TOWARDS SMART ZERO CO_2 CITIES ACROSS EUROPE

VITORIA-GASTEIZ + TARTU + SØNDERBORG

Deliverable 5.1: Sonderborg Diagnosis and Baseline

WP 5, Task 5.1

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Abbreviations and Acronyms

Abbreviation/Acronym	Description
SmartEnCity	Towards Smart Zero CO_2 Cities across Europe
LH	Lighthouse
RE / RES	Renewable energy / Renewable energy source
Sonderborg	Refers to entire area of Sonderborg Municipality (if nothing else stated)
ICT	Information and Communication Technologies
PSO	Public Service Obligation
TSO	Transmission System Operator
DEA	Danish Energy Agency

Table 1: Abbreviations and Acronyms in this report.

0 Publishable Summary

The overall objective of WP5 "Sonderborg Lighthouse Deployment" is to develop the detailed planning and coordination, to set up the management structures and procedures, and to implement construction works in the Sonderborg demo site according to the initial process layout.

This deliverable develops an in-depth characterization of Sonderborg at a municipal level, making use of the indicators system provided in WP7. The main outputs of this deliverable are a comprehensive diagnosis of Sonderborg, and the baseline evaluation framework to be used for the interventions (demonstration projects). This diagnosis phase, including baseline calculation and city needs identification and prioritization should be the first step of any intervention process.

This deliverable has been divided in four parts describing main aspects of Sonderborg diagnosis and baseline definition.

Chapter 4 delves on the diagnosis process definition, regarding activities, phases, agents, methods and tools, among others factors.

Chapter 5 relies on indicators to describe and characterize Sonderborg performance regarding local conditions, energy supply and consumption, building stock and retrofitting needs, urban mobility, ICTs infrastructures and services, and stakeholder engagement.

Chapter 6 identifies and prioritizes city needs by building upon work within existing analyses of Sonderborg and use SWOT analysis to qualify and support the interventions. This analysis will set the ground for the intervention baseline definition, which framework is presented in chapter 7.

Finally, last chapters 8 and 9 describe deviations of the deliverable and draw outputs for other WPs.

As Annex is found Annex 1 containing the gross list of indicators used in Chapter 5 and Annex 2 presenting background information about Geographical Energy Balance 2015 for the municipal area of Sonderborg.

1 Introduction

1.1 Purpose and target group

The aim of this deliverable is an in-depth evaluation of the situation in the municipal area of Sonderborg, making use of the indicators system developed in WP7 of the SmartEnCity project. The main outputs of this deliverable are a comprehensive diagnosis of Sonderborg Municipality as an area of intervention and the baseline framework definition. In a wider perspective, D5.1 can be useful for other European cities with the ambition to identify needs and prioritize interventions.

In regards to other deliverables, D5.1 is a stepping-stone for remaining WP5 deliverables related to Sonderborgs interventions. D5.1 provides inputs for designing citizen engagement strategies of D2.6 and the integrated and systemic SmartEnCity urban regeneration strategy of D2.7 and D2.8. Furthermore, the city diagnosis will be taking into account the evaluation process of impacts in D7.13.

Project stakeholders are also a target group of D5.1, helping them to visualize a comprehensive scenario for setting goals, further development and assistance for decision making in down-the-line integrated planning.

1.2 Contributions of partners

The following Table 2 depicts the main contributions from participant partners in the development of this deliverable.

Participant short name	Contributions
TEC	Overall structure of report, Chapters 1, 2 and 3.
PLAN	General structure and coordination, editor of report. Chapter 4 *Defining the process as a whole.* Section 5.2 *Energy supply and consuming patterns,* Contributions to Chapter 5. Chapter 6 *City needs definition and prioritization*, Chapter 8 and annex 2 *Geographical Energy Balance 2015: Sonderborg Municipality*.
SONF	Section 5.1 *Local Conditions* and Section 5.5 *ICT Infrastructures and Services*. Review of 2nd draft.
ZERO	Section 5.3 *Building stock and retrofitting needs*, Section 5.4 *Urban Mobility*, Section 5.6 *Stakeholder engagement*. Review of 2nd draft.
CAR	Chapter 7 *SmartEnCity Evaluation Framework for Intervention Baseline.* Contributions to Chapter 4 and Chapter 9. Annex 1 *List of indicators for City Diagnosis*. Review of Final draft.
AAU	Review of Final draft.

Table 2: Contribution of partners.

1.3 Relation to other activities in the project

The following Table 3 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the SmartEnCity project and that should be considered along with this document for further understanding of its contents.

Deliverable Number	Contributions
D2.4	D2.4 describes the overall method and process, as well as the template to be applied in diagnosis and baseline definition of D3.1, D4.1 and D5.1
D7.1	D7.1 provides a first proposal of city characterization indicators that has been filtered by LH cities to define the definitive list of common and optional indicators included in D2.4 and applied in D3.1, D4.1 and D5.1.
D2.1, D2.2, D2.3	D2.1, D2.2, D2.3 give input on specific topics (Policy & Regulation, Standards, Business environment) for diagnosis and baseline definition of LH cities on D3.1, D4.1 and D5.1.
D4.1, D5.1	D3.1, D4.1 and D5.1 are aligned providing a diagnosis and baseline definition for each LH city, following a parallel process described in D2.4.
D5.2	D5.1 provides the first step for the baseline, which is set to be included in D5.2
D5.3-D5.8	D5.1 provides characteristics of Sonderborg and an overall description of the demonstration projects in WP5, to be used in other WP5 deliverables.
D2.6, D2.7	D5.1 provides information for designing the Citizen Engagement Strategy of D2.6 and the integrated methodology strategy of SmartEnCity to be defined on D2.7
D7.13	City diagnosis will be the starting point for the city impact evaluation to be done at WP7 (D7.13, *Assessment of the overall performance*)
D8.6	D5.1 becomes a relevant output for defining Integrated Urban Plans.

Table 3: Relation to other activities in the project.

2 Objectives and expected Impact

Introduction to the objectives of the WP/Del.; objectives reached with this deliverable, expected impact

2.1 Objective

The overall objective of work package 5 "Sonderborg Lighthouse Deployment" is to develop the detailed planning and coordination, to set up the management structures and procedures, and to implement demonstration projects in Sonderborg according to the initial process layout.

Task 5.1 is closely linked to this work package. The main objective of task 5.1 is to carry out an in-depth evaluation of the situation in demonstration area of Sonderborg, making use of the indicators system developed in WP7 and the methodology developed in WP2. Furthermore, this task seek to allow stakeholders to visualize a comprehensive scenario for setting goals, further development and assistance for decision making in down-the-line integrated planning, as well as to serve as valuable input for citizen-engagement processes.

This deliverable 5.1 accomplishes these goals through the evaluation of Sonderborg municipal area and points to the needs and priorities of the area as a whole, having an accurate approach to define the intervention baseline.

2.2 Expected Impact

D5.1 becomes the stepping-stone for remaining WP5 deliverables, providing qualitative and quantitative data of energy system, buildings, mobility, ICT, stakeholder engagement and Sonderborg in general, to feed into relevant deliverables to come.

D5.1 is also laying out the base of Sonderborg lighthouse demonstration projects. Furthermore, D5.1 provides valuable inputs for both designing the stakeholder engagement strategies of D2.6 and the integrated and systemic SmartEnCity urban regeneration strategy of D2.7 and D2.8.

In a wider sense, D5.1 can be useful for any European city willing to identify and prioritize its needs before defining any urban regeneration process.

3 Overall Approach

Task 5.1 focused on diagnosis and baseline of Sonderborg applies inputs from several previous SmartEnCity tasks.

Firstly, D5.1 makes use of the indicators system developed in WP7 (D7.1), transforming city performance into numbers in order to quantify the characteristics of Sonderborg, and prepare for intervention baseline.

Secondly, D5.1 is steered by the methodology described in WP2 (D2.4). According to this methodology, this deliverable has been divided in four parts, describing main aspects of Sonderborg diagnosis and preparations for baseline definition:

- Defining the process as a whole
- City characterization: Sonderborg
- City needs definition and prioritization
- Preparations for SmartEnCity Evaluation Framework for intervention baseline

Thirdly, the knowledge about potential barriers for demonstration projects analyzed in D2.1 is closely connected to the definition of Sonderborg's demonstration projects in chapter 6.

Chapter 4 delves on the intervention process definition, regarding activities, phases, agents, methods and tools, among other factors.

Chapter 5 relies on indicators to describe and characterize Sonderborg's performance regarding local conditions, energy supply and consumption, building stock, mobility, ICT infrastructures and services, and stakeholder engagement.

Annex 1 includes a detailed table of indicators provided by CAR, where all indicators used in chapter 5 are explained, providing common units and framework for the three LH interventions of SmartEnCity.

Chapter 6 describes city needs and prioritizing through knowledge and analysis from existing plans for Sonderborg, defining the scope of the demonstration actions in the intervention area.

Preparation of the intervention baseline framework is presented in chapter 7.

Finally, last chapters 8 and 9 describe deviations of the deliverable and draw outputs for other WPs.

As Annex is found Annex 1 containing the gross list of indicators used in Chapter 5 and Annex 2 presenting background information about Geographical Energy Balance 2015 for the municipal area of Sonderborg.

4 Defining the process as a whole

SmartEnCity project aims to contribute to create Smart Zero CO2 Cities across Europe through urban regeneration strategies, integrated urban plans and district integrated interventions. This process needs to be well defined and coordinated using a specific methodology that permits developing such a task.

In Sonderborg sustainability has already been on the agenda for many years. Local authorities, businesses and citizens are all involved in a process in Sonderborg steered by a common goal but open for inputs from all stakeholders. This approach is described in the following section as well as the methods used for the diagnosis in D5.1.

4.1 Process in Sonderborg

In Sonderborg the process of transition has been ongoing since 2007, and the diagnosis in this report builds to the work already done in this process.

