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A COMPANY'S CARBON FOOTPRINT AND SUSTAINABLE DEVELOPMENT

OGLJIČNI ODTIS PODJETJA IN TRAJNOSTNI RAZVOJ

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Abstract

Climate changes are already here. And they will get much worse in time. The main reason for global warming is GHG emissions from anthropological sources. That includes transportation, industry, electricity production, agriculture, and others. The European Union has introduced a new Green Deal as an answer to climate change. The European Green Deal puts more pressure on companies to mitigate their carbon footprint and implement sustainable development. One of the basic steps in the analysis of the environmental profile of a company is the identification of hot spots by using the carbon footprint methodology. The workflow of the carbon footprint calculation follows GHG Protocol standardised methodology. The calculation was made for a medium-sized company in the plastics industry. For all GHG emission sources, hot spots were identified and analysed. Based on the hot spots, sensitivity analysis for different pre-defined scenarios has been made, which are aligned with the company's mid- and long-term sustainability goals. The three main hot spots of the company within scopes 1 and 2 are purchased heat, purchased electricity, and combustion of fuels in company vehicles. GHG emissions of heat and electricity are dependent on their distributor and their electricity and heat sources. The hot spot of scope 3 is purchased goods, especially plastic granulate. In the study, we focus only on scope 1 and scope 2.

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Povzetek

Podnebne spremembe so že tu in s časom postajajo vse hujše. Glavni razlog za globalno segrevanje so toplogredne emisije iz antropogenih virov. Te vključujejo transport, industrijo, proizvodnjo električne energije, kmetijstvo in ostale. Odgovor Evropske unije na podnebne spremembe je Evropski zeleni dogovor. Ta povečuje pritisk na podjetja za zmanjšanje njihovim toplogrednih emisij in implementacijo trajnostnega razvoja. Eden temeljnih korakov pri analizi okoljskega profila podjetja je identifikacija vročih točk z uporabo metodologije ogljičnega odtisa. Potek izračuna ogljičnega odtisa podaja standardizirana metodologija GHG Protocol. Analiza je narejena za srednje-veliko podjetje iz sektorja plastične industrije. Med vsemi viri toplogrednih emisij so identificirane in analizirane vroče točke podjetja. Glede na identificirane vroče točke je narejena tudi občutljivostna analiza za različne scenarije, ki so v skladu s srednje in dolgoročnimi trajnostnimi cilji podjetja. Vroče točke podjetja znotraj obsega 1 in 2 so toplota, elektrika in uporaba osebnih avtomobilov podjetja. Toplogredne emisije toplote in elektrike so odvisne od distributerja in njegovih virov energije. Najvplivnejša kategorija obsega 3 je kategorija kupljeno blago in storitve, predvsem nakup plastičnega granulata. V študiji se osredotočamo zgolj na obseg 1 in obseg 2.

1 INTRODUCTION

Climate change represents one of the biggest threats to humanity. The Intergovernmental Panel on Climate Change (IPCC) in their last report [1] states that because of the excessive use of fossil fuels, the concentration of greenhouse gases (GHG) in the atmosphere has been increasing since 1750. Today we have the highest level of concentration of GHG emissions of the last 2 billion years. GHG emissions are the main cause of the global warming we are facing today. The last four decades have been the warmest since 1850. Although we are aware of the situation, and according to Kacha et. al. [2] around 94% of Europeans believe that the climate is definitely or probably changing, we do not act. Energy consumption is still rising, according to the International Energy Agency (IEA) [3].

Climate change is not only a threat to our physical environment, but according to Letcher [4], it also causes social injustice and creates climate refugees. Social inequalities continue to increase, and the gap between social classes is widening. More and more people already live in almost uninhabitable areas, from where they migrate to other, more climate-friendly countries. This, unfortunately, causes tensions between people of different cultures, values and races. All this social tension, which is indirectly caused by climate change, further distances us from solving this global crisis.

