



## **Future city visions. The energy transition towards carbon-neutrality: lessons learned from the case of Roeselare, Belgium**

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3 **Future City Visions - The Energy Transition Towards Carbon-Neutrality – Lessons**  
4 **learned from the case of Roeselare, Belgium**

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16  
17 **Abstract**

18 As climate change develops, with most of the world population living in urban areas, decarbonisation of cities is  
19 among the greatest challenges of the coming decades. In the framework of the EU City-zen project, a number of so-  
20 called *Roadshows* has been organised in ten cities within and outside Europe in order to plan and kick-off their  
21 transition towards an energy- and climate-neutral economy. During the *Roadshows*, a group of experts is engaged to  
22 perform co-working activities and participative labs involving local stakeholders. These activities support cities in  
23 identifying their own decarbonisation pathways, mainly by combining three mutual processes, i.e. energy design,  
24 urban design and carbon accounting. The latter, in particular, has been used to quantify the greenhouse gas emissions  
25 of cities and neighbourhoods and to estimate the mitigation effect of a combination of measures towards the  
26 desirable condition of carbon neutrality. This exploratory and proactive design process has been successfully  
27 demonstrated through intensive workshops and can be potentially replicated in other cities. This paper provides a  
28 schematic overview of the main results achieved in the Belgian town of Roeselare, but more significantly it describes  
29 the techniques needed to make that cooperative process understandable, impactful and implementable. It is likely  
30 that 2050 European goals will drastically change urban environments and socio-economic dynamics in cities, due to  
31 the fragmentation of energy sources. Hence, from this standpoint there is a vital need for integrated technologies and  
32 infrastructures, a circular economy and community-based processes such as food production, sharing of facilities and  
33 valorisation of ecosystem services. The City-zen Roeselare Roadshow brought over 300 stakeholders into the process  
34 of re-imagining and visualising their 2050 future city with these solutions. Stakeholders, with no particular expertise in  
35 carbon accounting or sustainability, would now have the capability of understanding and applying these solutions in a  
36 combined effort to meet the zero-carbon challenge. The approach is generally replicable elsewhere being highly  
37 visual, impactful, transferable, and multi-stakeholder friendly. Given that data are made locally available, the  
38 combination of this general approach, site-specific assessments and the involvement of both experts and local  
39 stakeholders (i.e. policy makers, citizens, etc.) allow the transition to start by referring to any real city or  
40 neighbourhood.

41  
42 **Keywords:** Greenhouse Gas Inventory; Decarbonisation Strategy; Energy Potential Map; Roadshow; Sustainable City.

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## 1. Introduction

Today 55% of the world’s population lives in urban areas, a proportion that is expected to increase to 68% by 2050 (UN 2018); moreover, as the world population is expected to increase by a further 30%, the associated change in climate will be significantly affecting ecosystems and global land use. In Europe, the level of demographic urbanization is approximating 74%. Accordingly, the European Commission’s long-term strategy (EC 2018) interprets cities as ideal laboratories for transformative and sustainable solutions. City refurbishment and better spatial planning, including that of green spaces, can be major drivers to pursue the aim of net-zero greenhouse gas (hereafter, GHG) emissions by 2050, likely through a socially fair transition in a cost-efficient manner.

The EC strategy (EC, 2018) points the way forward to a carbon-neutral economy by referring to a set of joint actions:

- improving energy efficiency in buildings, which today are responsible for 40% of energy consumption;
- maximising the deployment of renewables and the use of electricity to fully decarbonise Europe’s energy supply;
- embracing clean, safe and connected mobility, currently responsible for around a quarter of the GHG emissions in the EU;
- fostering circular economy as a key enabler to reduce GHG emissions, starting from reducing the input of materials through reuse and recycling, and significantly modernising or replacing existing installations;
- developing an adequate and smart infrastructure ensuring optimal interconnection, especially to support the major developments framing the energy transmission and distribution landscape of tomorrow;
- reaping the full benefits of bio-economy enhancing capacity of agriculture and forestry to provide sufficient food, feed, and fibres as well as to support the energy sector and various industrial and construction sectors.
- enforcing carbon sinks, as important as reducing emissions, by maintaining and further increasing the natural sinks of forests, soils, and agricultural lands and coastal wetlands;
- tackling remaining CO<sub>2</sub> emissions with carbon capture and storage previously seen as a major decarbonisation option for the power sector and energy-intensive industries.

Urban areas will be the first centres of innovation regarding most of the actions mentioned in the EC strategy. The strategy also states that, combined with the transition to carbon-free technologies, behavioural changes by individuals and companies must underpin any evolution: “making the transformation towards a net-zero GHG economy is not just about technologies and jobs, it is about people and their daily lives, about the way Europeans work, transport themselves and live together” (EC 2018).

Before the delivery of the last EC directives for climate action, an articulated framework to kick-off decarbonisation of European city neighbourhoods has been implemented in the work-plan of the EU City-zen project (City-Zen 2015-2019), much in advance and fully in line with the EC strategy actions. It has been tested since 2015 in a series of events organised throughout cities in Europe and outside. The so-called ‘City-zen Roadshows’ have been conceived as itinerant laboratories involving a group of international experts together with local stakeholders. The Roadshow aims to point the way towards energy and carbon neutrality of the hosting cities and their neighbourhoods. Combining global expertise of specialists with local stakeholder knowledge of specific contexts and lifestyle, the Roadshows perform a participative design process to figure out future scenarios and finally co-create a sustainable “city vision” resulting from a progressive and reliable transition plan. The scope of each Roadshow is to imagine how our cities would appear, operate and contribute to healthier lifestyles by 2050, imaging their energy transition accomplished, and use these forecasts to inspire local stakeholders, unlock stasis and kick-off the decarbonisation way-out.

The City-zen Roadshow series has been hosted in Amsterdam (NL), Belfast (UK), Izmir (Turkey), Dubrovnik (HR), Menorca (ES), Sevilla (ES), Roeselare (BE), Preston (UK), Nicosia (CY), and Amersfoort (NL). Dobbelsteen et al. (2018a) presented outcomes from the Roadshow in Dubrovnik focussing on the Gruž neighbourhood. The decarbonisation scenario presented combines technologies for renewable energy generation, such as PV panels and wind turbines, with innovative solutions of circular economy concerning sewage treatment from cruise ships and algae farms to generate biogas, biofuel and other materials (e.g. fish-feed for aquaculture). Moreover, the transport system from the harbour to the old town of Dubrovnik was reorganised to respond to significantly high flows of tourists and cruise ship passengers. Pulselli et al. (2018b) showed results from the Roadshow in Sevilla, mainly referring to a district heating/cooling network fed by heat pumps connected to underground aquifers as renewable heat/cold source in the Tiro de Linea neighbourhood. Electrification through PV panels on roofs and canopies and greenery systems on facades were advised, also to mitigate the intense urban heat island (UHI) effect. Marchi et al. (2018) presented a similar approach for the energy transition of the historical centre of Siena, a UNESCO heritage site, through full electrification and the provision of a “solar belt” on available flat roofs of productive and commercial districts around

1 the city centre. [Marchi et al. \(2017\)](#) also assessed the effect of green valleys within the historic centre in terms of  
2 carbon uptake.