In 2007 ProjectZero was established as the vision for transitioning the territory of Sonderborg Municipality into a zero CO_2 community by 2029. It was established as a public private partnership by the Sonderborg city council, local business and utility companies and national partners, and the implementation of the vision is based on strong citizen participation, an action oriented approach, and connected to the opportunity to create new jobs.

Bright Green Business ProjectZero

THE ZEROCARBON GOAL

"The goal of ProjectZero is to make the entire Sonderborg-area ZEROcarbon by 2029 in relation to all energy-related purposes, including road transportation. Energy imported from outside the municipality should also be ZEROcarbon and therefore come from wind turbines or other renewable energy sources. Imports and direct emissions of greenhouse gases from agriculture and waste sites are not included in the energy balance calculation." – ProjectZero Masterplan 2029

Figure 1: The goal for Sonderborg envisioned in the ProjectZero Masterplan 2029.

Since 2007 ProjectZero has been a main driver for creating various analyses and plans of how to meet the goal for Sonderborg by 2029. In 2009, an initial ProjectZero Masterplan 2029 was created as an overall plan for the complete transition, along with a ProjectZero Roadmap 2010-2015 addressing specific actions in that period. In 2013, an updated Roadmap for the period 2015-2020 was formulated, and in 2015, an overall Strategic Energy Plan for Sonderborg was developed including modelling scenarios for the complete transition of Sonderborg.

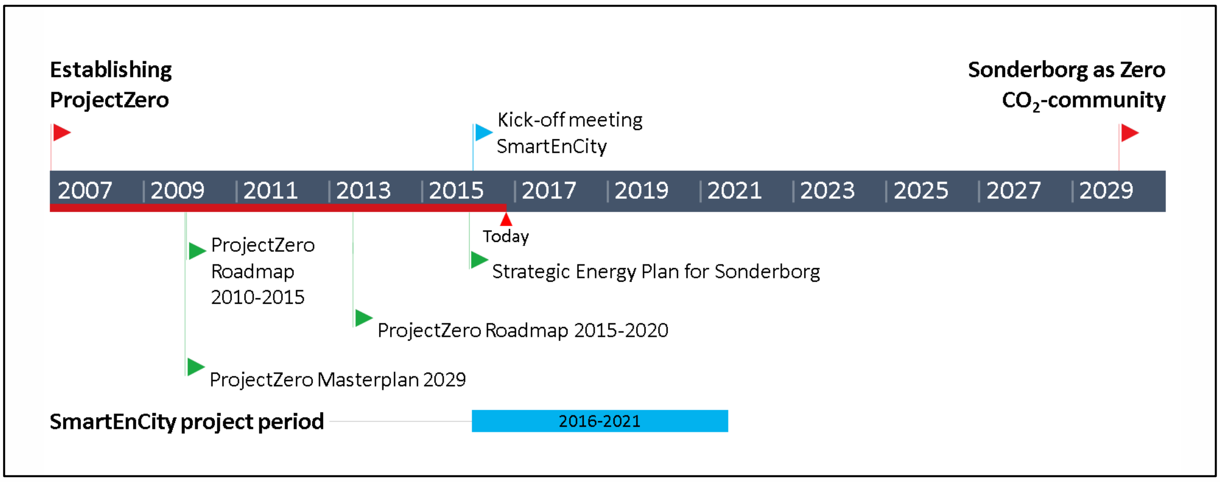

Figure 2: Timeline showing a selection of the most important overall plans for the Sonderborg area since establishing ProjectZero in 2007, and the temporal relation between the SmartEnCity-project and Sonderborg's goal of becoming a zero CO_2 community.

Along with several specific sector plans (e.g. heat plan and transport plan) and an annual monitoring plan, these overall plans are used to steer the process and actions in Sonderborg, while Sonderborg's activities in the SmartEnCity project also connects to these plans and hopefully supports and accelerates their content.

4.2 Governance

In this section, the process behind Sonderborg's Strategic Energy Plan is used as an example to describe how Sonderborg are working with governance, involvement and public ownership to reach a zero CO_2 community. The Strategic Energy Plan for Sonderborg involved a wide range of local stakeholders and ended up with agreement and support of the plan among all stakeholders.

As mentioned previously, a number of activities and initiatives have been initiated in Sonderborg since establishing ProjectZero in 2007. These initiatives have included public authorities, businesses, citizens, the energy sector and other stakeholders.

The Strategic Energy Plan for Sonderborg is a concretization and further development of these initiatives – and it was a priority that the aforementioned stakeholders were (and still are) a central part of the process creating this.

Municipal departments	Politicians and officials from energy-, environmental-, building-, technical-, cultural departments from Municipality of Sonderborg.
Public bodies	Municipality of Sonderborg and Region of Southern Denmark.
Local stakeholders	Housing organizations, industries, sports club and others.
Energy suppliers	District heating companies, SE (electricity distributor) and DONG Energy (natural gas distributor).
Knowledge and technology partners	DTU (Technical University of Denmark), EUC Syd (Vocational Educational Centre South) and others.

Table 4: Stakeholders involved in the process of the Strategic Energy Plan in Sonderborg.

These stakeholders make up a local partnership based around ambitions for the transition of the energy system in Sonderborg, similar to what is described in deliverable 2.4 of SmartEnCity (diagnosis methodology), as an 'initial partnership' of local stakeholders should be formed to provide the necessary local knowledge on city needs:

> *"…a critical decision to make at the earliest (in the diagnosis process ed.) should be the definition of an **initial partnership**, which should bring together different municipal departments and public bodies, local stakeholders, as well as knowledge and technology partners to take part in the whole process. Different levels of participation, specific coordination procedures, etc. should be defined and periodically revised." – D2.4, p. 38*

Engagement of the stakeholders in Sonderborg was ensured by inviting them to participate in a series of workshops addressing energy at different levels in Sonderborg now and in the future. The workshops was organized around the topics:

- Workshop 1: Common understanding of goals and challenges.
- Workshop 2A, 2B and 2C: Three separate workshops concerning three geographical areas within Sonderborg, addressing topics related to these specific areas.
- Workshop 3: Presentation and discussion of initial energy scenarios for Sonderborg.
- Workshop 4: Agreement of Strategic Energy Plan.

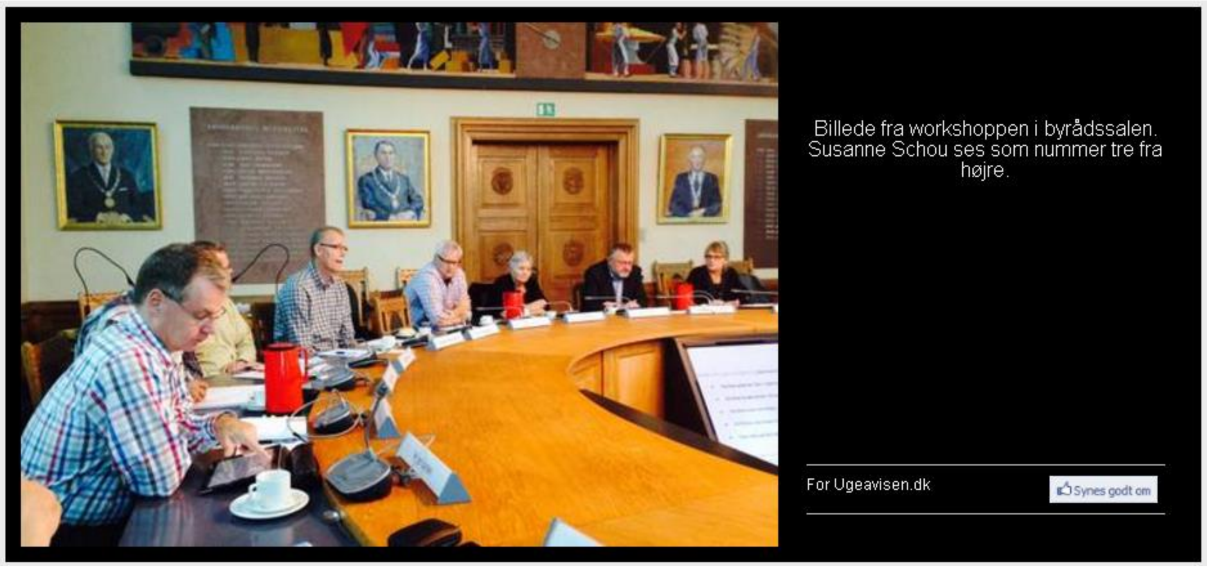

Figure 3: Extract from article in local newspaper reporting about the workshops organized in Sonderborg as part of the process for creating a Strategic Energy Plan. The photo shows local politicians discussing the plan (Source and photo: www.ugeavisen.dk[1]).

Generally speaking the process behind the plan followed four steps: Kick-off, mapping, model calculations and plan and implementation (see figure below). From these steps and especially the workshop process, the Strategic Energy Plan has become a common platform for policymakers, energy consumers, energy producers and planners, so that decisions are made with an awareness that these are part of an overall plan and a final goal.

[1] http://ugeavisen.dk/artikel/75023:SOenderborg--SoeNDERBORG--Energistrategi-i-kommuneregi

The Strategic Energy Plan is now starting point for more concrete plans and detailed analyzes, which specify the objectives and provide practical basis for decision-making. For example, the strategic energy plan has been implemented in a specific heat plan and a more detailed mapping and action plan for transport, and most recently a specific analysis of surplus heat in industries in Sonderborg has been conducted.

