How to reduce CO2 emissions by increasing green areas in Elgesetergate

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Individual assignment

Candidate number: 10006

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Abstract

The following study aims to analyze one of the busiest areas, and consequently with more traffic, in Trondheim. This area is the street named Elgesetergate, which connects Trondheim hospital, the Lerkendal stadium and the Studentersamfundet near the Elgeseter bridge. The study was performed with greater emphasis on the air quality aspect. First of all the importance of this type of study in the area, the negative effects on human health of CO_2 emissions, the European legislation about air quality and the mitigating effects of vegetation on the negative effects of CO_2 were researched. After that, three parts of the road were selected and modeled through ENVI-met, a software through which CO_2 emissions, expressed in $mgCO_2/m^3$, were quantified. The software required the amount of cemented and green areas and the meteorological data. Here was used data from the hottest day and the coldest day in 2021. Many solutions are possible to reduce the amount of CO_2 including increasing green areas or using paints for building facades that capture CO_2. In this study, increase green areas was the mail proposal and this change was modeled again through the ENVI-met software by reducing asphalt area in favor of more natural areas. This change helps to reduce the amount of CO_2 in the air, consequently improving the quality of life and health of citizens.

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Introduction

ElgeseterGate is one of the main streets of the city of Trondheim. It represents the junction from the south part of the city to the center and for that it is easy to understand that lots of problems, related to the high use of this road, arises, and need to be assessed. The street is characterized by high traffic, a lot of noise, and is known to be one of the most polluted streets of Norway. It also acts as a barrier for the area and is facing a lot of issues. The study in its whole is an analysis on the ways to improve the quality of life of the neighborhood by reducing air pollution. This paper focuses its interest on the topic of air quality. The street and its surroundings are mainly made of concrete and asphalt which do not help with the air.

Air pollution in ElgeseterGate represents a huge issue. It is a fundamental goal for an urban street that the latter responds to the local environment in its design. In this case it is analyzed how the street and the structure of the surrounding environment reacts to the arising problem of climate change, in detail CO2 emissions.

The street that is the object of this study is the main road into the city center from the south. It also represents one of the most important streets of the city of Trondheim because of the presence of the university campus of NTNU which is one of the largest in the whole country, the hospital, many companies, and the stadium. It is important to maintain high the quality of air of this street for human health and environmental protection.

The purpose of this study is to carry out an analysis of CO2 emissions in the road in question, to identify the most critical areas for CO2 mitigation and propose solutions to improve the situation. As this is the main objective of this paper, the research question is: How to reduce CO2 emissions by increasing green areas in Elgesetergate?

It is of fundamental importance to start the analysis with a theoretical basis on European standards and regulations on air quality, this type of research was done with the method of literature review. The latter was also used to find relevant studies on the importance of vegetation in urban areas as means to improve the air quality my mitigating the negative effects of CO2. These results represented the theoretical basis to the practical step of this project: the use of the software called Envimet.

A quantitative analysis of emissions was then carried out using software called Envimet. This software allows to analyze different parameters that describe, in their totality, the quality of a given area from different points of view. In this study the potential of the software has found practical implications in a quantitative analysis of CO2 emissions. In addition to the analysis, with the same software, it was possible to simulate changes in the most critical area of the road. The changes made were to add vegetation and remove asphalt to verify the possible reduction of mg of CO2 per cubic meter.

Methodology

In this study the methods used are mainly two: literature review and the use of a software called Envimet. The following paragraphs have the purpose to explain in detail all the steps of this project describing the process that involves these two methods.

Literature Review

The literature review was carried out to research European regulation on air quality, the importance of air quality in Elgesetergate and the mitigating effects on the air of vegetation in urban areas. This type of research was fundamental to create the theoretical, qualitative basis of this project that will be reported in the first three paragraphs of the section of the results and analysis. These scientific arguments give relevance to the second part of the methodology, creating the basis for trying to answer the research question of this paper.

Software ENVI-met

After the theoretical research a practical part of this project was carried out through the use of a software. The latter, ENVI-met, has been used in the past in the field of urban climatology as an excellent way to analyze the microclimate conditions of urban areas and to identify critical issues and possible solutions. The version used for this project is not the latest, but it is still efficient in reporting the condition of the CO2 values expressed in mg per cubic meter in the area of interest.

"The software is based on a model of the three-dimensional holistic microclimate. It simulates the climatological interactions between surfaces, plants, and atmosphere. In addition to generating accurate microclimate calculations up to the square meter, ENVI-met also analyses the effects of mitigation measures on the urban climate. The simulations are carried out with a horizontal resolution of a few meters and a time frame generally between 24 hours and a few days. The result: climate-friendly urban planning for more livable cities of the future." (ENVI-met, 2022)

The use of the software is divided into several steps. First of all, the area of interest and the time frame must be selected. The study area being a long road (about 1.5 km) it was necessary to divide it into several areas and select some for the analysis in question. With this procedure the spatial boundaries of the analysis were defined. In particular, three parts of the road were selected. The first near the Lerkendal stadium, the second more or less halfway between the stadium and the StudenterSamfundet, an artistic social center run by students, and finally the third part identified as the area where there are the Saint Olav's hospital and the StudenterSamfundet are. As for the temporal boundaries, two characteristic days were selected for their temperature conditions extreme to their opposite. The warmest and coldest day of the year 2021. The following days were identified: 3rd of December and 5th August.

After having delimited temporally and spatially the object of the analysis, it is necessary to obtain from Google Earth images in bpm format of the three areas considered. These images are then uploaded to the first section of the software: File Editor. In this section the analysis begins.

The section of the File Editor is where the territory is created, modeled in all its characteristics. After loading the bpm image, it is necessary to check that the dimensions of the grid on which the model will be made, conform to those of the territory. Specifically, there must be a margin on the sides to allow a more precise analysis. Geolocation features are also included: place name, position on earth expressed in latitude and longitude and reference time zone with name and reference longitude. In this study the information is the following:

- Name of location: Trondheim/Norway
- Position on earth: Latitude (deg, +N, -S) 63.26 and Longitude (deg, -W, +E) 10.23
- Reference time zone: Name CET/GMT +1, Reference longitude 15.00

After setting the characteristics just described it is possible to proceed with the creation of the model of the chosen area. In this section are added palaces, vegetation and the type of material that makes up the soil. As for buildings and vegetation, they are added according to their height, while for the type of soil, it is selected according to the conformation of the territory. Models of the three areas examined are given in the appendix.

After finishing the models, it is necessary to go to the second section of the software: the Configuration Editor. This step is the one in which the weather characteristics of the area during the days that one wants to analyze are addded. Specifically, the meteorological parameters examined are:

- Wind speed in meters per second

- Direction of wind in degrees: N-0°, NNE-22.5°, NE-45°, ENE-67.5°, E-90°, ESE-112°, SE-135°, SSE-157.5°, S-180°, SSW 202.5°, SW 225°, WSW 247.5°, W.270°, WN2.5°, NW-315°, W-337.5°

-Temperature in Kelvin degrees

- Relative humidity as a percentage.