Global warming is happening due to the change in the equilibrium of energy flows between the Earth and space. With an increased concentration of greenhouse gases in the atmosphere, more energy can be absorbed in the atmosphere, meaning that the greenhouse effect would also increase. Consequently, more energy is held by the atmosphere, and therefore the Earth's climate is warming. The Earth's energy balance is presented in Figure 1.

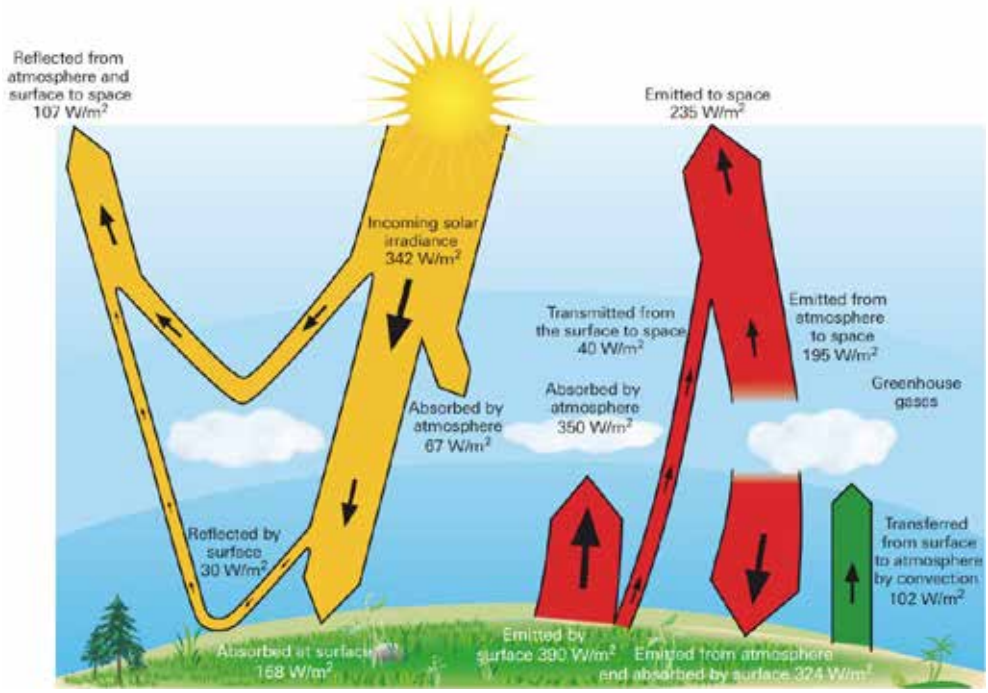

Figure 1: *Earth energy balance, [5]*

One of the biggest reasons why global warming is such a serious problem is the feedback mechanism, fuelling itself when triggered, as is explained by Letcher [4]. And it has already been triggered. The concentration of water vapour, which is an important GHG, is increasing, as ice is melting, making the surface of the Earth less reflective and therefore absorbing more solar radiation, as land and open water takes the place of ice, etc. With the ocean's temperature increasing, less carbon dioxide (CO_2) can be stored within in, which again increases the concentration of CO_2 in the atmosphere. Meaning that even if we stopped emitting GHGs, feedback mechanisms would still continue global warming to some extent. The scientists on the IPCC [1] agree that the point of no return is an increase in global temperature of more than 2°C compared to the pre-industrial average. Scientists believe that if global temperatures increase above 2°C it would cause irreversible changes in the Earth's climate, with it gradually becoming uninhabitable for the human race.

If we want to preserve the human race, countries need to act according to the international climate agreements they signed. The Paris Agreement, and in particular the Glasgow Climate Pact, set up measures for GHG reduction that would slow down and eventually stop global temperature rise. But with the Covid-19 pandemic and the Ukraine-Russia crisis, countries are unlikely to meet these goals and stop this global catastrophe. Nevertheless, the European Union (EU) took a step in the right direction with its new Green Deal, which puts pressure on companies to follow sustainable development guidelines. One of the core sustainable development elements is a company's carbon footprint.