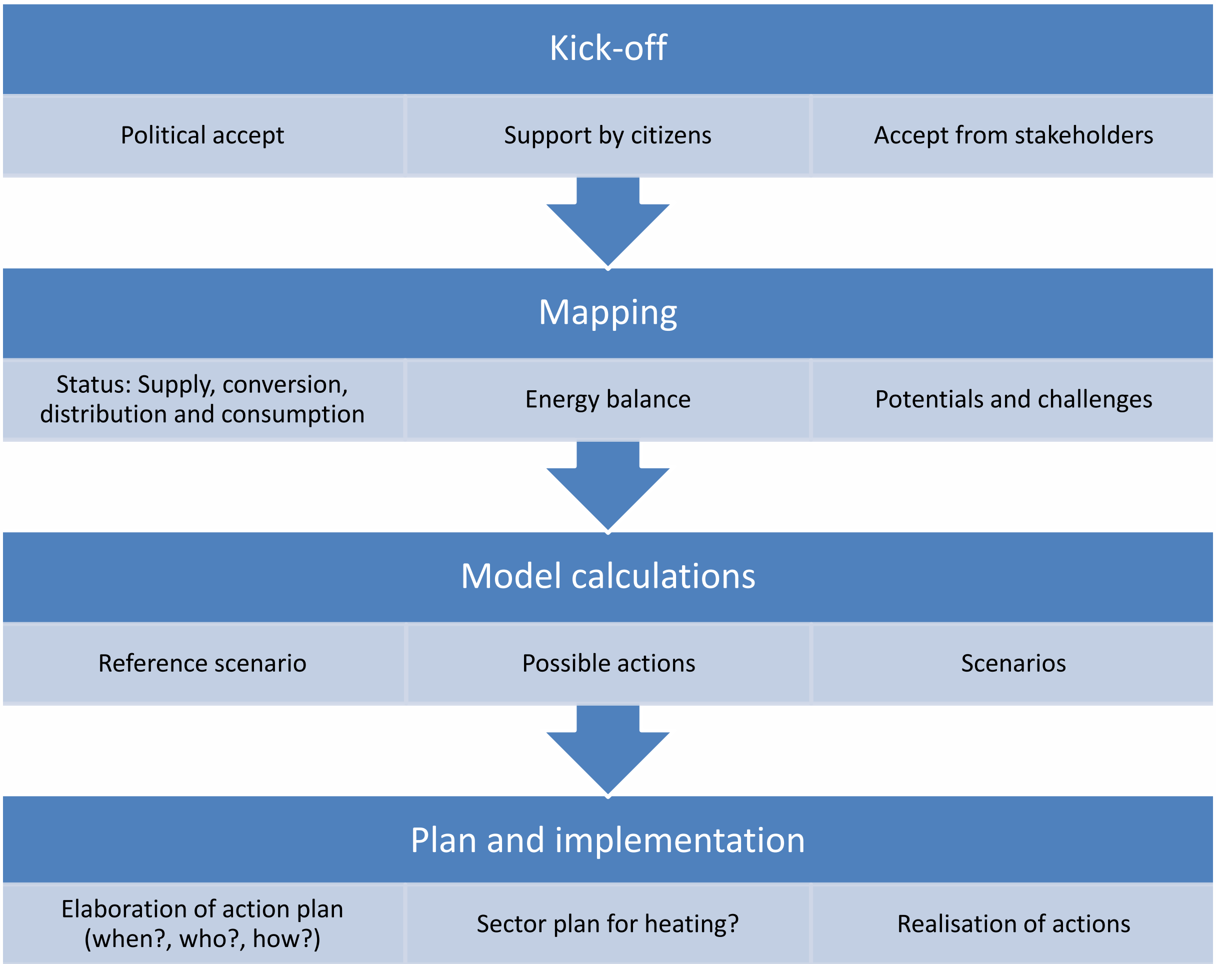

Figure 4: The process of creating Strategic Energy Plan in Sonderborg (Source: PlanEnergi).

4.3 Methods

4.3.1 Knowledge domains

As already analyzed in D2.4 in the SmartEnCity project, the Aalborg Commitments defined a set of domains in which could be divided the actions carried out towards sustainable urban development. Also the Leipzig Charter and LC-FACIL URBACT II defined later on a reference framework for sustainable cities with 30 objectives and 5 dimensions.

All these actions are related to the city scale, while district level is much more undeveloped. At district level, there are several certification tools which deal with common aspects (environmental, social and economic issues). However, other aspects vary depending on the certification tool (mobility and governance are the most extended ones while energy is the most popular).

Domain	Subdomain
City characterization	Key features of the city Land use characterization Socio-economic features of the city Environmental features of the city
Energy supply net-work	City energy profile Potential local energy resources in the city Environmental impacts in the city due to energy consumption
Transport and mo-bility	Mobility City profile City statistics for mobility Environmental impact of the mobility
Urban infrastruc-tures	Available infrastructures in the city for managing transport, waste, water and environment Existing transport utilities Existing environment monitoring infrastructure Existing city monitoring infrastructure Communication infrastructure in the city
City plans & regula-tion and governance	City plans and strategies Public procurement procedures & regulations and normative Governance
Citizens	Existing actions for citizen engagement Channels for citizen engagement Current scenarios of citizen engagement

Table 5: City characterization indicators – domains and subdomains.

4.3.2 Procedure for the selection of indicators

SmartEnCity aims to contribute to create Smart Zero CO_2 Cities across Europe through urban regeneration strategies, integrated urban plans and district integrated interventions.

In the framework of the project, indicators have been selected as a potential tool to be employed for any city that intends to be transformed into a Smart Zero City.

In deliverables D3.1, D4.1 and D5.1 this selection of indicators are used to characterize and diagnose the three lighthouse cities in a comparable form.

Through a city diagnosis based on these indicators and supplemented by qualitative knowledge for different application areas (named as domains), main needs can be identified which lead to define the objectives and strategies to be implemented in the cities as well as to take decisions on suitable interventions.

Consequently, once the city demand is known, strategic plans can be launched with the roadmap of the city and actions to overcome the barriers detected which help to promote those technologies which better can reach the city objectives. Finally, specific plans can be developed for the implementation of these technologies.

From this basis, main partners in charge of the evaluation framework in SmartEnCity (CAR and TEC) defined application areas as well as a set of indicators, to be proposed to the cities involved in SmartEnCity (lighthouse cites and follower cities), in order to assist them in the general process of developing smart and sustainable urban plans for their city (WP7, Deliverable 7.1).

These indicators were selected after a review of the available sources for indicators focused on the measurement of the city in terms of sustainability since there is not only one source which satisfies all the application areas previously identified. The indicators chosen came from documents which have worked previously with indicator systems among a wide sample of stakeholders.

These documents were:

- ISO 37120: It is the only standard already developed for city indicators although it is not focused in indicators for smart cities but in city services and quality of life.
- SCIS and CITYKeys which integrate the existing results from previous smart city initiatives.
- PLEEC and STEEP projects where the selection of indicators were done by representative of cities.
- ITU as main source for indicators in ICT issues.

Criteria for this first selection of indicators were:

- **Relevance**. Each indicator has a significant importance for the evaluation process and for the goals of the project.
- **Completeness**. The set of indicators consider all aspects of the planning and implementation of smart city projects, covering all the pillars of the project: interventions (building, mobility, ICT), actions (engagement), impacts (energy, economy, social, environment) and non-technical barriers (governance, people and finance).
- **Reliability**. The definitions of the indicators tried to be clear and not open for different interpretations. This holds for the definition itself and for the calculation methods behind the indicator.
- **Measurability**. The identified indicators were accompanied by units (for quantitative data available in data sources) and with a Likert scale (for qualitative information linked with own criteria of respondent).
- **Non-redundancy**. Indicators within a system/framework should not measure the same aspect of a subtheme.
- **Independence**. Small changes in the measurements of an indicator should not impact preferences assigned to other indicators in the evaluation.

In a further stage, partners involved directly with LH cities *(CEA from Vitoria, TREA from Tartu and SONF, ZERO, VG and PLAN from Sonderborg*) participated in the selection of most suitable indicators for their cities taking into account the below set of criteria. This process was done in Deliverable 2.6.

- **Relevance**. Each indicator has a significant importance for the evaluation process and for the goals of the project in the city.
- **Availability**. Data for the indicators seem to be easily available.
- **Familiarity**. The indicators were easy to understand by the users.

This process finished with the question: *Would you like this indicator to be included in the template for **city** diagnosis?*

A posterior analysis of the answers received from the three cities established two types of indicators for this process of city diagnosis:

- **Mandatory** indicators correspond to those indicators selected by the three cities.
- **Optional** indicators correspond to those indicators not selected by the three cities.

The agreement reached consisted of the search of mandatory indicators for the three cities in order to make a comparable analysis of the three lighthouse cities. The indicators that have been answered by Sonderborg are found in fact boxes in chapter 5 of this document. In Annex 1 the complete list of indicators – including definitions – is found.

Procedure for the search of indicators

The city diagnosis process had several difficulties in the city of *Sonderborg* to gather all the information requested. Main difficulties concerned timing (very tight deadlines for data collection) and scope of data/quantification of data (fixed scale units with little flexibility and lack of data).

Data collection is a time consuming process that requires many resources (more than the period available at hand for this deliverable) and in this light, the indicator list provided is too ambitious.

A recommendation onwards would be to use more resources on identifying which indicators are most relevant for our specific use, so resources are spend on these to ensure that all LH cities can deliver results for these.

Indicator initiative in Sonderborg: Geographical Energy Balance 2015

A Geographical Energy Balance 2015 for the Municipal area of Sonderborg has been set up by PLAN in relation to D5.1, and compose a main part of the diagnosis for Sonderborg (and potentially also provide input for baseline in D5.2).

The Geographical Energy Balance consists of a large variety of data that has been collected during D5.1 and calculated in several separated steps (referred to as appendixes), before being applied in a common data model that summarizes and calculates energy performance of the area. A screenshot of this data model and a short summary of the appendixes can be found in Annex 2. The principles and methods of the Geographical Energy Balance follow the Danish Energy Agency's (DEA) guidelines described in the *"Guide to mapping methods and data capture for the municipal strategic energy planning - Method Description"* (DEA, 2012[2]).

Results are useful to identify focus areas for actions, show development towards energy goals and can also be converted and applied in the Baseline Emissions Inventory of the Covenant of Mayors initiative.