The weather data was taken from the Iowa State University Iowa Environmental Mesonet database. The tables containing the data are as follows:

Table 1 Meteorological Data (05/08/2021)

Station	Date and hour	Longitude	Latitude	Elevation	Temperat.	Temperat.	Humidity	WDirection	WSpeed	WSpeed
ENVA	05/08/2021 00:20	10.935	63.4592	17	10	283.15	87.37	130	6.9	3.084488154
ENVA	05/08/2021 00:50	10.935	63.4592	17	10	283.15	87.37	130	8.05	3.598569513
ENVA	05/08/2021 01:20	10.935	63.4592	17	9	282.15	93.45	110	6.9	3.084488154
ENVA	05/08/2021 01:50	10.935	63.4592	17	9	282.15	93.45	130	8.05	3.598569513
ENVA	05/08/2021 02:20	10.935	63.4592	17	9	282.15	87.28	130	9.2	4.112650872
ENVA	05/08/2021 02:50	10.935	63.4592	17	8	281.15	93.4	130	8.05	3.598569513
ENVA	05/08/2021 03:20	10.935	63.4592	17	8	281.15	93.4	130	6.9	3.084488154
ENVA	05/08/2021 03:50	10.935	63.4592	17	8	281.15	93.4	130	6.9	3.084488154
ENVA	05/08/2021 04:20	10.935	63.4592	17	8	281.15	93.4	130	6.9	3.084488154
ENVA	05/08/2021 04:50	10.935	63.4592	17	10	283.15	81.61	140	9.2	4.112650872
ENVA	05/08/2021 05:20	10.935	63.4592	17	10	283.15	87.37	130	6.9	3.084488154
ENVA	05/08/2021 05:50	10.935	63.4592	17	11	284.15	81.74	120	6.9	3.084488154
ENVA	05/08/2021 06:20	10.935	63.4592	17	12	285.15	76.5	110	8.05	3.598569513
ENVA	05/08/2021 06:50	10.935	63.4592	17	14	287.15	71.83	110	5.75	2.570406795
ENVA	05/08/2021 07:20	10.935	63.4592	17	14	287.15	71.83	110	5.75	2.570406795
ENVA	05/08/2021 07:50	10.935	63.4592	17	15	288.15	72.01	120	3.45	1.542244077
ENVA	05/08/2021 08:20	10.935	63.4592	17	18	291.15	59.5	0	0	0
ENVA	05/08/2021 08:50	10.935	63.4592	17	17	290.15	63.38	280	6.9	3.084488154
ENVA	05/08/2021 09:20	10.935	63.4592	17	17	290.15	67.75	260	9.2	4.112650872
ENVA	05/08/2021 09:50	10.935	63.4592	17	17	290.15	63.38	250	10.35	4.626732231
ENVA	05/08/2021 10:20	10.935	63.4592	17	17	290.15	63.38	260	10.35	4.626732231
ENVA	05/08/2021 10:50	10.935	63.4592	17	18	291.15	63.6	250	11.5	5.14081359
ENVA	05/08/2021 11:20	10.935	63.4592	17	18	291.15	67.95	250	12.65	5.654894949
ENVA	05/08/2021 11:50	10.935	63.4592	17	18	291.15	63.6	250	13.8	6.168976308
ENVA	05/08/2021 12:20	10.935	63.4592	17	19	292.15	59.74	250	13.8	6.168976308
ENVA	05/08/2021 12:50	10.935	63.4592	17	20	293.15	52.51	240	12.65	5.654894949
ENVA	05/08/2021 13:20	10.935	63.4592	17	19	292.15	55.88	240	13.8	6.168976308
ENVA	05/08/2021 13:50	10.935	63.4592	17	19	292.15	59.74	240	13.8	6.168976308
ENVA	05/08/2021 14:20	10.935	63.4592	17	18	291.15	67.95	240	11.5	5.14081359
ENVA	05/08/2021 14:50	10.935	63.4592	17	18	291.15	82.62	270	6.9	3.084488154
ENVA	05/08/2021 15:20	10.935	63.4592	17	20	293.15	68.35	190	4.6	2.056325436
ENVA	05/08/2021 15:50	10.935	63.4592	17	20	293.15	64.04	M	4.6	2.056325436
ENVA	05/08/2021 16:20	10.935	63.4592	17	18	291.15	72.56	0	0	0
ENVA	05/08/2021 16:50	10.935	63.4592	17	18	291.15	77.45	350	4.6	2.056325436
ENVA	05/08/2021 17:20	10.935	63.4592	17	17	290.15	88	190	6.9	3.084488154
ENVA	05/08/2021 17:50	10.935	63.4592	17	17	290.15	72.38	290	20.7	9.253464461
ENVA	05/08/2021 18:20	10.935	63.4592	17	15	288.15	87.83	280	20.7	9.253464461
ENVA	05/08/2021 18:50	10.935	63.4592	17	14	287.15	93.69	320	11.5	5.14081359

ENVA	05/08/2021 19:20	10.935	63.4592	17	14	287.15	93.69	240	8.05	3.598569513
ENVA	05/08/2021 19:50	10.935	63.4592	17	14	287.15	93.69	130	5.75	2.570406795
ENVA	05/08/2021 20:20	10.935	63.4592	17	14	287.15	93.69	140	6.9	3.084488154
ENVA	05/08/2021 20:50	10.935	63.4592	17	13	286.15	93.65	150	3.45	1.542244077
ENVA	05/08/2021 21:20	10.935	63.4592	17	12	285.15	100	70	3.45	1.542244077
ENVA	05/08/2021 21:50	10.935	63.4592	17	12	285.15	93.6	0	0	0
ENVA	05/08/2021 22:20	10.935	63.4592	17	12	285.15	93.6	0	0	0
ENVA	05/08/2021 22:50	10.935	63.4592	17	11	284.15	100	120	3.45	1.542244077
ENVA	05/08/2021 23:20	10.935	63.4592	17	11	284.15	93.55	110	5.75	2.570406795
ENVA	05/08/2021 23:50	10.935	63.4592	17	11	284.15	93.55	110	5.75	2.570406795

Table 2 Meteorological Data (03/12/2021)

