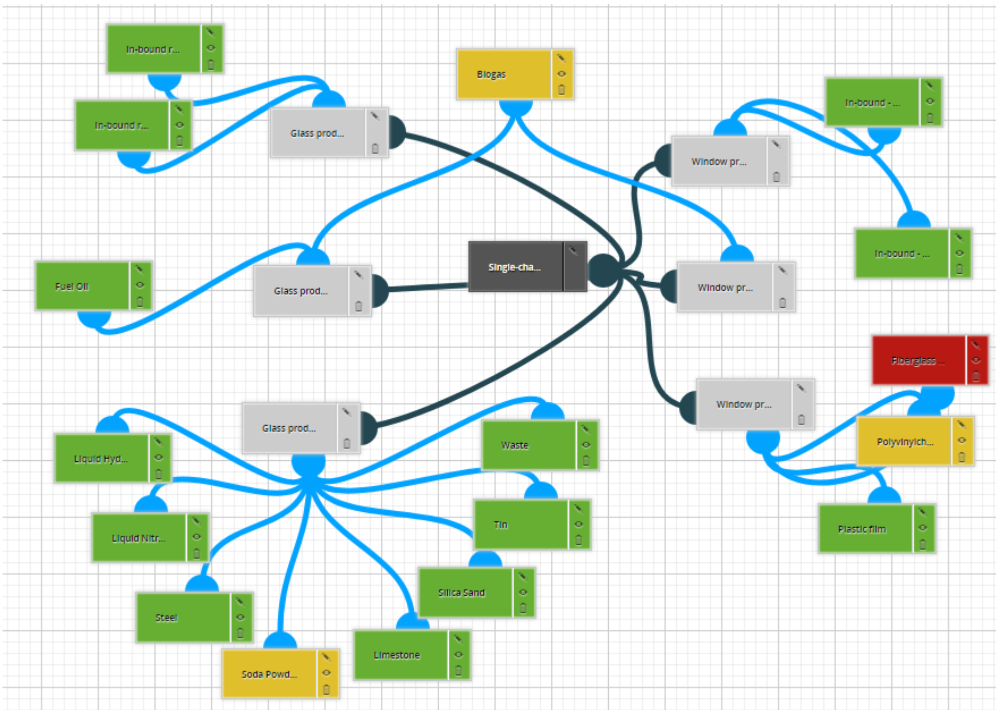
Our final solution enables to reduce all three expressed issues. Biogas is expected to be a feasible replacement for natural gas as well as a perfect source of energy in two processes. It is produced from plants by numerous firms in Poland. We have chosen agriKomp located in Ostrzeszow, 150 km from Lodz.

A. Table of SC Carbon Map

	Input	Quantity	Unit	GHG Intensity [kg CO_2eq/unit]	Unit Price [€/Unit]
Glass production - transport	In-bound road	1.214088	tkm	0,16743	
	In-bound rail	1.202769	tkm	0,039603	
Glass	Liquid Hydrogen	0.00000747	m3	2.0774	