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[2] http://www.eaenergianalyse.dk/reports/1154_vejledning_i_kortlaegningsmetoder_til_strategisk_energiplanlaegning_metodebeskrivelse.pdf

In SmartEnCity, it will specifically generate results to indicators defined in WP7. Results connect with the full range of indicators within 'Energy supply and consuming patterns', and certain indicators within 'Mobility'.

The data sources and data quality used is described in the table below. At the time of deadline of D5.1, 2015-data from DEA on production composition of residual electricity[3] and Energy Statistic 2015 (for example used to allocate non-road energy use and individual solar heating) is still awaited, which is why latest data available for both (2014) is used instead.

Data Quality	Area	Data supplier
High Measured consumption / production	Electricity production from wind power	Danish Energy Agency
	District heating consumption and grid loss	Local district heating plants
	Fuel consumption for public electricity and heat supply	Local plants producing energy to public electricity or district heating grids (via ProjectZero)
	Electricity consumption	Local electricity distribution companies
	Natural gas consumption	Local natural gas distribution company
Medium Estimated / local data	Electricity production from photovoltaic	Energinet.dk (TSO)
	Individual heating (excl. natural gas)	Local chimney sweep masters, number of heating units
	Road transport	Statistics Denmark, number of registered vehicles
	Fuel consumption of the industry (excl. natural gas)	Statistics Denmark, information from industries with more than 20 employees
Low Estimated / allocated on population etc.	Transport non-road, aviation fuel (aircrafts), fuel oil (ships), diesel (train)	Danish Energy Agency's Energy Statistic and Statistics Denmark
	Individual solar heating	Danish Energy Agency's Energy Statistic and Statistics Denmark

Table 6: Overview of data quality for the primary data sources for the creation of the Geographical Energy Balance 2015 for Sonderborg. More information on data collection and use is found in Annex 2.

[3] 'Residual electricity' is explained in Section 5.2 of Chapter 5.

5 City characterization: Sonderborg

This chapter develops a thorough characteristic of Sonderborg's current situation, deepening on relevant aspects that can affect the design and implementation of LH project intervention. For this purpose, Chapter 5 makes use of a common framework for the LH cities in SmartEnCity based on a set of indicators designed for the evaluation of the city (D7.1).

Thus, the characterization is divided in six sections, which are in line with both the indicators defined in WP7 and the necessary data to develop a comprehensive diagnosis of the city, presented in Chapter 6. These sections are:

- Local conditions
- Energy supply and consuming patterns
- Building stock and retrofitting needs
- Mobility
- ICT infrastructure and services
- Stakeholder engagement

5.1 Local conditions

5.1.1 Sonderborg in text

Sonderborg Municipality is a Danish Municipality located near the Baltic Sea in Southern Denmark 300 km in driving distance from Copenhagen, and 200 km drive from Hamburg Germany. It is the sixteenth largest municipality in Denmark and is part of Region Syddanmark (Southern Denmark Region). Danfoss, one of Denmark's largest industrial companies has its headquarters and some production facilities in the area. The area is home to extensive agriculture and has some of Denmark's most beautiful natural resorts with a long coastline and multiple forests.

Socio-economic characteristics

Sonderborg Municipality has approximately 75,000 residents of which approximately a third live in the city Sonderborg. The area has a declining population, a trend predicted to continue at least until 2030.[4] On a national level the population of Denmark is aging, and the same trend is true for Sonderborg; 56% of the population is 25-69 years old,[5] the average age range is 44-52. The average range of the population in Sonderborg Municipality is 43.2 years and the median age is 45 years.

Degreeholders make up 27.7% of the population.[5] The personal income level in Sonderborg is the 10th lowest among the 29 cities in the Southern Denmark Region, a level which is €1260/year below the regional average.[5] The average disposable income for the area has increased steadily except in 2009 during the financial crisis.[6] The unemployment rate is currently at 4.2% but has ranged between 1.9% and6.8% in the past 8 years.[7] There are several smaller tertiary educational facilities.

[4] http://www.kl.dk/ImageVaultFiles/id_67009/cf_202/Analyserapport_-_kapitel_1.PDF
[5] https://issuu.com/region-syddanmark/docs/byanalyse-demografi
[6] http://www.dst.dk/da/Statistik/kommunekort/indkomster/disponibel-indkomst
[7] http://www.dst.dk/da/Statistik/kommunekort/arbejdsloeshed/bruttoledige

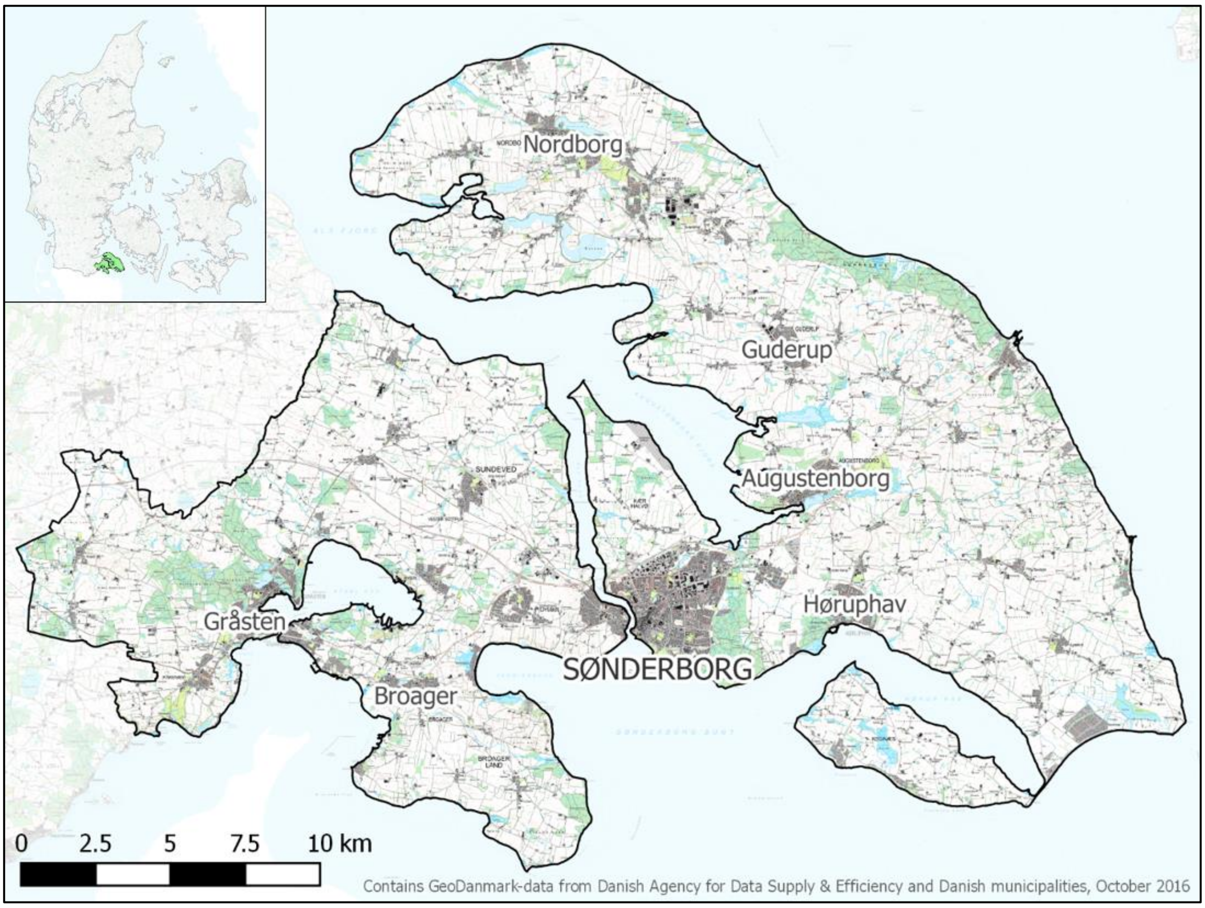


Figure 5: Map showing location of Municipality of Sonderborg in Denmark and location of the city of Sonderborg (and other municipal towns) within the municipality (source: PlanEnergi).

Figure 6: Aerial view of the city of Sonderborg in Sonderborg Municipality (Photo: ProjectZero).

Business and funding

Sonderborg has seen a decline in industrial jobs since the recent financial crisis, which affects the number of residents in the municipality and therefore the income from taxes. Since establishing ProjectZero the area has seen a job increase in the green business sector.

Public procurement is regulated according to EU regulations. It is mandatory for all state, regional and local authorities to invite tenders for work which meet or exceed thresholds set out by the EU (thresholds vary between sectors)

Public-private partnerships (PPP) also create opportunities for funding initiatives. ProjectZero is the vision of the municipality of Sonderborg to become carbon neutral in the year 2029. The vision is anchored in a PPP with broad backing from large local businesses, the municipality and financial institutions. The ProjectZero company, which actively facilitates the transition of the area and works as a catalyst for the vision is financed through this partnership. As part of the PPP ProjectZero the area has seen a job increase of 800+ in the green business sector. [8]

Residents in Denmark pay income tax according to the level of income generated, generally between 38-65%. Part of this goes directly to the municipality in which you live, and which finances investments in the municipality. Investments made by a municipality must meet strict socioeconomic analyses. If particularly large investments or investments with a long return on investment are undertaken, the municipality can make use of KommuneKredit as a financing partner. KommuneKredit is a membership organization for municipalities and regions only, and is supervised by The Ministry for Social Affairs and the Interior. [9]

Environment

Denmark has a temperate climate with monthly average temperatures above zero °C year round. [10] The weather is linked to the surrounding ocean and the direction of wind. The country is relatively warm compared to other countries at the same latitude due to the warm North Atlantic current.[11] The four seasons differ and offers great variety in hours of sunlight, temperatures, and precipitation. The environmental characteristics of Sonderborg Municipality are similar to the Danish average as described above, although with slightly more precipitation and wind.[10]

According to the Koppen climate classification map, the climate in Sonderborg is considered as “temperate oceanic climate”, in a bordering area with colder, (CFB).