Station	Date and hour	Longitude	Latitude	Elevation	Temperat.	Temperat.	Humidity	WDirection	WSpeed	WSpeed
ENVA	03/12/2021 00:20	10.935	63.4592	17	-16	257.15	84.56	140	8.05	3.598569513
ENVA	03/12/2021 00:50	10.935	63.4592	17	-19	254.15	91.78	120	8.05	3.598569513
ENVA	03/12/2021 01:50	10.935	63.4592	17	-17	256.15	84.43	130	10.35	4.626732231
ENVA	03/12/2021 02:50	10.935	63.4592	17	-15	258.15	84.68	130	10.35	4.626732231
ENVA	03/12/2021 03:50	10.935	63.4592	17	-14	259.15	78.01	80	5.75	2.570406795
ENVA	03/12/2021 04:20	10.935	63.4592	17	-14	259.15	78.01	140	9.2	4.112650872
ENVA	03/12/2021 04:50	10.935	63.4592	17	-15	258.15	84.68	130	12.65	5.654894949
ENVA	03/12/2021 05:20	10.935	63.4592	17	-15	258.15	84.68	130	10.35	4.626732231
ENVA	03/12/2021 05:50	10.935	63.4592	17	-16	257.15	84.56	120	10.35	4.626732231
ENVA	03/12/2021 06:20	10.935	63.4592	17	-16	257.15	84.56	130	11.5	5.14081359
ENVA	03/12/2021 06:50	10.935	63.4592	17	-16	257.15	84.56	130	11.5	5.14081359
ENVA	03/12/2021 07:20	10.935	63.4592	17	-16	257.15	84.56	110	11.5	5.14081359
ENVA	03/12/2021 07:50	10.935	63.4592	17	-15	258.15	84.68	120	13.8	6.168976308
ENVA	03/12/2021 08:20	10.935	63.4592	17	-14	259.15	78.01	130	11.5	5.14081359
ENVA	03/12/2021 08:50	10.935	63.4592	17	-14	259.15	78.01	130	11.5	5.14081359
ENVA	03/12/2021 09:20	10.935	63.4592	17	-14	259.15	78.01	130	11.5	5.14081359
ENVA	03/12/2021 09:50	10.935	63.4592	17	-13	260.15	78.18	140	5.75	2.570406795
ENVA	03/12/2021 10:20	10.935	63.4592	17	-13	260.15	78.18	120	6.9	3.084488154
ENVA	03/12/2021 10:50	10.935	63.4592	17	-13	260.15	78.18	130	9.2	4.112650872
ENVA	03/12/2021 11:20	10.935	63.4592	17	-13	260.15	78.18	130	9.2	4.112650872
ENVA	03/12/2021 11:50	10.935	63.4592	17	-12	261.15	78.35	130	9.2	4.112650872
ENVA	03/12/2021 12:20	10.935	63.4592	17	-12	261.15	78.35	120	6.9	3.084488154
ENVA	03/12/2021 12:50	10.935	63.4592	17	-11	262.15	72.33	110	11.5	5.14081359
ENVA	03/12/2021 13:20	10.935	63.4592	17	-11	262.15	72.33	110	10.35	4.626732231
ENVA	03/12/2021 13:50	10.935	63.4592	17	-10	263.15	72.53	90	6.9	3.084488154
ENVA	03/12/2021 14:20	10.935	63.4592	17	-9	264.15	72.73	60	6.9	3.084488154
ENVA	03/12/2021 14:50	10.935	63.4592	17	-8	265.15	67.28	80	9.2	4.112650872
ENVA	03/12/2021 15:20	10.935	63.4592	17	-8	265.15	67.28	70	8.05	3.598569513
ENVA	03/12/2021 15:50	10.935	63.4592	17	-8	265.15	67.28	70	10.35	4.626732231

ENVA	03/12/2021 16:20	10.935	63.4592	17	-7	266.15	62.28	40	5.75	2.570406795
ENVA	03/12/2021 16:50	10.935	63.4592	17	-6	267.15	57.69	110	11.5	5.14081359
ENVA	03/12/2021 17:20	10.935	63.4592	17	-6	267.15	57.69	110	13.8	6.168976308
ENVA	03/12/2021 17:50	10.935	63.4592	17	-6	267.15	57.69	120	16.1	7.197139025
ENVA	03/12/2021 18:20	10.935	63.4592	17	-6	267.15	53.18	110	13.8	6.168976308
ENVA	03/12/2021 18:50	10.935	63.4592	17	-6	267.15	57.69	110	16.1	7.197139025
ENVA	03/12/2021 19:20	10.935	63.4592	17	-6	267.15	57.69	110	14.95	6.683057667
ENVA	03/12/2021 19:50	10.935	63.4592	17	-6	267.15	57.69	110	17.25	7.711220384
ENVA	03/12/2021 20:20	10.935	63.4592	17	-5	268.15	57.96	120	23	10.28162718
ENVA	03/12/2021 20:50	10.935	63.4592	17	-5	268.15	57.96	130	20.7	9.253464461
ENVA	03/12/2021 21:20	10.935	63.4592	17	-4	269.15	58.22	130	23	10.28162718
ENVA	03/12/2021 21:50	10.935	63.4592	17	-4	269.15	58.22	130	18.4	8.225301743
ENVA	03/12/2021 22:20	10.935	63.4592	17	-4	269.15	58.22	140	16.1	7.197139025
ENVA	03/12/2021 22:50	10.935	63.4592	17	-4	269.15	58.22	140	17.25	7.711220384
ENVA	03/12/2021 23:20	10.935	63.4592	17	-4	269.15	58.22	130	16.1	7.197139025
ENVA	03/12/2021 23:50	10.935	63.4592	17	-4	269.15	58.22	100	14.95	6.683057667

For the analysis only one value of each parameter is needed, so an average has been calculated for all the parameters for the two representative days:

Table 3 Average Value of Meteorological parameters (05/08/2021)

Average Values (05/08/21)		
Wind Speed	3.512889	[m/s]
Wind Direction	169.3617	[°]
Temperature	287.3375	[K]
Relative Umidity	79.78563	[%]

Table 4 Average Value of Meteorological parameters (03/12/2021)

Average Values (03/12/21)		
Wind Speed	5.335022	[m/s]
Wind Direction	115.5556	[°]
Temperature	262.7056	[K]
Relative Umidity	71.46222	[%]

With these values the Configuration Editor is created for the two days and saved, the images of the two configuration editors are in the appendices.

The next step is to run the software. After that, it is possible then to view the results graphically on the Leonardo section. The representative images of the CO_2 emission graphs are given in the appendix.

After carrying out this representative two-day 2021 quantitative analysis for the selected areas, the Envimet software was used to simulate changes in the territory to try to improve the CO2 emissions situation. The same procedure was then used: creation of the model of the territory (in this case with changes related to the presence of asphalt and vegetation), insertion of meteorological data, Software run and graph analysis with mg CO2 values per cubic meter. The analysis of the results will be presented in the section of the results of the analysis with the software.

Results and Analysis

Relevance of air quality in ElgeseterGate

The area under consideration includes numerous citizen services, commercial activities of all kinds, and points of interest for the population. These include three main polarities: Saint Olav's Hospital, Lerkendal Stadium and NTNU University buildings which attract a large part of the population every day. For this reason, the area must be designed in a way that is sustainable both from an environmental and human health point of view.

Knowing from studies that CO2 emissions can harm human health provoking different diseases such as malaria, diarrhea, cardiovascular disease, malnutrition; and the environment helping in the occurring of coastal flooding and inland flooding (L., 2015) - it is extremely important to reduce the concentration of this pollutant in order to comply with European regulations and safeguard the health of citizens.

