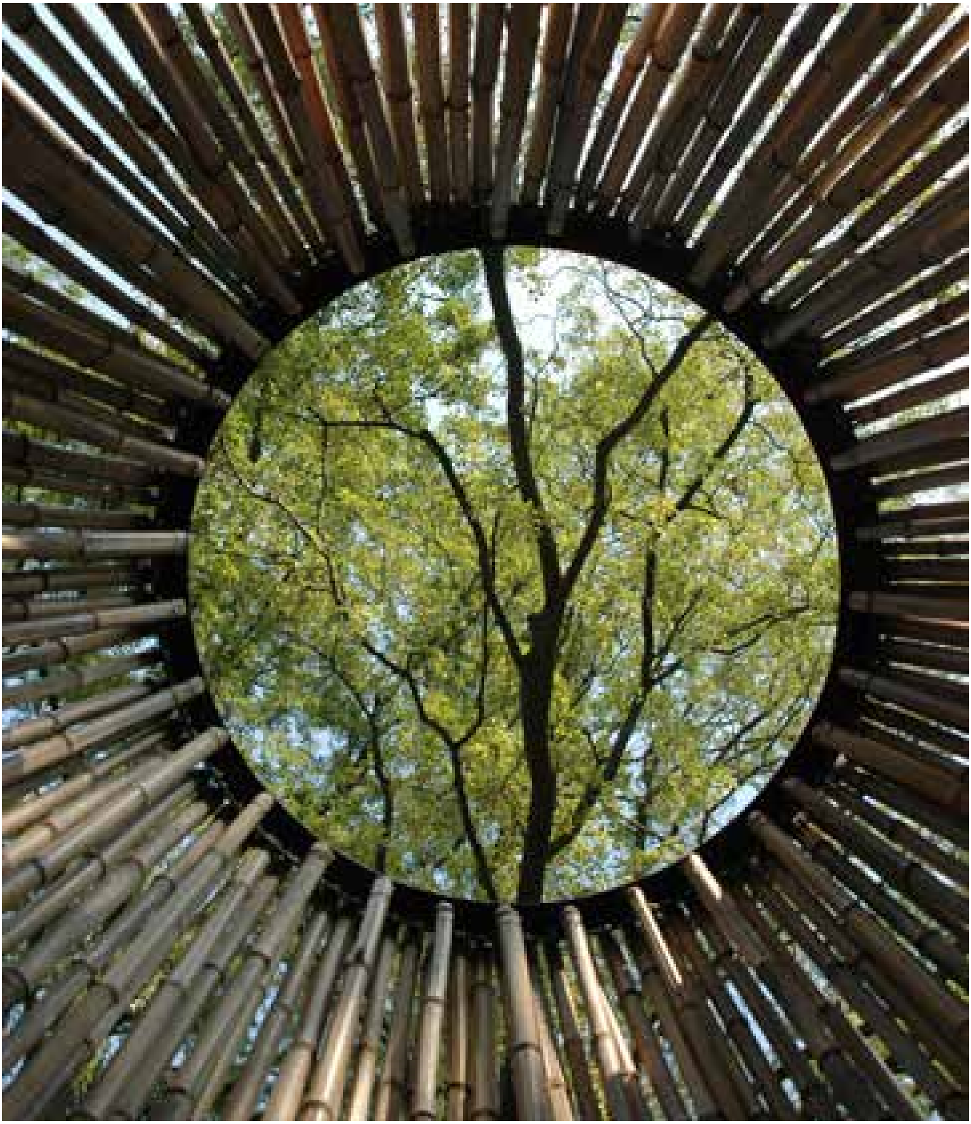
Teaching Decarbonisation

Methodologies and experiences from CITY MINDED

NU3
leNote di U3
number 4
November 2022
ISSN 1973-9702

edited by Anna Laura Palazzo, Lorenzo Barbieri, Romina D'Ascanio, Federica Di Pietrantonio and Francesca Paola Mondelli



NU3
leNote di U3
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leNote di U3 are a section of the online journal UrbanisticaTre
urbanisticatre.uniroma3.it/