[8] http://www.projectzero.dk/da-DK/TopPages/Om-ProjectZero.aspx
[9] http://kommunekredit.com/About-KommuneKredit/One-Pager.aspx
[10] http://www.dmi.dk/vejr/arkiver/normaler-og-ekstremer/klimanormaler-dk/
[11] http://www.dmi.dk/klima/klimaet-frem-til-i-dag/danmark/temperatur/

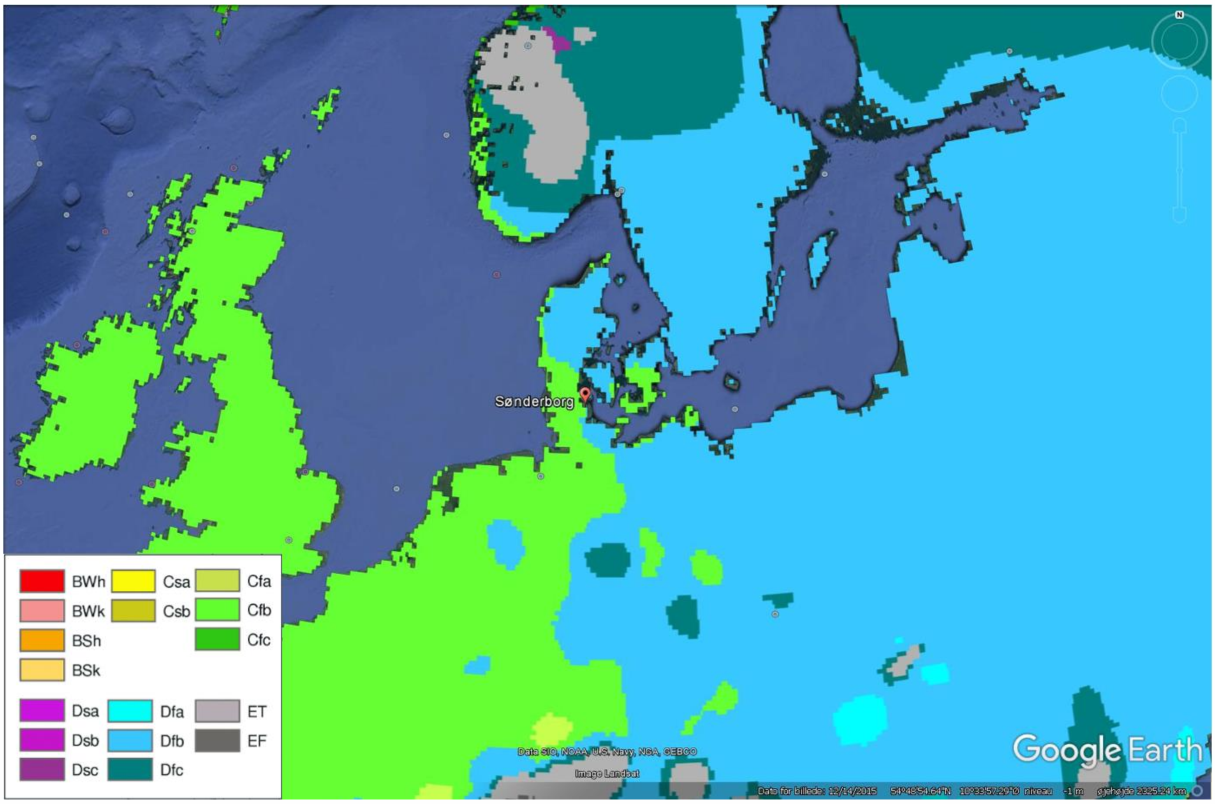


Figure 7: Map displaying Sonderborg's location in relation to Köppen-Geiger's climate classification (source: Peel et al., 2007[12] via Google Earth)

The natural environment surrounding the city includes patches of forest, agricultural land and livestock, coastal shoreline and natural harbors and fjords. The municipality borders a Natura 2000 habitat area to the south and east.

Policies and regulations

The public-private partnership – ProjectZero – was created to inspire and drive Sonderborg´s transition to a zero CO_2 community by 2029.This transition is based on improved energy efficiency, conversion of energy sources into renewables and by creating participation of all stakeholders to reach the ambitious goal: CO_2 neutral growth and sustainable urban development.

ProjectZero is one of the lighthouse beacons of the city of Sonderborg and both ProjectZero's masterplan and roadmaps are well accepted and agreed on by a broad majority of the city council. In order to achieve this goal the daily business of ProjectZero is anchored in the ProjectZero company.

Citizen engagement and behavioral change, building retrofits, and electrical vehicles are among the household level initiatives ProjectZero organizes. On a higher level, ProjectZero also brings businesses into this mindset and facilitates new plants such as biogas-production facilities.

In 2010, Denmark set the goal of being free of fossil fuels by 2050. This goal resulted in an agreement known as the Energy Agreement of 2012, which was a roadmap for financing the

[12] Peel, M. C., Finlayson, B. L., and McMahon, T. A. 2007: Updated world map of the Köppen-Geiger climate classification, Hydrol. Earth Syst. Sci., 11, 1633-1644, doi:10.5194/hess-11-1633-2007

transformation to an energy-efficient and renewable energy producing economy. This roadmap included sub goals, Public Service Obligation (PSO) fees on electricity and space heating, and incentives for district heating companies to move from coal to biomass.

A ruling by the EU in the spring 2016 stated that the PSO fee was against EU regulations, the government announced changes to the Energy Agreement of 2012. Budget negotiations in the fall 2016 will show whether renewable energy will have financial support in the future, and if so what that will look like.

5.1.2 Fact box: Sonderborg in numbers

Area	Field	Indicators	Value	Units	Data source	Comments
City characterization	Key features of the city	Size	495	km^2	GeoDanmark-data 2016	
		Population	74,937	Inhabitant (inh)	Statistics Denmark (2015)	
		Population density	151	Inh./km^2	GeoDanmark-data 2016, Statistics Denmark	
		Annual population change	-0.3	%	Statistics Denmark (2014-2015)	
		Median population age	45	Years	Statistics Denmark (2015)	
		% of population > 75	8.8 (≥ 75: 9.8)	%	Statistics Denmark (2015)	
		Land consumption	53/495 (10.7 %)	Km^2/Km^2	GeoDanmark-data 2016	
		Median disposable income	44,018	€	Statistics Denmark (2015)	Avg. per household (data to calculate median not accessible)
		Proportion of working age population with higher educa-tion	27.7	%	Statistics Denmark (2015)	
	Socio-economic fea-tures of the city (Equity)	City unemployment rate	4.2	%	Statistics Denmark (2015)	

Table 7: City characterization. All data is for the municipal area of Sonderborg (if nothing else stated).

Area	Field	Indicators	Value	Units	Data source	Comments
City plans and regulation & Governance	City plans and strategies	Existence of plans/programs to promote energy efficient buildings	YES	YES/NO	ProjectZero	
		Existence of plans/programs to promote sustainable mobility	YES	YES/NO	ProjectZero	
		Existence of local sustainability action plans	YES	YES/NO	ProjectZero	
		Signature of Covenant of Mayors	YES	YES/NO	ProjectZero	
		Existence of Smart Cities strategies	YES	YES/NO	ProjectZero	
		Existence of public incentives to promote energy efficient districts	N/A	YES/NO		Data not available
		Existence of public incentives to promote sustainable mobility	YES	YES/NO		Free electricity for EVs
	Public procurement procedures & Regulations and normative	Existence of regulations for development of energy efficient districts	YES	YES/NO		Danish building regulation
		Existence of regulations for development of sustainable mobility	N/A	YES/NO		Data not available
	Governance	Involvement of the administration on smart city projects	Agree	Likert scale Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree	ProjectZero	
		Multilevel government	Disagree	Likert scale Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree	ProjectZero	
		Paperless governement (incl. e-signature)	Agree	Likert scale Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree	ProjectZero	

Table 8: Governance, city plans & regulation. All data is for the municipal area of Sonderborg (if nothing else stated).

5.2 Energy supply and consuming patterns

Geographical Energy Balance 2015 for Sonderborg Municipal area is the source throughout this section 5.2. For more information about the Geographical Energy Balance and data used, see chapter 4.

5.2.1 Energy system of Sonderborg in text

Today the energy system in Sonderborg Municipality is a complex system, which in a simplified matter can be described in five primary energy producing and consuming sectors of electricity, district heating, individual heating, industry and transport.

The total primary energy consumption from activities in the Sonderborg Municipal area was in 2015 about 2,310,000 MWh of which about 740,000 MWh was renewable energy corresponding to about 32%. However, a majority of the energy consumption was still covered by fossil-based energy and particularly within the transport sector lies a future task of converting to renewable energy sources as the figure below shows.