3 Regarding the practice of participative design and visioning of future scenarios, [Krzywoszynska et al. \(2016\)](#) presented  
4 outcomes from a participatory process developed in Stocksbridge (UK) based on models and visualizations, using  
5 images, maps and physical representations to enable a bottom-up engagement of citizens, bringing together scientific  
6 knowledge and local perspectives. The process aimed at creating models of desired future for energy systems,  
7 matching electricity generators and energy storage with electricity demand, and demonstrated how technological and  
8 social innovation may result in greater diversity and appropriateness of solutions, depending on local contexts. [Acero  
9 López et al. \(2019\)](#) experienced a design process based on a Soft Systems Methodology that engages the participants  
10 to figure out innovative solutions in the specific field of water management and saving. The active involvement of the  
11 community in the design process, including prototyping, allows to give visibility to the initiatives and rise awareness  
12 about the use of natural resources. [Nevens et al. \(2013\)](#) show a framework for Urban Transition Labs based on a  
13 sequence of steps. After a preliminary analysis, a participative process of imaginary scenario building (envisioning) is  
14 employed to create inspiring visions, based on shared principles of sustainable development. Starting from these  
15 visions, different strategic transition pathways, including the experimentation of alternative ways of living, to realise  
16 the desired future situation are outlined. To this aim, monitoring instruments for assessing potential effects of the  
17 actions planned are used, not just to 'measure' but rather to trigger action, to enhance system change in a desired  
18 direction. More in general, a comprehensive overview on quality criteria for sustainability visioning practices, as a  
19 method for depicting how a desirable future might look and for planning urban transformations, is provided by [Wiek  
20 & Iwaniec \(2014\)](#). The authors highlight how creating models of desired futures, made of images, maps and physical  
21 representations, is part of the visioning process; rather than being just informative as common scenarios, visions must  
22 be visionary (including aspirational surprise), systemic, coherent, plausible, tangible, relevant (focus on people, their  
23 roles, and responsibilities), nuanced, motivational and shared.

24 This paper makes a further step in the direction of determining consistent procedures to quickly support decisions and  
25 efficiently address participative processes to plan action for climate. As main reference for the evaluation and  
26 assessment performed in this study, [Pulselli et al. \(2018a\)](#) provided a comprehensive carbon accounting framework as  
27 implemented and tested through City-zen Roadshows; in order to provide a robust benchmark, it refers to an average  
28 European household and neighbourhood based on Eurostat data. The experience in Roeselare here presented is a  
29 practical demonstration of this framework, first applied to assess the carbon emission of the targeted neighbourhood  
30 and then to determine the decarbonisation strategy. Moreover, the co-creative and socially impactful methodology  
31 has been described by [Martin et al. \(2017\)](#) to be replicable in any context and for demographically diverse audiences  
32 whose specialisms may, or may not be sustainability based.

33 The paper shows outcomes from one of the most successful City-zen Roadshows hosted in Roeselare (Belgium) and  
34 demonstrates how creative inputs from a multidisciplinary assembly of experts and local stakeholders can drive cities  
35 though the process of becoming energy and carbon neutral. This research does not cover all aspects of energy and  
36 urban planning or carbon accounting but rather provides a partial but operative tool to inform processes of instant  
37 planning, meaning with "instant" that the proposed framework allows experts to interact, collect information and  
38 discuss with local stakeholders, accordingly elaborate plans and assessments and finally communicate results to a  
39 wide audience of non specialists, within 5 days of intensive workshop. More complete models exist that can provide  
40 exact and exhaustive outcomes, for example on Carbon Accounting of cities or regions ([Marchi et al. 2012](#); [Bastianoni  
41 et al. 2014](#)), but the experience made in Roeselare has a crucial time factor. The present paper shows a combination  
42 of practices that can be replicated and implemented in any city or neighbourhood in a few days to deliver an amount  
43 of information, data and graphical issues, rising awareness on sustainable assets, giving visibility to longings and  
44 ambition of citizens and filling them with enthusiasm to start a consistent transition towards sustainability. The City-  
45 zen Roadshow is a disruptive kick-off that fosters experts, policy makers, entrepreneurs and citizens to cooperate and  
46 finally look at one possible future to pursue and share. How does the 2050 Roeselare (or any other city or  
47 neighbourhood) look like? What is the most desirable future for the city? Where should we start from and proceed to  
48 achieve the desired results?

49

## 50 **2. Materials and methods**

51 This section is dedicated to the presentation of case studies and methods that are built on the interaction with local  
52 stakeholders to collect data from different sources, identify potentials based on surveys and interviews and make  
53 observations through open discussions in round tables. The participative process commits local stakeholders since the  
54 beginning to observe and refer on specific issues suggested by experts within their own neighbourhood. Driven by

1 experts that give a direction and take the story at their own pace, assuring a certain methodological rigour,  
2 information and inputs from people attending the workshop constitute the materials for the next elaborations.

3

## 4 **2.1 The City-zen Roadshow method**

5 The scope of City-zen Roadshows is to engage city stakeholders with innovative design and technological solutions and  
6 facilitate the development of a city roadmap for energy transition and decarbonisation. This aim is met through  
7 multidisciplinary group co-working and interactive sessions for knowledge transfer and capacity building, during which  
8 a team of international experts, involved as City-zen partners, works closely with people from the hosting city – policy  
9 makers, energy planners, practitioners, entrepreneurs, researchers, students and of course, the citizens themselves –  
10 no matter what age or background.

11 Roadshows are conceived to be implemented in just a few working days, including data collection and elaboration.  
12 Activities and events taking place over the five-day programme include onsite investigations, Energy Potential  
13 Mapping, creative design workshops relating to social, energy and carbon challenges. Before and during Roadshows,  
14 the characteristics of the hosting city/neighbourhood are systematically analysed, leading to good insight into the  
15 current challenges and potentials of the city. In close collaboration with local stakeholders, the team of experts  
16 investigates the use of energy and emission of GHG, in total numbers and per household, and develops a proposal for  
17 interventions that are coherently informed by available hard data from the city and validated by energy and carbon  
18 calculations. Designs, calculations and proposed embedment in governance leads to a “City Vision” that is presented  
19 to city audience and key decision makers on the final morning.

20 The extemporary nature of Roadshows, as intensive cooperative sessions with a strict timeline, in certain cases  
21 requires assumptions and approximations, but nevertheless provides reliable outcomes. Considering the short term of  
22 political mandates and the instability of social-economic-legal variables in our changing world, timely and effective  
23 decision support systems are critical.

24 The Roadshow approach concerns three mutual processes that are complementary implemented, i.e. energy design,  
25 urban design, carbon accounting. Energy design is mostly based on the *City-zen urban energy transition methodology*  
26 ([Dobbelsteen et al. 2018b](#); [Dobbelsteen et al. 2019](#)). References for the urban design process are [Campbell \(2018\)](#) and  
27 [Keeffe \(2014\)](#). The city of Roeselare, with a populace of 61,657 inhabitants (2017) has been taken as a test bed.

28

## 29 **2.2 Carbon Accounting**

30 The carbon accounting framework refers to a typical GHG emissions inventory, focussing on a limited set of items.  
31 These include energy consumption for households and private cars, water use and domestic waste management thus  
32 representing a portion, and not the totality, of GHG emitted by the citizens. Several studies concerning the Carbon  
33 Footprint of cities have highlighted the importance of other factors not included in this assessment, for example the  
34 indirect emissions released in the global supply chain during the production of final goods and services ([Minx et al.](#)  
35 [2013](#); [Lenzen and Peters 2010](#); [Suh et al. 2004](#); [Chen et al. 2016](#); [Fry et al. 2018](#)) or those associated to trade (import  
36 and export of goods) through a consumption-based approach ([Lenzen 2001](#); [Wiedmann et al. 2010](#), [Caro et al. 2014](#),  
37 [2017](#)). Nevertheless, the GHG inventory performed here, far from being exhaustive, aims at monitoring energy, waste  
38 and water flows as crucial information to drive design practices.