The carbon footprint is a methodology for calculating the GHG emissions made by a company. There are many different definitions of the carbon footprint, as discussed in the study by Wright

et. al. [6]. In this paper, the carbon footprint is defined as "A measure of the total amount of GHG emissions determined in the Kyoto Protocol plus NF3 emissions of a defined company, taking into account all relevant sources, sinks, and storage within the spatial and temporal boundary of the company, calculated as CO_2eq using the relevant 100-year global warming potential (GWP100)".

2 GHG PROTOCOL METHODOLOGY

Over time, different methodologies for the calculation of carbon footprint have been defined. Out of the need for a standardised method, so that comparison between different carbon footprints is possible, ISO Standard 14064 [7] was introduced. In this study the GHG Protocol methodology was used, which is defined in the GHG Protocol Corporate Accounting and Reporting Standard [8]. In addition, the Technical Guidance for Calculating Scope 3 Emissions [9] was also used. GHG Protocol methodology is used and recognised worldwide and was used as the basis of ISO Standard 14064.

2.1 Organizational Boundaries

Organizational boundaries are the first step in the GHG Protocol methodology. Organizational structures of companies come in many forms, therefore the definition of organizational boundaries is a necessary and very important step. Two different approaches could be used: the equity share approach and the control approach.

With the equity share approach, the company accounts for GHG emissions from GHG sources based on its share of equity in the operation of the GHG source. The equity share reflects the economic interest of the company.

With the control approach, the company accounts for all GHG emissions from GHG sources over which the company has control. It does not account for GHG emissions from operations in which it owns an interest but has no control. Control can be financial or operational.

2.2 Operational Boundaries

The next step in the GHG Protocol methodology is the definition of operational boundaries. First, all GHG emission sources must be identified, then the GHG sources are categorised as direct or indirect emissions and put into a suitable scope. Direct GHG emissions are emissions from sources that are owned or controlled by the company. Indirect GHG emissions are emissions that are a consequence of the company's activities but occur at sources owned or controlled by another company.

As is shown in Figure 2, in GHG Protocol three scopes are defined: scope 1, scope 2, and scope 3. Scope 1 includes direct emissions. The most common GHG sources within scope 1 are generation of electricity, heat or steam; physical or chemical processing; transportation of materials, products, waste and employees; and fugitive emissions.

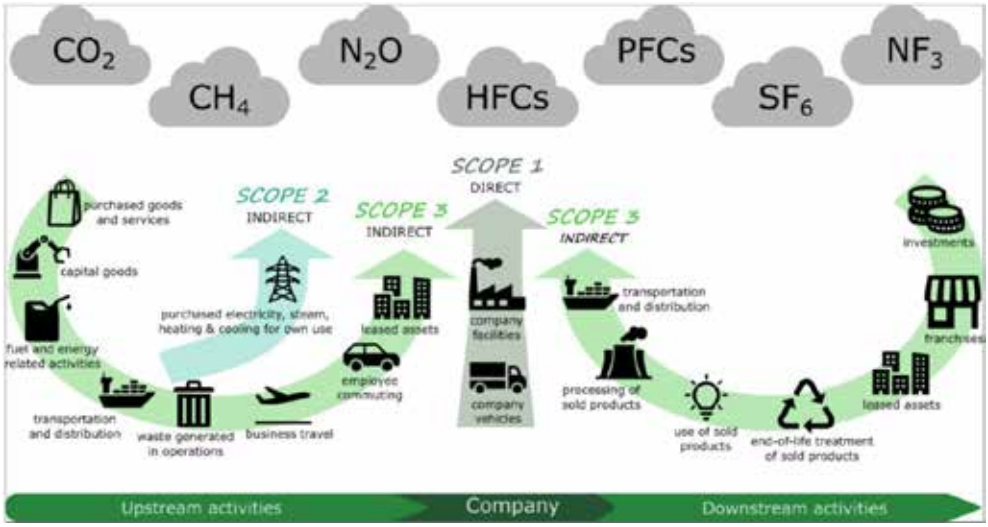

Figure 2: *Scopes of Carbon Footprint,* [9]

Scope 2 includes indirect GHG emission sources from purchased electricity, heat or steam. Electricity, heat or steam are consumed by the company, but the generation of electricity, heat or steam, and therefore its GHG emissions, do not occur within the company, but somewhere else.