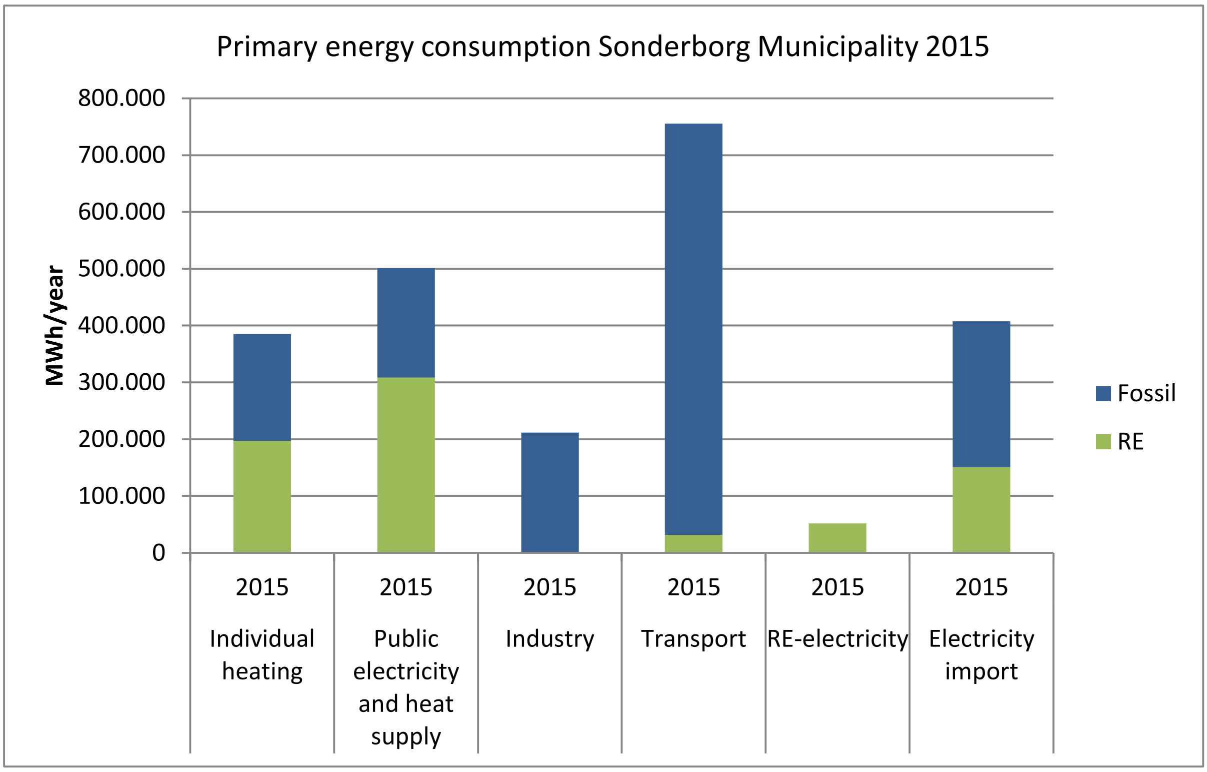


Figure 8: Primary energy consumption of fossil (blue) and renewable (green) energy allocated to sectors in Sonderborg municipal area in 2015 (RE = renewable energy).

A closer look at the different renewable energy sources used in the Sonderborg Municipal area shows that the majority comes from biomass (mainly used for individual and district heating), biodegradable waste (used in CHP production), and imported electricity produced from renewable energy sources. The use of local wind power, biogas, solar PVs, solar thermal, ground heat and geothermal represent smaller proportions, but are all continuously increasing.

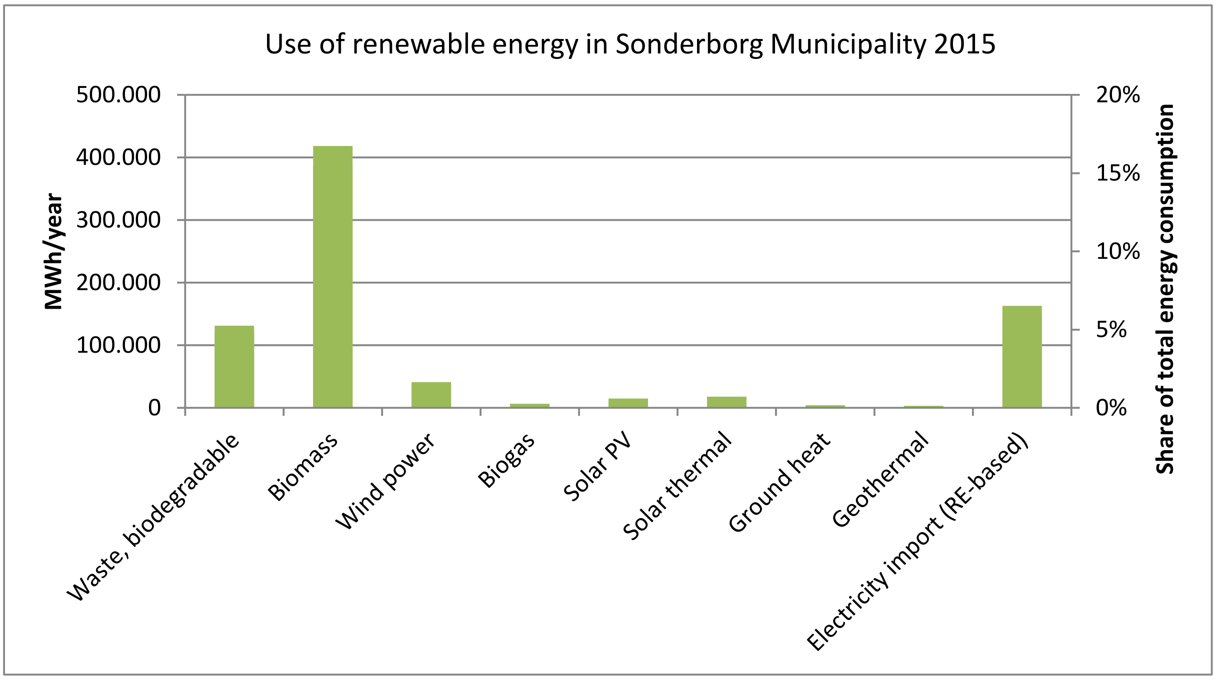


Figure 9: Use of renewable energy resource types as primary energy consumption (left axis) and as share of total primary energy consumption (right axis) in Sonderborg municipal area in 2015 (RE = renewable energy).

Electricity

Within Sonderborg Municipality electricity is produced from several plant types: A waste incineration CHP plant, four natural gas CHP plants, onshore wind turbines and photovoltaics. In 2015 the onshore wind turbines produced about 38,000 MWh making wind turbines the largest electricity producing plant type within the municipality.

Figure 10: Wind turbines located in Sonderborg Municipality (Photo: ProjectZero).

The total electricity production within the municipality was in 2015 about 86,000 MWh. This corresponded to about 17.5 % of the total electricity consumption in the municipality of about 493,000 MWh. Thus, to cover the electricity demand, about 407,000 MWh was imported from outside the municipality in 2015. These numbers include losses in the electricity grid.

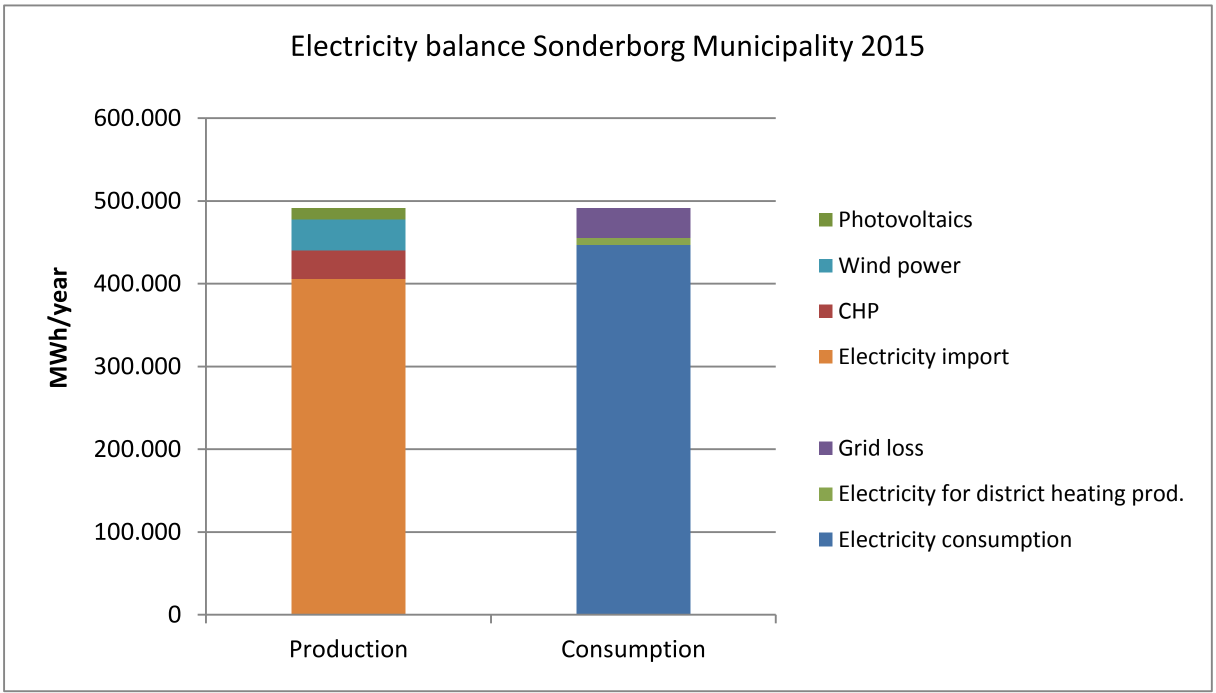


Figure 11: Balance between electricity production (incl. electricity import) and electricity consumption in the municipal area of Sonderborg in 2015.

This electricity is imported from the Western-Danish electricity grid (DK1), which Sonderborg Municipality is connected to by an effective transmission capacity of 270 MW.

From a technical perspective this imported electricity is assumed to be 'residual electricity' produced by central Danish power plants in condensing mode and offshore wind turbines (following calculation methodology prescribed by Danish Energy Agency). The production composition of the imported residual electricity can be expressed simply as an average CO_2 emission and renewable energy share per MWh produced.

In areas with large electricity import, such as Sonderborg, the ever-present production composition of the imported electricity becomes highly influential to the areas' total energy performance regarding CO_2 emissions and renewable energy share. As Danish central power plants continuously have been converting from electricity production based on fossil fuels to renewable energy sources, and as new offshore wind turbines have been installed, the renewable energy share has increased during the last 10+ years and CO_2 emissions decreased (see figure below).