U3 - UrbanisticaTre
ISSN 1973-9702
November 2022

Graphic design of the editorial staff
Layout editing and graphics: Lorenzo Barbieri and Francesca Paola Mondelli
Cover: *Eye of nature*, 2014 (Credit: Davide Avantini)

How to cite this publication: Palazzo, A. L., Barbieri, L., D’Ascanio, R., Di Pietrantonio, F., and Mondelli, F. P.(eds), (2022) Teaching decarbonisation. Methodologies and experiences from CITY MINDED, leNote di U3, n. 4, ISSN 1973-9702

CITY MINDED

Co-funded by the Erasmus+ Programme of the European Union

3. Carbon Accounting of urban areas and Carbon Footprint mitigation measures

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Abstract

The Carbon Accounting Methodology proposed by the University of Siena in the City-Minded Workshops is based on a framework that offers the opportunity to modelling the effects of different environmental solutions to mitigate the current Carbon Footprint of an urban system at different scales (i.e., neighborhood, household, and person). The framework is inspired by the Intergovernmental Panel on Climate Change standard methodology for Greenhouse Gas emissions inventory of Nations and the assessment approach proposed in the EU FP7 City-Zen Project, which combine new technologies and citizens' behavior. This framework allows to both assess the Carbon Footprint of urban areas and to estimate the effects, in terms of Carbon Footprint mitigation, of a series of actions with the goal to reach the Carbon Neutrality. The Workshops have been divided into lessons and co-working sessions, carried out in presence or online (considering the pandemic COVID-19 restrictions). In the case of a face-to-face experience, teachers, students, and stakeholders have the opportunity to carry out the site visit of the studied urban area, conducting interviews with citizens and experimenting with the effects of a greater variety of strategies, not limiting them only to the production of electricity from renewable resources (as in the case of the online workshop). To better understand the methodological framework, the case study of the online Workshop conducted in Seville (Spain) was presented. The developed approach offers the opportunity to provide an integrated vision of the city of the future.

1. Introduction

The growing attention paid to anthropogenic greenhouse effect is leading Nations and International Organizations to pursue common goals to limit the inevitable climatic impacts that the Planet is already experiencing and will increase in the coming years. The 195 States that signed the Paris Agreement in 2015 have set a common goal to limit global warming well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C, recognizing that this would significantly reduce the risks and impacts of climate change (UN, 2015). The European Union, following its commitment to global climate action, has set itself the goal of becoming climate neutral (i.e., a Country with net-zero greenhouse gas (GHG) emissions) by 2050 (EU, 2022). This ambitious goal is the cornerstone of the "European Green Deal" and, to achieve it, it has set the intermediate target of a net domestic reduction of at least 55% in GHG emissions by 2030 compared to 1990 levels (EC, 2021). The long-term strategy of the European Commission has identified cities as strategic points and ideal laboratories for the

On the left:
Square Leon Serpollet, Parigi
Credits: Anna Laura Palazzo

study and application of transformative and sustainable solutions (EC, 2018).
A new city planning system can be the main driver to achieve net GHG emissions by 2050. The *City Minded* Project and the Methodology developed and tested during its City Decarbonization Itinerant Workshops fit perfectly into the objectives of the GHG emissions reduction, set by Europe. For this reason, it represents a valid tool for the climate impact assessment in the urban contexts, suggesting also specific environmental policies for the improvement of inhabited areas.
The Carbon Accounting Methodology proposed in the Project's City Minded Workshops is based on a framework that offers both the opportunity to quantify the current GHG emissions (or Carbon Footprint) of urban systems at different scales (i.e., city, neighborhood, household, and single person) and to estimate the effects, in terms of Carbon Footprint mitigation, of a series of actions with the goal to reach the Carbon Neutral condition. The City Minded Workshops have been divided into training and co-working sessions, carried out in presence or online (considering the pandemic COVID-19 restrictions), creating a learning approach based on both theoretical and practical skills. In the case of a face-to-face experience, teachers, students, and stakeholders could carry out the site visit of the studied urban area, conducting interviews with citizens, activities that cannot be done if the workshop take place online. To better understand the methodological framework, the case study of the online Workshop conducted in Seville (Spain) was presented.
The developed approach offers the opportunity to provide an integrated vision of the city of the future.