How vegetation can mitigate the negative effects of CO2

Over the years, anthropogenic activities carried out via urbanization processes have had a noticeable impact on the natural environment, with air pollution being one of the leading causes of human health deterioration in the long term (Faiz, 1993) (Akbari, 2001) (Akimoto, 2003) (Wang, 2004). As a matter of fact, the World Health Organization (WHO) estimates that air pollution in urban environment is responsible for 6.4 million years of life lost per year around the world (Cohen, 2004) (Chen, 2012). Based on their effects on human health and the environment, there are six major air quality indicators identified as pollutants in ambient conditions (United States Environmental Protection Agency, 2022) : Carbon Monoxide (CO), Ozone (O3), Nitrogen Dioxide (NO2), Sulphur Dioxide (SO2), Particulate Matter (PM10 and PM2.5) and Lead (Pb). This being said, this study will be focusing on the hazardous effects of Carbon Dioxide in the area of Elgesetergate.

Despite the health hazards associated to urbanization, urban development stands as a crucial indicator of the world's growth, meaning that the deterioration of air quality is basically inevitable. Hence, ecologists and urban planners have researched ways in which the latter can be reduced via the introduction of urban greening as a low-cost mitigation strategy (Beckett, 1998) (Nowak, 2006). Green Infrastructure (GI) practices, such as trees, shrubs, green roofs, and green walls, have been used in many different urban areas across the world, and have been proven efficient in reducing the aforementioned pollutants, as well as reducing Green House Gas (GHG) emissions within cities (Nowak, 2006) (Akbari, 2001) (Tzoulas, 2007). Vegetation acts as a natural filter for both gases and particulate matter: the uptake and ousting of the pollutants through GI practices have not only led to direct air quality improvement but have also contributed to energy savings by granting cooling thanks to the shade provided by urban trees during the summer months, which in turn reduces the energy demand, thereby decreasing the emissions of power plants. The overall air quality improvement achieved via GI practices consists of various direct and indirect benefits, both in monetary terms as well as resource units (Akbari, 2001) (Foster, 2001). For example, it has been estimated that a total annual air pollution of 711,000 metric tons removed by urban trees across 55 American cities represented $3.8 billion in public value (Washington, 2022). It is also worth mentioning that GI practices have not only improved air quality, but also improved water quality, noise abatement and improved soils.

Air quality regulation in Europe

Throughout the years, air pollution has had gradual, ever-increasing, adverse effects on human health, representing the biggest environmental risk according to the World Health Organization (WHO). In the EU alone, it is estimated that around half a million people die prematurely because of toxic exposure to particulate matter, nitrogen dioxide and ozone, with central and eastern Europe being the main geographical targets. (Bourguignon, 2018)

Because air pollution is mobile, norms that regulate air quality obviously have a cross-border dimension. Both international agreements and EU legislation on the subject can be divided into three groups, according to their objective: 1) air quality standards, 2) reduction targets for national emissions of air pollutants, 3) reduce emission of pollutants at specific sources. (Bourguignon, 2018)

The European directive on the reduction of national emissions sets targets for the reduction for anthropogenic emission of five pollutants: sulphur, dioxide, nitrogen oxides, non-methane volatile organic compounds, ammonia, and fine particulate matter. The goals set are to be met by 2020 and 2030. The program implies a national air pollution control program with specifications on the policy options to meet. All the member states bust draw up national emission inventories covering the five pollutants subject, prepare every two years national emission projections, monitor impacts of air pollution on ecosystems and spread information on control programs among the citizens. (Bourguignon, 2018)

Amongst the many international agreements, the following can be identified as the most distinguished:

- 1998 Aarhus Protocol: focusing on persistent organic pollutants, it requires parties to reduce their emissions of pollutants below their 1990 standards – it was amended in 2009 to include additional pollutants to the list; the agreement also focused on heavy metals, specifically on reducing the emission of cadmium, lead and mercury on behalf of parties below their 1990 standards – it was amended in 2012 to introduce stricter controls on heavy metals emissions.

- 1999 Gothenburg Protocol: focus on the acidification, eutrophication, and ground-level ozone – the protocol has the aim to set national emission targets to be met by 2010 for four pollutants (sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia) – it was amended in 2012

- 2015 Paris Agreement: it requires all parties to act on the reduction of greenhouse gas emissions and to report the progresses achieved – the GHG included in the agreement is also methane, considered a precursor to ground-level ozone.

(Bourguignon, 2018)

The problems related to the legislations on air quality are several. First of all, the different pollutants come from a huge variety of sources and from the economical point of view a lot of sectors are involved. Another reason for the complexity of these regulations is the fact the big amount of different air pollutants that can also generate secondary pollutants. Other factors that control air contaminants are out of man's control, like geography, weather conditions and natural sources of emissions. For all these reasons it is hard to obtain a linear reduction of the pollutants' concentration in the atmosphere connected to the action for their reduction. (Bourguignon, 2018)

Lastly it is important to mention the different layers of governance involved in the maintenance of air quality. It is clear how this problem is affecting our world at a global level, at the level of large world regions and at the European level. Coordinated actions are fundamental and the Urban Agenda partnership on air quality is a good example of initiative seeking to address this multilevel governance challenge. (Bourguignon, 2018)

Quantitative analysis and simulation of changes with the software Envimet

In this section we will analyze the results of the quantitative analysis carried out with the Envimet software. After the interpretation of the graphs, it was possible to identify as "worst" situation (referring to the value of mg of CO_2 per cubic meter) the one of the central areas of the street during the coldest day, December 3rd, of the year 2021.

This is the representative graph of this parameter for the area identified as worst:

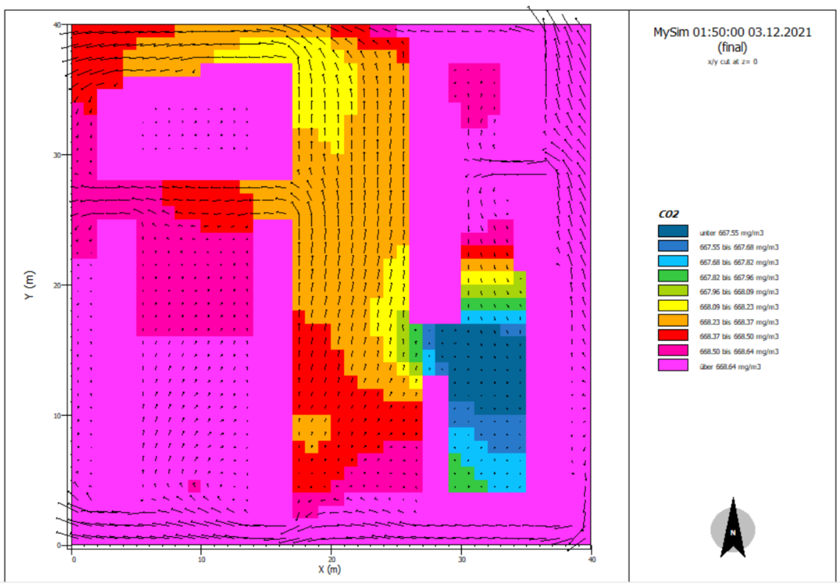

Figure 1 Graph of the CO2 emissions in the middle part of Elgesetergate

The CO_2 value is between 667.55 and 668.68 mg per cubic meter. The other representative graphs of emissions in the other two areas during the warmer day and the colder day are in the appendix.