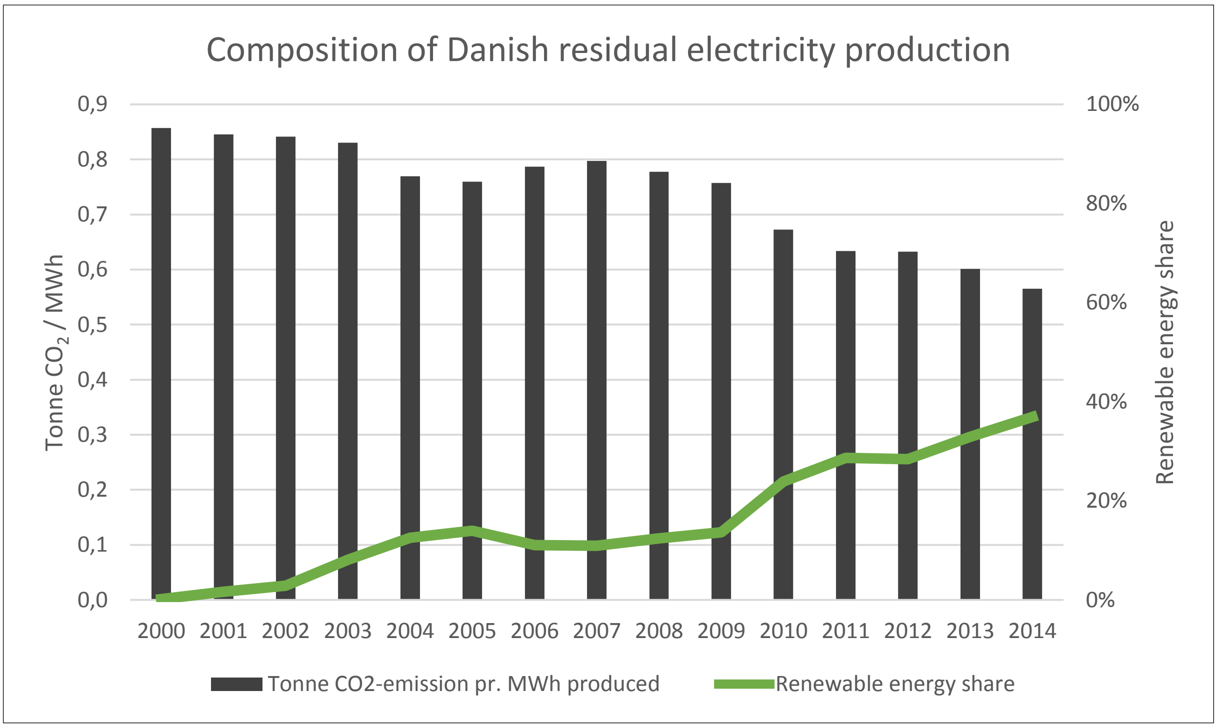


Figure 12: CO_2 emissions (black pillars: left axis) and renewable energy share (green line: right axis) of Danish residual electricity from 2000-2014 (Danish Energy Agency, 2016)

District heating

Sonderborg Municipality has an extensive district heating system, which is composed of five separate district heating networks.

In 2015 about 354,000 MWh district heating were supplied to district heating customers in Sonderborg Municipality. This corresponds to about 53 % of the total end-use heat demand in the municipality in 2015. District heating is supplied to about 40 % of all households.

To account for heat losses in the transmission pipes of the district heating networks (average grid loss about 24 % for the system as a whole) the district heating plants in 2015 produced about 439,000 MWh to the district heating networks. Own-consumption of district heating in industries was about 19,000 MWh, which gives a total district heating production of about 458,000 MWh in 2015.

Several combined heat and power (CHP) plants produce heat for the district heating system in Sonderborg Municipality. The largest is located in the city of Sonderborg and consists of a waste incineration part and a gas turbine part (combined cycle). The remaining CHP plants are smaller gas engines located in relation to other urban areas in the municipality. In addition to the CHP plants, several boilers running on natural gas, biomass and electricity exist in the municipality.

Figure 13: Waste incineration CHP plant in Sonderborg Municipality (Photo: ProjectZero).

During the last ten years, large-scale solar thermal plants have been installed and connected to three of the district heating networks in Sonderborg. One geothermal plant, which is connected to an absorption heat pump driven by a biomass boiler.

Figure 14: One of three large-scale solar thermal plants supplying district heating in Sonderborg (Photo: ProjectZero).

Individual heating

Approximately 319,000 MWh, corresponding to about 47% of the total end-use heat demand in Sonderborg Municipality, was in total supplied by individual heating forms in 2015. Individual heating refers to the heat supply in buildings that are not connected to a district heating network. The figure below shows how the total end-use of heat in Sonderborg is covered by 47% individual heating allocated on individual plant types and 53% district heating.

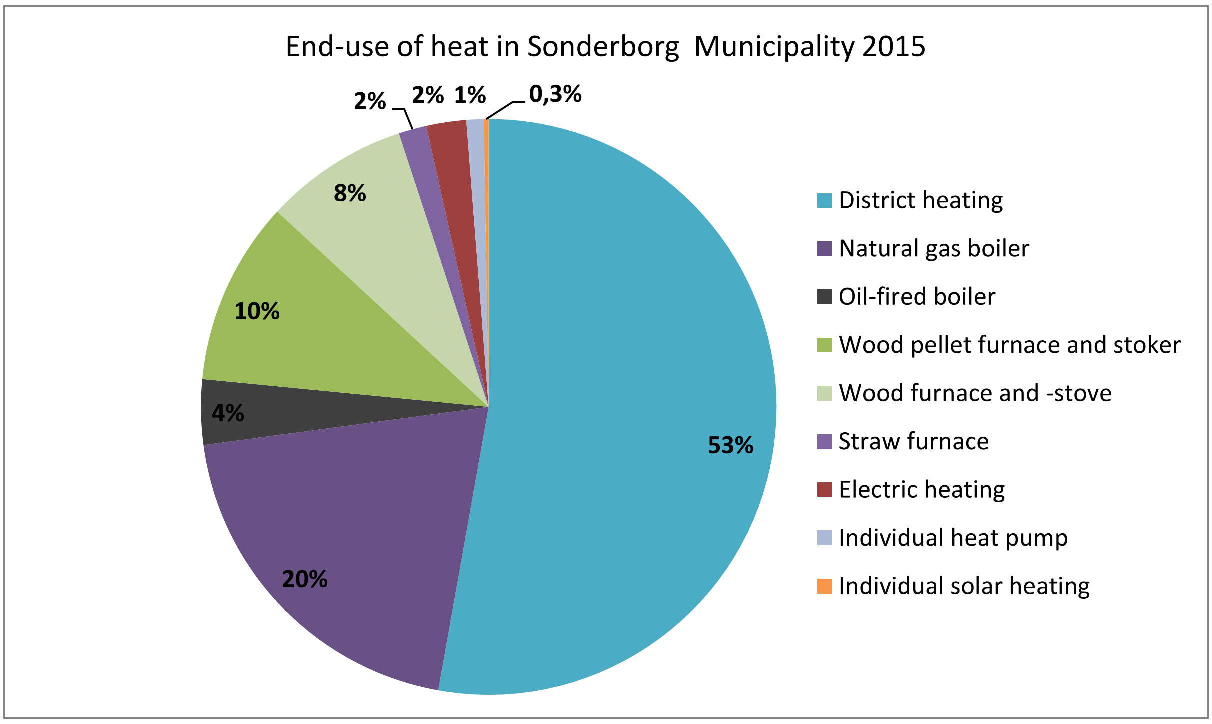


Figure 15: End-use of heat allocated on heating forms in Sonderborg municipal area in 2015.

Natural gas for individual heating is primarily used in households but also in some public service buildings, the trade and private service sectors as well as in industries. Wood and wood pellets are almost exclusively used in households, while heating oil is used in households and industries. Straw is mainly used for heating of farmhouses in relation to farms and for agricultural purpose, while individual heat pumps are generally used in households outside district heating areas. Electric heating is also mainly used in households and is the most common heating source for holiday houses.

Transport

Converting transport systems to renewable energy remains a key challenge for communities worldwide, as well also in Sonderborg Municipality where it is as mentioned based primarily on fossil fuels today.

The most energy for transportation in Sonderborg was in 2015 used in conventional internal combustion engine vehicles, fueled by petrol or diesel (see figure below). The fact that transport in Sonderborg is highly individualized entails that development of the transport system for a major part is dependent on actions taken by the individual citizens in Sonderborg Municipality.