39 The GHG inventory is made in compliance with the Global Protocol for Community-Scale GHG Emissions Inventories  
40 (GPC) ([GHG Protocol, 2014](#)); in particular, the GHG emissions monitored occur within the city and refer to the GPC  
41 scope 1. Nevertheless, the Emission Factors selected include indirect emissions generated by lifecycle processes of  
42 electricity generation (by referring to the national grid mix), fuel production, water and waste management; the  
43 accounting framework adopted therefore refers to the GPC scope 2 concerning input flows crossing throughout city  
44 boundaries. [Kennedy and Sgouridis \(2011\)](#) define this category as external emissions directly caused by core municipal  
45 activities. Emissions occurring outside (scope 3) are not included in the observation. The classification of urban  
46 emissions into three scopes, allows for the definition of carbon strategies and aims to enforce technical constraints on  
47 activities that fall under the jurisdiction of a municipal authority, while allowing for flexibility in balancing emissions  
48 for activities outside the city boundaries; accordingly, the Carbon Neutral label mentioned in this study implies that  
49 any and all emissions for which the city is responsible under Scopes 1 and 2 are fully eliminated or balanced through  
50 internal or external sequestration ([Kennedy and Sgouridis 2011](#)).

51 The Carbon Accounting procedure developed during the Roadshow has a dual role: first, to assess the GHG emissions  
52 of the city and, afterwards, to ex-ante estimate the effects of GHG emission mitigation measures.

1 Statistical data refers to the Municipality of Roeselare. Datasets have been provided directly by the “climate group” of  
2 the Municipality mainly referring to the [West-Vlaanderen Province \(2015\)](#) online database and the statistics on energy  
3 use in Belgium ([Febeg 2015](#)). The energy demand for industry has been partially considered (estimated 100  
4 GWh/year) because the energy supply of industrial production has been omitted (this would need very specific  
5 interventions for optimisation and impact mitigation such as that concerning a product and its lifecycle processes).  
6 The Carbon Accounting procedure systematically follows the framework presented by [Pulselli et al. \(2018a\)](#), including  
7 values of Emission Factors (EF). In particular, the EF for electricity has been assessed based on the electricity grid mix  
8 of Belgium (i.e. 0.181 kg CO<sub>2</sub>eq/kWh, given: 29% thermoelectricity powered by natural gas; 51.7% nuclear; 17.9%  
9 renewables; 1.4% net import). The impact of energy use in different sectors has been assessed based on the use of  
10 different fuels. Both electricity and fuel mix per sector are shown in Table 2.1.1, together with the EF used per each  
11 fuel ([IPCC 2006](#)) and the calculation of EF of fuel mix per each sector, based on current uses (Data sources: [West-  
12 Vlaanderen Province 2015 and Febeg 2015](#)).

13  
14 <TABLE 2.1.1>

15  
16 Results from the Carbon Accounting process are shown in Table 2.1.2 considering different emission sources. The  
17 carbon accounting follows the framework provided by [Pulselli et al. \(2018a\)](#), including the Emission Factors per  
18 emission source ([IPCC 2006](#)) and the assessed EF per fuel mix. These also include impacts of waste and water  
19 management systems. In particular, the impact of domestic waste treatment depends on the waste management  
20 system that currently exists in the area (i.e. 0.256 kg CO<sub>2</sub>eq/kg, given: 29% waste to energy; 21% organic; 4% landfill;  
21 46% recycling). Electricity has been aggregated considering the demand of the different sectors ([West-Vlaanderen  
22 Province 2015 and Febeg 2015](#)). Only electricity for public lighting is shown separately in the table. The carbon  
23 emission of Roeselare has resulted in 351,842 t CO<sub>2</sub>eq on annual basis (2017).

24  
25 <TABLE 2.1.2>

26  
27 In order to drive the transition process, with special attention for the housing sector, a typical household in Roeselare  
28 has been profiled by scaling down municipal data (26,349 households have been assumed within the municipality,  
29 given 2.34 inhabitants per household and 61,657 inhabitants – Our assessment from: [Roeselare in cijfers 2017](#)). The  
30 GHG emission of a household in Roeselare is therefore 6.75 tonne CO<sub>2</sub>eq/year.

31  
32 <TABLE 2.1.3>

33  
34  
35 The Carbon Accounting procedure has been incrementally developed to perform in the intensive and short period of a  
36 Roadshow. Compared to a standard GHG inventory, it allows for assumptions and approximations, nevertheless  
37 outcomes are coherent and have a required level of detail. From the scale of the household to that of the city, they  
38 are used to evaluate strategies of energy transition and drive choices of both energy and urban designers.

39  
40 **2.3 Energy Potential Mapping**

41 The basic approach of Energy Potential Mapping concerns the definition of current energy demand and energy  
42 potentials in the first step, to calculate feasible scenarios in the next step ([Broersma et al. 2013](#)). This includes  
43 interventions from the scale of single households to that of building blocks and streets, up to the neighbourhood and  
44 the whole city.

45 Statistical data of the current energy use in Roeselare have been analysed and compared to realistic energy potentials  
46 from renewable sources in the city to plan for the most realistic energy strategy with the goal of becoming carbon  
47 neutral. Electricity demand has been calculated to be almost 500 GWh<sub>e</sub>/year, whereas the potentials are estimated to  
48 be almost 780 GWh<sub>e</sub>/year. For proper estimations, the physical context, local climatic conditions and technical  
49 limitations of electricity production have been studied, e.g. available roof surfaces and non-roof surfaces for energy

1 production, annual solar radiation, average wind speed, efficiencies of solar panels and wind turbines and the  
2 availability of waste (Figure 2.2.1).

3 For the installation of photovoltaic (PV) panels 235 hectares of roof are available (around 45% of the built  
4 environment is residential representing around 26,250 units – Source: [Roeselare in cijfers 2017](#); with an estimated  
5 average of 100 m<sup>2</sup> per residential unit divided by an estimated 2.5 layers implies 40 m<sup>2</sup> of roof surface per residential  
6 unit and 235 ha for the entire BE of Roeselare), of which 50% is considered to be suitable for energy production. 80  
7 hectares are estimated (for non-roof PV installation) to be available along roads (along an estimated 160 km of large  
8 roadways and railways, a strip of 5m width of panels can be installed) and there is space for 40 large 4MW wind  
9 turbines considering a reasonable distance between turbines (around 450 m for 160m high towers) and, keeping local  
10 regulations for installation in mind, minimum distance from buildings (usually around 200-250 m). General criteria for  
11 designing wind farms have been systematically discussed by the *Landscape Observatory of Cataluniya* (OPC 2013).  
12 And finally the amount of waste-to-energy power is estimated.

13 Similarly, the heat demand (around 712 GWh/year) can be supplied by a series of potentials of high-temperature (HT),  
14 medium-temperature (MT) and low-temperature (LT) sources with an estimated potential of 4735 GWh/year (Figure  
15 2.2.2). The use of MT and LT sources in existing buildings most often requires energy renovations.

16 HT sources (above 65°C) include heat from waste incineration, based on the caloric value of the current waste stream  
17 of Roeselare (130 GWh<sub>th</sub>/year), the estimated amount of industrial waste heat (100 GWh<sub>th</sub>/year) and some of the  
18 potential of solar heat from solar collectors mounted on the available roof surface (1480 GWh<sub>th</sub>/year). In figure 2.2.2  
19 half of this last potential is dotted, to indicate that the potential from energy on roofs is ‘shared’ with the potential of  
20 PV(T). The estimate of residual heat is prudential and covers a limited range of thermal energy potentials (6% from  
21 industrial processes and 8% from waste incineration) assuming that some industrial sources in the future might  
22 change into MT and LT thanks to renovation and waste incineration be replaced by alternative treatments.

23 MT (40°C - 65°C) sources include most of the potential of solar heat from solar collectors and residual heat from  
24 cooling and some industrial processes (estimated to be 25 GWh<sub>th</sub>/year). Heat of this temperature can be stored in  
25 closed-loop Borehole Thermal Energy Storage (BTES).

26 LT (below 40°C) sources are PV-thermal heat, which is heat of around 30-35°C from PVT panels, solar panels that  
27 produce electricity and heat, and waste heat from greenhouses and buildings themselves, which can be stored in  
28 open-source Aquifer Thermal Energy Storage (ATES) systems in the underground.