This area was then selected to perform a simulation in which part of the asphalt was removed and vegetation was added. Of continuation it is possible to see the two models of the zone: that one that represents the reality and that of the simulation:

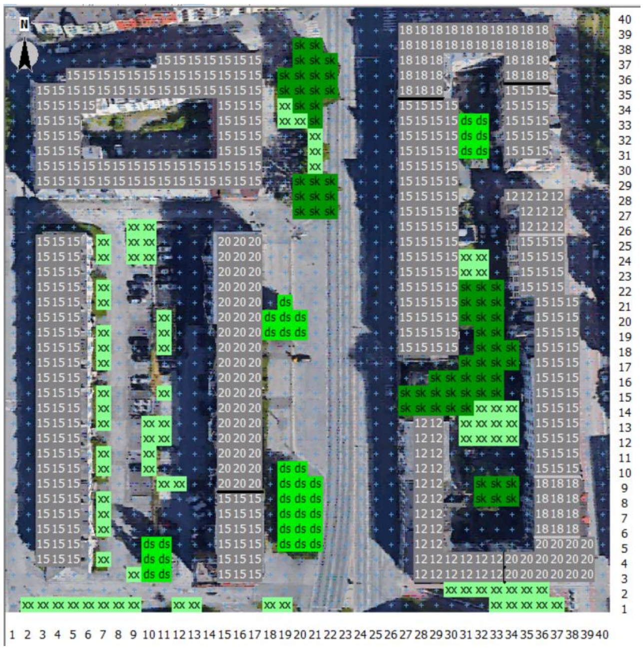

Figure 2 Model of the middle part of Elgesetergate

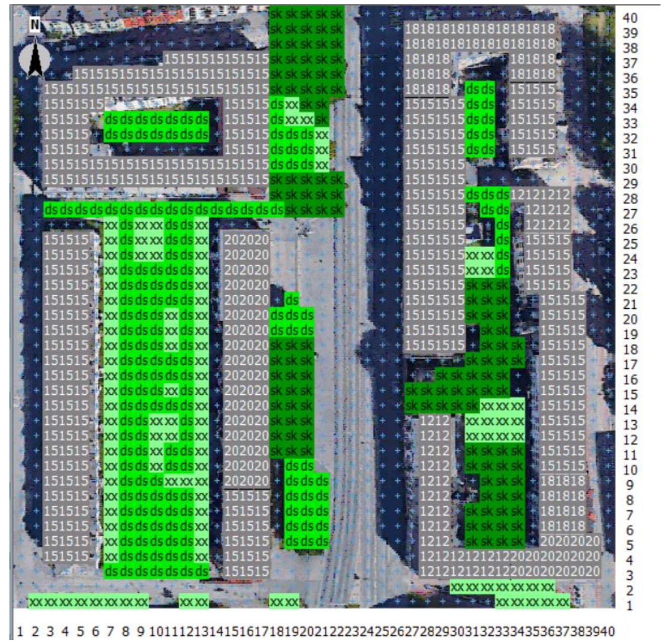

Figure 3 Model of the middle part of Elgesetergate with changes

The results of this land characteristics change, have led to a slight decrease in CO2 values. We can see from the analysis graph of the model simulating the changes, that the new range is for values of mg of CO2 per cubic meter ranging from 664.87 to 668.45.

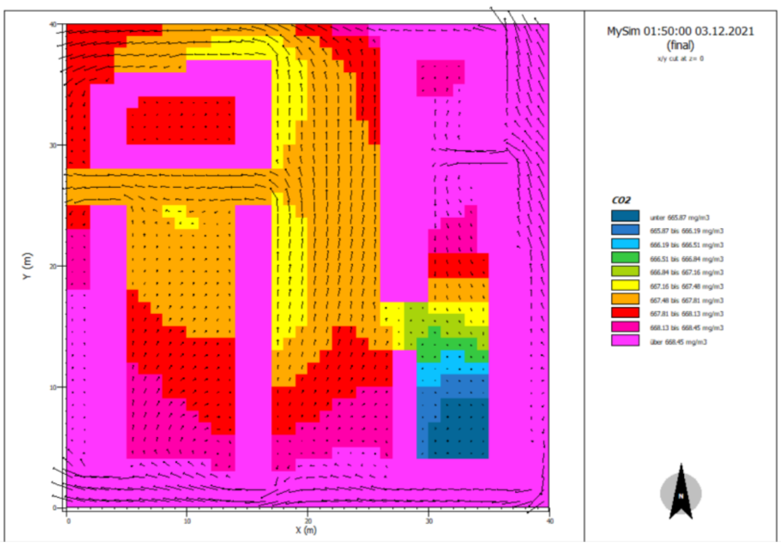

Figure 4 Graph of the CO2 emissions in the middle part of Elgesetergate after changes

Discussion

The study that has been carried out must be a starting point for possible future developments. It is essential to use increasingly sophisticated means to quantitatively analyze pollutants to have the precise values and the location of them. In this way it is possible to improve the situation by acting with a precise target and managing to create specific solutions for the situations analyzed. As mentioned, several times in this project, the high traffic in Elgesetergate makes it one of the most polluted roads in Norway. This study aims to represent a preliminary analysis to be deepened and improved. The proposed solution, that of removing asphalt and adding different green areas, would be effective if placed side by side with other solutions such as green facades and paints that absorb CO2. Together they could lead to significant decreases in CO2 values, that would represent an improvement of the quality of the livability of the street.

Conclusions

The most important arteries in cities, the busiest areas, the major points of interest, are unfortunately also the worst from an environmental point of view. This occurs because the many people who frequent them use many services that increase concentrations of pollutants in the surrounding environment.

An important aspect to consider in these types of areas is air quality. An area as busy as the one under analysis is, by logical consequence, also crowded with transportation. The latter emit CO2 into the air bringing the concentration (mgCO2/m3) above the minimum thresholds required by European regulations to safeguard human health.

For this reason, the CO2 concentration must be reduced as much as possible to safeguard the health of all the many citizens who constantly frequent this area, especially the frail ones like seniors and children.

Several strategies can be applied such as increasing green areas and consequently reducing concrete or using special paints that capture CO2 from the air.

This would provide better air quality along with the availability of more green spaces for citizens. Increasing green areas brings with it many benefits in addition to improving air quality. With operations like these, the effort required from the community would not even be that great: would it be a great effort to convert some areas like parking to green zones and change the location of them.