Scope 3 includes all other indirect emission sources. They are divided into 15 categories, as presented in Figure 2. Scope 3 GHG emission sources are a consequence of the company's activities, but they are not owned or controlled by the company.

Indirect GHG emissions are divided into two scopes (scope 2 and scope 3), of which only scope 2 is mandatory to report (along with the direct GHG emissions of scope 1, of course). Scope 3 is optional, as the company does not have full control over these GHG sources. Therefore, the company has limited data that is needed for carbon footprint calculation. Also, the intensity of GHG emissions for each category varies from company to company. In contrast, GHG emission sources in scope 2 are very common, and almost every company purchases electricity or heat. Data for calculation of scope 2 GHG emissions is also easy to acquire because the distributor must state the energy sources of the electricity or heat provided.

2.3 Base Year

The company may need to track GHG emissions over time to compare carbon footprint over time, establish GHG targets, or for other reasons. To be able to make a meaningful and consistent comparison of GHG emissions over time the base year GHG emissions must be set. The company should choose the earliest relevant point in time for which they have reliable data as the base year. For consistent tracking of GHG emissions over time, the base year GHG emissions may need to be recalculated, as companies undergo significant structural changes, such as acquisitions, divestments and mergers.

3 ASSESSMENT OF CARBON FOOTPRINT IN A COMPANY

The workflow of the carbon footprint methodology is presented in Figure 3. The most time-consuming step is collecting data and choosing suitable emissions factors. Red arrows represent feedback loops that occur if there is no data or the quality of the data is not sufficient. With feedback loops, we ensure relevance, completeness and transparency.

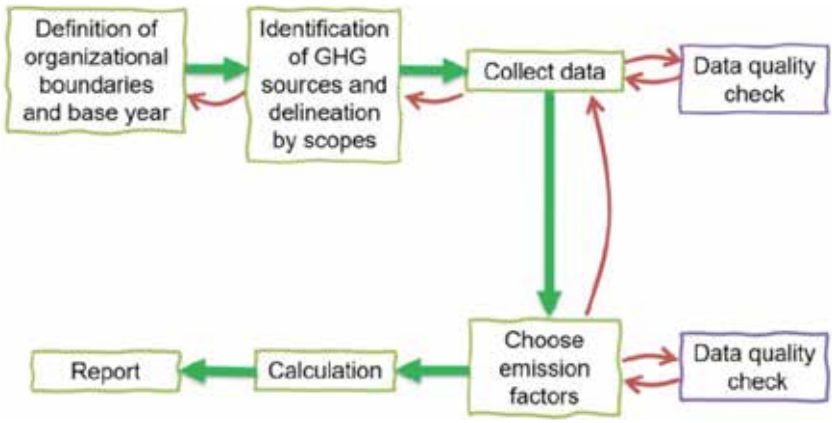

Figure 3: *Workflow of the carbon footprint methodology*

3.1 Boundary Conditions

A carbon footprint was made for a medium-sized company in the plastics industry. The year 2019 was chosen as the base year. We calculated only the base year's carbon footprint. Setting the organizational boundaries was very straightforward, as the company is located in only one place, where it has offices and production halls, and they do not have any joint operations. To define the organizational boundaries, we used the control approach.