29

30

31

<FIGURE 2.2.1>

32

33

<FIGURE 2.2.2>

34

35

## 36 2.4 Urban analysis

37 Urban designers drive the co-creative workshop sessions that primarily focus on spatial planning, social connections  
38 and design. The urban design team of the Roadshow aims to co-develop with the energy team a series of  
39 interventions that not only change the energy performance of the neighbourhood, but embody spatially the new  
40 lifestyles engendered in the carbon transition. Here, local context, community, culture and lifestyle influence the  
41 design outcomes, essentially starting from a focus on qualitative analyses of the built environment. Despite the high  
42 variability of conditions and challenges, the urban planning approach can be synthesized through a schematic  
43 sequence of design concepts, consisting in matching a set of identified challenges with a set of potential solutions.  
44 This is developed and communicated through producing a meta-language of ideograms. The ideograms themselves  
45 were created using a method similar to that described by [Lynch \(1964\)](#), which helped define a series of typologies of  
46 extant urban structure and identify sub-organisations based on existing urban morphology. These ideograms help  
47 frame a conversation around urban space, lifestyle and technological insertion, which at first is critical of the existing  
48 urban structure, and then develops new synergies which are centred around this place-based critique. The ideograms  
49 produce a clear and simple layered narrative, which can be easily communicated to stakeholders and which later  
50 provides a clear justification for new design trajectories, which will embody the climate transition. Figure 2.3.1 shows  
51 a series of 15 ideograms representing the main city-neighbourhood-specific challenges identified in Roeselare:



1 terms of policy change. An evidence is the study published by [Juwet \(2019\)](#) dealing with a district heating network in  
2 Roeselare; the 'heat backbone' is indicated as a new spatial figure carrying sustainable urban development and  
3 densification projects elaborated by the author "based on workshop drawings and discussions".

4 Various types of professionals, townhall representatives and citizens joined the event. Their backgrounds varied from  
5 specialised energy expert to interested local non-expert. A wide spectrum of volunteers and governmental local and  
6 regional bodies contributed. For example, the energy team from the Municipality of Roeselare, *Energie en*  
7 *Duurzaamheid bij Stad Roeselare*, worked alongside to volunteer community groups including many residents from  
8 the 'Collievijverbeek' neighbourhood, a focus area for the project. Worthy of special mention is the involvement of  
9 education and government organisations based outside Roeselare; a factor that demonstrated how the approach and  
10 subsequent findings are both specific to one city and its urban typology, but also generally transferable to the wider  
11 region, in this case Flanders. Moreover, the engaged stakeholder groups, from key city decision makers to voluntary  
12 organisations, allowed for emphasising the diversity of energy/design expertise, focus and location (local and regional)  
13 of the Roadshow participants. Among others, main focus areas and most active stakeholders have included:  
14 awareness and strengthening the institutional capacities at the regional scale (*Flemish Social Policy Organisation*;  
15 *West Flemish Municipalities*; *VRP Flemish Association for Space & Planning*); education and research into the energy  
16 network in Flanders (*Vrije Universiteit Brussel*); implementation of new cooperative models (*Timelab*); urban  
17 agriculture research & development concerned with intensive urban farming and job opportunities (*Inagro*; *Huis van*  
18 *de Voeding - House of Food*); protection of endangered plant species and nature in Flanders and Roeselare  
19 (*Natuurpunt - Voluntary Organisation*); waste recycling in Roeselare and Flanders (*Mirom*); replicability in European  
20 city neighbourhoods (*European Policy Officer DG ENER*).

## 21 22 **3. Results**

23 Outcomes from participative sessions concern a heterogeneous set of issues regarding urban and architectural design,  
24 energy and housing, mobility systems, waste and water resource management. As shown above, site-specific analyses  
25 include technical observations of buildings, settlements and infrastructures, social behaviours, local economy,  
26 environmental and landscape contexts, carbon emission of households, neighbourhoods and the city. Coherently with  
27 critical observations and data elaborations, technical and design issues show extant opportunities for energy  
28 reduction and reuse, renewable energy potentials, urban infrastructures and services, nature-based systems and  
29 ecosystem services, architecture and urban agriculture, technological and other integrated measures for GHG  
30 emission mitigation. Any knowledge, concept, suggestion and proposed design is made understandable through  
31 graphics, schemes, draws, sketches, 3D models and images and infographics in order to guarantee a clear and  
32 effective communication, and to target the largest audience possible. The final outputs of Roadshows include firstly  
33 the production of a comprehensive and coherent narrative of urban space and energy use in that place, and then a  
34 process and time-based set of interventions, in both the spatial and technical spheres that allow the development of a  
35 new narrative of the city, based on a progressive series of planned actions, which have emerged from co-creative  
36 working with the original constructive narrative.

### 37 38 **3.1 Energy design**

39 The energy design strategy concerns an accurate selection of energy systems and technologies that are to be  
40 integrated in the urban context. The 2050 objectives of energy neutrality have been determined and specifically  
41 structured based on the most suitable solutions that are identified out of the energy potential analysis.

42 The electricity demand (495 GWh<sub>e</sub>/year), is expected to further increase towards 2050 due to electrification of heating  
43 systems (by the use of heat pumps) and to the electrification of transportation. Although the urban population is  
44 expected to grow (Roeselare has grown quickly with around 10% in the last 10 years, a relative slower growth for the  
45 next 3 decades is assumed), the increase of electricity use caused by this is expected to be compensated by a relative  
46 reduction of electricity use from residential, tertiary and industrial sectors (see figure 3.1.3). This final electricity  
47 demand can potentially be supplied by different renewable energy sources including 240 hectares of PV modules  
48 (around 350 GWh<sub>e</sub>/year), 25 4MW wind turbines (around 200 GWh<sub>e</sub>/year) and the co-generation by waste  
49 incineration (20 GWh<sub>e</sub>/year). The impact of waste incineration remains accounted in the GHG emission of waste that  
50 cannot be fully avoided and will be finally compensated.

1 <FIGURE 3.1.1>

2  
3 The heat demand of the current building stock (712 GWh<sub>th</sub>/year) is assumed to decrease in time, because significant  
4 effects (20% reduction is assumed here for the full built environment considering that a usual full energy  
5 refurbishment saves around 40% in heat demand. See [Tabula WebTool 2018](#)) can be achieved in terms of energy  
6 saving (and replacement of poor performing buildings) due to a robust campaign of building retrofitting. New  
7 buildings will have a low additional heat demand and are supposed to be almost energy neutral, so they will produce  
8 their own demand. The remaining heat demand for the current building stock (565 GWh<sub>th</sub>/year) can potentially be  
9 generated by a combination of HT (30%), MT (25%) and LT (25%) sources (assumed that all available HT waste heat,  
10 including from biomass, meets 30% of the demand, for which the use requires no energy refurbishments and is often  
11 the most convenient to get a sustainable heating system. The remaining heat demand will equally be met with solar  
12 heat, with seasonal storage, at Medium temperature and Low Temperature) and distributed at the urban scale in  
13 collective projects by District Heating Networks (DHN) and Mini Heat Grids (MHG) or by individual systems on heat  
14 pumps or other devices.

15  
16  
17 <FIGURE 3.1.2>

18  
19 The mobility system also calls for major changes. In figure 3.1.3 the proposed scenario for mobility is shown. The left  
20 scheme visualizes the scenario of the modal split. The share of car use of the current modal split (based on data from  
21 [Klimaat+Plan Roeselare](#)) is assumed to be halved by 2050 by measures concerning improved public transport  
22 and behavioural changes with a high increase of light mobility systems like cycling and pedestrian kilometres. In the  
23 right scheme the scenario of the electrification of the transport is visualized. With a reduction of around 50% of the  
24 car kilometres, and due to better efficiency of over 50% of electric engines the final energy demand for transport in  
25 2050 is over 4 times less.