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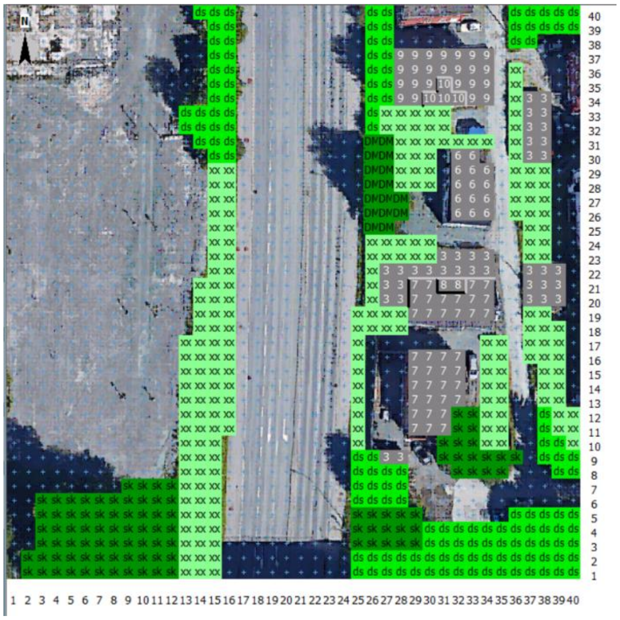
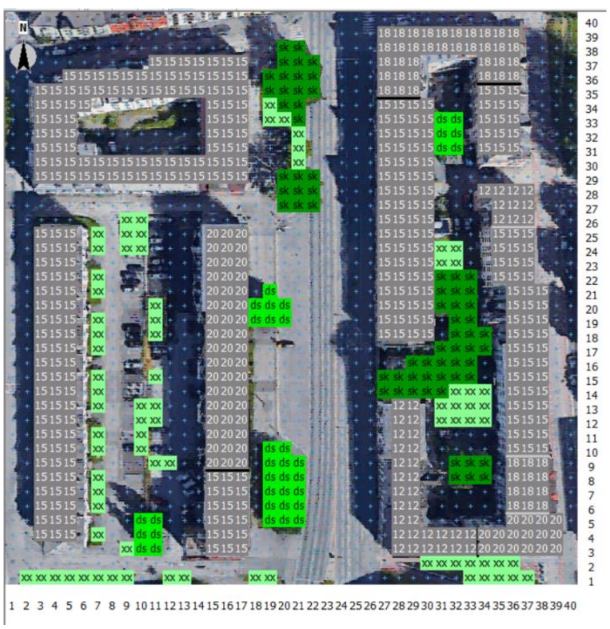
Appendices

Models of the three parts of Elgesetergate selected to be analyzed

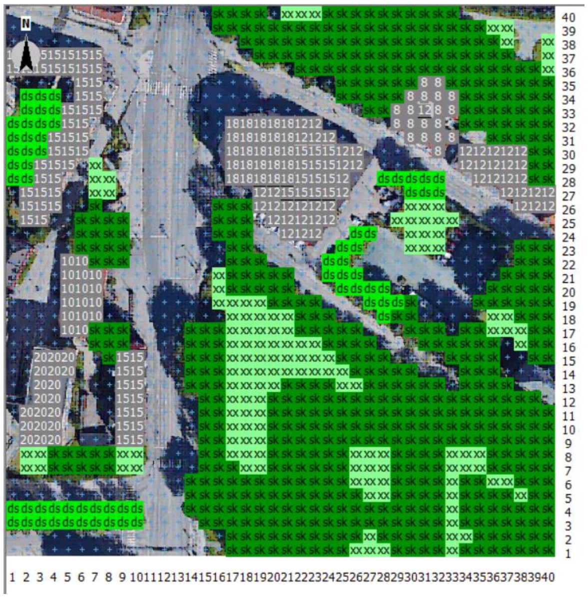
First zone



Second zone

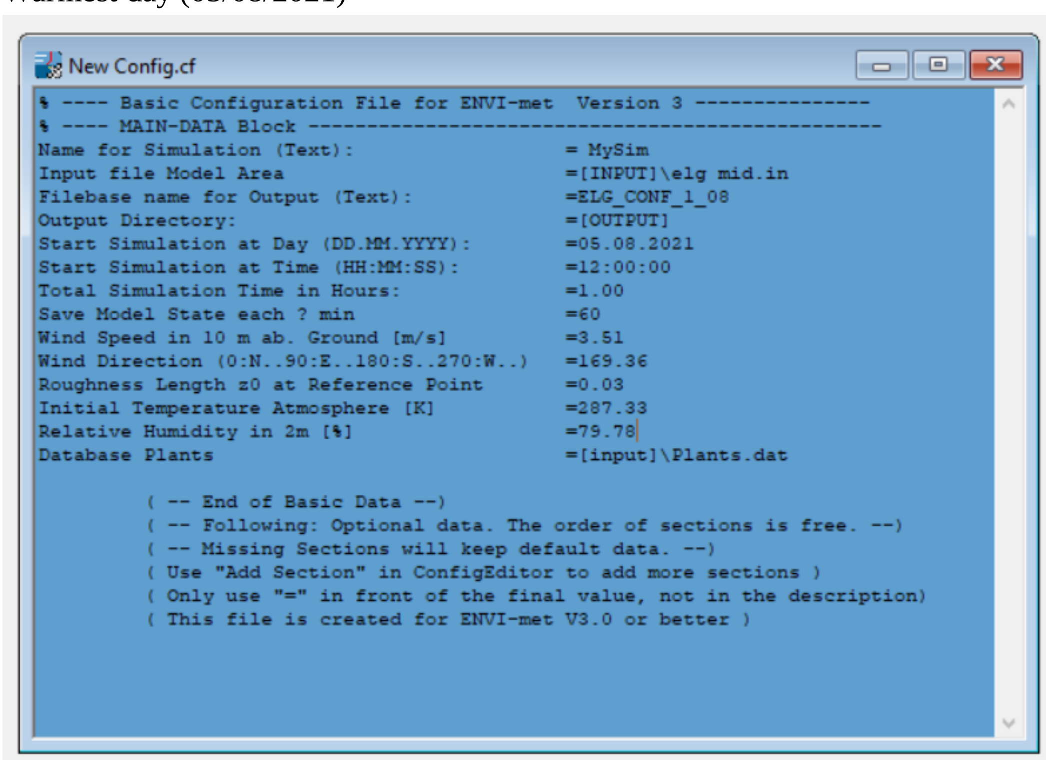


Third zone



Configuration Editors for the two representative days selected for the analysis

Warmest day (05/08/2021)