3.2 Identification of GHG Sources

GHG emission sources for scopes 1 and 2 are presented in Table 1. GHG emission sources within scope 1 include vehicles and fugitive emissions. The company has passenger cars, delivery vehicles and forklifts. All of the passenger cars and delivery vehicles run on diesel, while one forklift is diesel, two run on liquefied petroleum gas (LPG), and the rest are electric. The company's fugitive emissions consist of refrigerants from cooling and air conditioning systems. All of them undergo annual checks. In the base year, leaking of only one refrigerant was detected. From one of the cooling systems, 8 kg of refrigerant R410A was emitted into the environment.

GHG sources within scope 2 are electricity consumption and district heating consumption. The company purchased electricity from a hydro energy source, while the energy source of district heating is lignite. Heat is provided from a cogeneration heat and power (CHP) plant.

Table 1: *GHG emission sources for scope 1 and scope 2*

GHG Sources	Base year (2019)
SCOPE 1	
Vehicles consumption	
Diesel [L]	22200
Passenger cars [L]	15200
Delivery vehicles [L]	4400
Forklifts [L]	2600
LPG – forklifts [kg]	2000
Fugitive emissions	
Refrigerant – R410A [kg]	8
SCOPE 2	
Electricity consumption [kWh]	7025
District heating consumption [MWh]	380

GHG emissions of scope 3 are not discussed in this study, although a calculation of scope 3 emissions has been made. The calculation includes the following scope 3 categories: purchased goods and services, upstream and downstream transportation and distribution, waste generated in operations, business travel, and employee commuting.

3.3 Uncertainty

The uncertainty of the carbon footprint calculation depends on the uncertainty of emissions factors and the uncertainty of activity data. Emissions factors are used from official databases, and therefore uncertainty is relatively small. Emissions factors from databases represent average processes for a specific nation or region. The use of averaged data and not specific data for processes is the biggest source of uncertainty of emissions factors. With additional checks of emissions factors, we make sure that the most appropriate emissions factor is selected, which means that the uncertainty is as low as possible.

The second uncertainty is the uncertainty of activity data. While the company owns all the processes, activity data has negligible uncertainty. Uncertainty of activity data is mostly due to uncertainty of measuring equipment and data processing within the company.

Overall, uncertainty for scopes 1 and 2 is small. The company has first-hand activity data, which has negligible uncertainty, and second-hand emissions factors, which are taken from official databases. Uncertainty of emissions factors could be lower if specific processes would be included in the databases.

Uncertainty of scope 3 is much bigger than the uncertainty of scopes 1 and 2, as the activity data is second-hand and often averaged, estimated, and generalised. Therefore, activity data is the main source of uncertainty for scope 3, as the databases from which emission factors are used

remain the same. The high uncertainty in scope 3 is one of the reasons why scope 3 is optional and is not included in this study.

4 RESULTS

In this section, carbon footprint results for scope 1 and scope 2 are presented for a medium-sized company in the plastics industry. Along with the results of the carbon footprint, which are presented in Table 2, we analyse and identify hot spots in scopes 1 and 2. Additionally, sensitivity analysis is also presented for various scenarios that could be implemented in the company and have the potential to reduce the carbon footprint.

Table 2: *The carbon footprint of scope 1 and scope 2*

GHG Sources	**Carbon footprint [t CO_2 eq.]**
SCOPE 1	**76.5**
Vehicles	61.1
Passenger cars	40.7
Delivery vehicles	11.8
Forklifts	8.6
Fugitive emissions – R410A	15.4
SCOPE 2	**159.8**
Electricity consumption	38.2
District heating consumption	121.6
TOTAL SCOPE 1 AND SCOPE 2	**236.3**

As presented in Table 2, scope 2 has a much bigger carbon footprint than scope 1. The carbon footprint of scope 1 is 76.5 t CO_2 eq., while the carbon footprint of scope 2 is 159.8 t CO_2 eq., which represents a 108% increase in carbon footprint. The total carbon footprint of scopes 1 and 2 is 236.3 t CO_2 eq., which is negligible compared to the scope 3 carbon footprint, which is 17915.5 t CO_2 eq. The carbon footprint of scopes 1 and 2 represent only 1.3% of the carbon footprint of scope 3.