2. Material and methods

The training session consisted in two presentations:

1) An overall description of the Carbon Accounting Methodology developed and applied during the City Minded Workshops, with a brief historical report of the working path that led to this framework. The developed framework was inspired by the Intergovernmental Panel on Climate Change (IPCC) Guidelines for GHG emissions inventories of Nations (IPCC, 2006; 2019), and the advances carried out by the Ecodynamics Group of the University of Siena (Italy) in much scientific research (Bastianoni et al., 2014; Maccanti et al., 2017; Marchi et al., 2012; 2017; 2018), including that of the EU FP7 City-Zen Project (Pulselli et al., 2018, 2019, 2020, 2021);
2) A detailed explanation of the exercise that students had to carry out (in the provided Excel file) during the co-working session. The purpose of the exercise was the estimation of the current Carbon Footprint (CF) of the study area (in this case the Municipality of Seville), the related Virtual Equivalent Forest surface (i.e., the forest area needed to remove from the atmosphere the GHG emissions due to the human activities performed within the analyzed territorial boundaries) and the mitigation measures toward Carbon Neutrality, paying particular attention to energy production from renewable resources.

Students were divided into 2 virtual working classrooms, and they had about 2 hours to develop the exercise,

Emission sectors	Impact sub-categories
1) Energy	✓Transport ✓Heating for residential and tertiary sectors ✓Energy production in industry ✓Electricity production and consumption
2) Waste	✓Landfill ✓Anaerobic digestion ✓Wastewater treatment plants
3) Agriculture, Forestry and Other Land Uses (AFOLU)	✓Green areas uptake ✓Food consumption

Figure 1 - Emission sectors and impact sub-categories of the Municipality of Seville.

discussing among themselves.
The CF of the Municipality of Seville was inventoried, considering the emission sectors of origin, divided into impact sub-categories (Figure 1). The impact sub-categories, analyzed in the study, were the energy use (e.g., electricity, natural gas and other fuels used for lighting, appliances, cooling, heating, domestic water heating, and cooking), mobility (concerning all the fuels used for public and private vehicles), waste management, water consumption and eating habits. For the latter, three types of diet were considered: a diet with medium-high consumption of animal protein, a balanced diet, and a balanced diet with purchase of local food.

The accounting methodology considered carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions, converted in CO_2 equivalent (CO_2eq) applying the respective 100-year Global Warming Potential (GWP). Thus, a CO_2eq is a metric measure used to compare all GHG emissions other than CO_2 to their equivalent amount of carbon dioxide, on the base of their GWP values (IPCC, 2021).

GHG emissions were calculated, applying the following basic Equations (Eq. 1 and Eq. 2), proposed by the IPCC Guidelines (IPCC, 2006; 2019):

$$CF_i = AD_i \, x \, EF_i \qquad \text{(Eq. 1)}$$

$$CF_{TOT} = \sum_{i=1}^{n} CF_i \qquad \textit{(Eq. 2)}$$

where:
$\boldsymbol{CF_i}$ = the carbon dioxide equivalent emissions in one year (kg CO_2eq);
$\boldsymbol{AD_i}$ = the activity data (e.g., tons of gasoline consumed for transport);
$\boldsymbol{EF_i}$ = the specific emission factors per unit of activity (e.g., kg CO_2eq/t gasoline for transport).

The assessment methodology associated a specific emission factor (EF_i) to each human activity (AD_i).
The Virtual Equivalent Forest surface, needed to absorb the GHG emissions

from each human action, was quantified by the production between the CF of a specific activity and a conversion factor, that in average is equal to 1.3 kg of CO_2/m^2 of forestland. The sum of all Equivalent Forest surfaces provided the overall green area able to remove from the atmosphere all the GHG emissions of the analyzed territorial district (Pulselli et al., 2019).