26  
27 <FIGURE 3.1.3>

28  
29 In a next and successive step, roadmaps can be derived from the energy transition scenarios, that show measures and  
30 actions needed in order to get towards the 2050 vision. For the heat transition for example, renewable sources of  
31 high, medium and low temperatures are proposed to replace the current gas (and other fuels) to heat buildings. Yet,  
32 the current building stock will not always be suitable to be heated with medium or low temperatures. Therefore  
33 energy saving measures for buildings (energy retrofitting) will often be required. With knowledge of the energetic  
34 performances of the buildings, as we gradually get more and more in European cities (and as also demanded by the  
35 EU's Energy Efficiency Directive) expressed in energy performance labels, we can derive these. Assuming, in the case  
36 of Roeselare, that buildings with an A-label performance are able to be heated with low-temperature sources and  
37 buildings with a B- or C-label can do it with medium temperatures and need renovations for low-temperature sources.  
38 A large part of the building stock in Roeselare has poor labels (D, E, F or G) and can only be heated with high  
39 temperature sources or need renovations for medium (or low) temperature heating. The amounts and types of energy  
40 renovations can now be expressed in typical measures per year for certain time frames (e.g. 500 renovations from  
41 G,F,E or D label residential equivalents to a C or B label per year in the period of 2018-2050). Accordingly, the  
42 measures for heat production, storage and other types of renovations can be put in the roadmap as shown in figure  
43 3.1.4. Similar roadmaps were composed for the required measures related to high temperature sources as well as for  
44 electricity production. This step again tries to unravel the complexity of energy transitions and demonstrates for city  
45 councils for example what is needed to achieve their targets.

46  
47  
48 <FIGURE 3.1.4>

1 The proposed energy strategy for Roeselare is more concretely developed in a next phase through schematic plans  
2 such as shown in Figure 3.1.5. It visualises the layout and size of a city-scale DHN and neighbourhood-scale MHGs,  
3 with the location of the main heat energy sources. Moreover, it simultaneously shows the spatial distribution of wind  
4 farms, including 25 large turbines and the comprehensive area for 2050 of installed PV and solar thermal collectors. A  
5 schematic section representing the integration of different infrastructures, from DHN and MHG to PV on roofs or  
6 canopies and wind farms, is shown in Figure 3.1.6.

7  
8  
9 <FIGURE 3.1.5>

10  
11  
12 <FIGURE 3.1.6>

### 13 14 15 **3.2 Urban design**

16 Designers undertake to integrate technological and infrastructural solutions within local physical and social contexts,  
17 not only concerning the energy dimension, but also exploring environmental, social and economic issues of urban  
18 design. This part of the process aims to demonstrate how sustainable development can potentially bring consistent  
19 gains in the quality of life and wellbeing in general. In many aspects, the co-creative session on urban design is most  
20 relevant in terms of stakeholders' engagement and brainstorming. Currently, design decisions made during the urban  
21 design sessions are not seen by stakeholders to have a direct link to GHG emission mitigation, due to the lag between  
22 the design part of the process, and the re-calculation of the carbon emission taking place at a later time. Future  
23 Roadshows will address this by assessing the carbon impact in real time as the designs evolve. The role of designers is  
24 crucial to make the urban transition socially more acceptable and to explain more clearly through visual  
25 representation the benefits and added value of neighbourhoods becoming energy and carbon neutral.

26 Figure 3.2.1 shows a series of 10 ideograms representing the solutions for the transition to a sustainable mindset in  
27 Roeselare:

- 28 ▪ Star-city: connection between peripheral neighbourhoods and the city centre must be improved especially  
29 concerning sustainable mobility (e.g. walking and cycling roads) and a deeper penetration of urban facilities inside  
30 the neighbourhoods, thus extending the offer of accessible urban spaces and contexts, with different  
31 environments and services. In this regard, Figure 3.2.2 specifically focuses on Roeselare and the extension of  
32 functions from the centre to the neighbourhoods.
- 33 ▪ New green ring: the extension of urban green spaces and the enhancement of ecosystem services is also a  
34 desirable issue. This is expected to reconnect natural systems in both the radial and circular directions enforcing  
35 the green network of walking and cycling roads as well as ecological corridors.
- 36 ▪ Blurred boundaries: the removal of physical and visual barriers through design, including over-engineered  
37 roadways and fences, would potentially avoid disconnections and fragmentation and increase permeability  
38 among neighbourhoods, maximising opportunities of exchange and cross-fertilisation.
- 39 ▪ City unpacking: improved connectivity and accessibility will also contribute to increase attractiveness of different  
40 neighbourhoods by enhancing urban services and facilities, identifying specialisations and discovering  
41 peculiarities in each urban area, e.g. small businesses, sport facilities, thematic communities, circular economy  
42 initiatives or entrepreneurships, periodical events such as weekly markets and yard-sales.
- 43 ▪ Neighbourhood connectivity: coherently with the city unpacking, people mobility from place to place throughout  
44 peripheral areas will make sense, especially when neighbourhoods improve their attractiveness for specific  
45 peculiarities, services or natural environment.
- 46 ▪ Shared surface: public places, including roads and green areas, can host community level activities, from  
47 renewable energy generation to sport facilities, car and bike sharing, urban gardening and agriculture. Direct  
48 engagement of local communities is a desirable issue of urban design considering that most of current urban  
49 layouts do not facilitate this and often avoid the emergence of shared initiatives among people and stakeholders.
- 50 ▪ Productive landscapes: short supply chain for food provides different benefits including direct engagement of  
51 citizens, provision of fresh, healthy and low-carbon food products, emergence of micro-economies for example  
52 through local vegetable markets, improved attractiveness for external visitors. Besides food production, other

1 urban ecosystem services would concern recreational facilities, material and biomass production, improved air  
2 quality, carbon uptake, biodiversity, hydrodynamic regulation, among others (Costanza et al. 1997, De Groot et al.  
3 2010, Braat & De Groot 2012, Kremer et al. 2016).

- 4 ▪ Green-blue infrastructure: the integration of green and blue natural systems also relates to landscapes and  
5 biodiversity (through riparian ecosystems) and the accessibility to water systems, for their management and use,  
6 is among the issues to foster the deployment of nature based systems and add value to ecosystem based services.
- 7 ▪ Natural urban drainage: among ecosystem services, the regulation of water flows and flood prevention can be  
8 potentially implemented, properly designing and managing riparian ecosystems through implementation of  
9 cisterns and water storage on site and a re-naturalisation of waterways, which are currently over-engineered.
- 10 ▪ Safe and natural: coherently with the aim of improving urban drainage, peak flow can be reduced and flooding  
11 prevented: this is a final statement on the need of consistent nature based solutions and ecosystem services  
12 enhancement in urban contexts.

13  
14  
15 <FIGURE 3.2.1>

16  
17  
18 <FIGURE 3.2.2>

19  
20 The contribution of the Urban Design process in terms of GHG mitigation (see section 3.3) can be directly estimated by  
21 referring to passive systems of energy saving, such as by decreasing the UHIE through NBS, or by designing  
22 infrastructures for sustainable mobility (e.g. cycling roads), but more often, it supports the implementation of  
23 renewable energy systems and other solutions based on the energy potentials analyses. In particular, the role of  
24 urban design is crucial to combine solutions, concerning both the technological and the social spheres, that must be  
25 integrated in the urban environment, moving from the individual to the community scale. It allows for engaging  
26 citizens and emphasizing their role as members of the community, called to support private-public initiatives as well  
27 as to change their behaviours and lifestyles.

### 28 29 3.3 Carbon accounting

30 Out of the energy design and urban design sessions, the transition plan for Roeselare has finally identified a sequence  
31 of 14 measures that constitutes a potential scenario for carbon neutrality by 2050. Planned actions have been  
32 hypothesised based on energy potentials and the urban context, aiming at pursuing the objectives set in 3.1. Table  
33 3.3.1 shows the estimated size of interventions and their effects in terms of GHG emission mitigation.