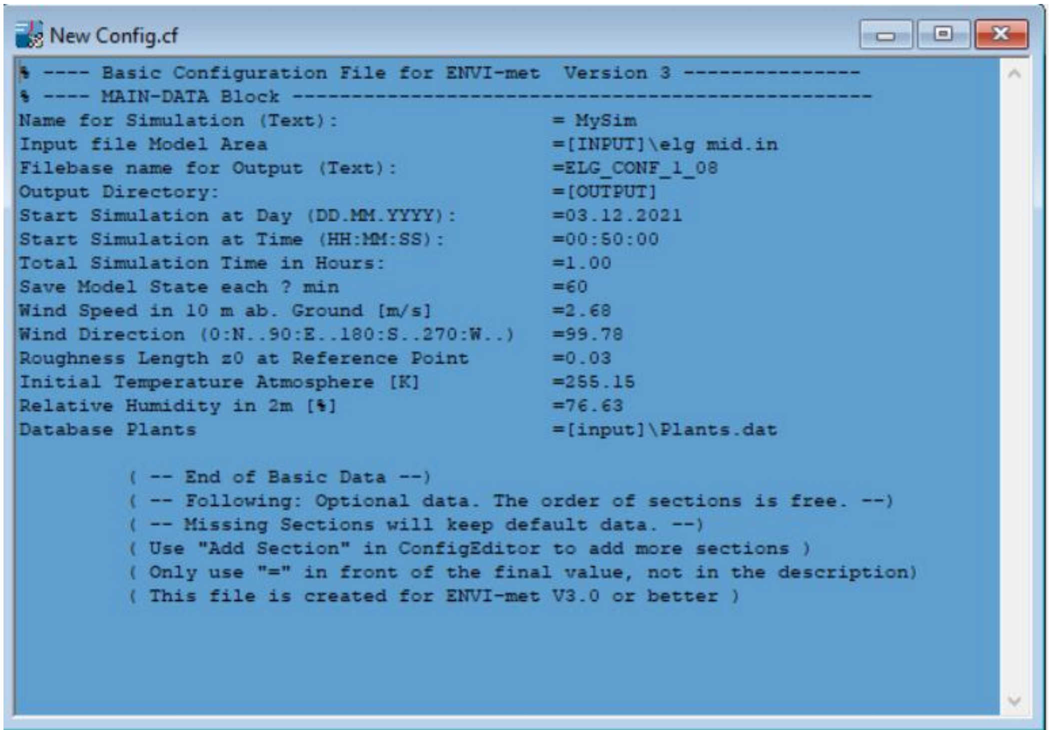


New Config.cf

```
% ---- Basic Configuration File for ENVI-met  Version 3 ---------------
% ---- MAIN-DATA Block -------------------------------------------------
Name for Simulation (Text):                        = MySim
Input file Model Area                              =[INPUT]\elg mid.in
Filebase name for Output (Text):                   =ELG_CONF_1_08
Output Directory:                                  =[OUTPUT]
Start Simulation at Day (DD.MM.YYYY):              =05.08.2021
Start Simulation at Time (HH:MM:SS):               =12:00:00
Total Simulation Time in Hours:                    =1.00
Save Model State each ? min                        =60
Wind Speed in 10 m ab. Ground [m/s]                =3.51
Wind Direction (0:N..90:E..180:S..270:W..)         =169.36
Roughness Length z0 at Reference Point             =0.03
Initial Temperature Atmosphere [K]                 =287.33
Relative Humidity in 2m [%]                        =79.78
Database Plants                                    =[input]\Plants.dat

         ( -- End of Basic Data --)
         ( -- Following: Optional data. The order of sections is free. --)
         ( -- Missing Sections will keep default data. --)
         ( Use "Add Section" in ConfigEditor to add more sections )
         ( Only use "=" in front of the final value, not in the description)
         ( This file is created for ENVI-met V3.0 or better )
```

Coldest day (03/12/2021)

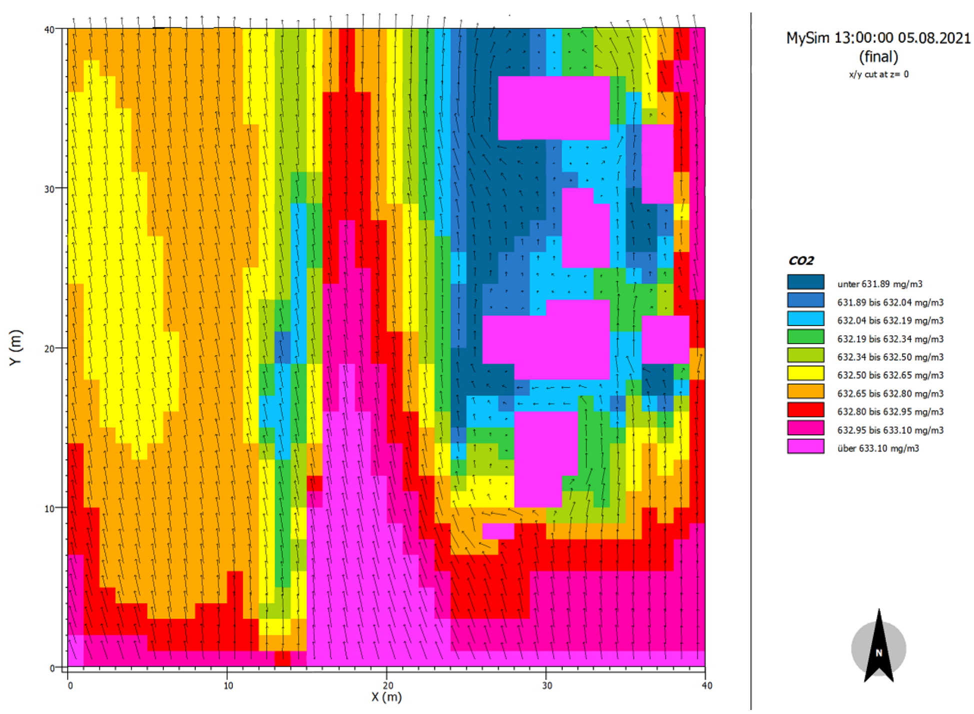


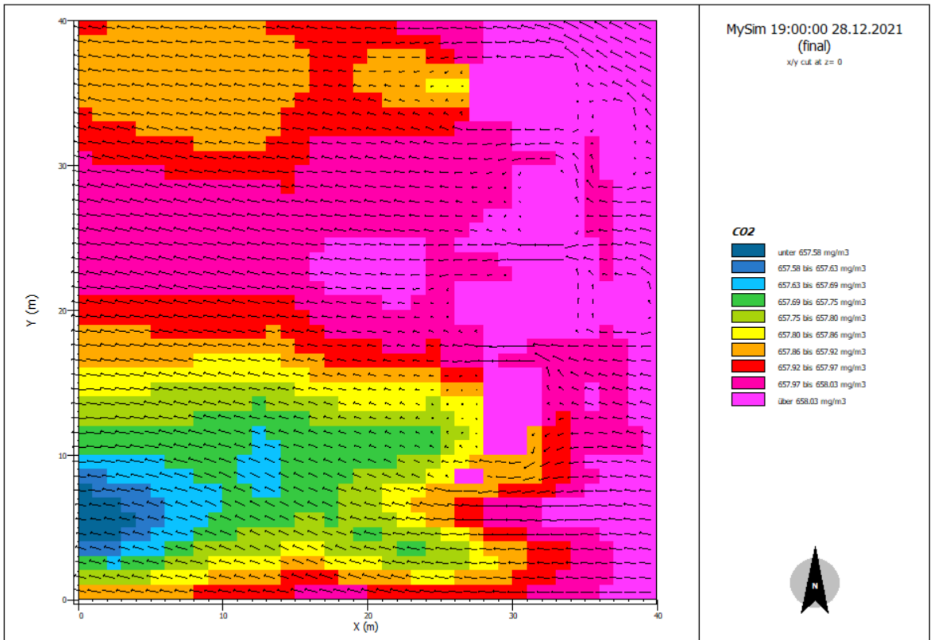
```
New Config.cf
% ---- Basic Configuration File for ENVI-met  Version 3 ---------------
% ---- MAIN-DATA Block --------------------------------------------------
Name for Simulation (Text):                         = MySim
Input file Model Area                               =[INPUT]\elg mid.in
Filebase name for Output (Text):                    =ELG_CONF_1_08
Output Directory:                                   =[OUTPUT]
Start Simulation at Day (DD.MM.YYYY):               =03.12.2021
Start Simulation at Time (HH:MM:SS):                =00:50:00
Total Simulation Time in Hours:                     =1.00
Save Model State each ? min                         =60
Wind Speed in 10 m ab. Ground [m/s]                 =2.68
Wind Direction (0:N..90:E..180:S..270:W..)          =99.78
Roughness Length z0 at Reference Point              =0.03
Initial Temperature Atmosphere [K]                  =255.15
Relative Humidity in 2m [%]                         =76.63
Database Plants                                     =[input]\Plants.dat

         ( -- End of Basic Data --)
         ( -- Following: Optional data. The order of sections is free. --)
         ( -- Missing Sections will keep default data. --)
         ( Use "Add Section" in ConfigEditor to add more sections )
         ( Only use "=" in front of the final value, not in the description)
         ( This file is created for ENVI-met V3.0 or better )
```