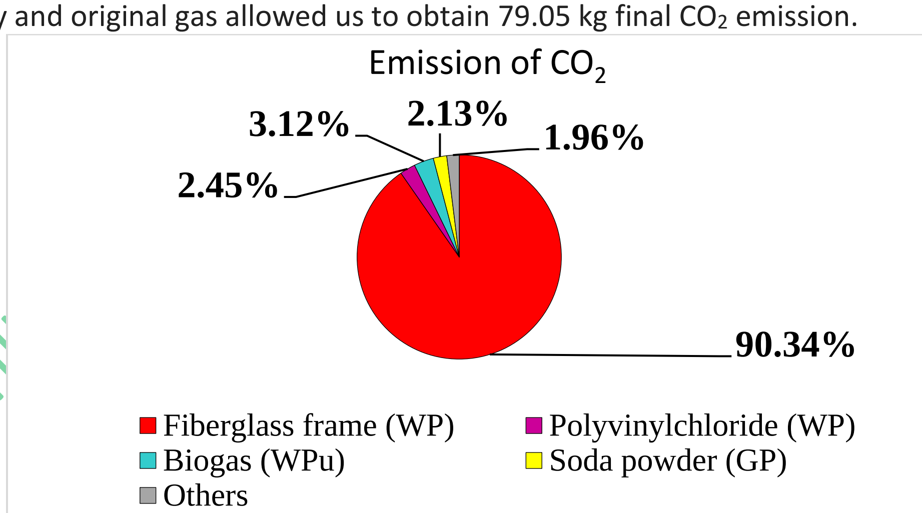
production (2 x 0,83 m^2=1,66m^2 is used for a 1m^2 of window)	Liquid Nitrogen	0.0664	m3	0.40767	
	Soda Powder	3.8014	kg	0.4418	
	Silica Sand	0.996	kg	0.044043	
	Steel	0.00022742	Kg	4.8454	
	Tin	0.00015206	kg	21.655	
	Limestone	6.723	kg	0.016485	
	Waste	0.29	kg	0.50486	
Glass production - utilities	Fuel Oil	1.22508	kg	0.097995	
Window production - transport	In-bound - road	0.57492	tkm	0.16743	
	In-bound - sea	18.18	tkm	0.011326	
Window production	Fiberglass frame	31.552	kg	2.2634	
	Plastic film	0.9	kg	0.60297	
	Polyvinylchloride	0.9	kg	2.1525	
Glass production & Window production - utilities	Biogas	109.7552	MJ	0.022463	

B. Picture from Scenat



Results

Value of tonokilometers in in-bound road transport increases by 0.491706. Finally, elimination of electricity and original gas allowed us to obtain 79.05 kg final CO_2 emission.



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4.2 Scenario 2

4.2.1 SC Carbon Map

Step 1

In the second scenario our team decided to build the wooden frame instead of the aluminium one. Change of the material supplier (BTH Drewno s. c., 10 km from our company) influenced in-bound road transport during window production process.

A. Table of SC Carbon Map

	Input	Quantity	Unit	GHG Intensity [kg CO_2eq/unit]	Unit Price [€/Unit]
Glass production - transport	In-bound road	0.722382	tkm	0,16743	
	In-bound rail	1.202769	tkm	0.039603	
Glass production (2 x 0,83 m²=1,66m² is used for a 1m² of window)	Liquid Hydrogen	0.00000747	m3	2.0774	
	Liquid Nitrogen	0.0664	m3	0.40767	
	Soda Powder	3.8014	kg	0.4418	
	Silica Sand	0.996	kg	0.044043	
	Steel	0.00022742	kg	4.8454	
	Tin	0.00015206	kg	21.655	
	Limestone	6.723	kg	0.016485	
	Waste	0.29	kg	0.50486	
Glass production -	Electricity	1.992	kWh	1.1625	
	Gas	59.096	MJ	1.0555	