4.1 Hot spots

Proportions of GHG emission sources are presented in Figure 4. By far the biggest source of GHG emissions is district heating consumption, which is responsible for 51% of the scope 1 and 2 carbon footprint. The reason for such high GHG emissions is the energy source of the district heat, which is lignite.

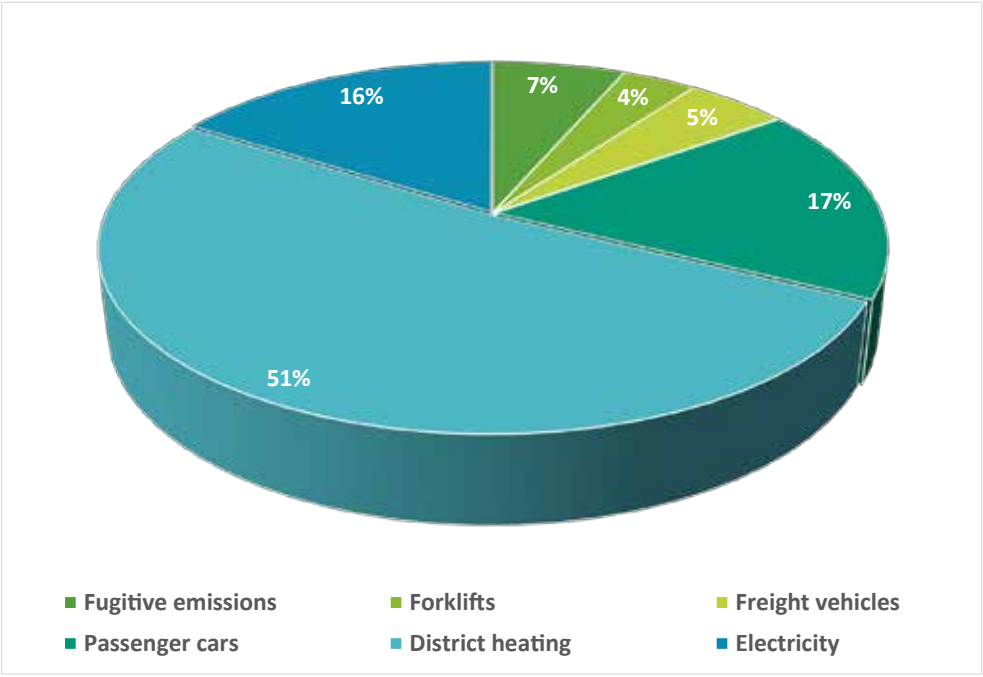

Figure 4: *GHG emission sources of scope 1 and scope 2*

If district heating is the hot spot of scope 2, the hot spot of scope 1 is passenger cars. Passenger cars are responsible for 53% of the carbon footprint of scope 1 and 17% of scopes 1 and 2. All the passenger cars are diesel. Other activities in scope 1 represent only small proportions of the carbon footprint.

Among noticeable activity is also electricity. It is responsible for 16% of the carbon footprint of scopes 1 and 2, which is almost the same as for passenger cars. Considering the amount of purchased electricity, its carbon footprint is really small. The reason for this is the source of electricity, which is hydro energy, one of the most carbon-neutral energy sources.

The hot spot of scope 3 is purchased goods and services, more precisely, purchases of plastic granulate. Plastic granulate is responsible for 86% of the carbon footprint of scope 3 and is the main reason why scope 3 GHG emissions are so high.

4.2 Sensitivity analysis

Different mitigation strategies that could be implemented by the company to reduce its carbon footprint of scopes 1 and 2 were analysed. Mitigation strategies are presented in the paper as activities A, B, C, D and E. After recalculation of the carbon footprint for each activity, a sensitivity analysis was conducted, analysing which activities contribute the most to GHG emission reduction. Results of the sensitivity analysis are presented in Figure 5.