34  
35 <TABLE 3.3.1>

36  
37 The GHG emission of Roeselare is 351,842 tonne CO<sub>2</sub>-eq per year (0 in the table) depending on different sources,  
38 including a total demand of 495 GWh/year electricity, 712 GWh/year from a fuel mix for space and water heating, 290  
39 GWh/year for mobility, 28,000 tonnes of waste/year treated and 2.5 million m<sup>3</sup> of water used/year. This marks the  
40 starting-point of any transformation process forward.

41 Next, the different mitigation measures are assessed on their single contribution to the reduction of the GHG  
42 emission, whereas in reality, the different measures will all contribute gradually over time towards the final vision for  
43 2050.

44 Consistent reduction of energy demand can be achieved by building retrofitting and improved insulation (Qian and  
45 Lee, 2014). *Energy savings* (1) have been hypothesised as follows: -15% electricity and -25% fuel demand for housing; -  
46 15% electricity and -20% fuel in tertiary; -10% electricity and -10% fuel in industry; -10% electricity and -20% fuel in  
47 farms; -50% electricity demand for public lighting through light replacement with LED lamps (King & Perry 2017). This  
48 action brings the GHG emission down by 14%.

49 Together with potential energy savings, a certain *growth* (G) of population and energy demand has been forecasted

1 by 2050 due to both population increase and economic growth: 25%, 10% and 20% electricity for housing, tertiary and  
2 industry, respectively; 10% and 5% fuel demand for private and public transport, respectively; 10% increase of  
3 domestic waste and water use. The expected increase of the GHG emission in Roeselare is 6%.

4 The heating supply can be achieved by a smart combination of HT, MT and LT systems. In particular, HT systems would  
5 refer to an urban DHN supplied by a combination of different sources; the hypothesised scenario includes 35 GWh  
6 supplied by industrial use of biomass (2), 55 GWh by waste incineration (3), 55 GWh by solar collectors connected to a  
7 MT underground storage (4), and 55 GWh by industrial heat waste (5). All numbers on energy (in GWh) are from the  
8 measures from the schemes in 2050 as presented in figures 3.1.1 – 3.1.3. The avoided use of fuels would correspond  
9 to 15% GHG reduction. Moreover, a combination of solar collectors with MT storage can potentially supply 165 GWh  
10 through MHG in given locations (6) with a corresponding GHG reduction of 12%. Similarly, LT MHG's can combine PV-  
11 thermal systems installed on roofs of single houses or housing blocks and LT Aquifer Thermal Energy Storages (7).

12 The electricity demand can also be supplied by local renewable sources. The selected scenario realistically forecasts 12  
13 GWh<sub>e</sub> provided by waste incineration (3), 345 GWh<sub>e</sub> by PV installed both on roofs and other horizontal or vertical  
14 surfaces (9), 138 GWh<sub>e</sub> by wind turbines (10). The latter will be further enlarged to 203 GWh<sub>e</sub> (13) to cover the  
15 additional demand of next measures.

16 Sustainable mobility is among the desirable measures to be implemented. The increased use of bicycles and public  
17 transport (11) would avoid the use of 125 GWh of fuels for private cars, corresponding to a GHG reduction of 10%.  
18 Moreover, a full transition to electric mobility (12) can be forecasted in the long run, providing an avoided use of 194  
19 GWh of fuels with an additional electricity demand of around 64 GWh<sub>e</sub> to be potentially supplied by wind farms (13).

20 GHG emission mitigation measures also concern waste recycling, with a drastically decrease of landfilled waste, and a  
21 consistent reduction of water use by behavioural changes and water harvesting systems for different uses (14).

22 The combination of designed measures above is supposed to bring the initial GHG emission to a much lower value, i.e.  
23 4810 tonne CO<sub>2</sub>-eq (just over 1% of the initial GHG). This residual GHG, that cannot be avoided due to physical rules (it  
24 is a form of entropy) and can be compensated by 356 ha of urban forestry (15).

25 The effects of GHG emission mitigation measures used in Roeselare have been estimated based on general  
26 assumptions determined in compliance with the carbon mitigation measures systematically presented in Pulselli et al.  
27 2018a. The sequence of measures above composes one possible scenario, among others, for a future energy and  
28 carbon neutral Roeselare.

29

30

#### 31 **4. Discussion**

32 Carbon accounting, combined with energy design and urban design, is a crucial aspect of the framework presented.  
33 Solutions for energy transition and climate-neutral cities can be designed considering different scales for  
34 interventions, both spatial (from the single household to the neighbourhood, to the city scale) and temporal (short-,  
35 medium-, or long-term implementation period). Moreover, they can include different strategies, referring to new  
36 technologies in buildings and infrastructures in the built environment, or even to behavioural changes, through  
37 specific campaigns for raising awareness (the Roadshow itself is part of these), involving citizens and communities. In  
38 this regard, communication plays a crucial and relevant role. In order to make the challenges, design steps and  
39 Roadshow proposals more easily understandable by stakeholders whose background is likely not one from  
40 environmental design or analysis, the visualisation of a city's GHG emission, and indeed new technological and spatial  
41 infrastructures can be an effective tool to motivate and foster climate action.

42 Roeselare's GHG emission has been represented graphically with an area of forestland needed to compensate GHG  
43 emission through carbon uptake, as demonstrated by Pulselli et al. (2018). Figure 4.1 impactfully shows that the  
44 virtual forest of Roeselare (26,062 hectares) is five times the area of the city itself (5,979 hectares). This schematic  
45 representation comprised on 1 km<sup>2</sup> squares of forest, empathises the influence of different emission sources through  
46 colours, allowing local stakeholders to become conscious of the initial challenge to be faced.

47 Similarly, the impact of any single household has been spatially visualised; the emission of 6.7 tonne CO<sub>2</sub>eq/year per  
48 household in Roeselare corresponds to 0.5 hectares forest, the size of a football pitch. Compared to the European  
49 average, i.e. 6.9 tonne CO<sub>2</sub>eq/year per household (Pulselli et al. 2018), citizens in Roeselare provide lower impacts but  
50 this modest result is mostly due to the low emission of the national electricity mix (52% nuclear, 18% renewables), not  
51 just on lower consumption or virtuous behaviours.

1 The schematic representation of proposed or required energy measures for energy and carbon neutrality over time,  
2 their visualisation in city maps and schematic sections and potential 3D visualisation of solutions at the building scale  
3 also contribute to the comprehension of what a full energy transition implies.

4  
5  
6 <FIGURE 4.1>

7  
8 The starting-point in Roeselare, as in most of EU cities, is very challenging and the goal of decarbonisation is ambitious  
9 enough. Nevertheless, the sequence of solutions selected in the 2050 decarbonisation scenario above clearly shows  
10 that paths have been set out. In order to be more effective in engaging local stakeholders, the GHG emission  
11 mitigation effect of each measure has been represented in terms of avoided emission and corresponding forestland.  
12 In particular, each of the actions has been represented in the sequence in Figure 4.2, including the current state (0),  
13 the expected growth by 2050 (G) and the residual emission (14) that requires final compensation by urban forestry.  
14 During a Roadshow this sequence is shown dynamically and, in order to highlight any step in the series, the yellow  
15 hero of the Pacman game is represented in the figures, crunching forest squares, to animate the sequence. Rather  
16 than dumbing down challenges, the Pacman contributes to attract the attention and let every stakeholder in the  
17 audience start their own personal transition process.