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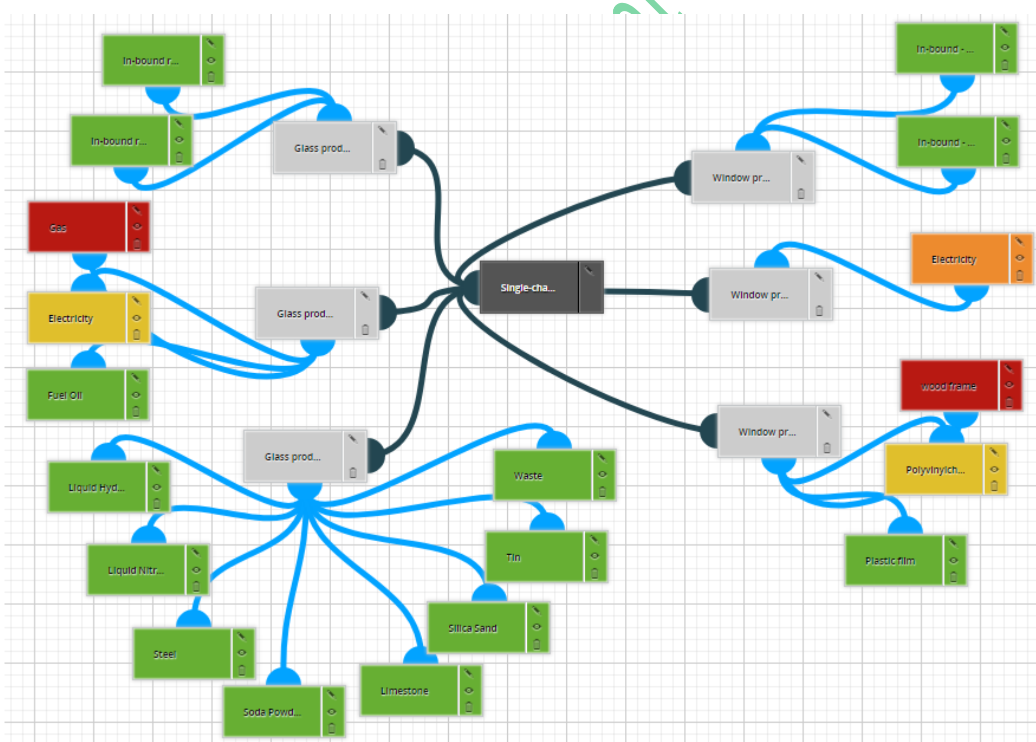
utilities	Fuel Oil	1.22508	kg	0.097995	
Window production - transport	In-bound - road In-bound - sea	0.45811 18.18	tkm tkm	0.16743 0.011326	
Window production	Wooden frame Plastic film Polyvinylchloride	10.846 0.9 0.9	kg kg kg	8.0586 0.60297 2.1525	
Window production - utilities	Electricity	12.08	kWh	1.1625	

B. Picture from Scenat



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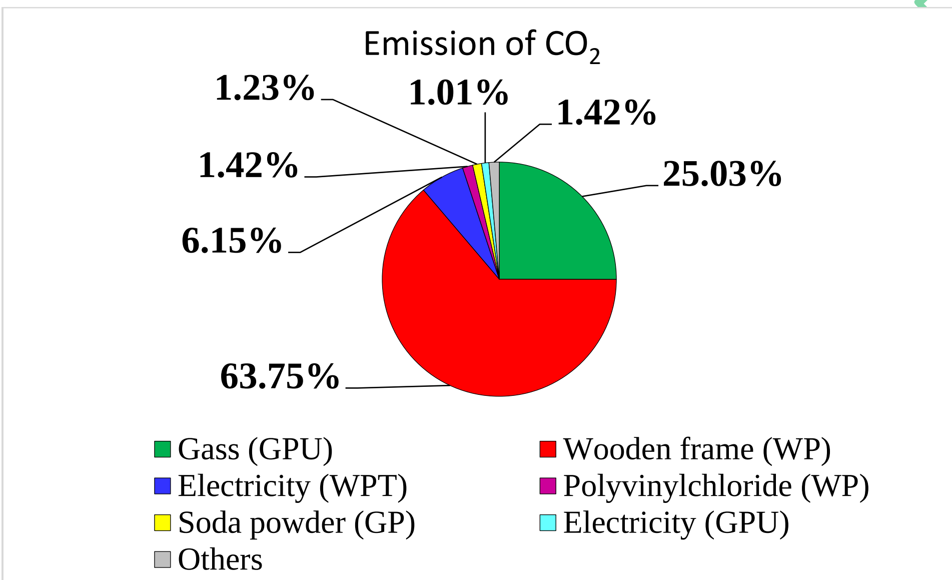
Results

Realisation of this step reduced CO_2 emission from 10 422.48 kg to 171.2 kg. Nevertheless, after this improvement the wooden frame is still the main source of CO2 emissions and it is marked as a hotspot. Similarly to the first scenario, different inputs appeared as environmentally-detrimental. Gas and electricity in glass and window production cause visible harm also in this case.