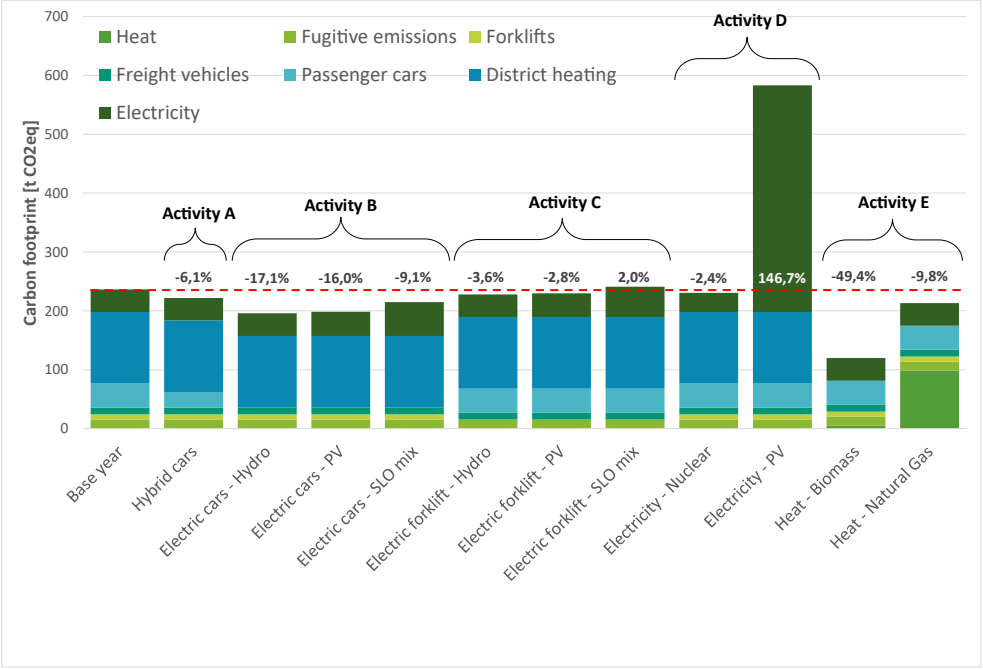

Figure 5: *Mitigation activities of carbon footprint for scopes 1 and 2*

The base scenario is the scenario for which we calculated the carbon footprint. Activity A substitutes diesel passenger cars with hybrid passenger cars. The emissions factor for the average hybrid car is taken from the DEFRA database [10]. Activity A contributes to a carbon footprint reduction of 14.4 t CO_2 eq., which means that the carbon footprint of scopes 1 and 2 would decrease by 6.1%.

Activity B is the electrification of diesel passenger cars. We compare the carbon footprint of electric cars for different electricity sources: hydro energy, PV energy, and the Slovenian electricity grid mix. We assume the power consumption of electric cars to be 22.5 kWh/100 km. With the use of hydroelectricity, the reduction in carbon footprint is 40.4 t CO_2 eq., which equals 17% of the carbon footprint of scopes 1 and 2. Similar reductions can be seen in the case of PV electricity. In this case, it is reduced by 37.9 t CO_2 eq., which is equivalent to 16% of the carbon footprint of scopes 1 and 2. For the Slovenian electricity grid mix, reductions are smaller, and only 21.5 t CO_2 eq. is mitigated, which equals 9% of the carbon footprint of scopes 1 and 2. If activity B was implemented, GHG emissions of scope 1 would drastically decrease, while scope 2 emissions would increase, because of the increase in electricity consumption.

Activity C is the electrification of diesel and LPG forklifts. We used the same electricity sources as in activity B. We assume that three electric forklifts would be needed, which are charged once a day and use 30 kWh of energy per charging. With hydroelectricity, GHG emission reduction is 8.4 t CO_2 eq. which equals 4% of the carbon footprint of scopes 1 and 2. Even smaller reductions are seen in the case of PV electricity, where only 6.7 t CO_2 eq. is reduced, which equals 3% of the carbon footprint of scopes 1 and 2. If the company electrified forklifts and used the Slovenian

electricity grid mix then the carbon footprint of the company would increase by 4.6 t CO_2 eq. As in activity B, if activity C is implemented GHG emissions fall within scope 2.