Lastly, students were invited to simulate the CF mitigation through the implementation of some environmental policies, considering the consumption savings, the policy penetration rate in the population and the electricity production yield from renewable resources. In particular, the GHG emissions reduction was developed, hypothesizing the installation of new devices (i.e., photovoltaic (PV) panels and wind turbines). Moreover, the location in which these technologies could be installed, and the potential electricity production have been identified. A series of actions concerning different spatial (from the household to the whole city) and time scales of implementation (short-, medium-, and long-term mitigation measures, which can be applied in 10-20-30 years) was performed. The Virtual Equivalent Forest surface was "crunched", because of the hypothesized decarbonization plan, using the Pac-Man Game as a visual tool.

3. Results and Discussion

The CF of the Municipality of Seville (3,371,865 t CO_2eq) was reported in Table 1, indicating that the protein diet had the greater impact (39.6%) on the total, followed by mobility (26.2%) and the fossil fuels used for the industrial sector (9.8%). The electricity consumption covered 9.6% of the overall emissions with a relevant contribution played by the residential activities (3.9%). The waste management contributed to 7.0% of the total GHG emissions, considering the low percentage of recycling and the massive waste disposal in landfills.

The current CO_2 uptake was indicated with a negative (-) sign because it represented the removal of this GHG from the atmosphere due to the local ecosystems. It showed a very low value (-2,596 t CO_2eq), determining a percentage abatement of the total emissions equal to 0.1%.

Figure 2 - Virtual Equivalent Forest surface of the Municipality of Seville (in yellow).

In the next page
Figure 3 - Carbon Footprint (CF) mitigation of Seville Municipality.

Table 1: Carbon Footprint (CF) of the Seville Municipality.

Activity sector	CF	Percentage of the total
	t CO2eq	%
1) ELECTRICITY CONSUMPTION	**322,095**	**9.6%**
Industrial sector	83,047	2.5%
Residential sector	131,135	3.9%
Transport	3,171	0.1%
Tertiary sector	93,409	2.8%
Agriculture sector	11,332	0.3%
2) FUEL CONSUMPTION	**584,903**	**17.3%**
Industrial sector	329,175	9.8%
Residential sector	93,504	2.8%
Tertiary sector	22,863	0.7%
Agriculture sector	139,360	4.1%
3) MOBILITY	**882,402**	**26.2%**
4) WASTE	**234,668**	**7.0%**
5) WATER	**11,592**	**0.3%**
6) FOOD (protein diet)	**1,336,203**	**39.6%**
TOTAL EMISSIONS (sum 1+2+3+4+5+6)	**3,371,862**	**100.0%**
ACTUAL UPTAKE	**-2,596**	**0.1%**