GP – Glass production, GPT – Glass production transport, GPU – Glass production utilities, WP – Window production, WPT – Window production transport, WPU – Window production utilities

4.2.2 SC Carbon Map

Step 2

After researching different databases, we encountered oxygen-gas jets Cleanfire – a modern technology for cutting down emissions during normal gas usage by 45%. It can hardly be overestimated when it comes to glass production. Furthermore, solar panels energy is an immensely profitable resource when the company desires to become more eco-friendly. 100 panels located on 202 m^2 perfectly replace electricity in two main processes.

A. Table of SC Carbon Map

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	Input	Quantity	Unit	GHG Intensity [kg CO_2eq/unit]	Unit Price [€/Unit]
Glass production - transport	In-bound road	0.722382	tkm	0.16743	
	In-bound rail	1.202769	tkm	0.039603	
Glass production (2 x 0,83 m^2=1,66m^2 is used for a 1m^2 of window)	Liquid Hydrogen	0.00000747	m3	2.0774	
	Liquid Nitrogen	0.0664	m3	0.40767	
	Soda Powder	3.8014	kg	0.4418	
	Silica Sand	0.996	kg	0.044043	
	Steel	0.00022742	Kg	4.8454	
	Tin	0.00015206	kg	21.655	
	Limestone	6.723	kg	0.016485	
	Waste	0.29	kg	0.50486	
Glass production - utilities	Electricity	1.1952	kWh	1.1625	
	Solar panel energy	0.7968	kWh	0.087935	
	Gas	32.5028	MJ	1.0555	
	Fuel Oil	1.22508	kg	0,097995	
Window production - transport	In-bound - road	0.45811	tkm	0.16743	
	In-bound - sea	18.18	tkm	0.011326	
Window	Wooden frame	10.846	kg	8.0586	

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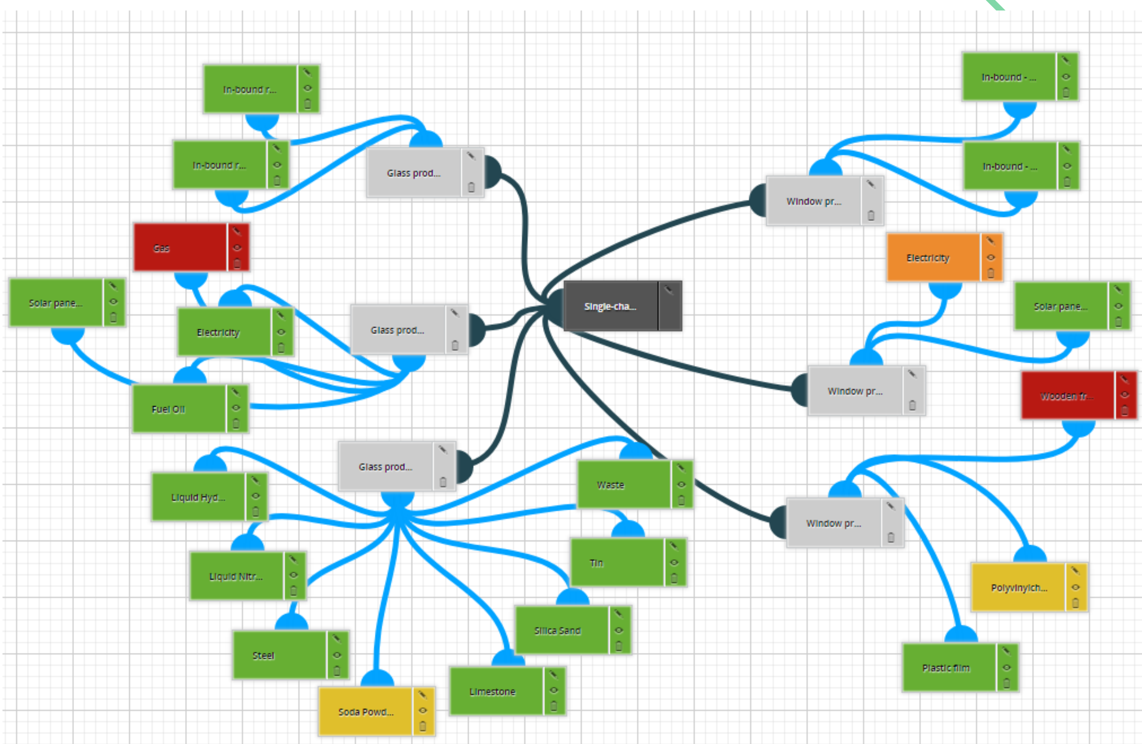
production	Plastic film	0.9	kg	0.60297	
	Polyvinylchloride	0.9	kg	2.1525	
Window production - utilities	Electricity Solar panel energy	7.248 4.832	kWh kWh	1.1625 0.087935	