Activity D is a comparison of different electricity sources. We compare hydro energy (base scenario), nuclear energy and PV energy. The nuclear energy source has slightly lower GHG emissions than hydro energy, meaning that the company could have a minimal reduction in carbon footprint if they used nuclear power electricity. The reduction would be 5.7 t CO_2 eq., which is equivalent to 2% of the carbon footprint of scopes 1 and 2. If the company uses electricity from PV energy then the carbon footprint would increase by 346.8 t CO_2 eq., equivalent to a 147% increase in the carbon footprint of scopes 1 and 2. Although this seems like a big increase, and it is, it would be even worse if the company used a Slovenian grid mix. In that case, the increase of carbon footprint would be 2596.2 t CO_2 eq., which is a 1099% increase in the carbon footprint of scopes 1 and 2. Even more worrying is the fact that the Slovenian grid mix is below the European average [11].

Activity E is a comparison of different heat sources. We compare district heating on lignite from the CHP power plant (base scenario), local furnace on biomass, and local furnace on natural gas. Local furnace on biomass would reduce GHG emissions by 116.7 t CO_2 eq., which equals a 49% decrease in the carbon footprint of scopes 1 and 2. Reduction in the case of a local furnace on natural gas is a bit lower, 23.2 t CO_2 eq., which is a 10% decrease of the carbon footprint of scopes 1 and 2. If the company implemented activity with a local furnace, GHG emissions would fall within scope 1.

As is presented in Figure 5, by far the biggest reduction is achieved by activity E. Local furnace on biomass could reduce GHG emissions by almost 50%. The second biggest reduction is the electrification of passenger cars. Reductions are dependent on the type of electricity; the biggest reduction occurs with hydro energy sources and PV energy sources. The Slovenian electricity grid mix achieves some reductions, but they are still high compared to other activities. Activities A, C and D have relatively small impacts (below 7%), therefore the implementation of these activities does not have a big impact on the mitigation of carbon footprint. If we implemented all the most optimistic versions of the activities, the company could reduce its carbon footprint by 55%.

Scenario analysis considers purely theoretical implementations of activities. Technical and economic aspects of the implementation of activities are not considered in this study.

5 CONCLUSIONS

In the paper, the GHG Protocol methodology and calculation of carbon footprint for a middle-sized company in the plastics industry is assessed. The calculation is made for all three scopes with additional scenario analysis for five mitigation activities. Although scope 3 represents the vast majority of GHG emissions, the emphasis is on mitigation of scope 1 and scope 2 activities, because the company has more control over these activities.

Activity data needed for calculation for scopes 1 and 2 is provided by the company, therefore the uncertainty of the data is small. Emissions factors from official databases were used, which have relatively small uncertainty. Therefore, the uncertainty of the scope 1 and scope 2 calculation of carbon footprint is fairly small. On the other hand, the uncertainty of scope 3 is high, as the activity data is not gathered within the company but from partners of the company. Data is often averaged, estimated, and generalised, which is one of the reasons for high uncertainty.

The greatest GHG emission reductions are achieved with activity E – local furnace on biomass. Some reductions are also achieved with activity B – electrification of passenger cars with a hydro energy source. Other activities have much smaller impacts on the mitigation of carbon footprint. If we implemented all the most optimistic versions of the activities, the company could reduce its carbon footprint by 55%.

The carbon footprint is one of the most important tools for fighting global warming. If we want to mitigate the effects of climate change, a carbon footprint policy should be mandatory for all companies. It is expected that it will be implemented into European Union legislation in the future. Until then, carbon footprint is only on the agenda of sustainability-oriented companies, companies that are motivated by their distributors, or companies that are already oriented towards the future.

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