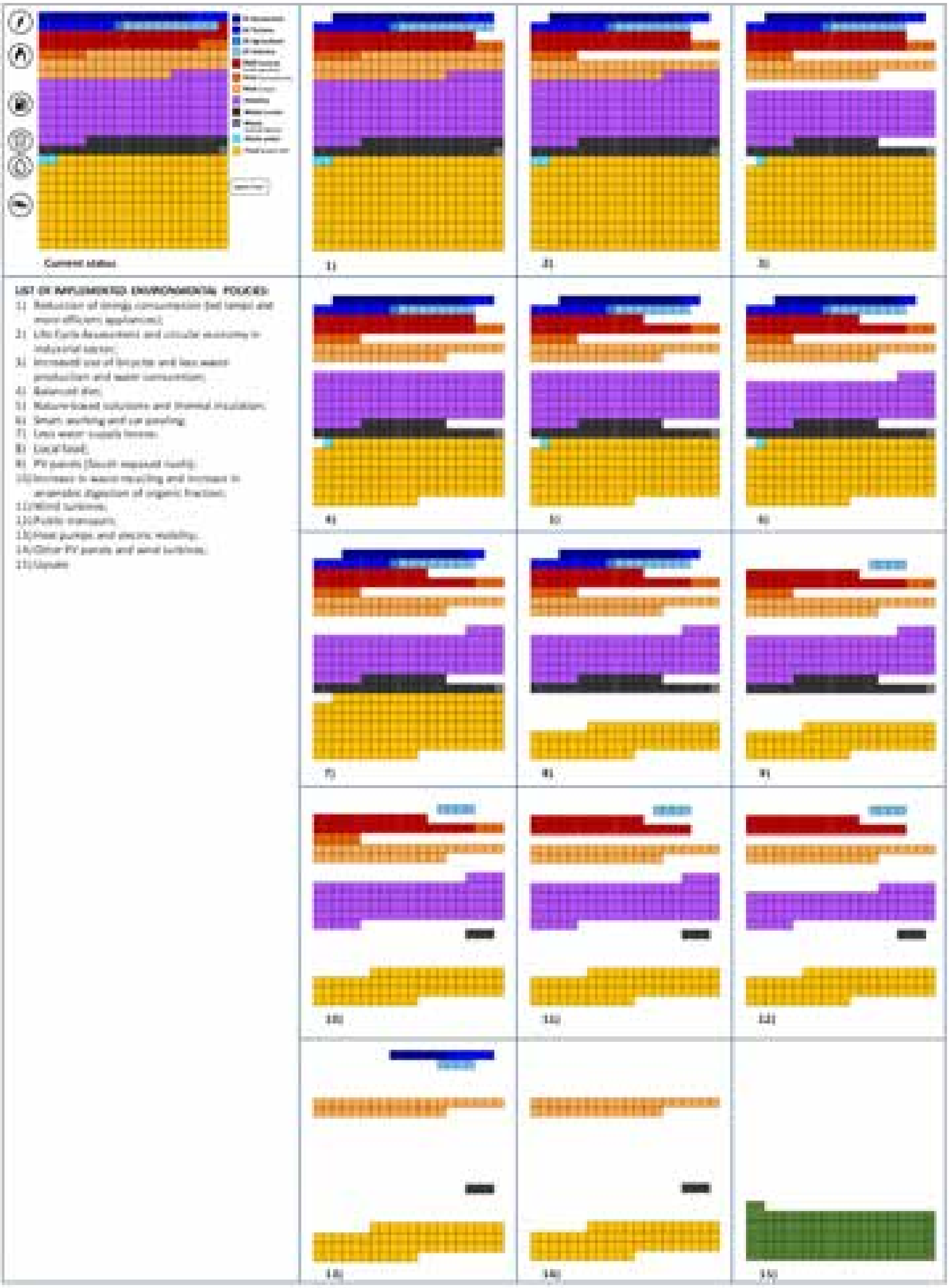
Current status
1)
2)
3)
LIST OF IMPLEMENTED ENVIRONMENTAL POLICIES:
1) Reduction of energy consumption (led lamps and more efficient appliances);
2) Life Cycle Assessment and circular economy in industrial sector;
3) Increased use of bicycles and less waste production and water consumption;
4) Balanced diet;
5) Nature-based solutions and thermal insulation;
6) Smart working and car pooling;
7) Less water supply losses;
8) Local food;
9) PV panels (South exposed roofs);
10) Increase in waste recycling and increase in anaerobic digestion of organic fraction;
11) Wind turbines;
12) Public transport;
13) Heat pumps and electric mobility;
14) Other PV panels and wind turbines;
15) Uptake
4)
5)
6)
7)
8)
9)
10)
11)
12)
13)
14)
15)

Figure 4 - Potential location of PV panels (a) [red boxes] and wind turbines (b) [yellow shape].