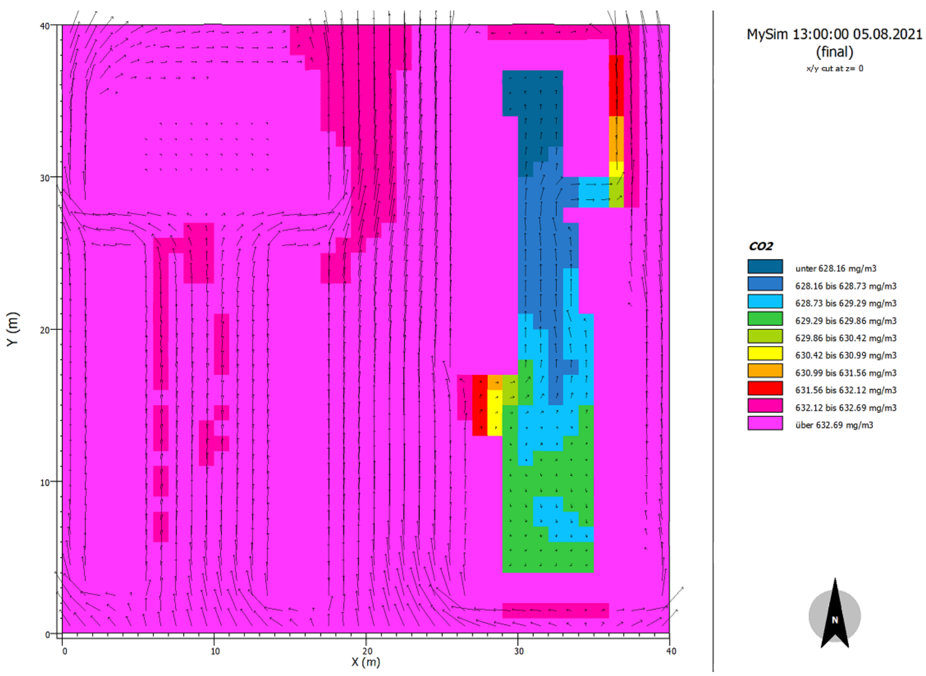
Graphs of the CO2 emissions for the three parts analyzed in the two days selected

First zone, warmest day

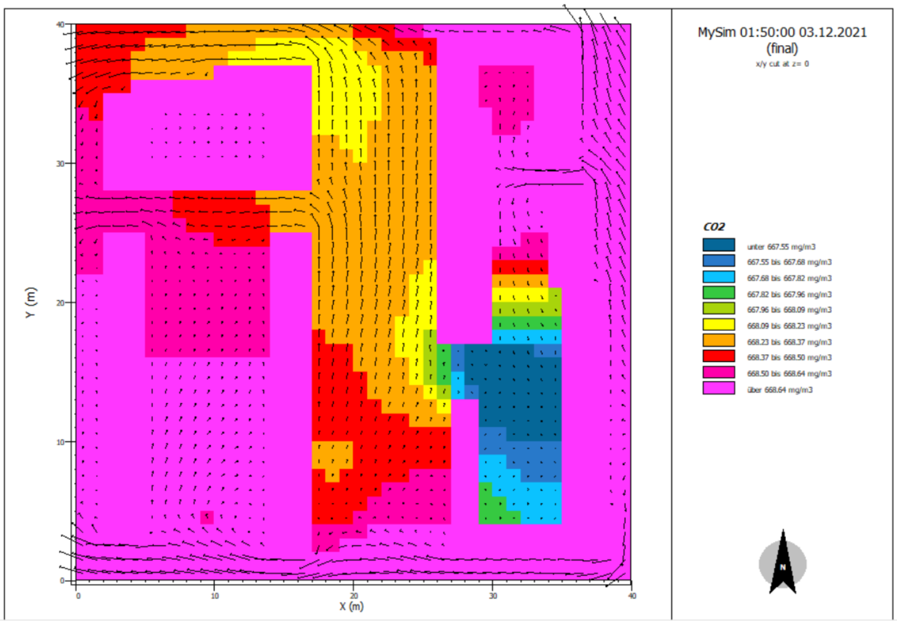




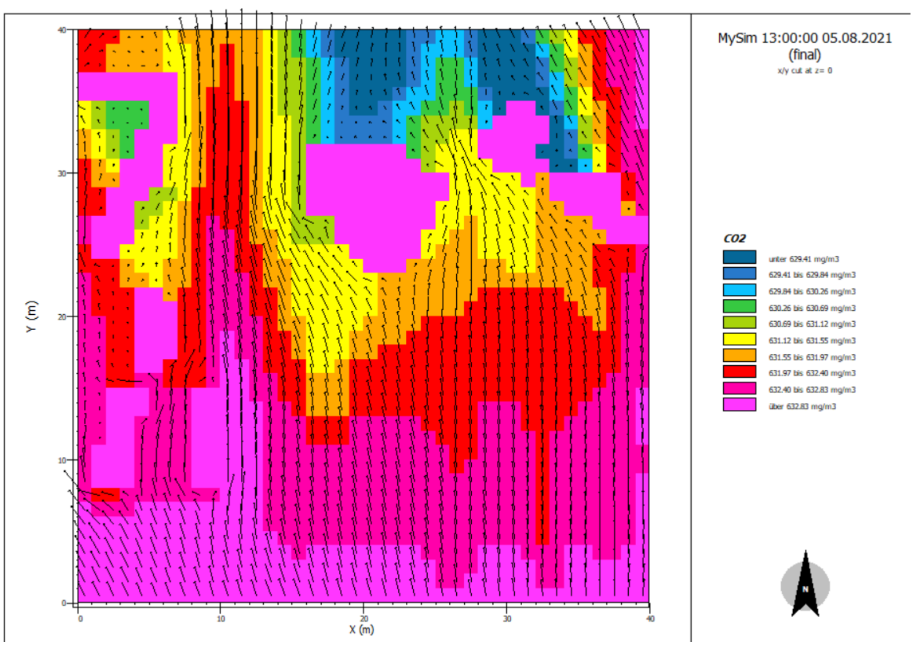
Second zone, warmest day



Second zone, coldest day



Third zone, warmest day



Third zone, coldest day