18  
19  
20 <FIGURE 4.2>

21  
22 Most of the GHG emission mitigation is clearly related to solutions planned through energy design. The effects of both  
23 behavioural and technological solutions have been accounted and contribute to the carbon crunching. By visually  
24 depicting a positive rewarding action, similar in behaviour to that of a world known arcade character who eats (or  
25 'crunches') objects to gain health, has been an extremely powerful tool in engaging non-expert and expert  
26 communities across Europe and beyond. Not only has the use of this character and its animated action helped explain  
27 how forestland can theoretically sequester and visual 'see' the carbon cause and effect of our lifestyles in current and  
28 future scenarios, it does so instantly at all scales from the individual to the infrastructural, through to the regional, and  
29 in the cases of Cyprus (2019) and Menorca (2016), the island scale. As described in the UN Sustainability Development  
30 Report (2019) projects should take on the challenge of developing tools and methods for multi-stakeholder  
31 engagement. This forestland carbon 'crunching' character is a highly disarming, non-patronizing feature that should  
32 not be underestimated having demonstrated immediate knowledge transfer impact in nine cities, capturing the  
33 imagination of many who have crossed both sides of the expert and non-expert divide.

34 The urban design approach is indirectly considered in numerical terms; it operates mostly on a qualitative sphere. The  
35 design of urban spaces, organisations and communities is nevertheless essential for the success of the initiative,  
36 particularly stressing the concept that more sustainable cities do not foresee any loss but, on the contrary, they would  
37 possibly imply gains for citizens from any social class, by improving welfare, investments and business opportunities.  
38 Urban design contributes to highlight social, economic and environmental benefits of the transition to carbon-neutral  
39 cities that end to look more desirable and appealing than they currently are. Figure 4.3 shows two of the street views  
40 released at the end of the Roadshow in Roeselare, particularly concerning urban agriculture and greenhouses  
41 integration in residential architecture. It strengthens opportunities to start a consistent climate action and kick off  
42 Roeselare's decarbonisation.

43  
44  
45 <FIGURE 4.3>

46  
47  
48  
49 From the outset in 2015 all Roadshow activities have been continually adapted to gain broad public support and buy-

1 in for a transition to carbon neutral cities. Factors that can now be officially referred to in the United Nations  
2 Sustainable Development Report (Sachs et al. 2019), a document mirroring the Roadshows position that transition  
3 cannot be the sole responsibility of government. As a consequence, the method is highly replicable and multi-  
4 stakeholder friendly, with a generalised framework allowing carbon comparisons between cities to be described easily  
5 to non-expert stakeholders. This giving trust in the calculations, but also contextualizing the challenge.

6 Though the start and the end (dataset and outcomes) are city specific, the journey is universal, that is the key.  
7 Roadshow recognition that stakeholders are expert in the way they live now, and how they want to live in the future,  
8 has demonstrated that sustainability is not the role of professionals within the European community and outside, the  
9 Roadshow having also taken place in Izmir, Turkey (2015). Stakeholders have varying interests and availabilities, they  
10 are unpaid volunteers; involving them meaningfully in complex design processes, and in often heavy technological and  
11 carbon scenarios, is the greatest challenge that urban sustainability faces. The success of the Roadshow lays in the  
12 unique way it can operate successfully within varying climates, cultures, languages, economies, transport modalities,  
13 urban topographies and political circumstances. All Roadshow elements being highly visual, impactful, transferable,  
14 replicable, compact, creative, amenable, entertaining and fun. Solutions for zero carbon cities are inevitably radical  
15 and the societal benefits are more easily conveyed to stakeholders through live-time, step-by-step, challenge-to-  
16 solution, illustrated 'storytelling', graphical 'before' and 'after' imagery that depicts community-familiar streets and  
17 landmarks now and in a desirable future.

18

19

## 20 **Conclusion**

21 City-zen Roadshows are highly successful in that they launch a city and their neighbourhoods into the challenge of  
22 decarbonisation. They are intensive co-creative laboratories, built on multidisciplinary competences of global experts  
23 interacting with local stakeholders. This paper has presented the procedural steps and outcomes from the Roeselare  
24 Roadshow. It makes a step forwards allowing for highlighting various aspects of the Roadshow approach as strengths  
25 and opportunities to further expand and improve the Roadshow experience:

- 26 ▪ It allows for planning a concrete energy- and carbon-neutral transition strategy by combining and integrating  
27 different measures, technologies, infrastructures, ecosystems, communities and lifestyles in the built  
28 environment.
- 29 ▪ It performs participative design practices to engage citizens and stakeholders, attract investments, launch new  
30 initiatives and point the way towards the 2050 goal. Their direct engagement makes design more site-specific and  
31 also contributes to increase social acceptance and feasibility of planned strategies.
- 32 ▪ It follows an extemporary approach that allows for presenting reliable plans in a few days. This instant process  
33 does not pretend to release exhaustive ultimate design but demonstrate benefits of different options and lets  
34 local authorities define policies and launch transformation processes within the short term of their political  
35 mandate.
- 36 ▪ It leverages on competences of global experts and combines three mutual approaches - energy design, urban  
37 design and carbon accounting - and finally delivers coherent energy transition plans of hosting cities.
- 38 ▪ It contributes to raise awareness on meanings and implications of the energy transition process and  
39 decarbonisation on real life through qualitative and quantitative evaluations and their visual representation. For  
40 example, energy potential maps, conceptual ideograms and virtual forestland clearly aim at involving the largest  
41 audience possible in the design process.
- 42 ▪ It delivers consistent and reliable "future city visions" that can be interpreted as a forecast view of cities in 2050,  
43 once the goal of carbon neutrality has been achieved.
- 44 ▪ It teaches that sustainable development does not deal with losses or resigns but instead with gains in quality of  
45 life, welfare, healthiness, resilience and fairness.

46 The Roadshow framework promotes design practices that can integrate multiple approaches, strategies, spatial and  
47 temporal scales, and strengthen the need of climate action based on multidisciplinary knowledge. Additional elements  
48 can be added to the framework to improve outcomes and effectiveness of the process. Indeed, the Roadshow concept  
49 shows a possible way to combine competences and efforts of different stakeholders and contribute to build capacities  
50 and quickly spread out initiatives of energy transition in Europe and worldwide.

51

52

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8 and enthusiasm brought the Roadshow in meaningful partnership with the city. The day to day organisation and  
9 'engine room' of the Roadshow would be powered by the tenacity, amenability and zeal of one young member of the  
10 Klimaatswitch team, Janne Ruskowski. We thank Kris and Janne for helping to make the Roadshow a highly attended  
11 and impactful success. The Huis van de Voeding (House of Food) in the city centre of Roeselare was the home of the  
12 Roadshow during our co-creative efforts to develop a sustainable City Vision.

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2	<b>FIGURE CAPTIONS</b>
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4	<b>Figure 2.2.1</b> – Current electricity demand compared to potentials in the Municipality of Roeselare.
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6	<b>Figure 2.2.2</b> – Current heat demand compared to potentials in the Municipality of Roeselare.
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**TABLE CAPTIONS**

**Table 2.1.1** – Energy demand per sector in the Municipality of Roeselare and Emission Factors per source and fuel mix.  
Data sources: West-Vlaanderen Province 2015; Febeg 2015. Emission Factors: IPCC 2006; Pulselli et al. 2018a

**Table 2.1.2** – GHG emissions of the Municipality of Roeselare per activity sector. Data sources: West-Vlaanderen Province 2015; Febeg 2015.

**Table 2.1.3** – GHG emissions of the typical household in Roeselare per emission source.

**Table 3.3.1** – Sequence of selected GHG emission mitigation measures for the Municipality of Roeselare towards the 2050 objective of carbon neutrality.