The Virtual Equivalent Forest surface of the Municipality of Seville was 249,855 ha, represented by 500 green squares of 5 km^2 each one (Figure 2). The actual green urban area (i.e., parks, gardens, and lawns) was only 806 ha, therefore, 94% smaller than the Virtual one.
The Current status, reported in Figure 3, showed that 198 squares of Virtual Equivalent Forest were needed to remove emissions from a high protein diet, 131 squares for the mobility, 49 for the fuel consumption in industrial activities and so on.
Figure 3, also, shows the CF mitigation, illustrating the implementation of 15 environmental policy in a decarbonization path. It was important to remember that to achieve ambitious results, such as Carbon Neutrality, a wide variety of measures had to be implemented. Among these, the electricity production from renewable resources (i.e., PV panels and wind turbines) and the transition to electrified devices for transportation and buildings heating demonstrated the highest emissions reduction.
During the exercise students identified in the Google Maps platform the surfaces available to install other PV panels, as well as the location and the number of new wind turbines that could be introduced in the municipal jurisdiction (Figure 4).
The installation of about 290 ha of PV panels on the buildings and warehouses roofs in the industrial area was simulated, suggesting an annual electricity production of 580 GWh, mitigating the CF due to the electricity consumption of 33% and that of the overall Municipality of 5%.
Moreover, the installation of about 42 wind turbines (3 MW each one) was hypothesized in the area near the Guadalquivir River, characterized by cropland, grassland, and vacant lots just outside the boundaries of the municipality. Inside the municipal area the installation of wind turbines was impossible because of the densely inhabited and built landscape. These turbines would be able to produce 294 GWh of electricity each year, mitigating the CF due to the electricity consumption of 17% and that of the overall Municipality of 7%.

4. Conclusion

The main objective of the Carbon Accounting Methodology was to develop and test an innovative and creative learning approach in which students, specialists and stakeholders could collaborate to identify and design the best solutions for decarbonizing cities. Specifically, the methodology focused on the development of an innovative urban landscape planning able to address site-specific challenges and to provide roadmaps toward carbon neutral cities. A tool such as the one presented in this paper shows how it is possible and relatively simple to carry out a preliminary study (which presents, of course, many assumptions) able to give an immediate idea of the greenhouse gas emissions amount for which a given urban area is responsible. This, in the first analysis, can be a valid starting point for putting in place preliminary reasoning for the redevelopment and optimization of an urban area in a medium- to long-term perspective in which to achieve carbon neutrality.

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Box_3_Ravacciano, Siena

Ravacciano is a residential neighborhood of the city of Siena (central Italy), and it hosts 1631 inhabitants, with an average density of 35.6 people/ha. The first settlement has been built during the ‘30s, in the years of the fascist regime. Then the built area has grown until the ‘70s and ‘80s. The valleys of Follonica and Ravacciano, separated by the medieval wall, connect the old city to the Ravacciano neighborhood and the productive and commercial district down the hill. These valleys are partially accessible to people and are fractioned into several private properties, besides a few areas with public ownership (Figure 1).

Although it is outside the medieval walls that surround the historic center of Siena, it represents a living and active reality of the city, an integrated part of it and certainly not a peripheral district.

Data on age and gender of the population in Ravacciano neighborhood show that females are almost 56% of residents. Moreover, almost 15% are under 18 years old (248), 38% are over 18 and under 50 (636), 26% are over 50 and under 70 (430) and the over 70 are almost 22% (362). The average age in district in 2019 is 48 years.

The Ravacciano neighborhood and the adjoining valleys are part, also, of the Horizon 2020 URBiNAT project (Urban Innovative & Inclusive Nature), which involves 28 partners, 7 cities (including Siena) and 15 countries. Taking the full physical, mental, and social well-being of citizens as main goal, the URBiNAT project aims to plan a healthy green corridor as an innovative and flexible Nature-Based Solution (NBS), which itself integrates many micro NBS emerging from community-driven design processes (e.g., the restore of the “Fonte d’Ovile” historical water basin and the creation of urban vegetable gardens in the Ravacciano valleys). The selection of Ravacciano neighborhood for the first online City Decarbonization Itinerant Workshop of the ERASMUS+ City Minded Project allows for joining efforts, creating synergies between these two European projects funded by different European Programs.

The objective of the City Minded Workshop was to put together teachers, researchers, students, and local stakeholders to address common onsite challenges and define collaborative urban decarbonization roadmaps for the Ravacciano neighborhood in Siena through a ‘learning-by-doing’ method.

Figure 1 - Case study area: Ravacciano neighborhood (orange box) and valleys.
Figure 2 - A view of the Ravacciano neighborhood, photographed from the Ravacciano Valley. Source: https://urbinat.eu/