B. Picture from Scenat



Results

Total CO_2 emission decreased from 171.2 kg to 137.08 kg thanks to an innovative implementation of the newest technologies.

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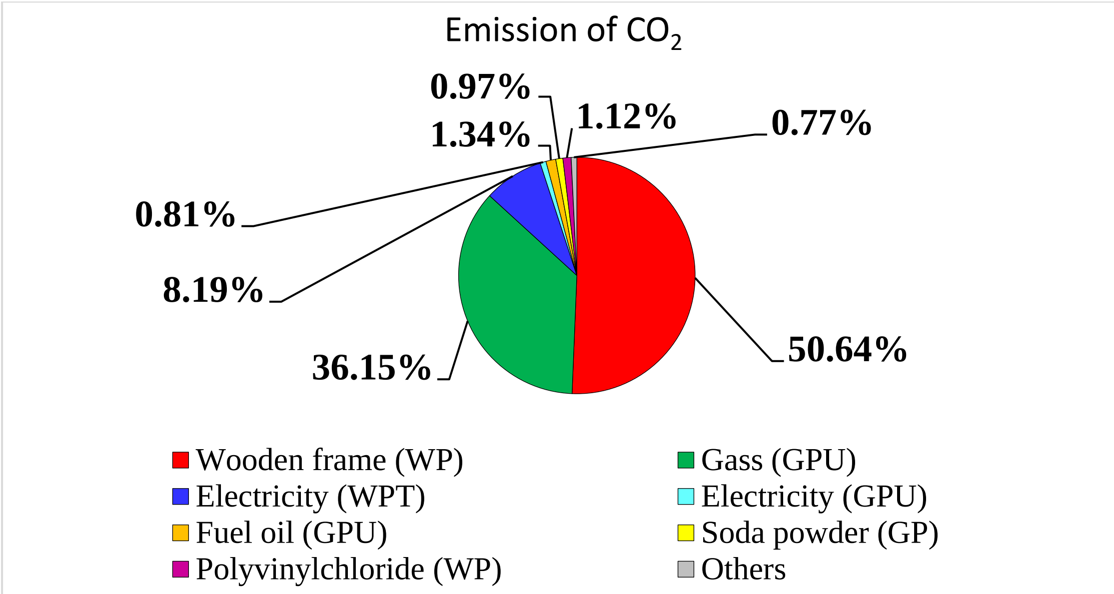

GP – Glass production, GPT – Glass production transport, GPU – Glass production utilities, WP – Window production, WPT – Window production transport, WPU – Window production utilities

5 Final conclusions

In fact, the production process of a single chamber is quite simple but it is very harmful to the environment. However, innovations which we proposed let reduce total emissions of CO_2 significantly. We suggested that it is possible to change a raw material in the production of the window frame. Fiberglass frame has been implemented with a success in Canada and United States of America. Producers claim that fiberglass frame is as energy efficient and strong as standard aluminium or wooden frame. Moreover, it is quite easy to find a supplier of fiberglass in the nearest area of our company. Next, we proposed to change aluminium frame to wooden frame. It can seem to be not very eco-friendly because of deforestation but the company can try to find some possibilities to use remains from wood processing in different companies. The changes of raw material let reduce not only the direct emission of CO_2 but also the influence of the transport. Other ideas in the majority are dedicated to replacement standard source of energy with modern, alternative ones as solar panels, biogas etc. We believe that this kind of solutions can help to protect the environment with a rule of sustainable development and let the company achieve high profits and great position to compete on the international market.

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