<TABLE 2.1.1>

	<b>ELECTRICITY</b> MWh/year	<b>FUEL MIX</b> MWh/year	Nat gas	LGP	Oil	Coal	Biomass	Solar-thermal	Geo-thermal	Diesel	Gasoline	Bio fuel	<b>Emission Factor of fuel mix</b> t CO <sub>2</sub> eq/MWh
<b>Emission Factors</b> (t CO <sub>2</sub> eq/MWh)	<b>0.181</b>	–	<b>0.252</b>	<b>0.263</b>	<b>0.281</b>	<b>0.400</b>	<b>0.114</b>	<b>0.000</b>	<b>0.000</b>	<b>0.285</b>	<b>0.266</b>	<b>0.000</b>	–
RESIDENTIAL	<b>93,402</b>	<b>321,820</b>	81.6%	3.8%	–	–	13.5%	0.3%	0.7%	–	–	–	<b>0.231</b>
TERTIARY	<b>176,876</b>	<b>265,771</b>	85.0%	1.1%	13.8%	–	–	–	0.1%	–	–	–	<b>0.256</b>
INDUSTRY*	<b>215,918</b>	<b>100,000</b>	100.0%	–	–	–	–	–	–	–	–	–	<b>0.252</b>
PUBLIC LIGHTING	<b>5,546</b>	–	–	–	–	–	–	–	–	–	–	–	<b>0.181</b>
AGRICULTURE	<b>3,419</b>	<b>24,973</b>	47.6%	0.4%	50.0%	2.0%	–	–	–	–	–	–	<b>0.270</b>
MOBILITY	<b>63</b>	<b>284,554</b>	–	0.2%	–	–	–	–	–	82.4%	14.3%	3.0%	<b>0.274</b>
PUBLIC TRANSPORT	–	<b>6,122</b>	0.5%	–	–	–	–	–	–	93.9%	2.5%	3.0%	<b>0.276</b>
<b>TOTAL</b>	<b>495,225</b>	<b>1,003,239</b>	<b>600,694</b>	<b>15,578</b>	<b>49,280</b>	<b>492</b>	<b>43,560</b>	<b>1,129</b>	<b>2,593</b>	<b>240,233</b>	<b>40,888</b>	<b>8,791</b>	

\* Only natural gas for space and water heating (estimate 100 GWh/year). Other fuels used as input in production chain processes are not included.

&lt;TABLE 2.1.2&gt;

Emission source	unit	rawdata	t CO <sub>2</sub> -eq/unit	t CO <sub>2</sub> -eq/year	%	Note
ELECTRICITY	MWh/year	489,679	0.181	<b>88,429</b>	25.1%	Electricity: total multi-sectorial demand
HOUSING	MWh/year	321,820	0.231	<b>74,251</b>	21.1%	Fuel mix: space & water heating and cooking
TERTIARY	MWh/year	265,771	0.256	<b>67,957</b>	19.3%	Fuel mix: private and public service buildings
INDUSTRY	MWh/year	100,000	0.252	<b>25,169</b>	7.2%	Nat. gas for heating. Production processes not included
PUBLIC LIGHTING	MWh/year	5,546	0.181	<b>1,002</b>	0.3%	Electricity: specific use for public lights
AGRICULTURE	MWh/year	24,973	0.270	<b>6,729</b>	1.9%	Fuel mix: machinery and management in farms
MOBILITY	MWh/year	284,554	0.274	<b>77,881</b>	22.1%	Fuel mix: private car use
PUBLIC TRANSPORT	MWh/year	6,122	0.276	<b>1,689</b>	0.5%	Fuel mix: public transport
WASTE MANAGEMENT	t/year	28,345	0.256	<b>7,260</b>	2.1%	Mass: domestic waste by households
WATER MANAGEMENT	m <sup>3</sup> /year	2,521,692	0.0006	<b>1,476</b>	0.4%	Mass: water use in households
<b>TOTAL</b>				<b>351,842</b>	<b>100%</b>	

&lt;TABLE 2.1.3&gt;

Household emission source	unit	rawdata	kg CO <sub>2</sub> -eq/unit	kg CO <sub>2</sub> -eq/year	%	
ELECTRICITY	kWh/year	3,545	0.181	<b>640</b>	9.5%	Lighting & appliances, cooling
HEAT	kWh/year	12,214	0.231	<b>2,818</b>	41.8%	Space & water heating, cooking
MOBILITY	kWh/year	10,802	0.274	<b>2,956</b>	43.8%	Private car use
WASTE	kg/year	1,076	0.256	<b>276</b>	4.1%	Domestic waste production and management
WATER	m <sup>3</sup> /year	96	0.583	<b>56</b>	0.8%	Tap water use
<b>TOTAL</b>				<b>6,746</b>	<b>100%</b>	

<TABLE 3.3.1>

	Sector	HOUSING		TERTIARY		INDUSTRY		PUBLIC LIGHTS	AGRICULTURE		MOBILITY		PUBLIC TRANSPORT		WASTE	WATER	GHG total	GHG %	
		Source	electricity	fuel mix	electricity	fuel mix	electricity	fuel mix	electricity	electricity	fuel mix	electricity	fuel mix	electricity					fuel mix
		unit	MWh <sub>e</sub> /year	MWh/year	MWh <sub>e</sub> /year	MWh/year	MWh <sub>e</sub> /year	MWh/year	MWh <sub>e</sub> /year	MWh <sub>e</sub> /year	MWh/year	MWh <sub>e</sub> /year	MWh/year	MWh <sub>e</sub> /year					MWh/year
0	CURRENT STATE	data	93,402	321,820	176,876	265,771	215,918	100,000	5,546	3,419	24,973	63	284,554	0	6,122	28,345	2,521,692	351,842	100%
		t CO <sub>2</sub> -eq/year	91,118		99,898		64,161		1,002	7,346		77,893		1,689		7,260	1,476		
1	ENERGY SAVING	data	-14,010	-80,455	-26,531	-53,154	-21,592	-10,000	-2,773	-342	-4,995							-47,800	-14%
		t CO <sub>2</sub> -eq/year	-21,093		-18,383		-6,416		-501	-1,408									
G	GROWTH 2050 forecast	data	19,848		15,034		38,865						28,455		306	2,834	252,169	22,064	6%
		t CO <sub>2</sub> -eq/year	3,584		2,715		7,019					7,788		84		726	148		
2	DHN – biomass	data						-35,000										-8,809	-3%
		t CO <sub>2</sub> -eq/year					-8,809												
3	DHN - waste incineration	data	-12,000	-25,000	-20,000	-20,000		-10,000										-17,011	-5%
		t CO <sub>2</sub> -eq/year	-7,935		-6,559		-2,517												
4	DHN - solar collectors & HT storage	data		-30,000		-25,000												-13,314	-4%
		t CO <sub>2</sub> -eq/year	-6,922		-6,392														
5	DHN - HT industrial waste	data		-30,000		-25,000		0										-13,314	-4%
		t CO <sub>2</sub> -eq/year	-6,922		-6,392		0												
6	MHG - Solar collector & MT storage	data		-60,000		-60,000		-45,000										-40,511	-12%
		t CO <sub>2</sub> -eq/year	-13,843		-15,342		-11,326												
7	PV Thermal on house blocks	data	-1891	-75,000														-19,195	-5%
		t CO <sub>2</sub> -eq/year	-19,195																
8		data		-21,365		-82,617				-19,978								-31,437	-9%

	MHG & LT ATEs	t CO2-eq/year	-4,929	-21,125			-5,383												
9	PV roofs / non roofs	data	-76,771	-118,034	-139,915												-60,446	-17%	
		t CO2-eq/year	-13,864	-21,315	-25,267														
10	WIND FARM	data		-39,345	-93,277	-2,773	-3,077											-25,006	-7%
		t CO2-eq/year		-7,105	-16,844	-501	-556												
11	SUSTAINABLE MOBILITY	data									-125,204							-34,268	-10%
		t CO2-eq/year									-34,268								
12	ELECTRIC MOBILITY	data								61,976	-187,805	2,121	-6,428					-41,600	-12%
		t CO2-eq/year								-40,210	-1,390								
13	WIND FARM	data								-62,039		-2,121						-11,587	-3%
		t CO2-eq/year								-11,203	-383								
14	WASTE recycling & WATER harvesting	data												-17,007	-756,508			-4,799	-1%
		t CO2-eq/year												-4,356	-443				
15	CARBON UPTAKE	Required forestland for compensation: 356 ha														-4,810	-1%		