Sonderborg's transport system is described further in section 5.4 Mobility

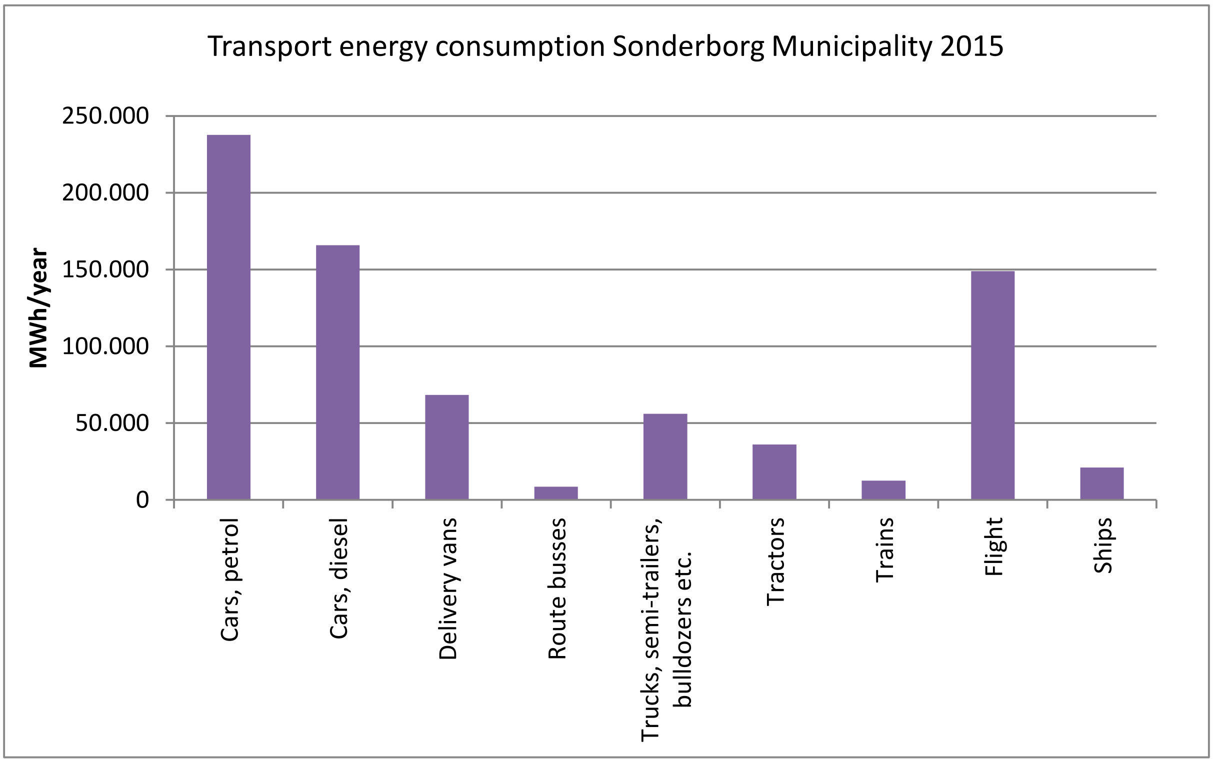


Figure 16: Transport energy consumption allocated on transport forms in Sonderborg municipal area 2015.

5.2.2 Fact box: Energy system of Sonderborg in numbers

Area	Field	Indicators	Value	Units	Data source	Comments
Energy supply network	**City energy profile**	Primary Energy Consumption in the city per year	2,310,000	MWh/year	Geographical Energy Balance 2015	
		Final Energy produced in the city per year	860,000 (Individual heating production 315,000. District heating production 459,000. Electricity production 86,000)	MWh/year	Geographical Energy Balance 2015	
		Primary Energy Consumption in the city per capita	30.8	MWh/year per inhabitant	Geographical Energy Balance 2015	
		Final Energy produced in the city per capita	11.5	MWh/year per inhabitant	Geographical Energy Balance 2015	
		Total residential biomass	2,550	kWh/year per	Geographical	Gross final

		energy use per capita		inhabitant	Energy Balance 2015	energy consumption (biomass used in public heat and electricity supply sectors is not included)
	Potential local renewable energy resources	Percentage of total energy derived from renewable sources	32	%	Geographical Energy Balance 2015	EUs calculation method
		Energy use from District Heating	6,120	kWh/year per inhabitant	Geographical Energy Balance 2015	Gross final energy consumption
		Energy use from Biomass	5,150	kWh/year per inhabitant	Geographical Energy Balance 2015	Primary energy consumption
		Energy use from PV	185	kWh/year per inhabitant	Geographical Energy Balance 2015	Primary energy consumption
		Energy use from Solar Thermal	220	kWh/year per inhabitant	Geographical Energy Balance 2015	Primary energy consumption
		Energy use from Hydraulic	0	kWh/year per inhabitant	Geographical Energy Balance 2015	Primary energy consumption
		Energy use from Wind	505	kWh/year per inhabitant	Geographical Energy Balance 2015	Primary energy consumption (all wind turbines within municipal area)
		Energy use from Geothermal	40	kWh/year per inhabitant	Geographical Energy Balance 2015	Primary energy consumption
		Energy use from Ground heat	50	kWh/year per inhabitant	Geographical Energy Balance 2015	Primary energy consumption
		Energy use from Waste (biodegradable)	1,615	kWh/year per inhabitant	Geographical Energy Balance 2015	Primary energy consumption
		Energy use from Biogas	80	kWh/year per inhabitant	Geographical Energy Balance 2015	Primary energy consumption
	Environmental impacts of the energy consumption	Global Warming Potential (GWP) per capita	7.4	Tn equi. CO_2 / year capita	Geographical Energy Balance 2015	

Table 9: Energy supply network. All data is for the municipal area of Sonderborg (if nothing else stated). For information about Geographical Energy Balance 2015 see chapter 4.

5.3 Building stock and retrofitting needs

5.3.1 Buildings in Sonderborg in text

History in the development of buildings

Sonderborg city was founded as a market place around 1150 and is for the first time mentioned as a city in 1256. In 1300-1400 the current city centre was established, and in 1590 Sonderborg received the municipal charter, which allowed the city to collect taxes. In 1803 there were 2761 inhabitants in Sonderborg, and the city centre was characterized by big merchant`s houses and craftsmen houses.

The war between Denmark, Preussen and Austria in 1864 had serious consequences for Sonderborg. The Danish army was besieged in Sonderborg, and the city was exposed to heavy bombardment in March to April 1864. This resulted in many demolished buildings in Sonderborg. Therefore there are not many buildings in Sonderborg older than 150 years.

Denmark lost the war in 1864, and the Sonderborg-region became a German/Preussen land until the end of the first world war in 1920. In 1905 the German Government decided, that Sonderborg should be the new headquarter for the German military fleet, which meant, that the population in Sonderborg was doubled in a period of 10 years.

There were constructed a lot of new buildings in this period, both big villas, apartment houses and many public buildings and institutions. Many of these new buildings were designed in the German Jugendstile (art nouveau), and the city centre of Sonderborg today is characterized by German architecture from the period around 1900.

Year	Inhabitants in city of Sonderborg
1803	2,761 inhabitants
1900	5,522 inhabitants
1912	11,521 inhabitants
1981	25,885 inhabitants
2008	27,286 inhabitants
2015	27,419 inhabitants

Table 10: Demographics – historical growth of population in the city of Sonderborg in mainly the 20th century increased the demand for dwellings.

Building stock distribution

In total there are 66,000 buildings in the Municipality of Sonderborg. Of these, about 30,000 are heated buildings and about 36,000 unheated buildings. Of heated buildings there are 20,000 one-family houses, 3,500 townhouses and 1,500 rise housing buildings.

Construction period	Share of total building stock in Sonderborg	Heat demand for houses (kWh/m²/years)
Before 1930	24%	168 kWh/m^2/year
1931-1950	7%	164 kWh/m^2/year
1951-1960	8%	144 kWh/m^2/year
1961-1972	22%	126 kWh/m^2/year
1973-1978	12%	102 kWh/m^2/year
1979-1998	18%	80 kWh/m^2/year
1999-2005	9%	64 kWh/m^2/year

Table 11: Building stock ages and heat demand in Sonderborg Municipal area.

Ownership of housing in Sonderborg

About a third of the population in Sonderborg city is living in public housing associations administrated by three different housing associations, which all are partners in the SmartEnCity project.

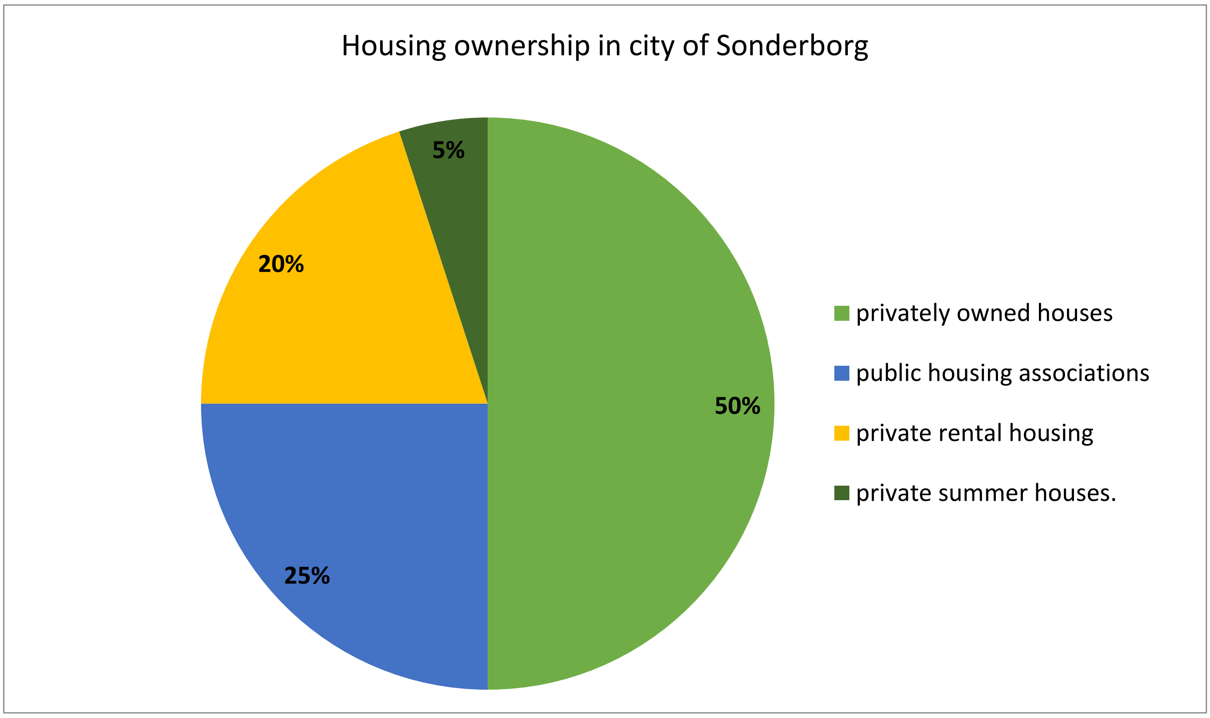


Figure 17: Distribution of home ownership in the city of Sonderborg.

Regulations and local building plans

All municipalities in Denmark have prepared specific local building plans for the different areas of the city. These local building plans have to be followed, if building owners want to construct new buildings or make comprehensive changes of existing buildings. The local plans specify, which kind of buildings for specific use can be constructed in the area, which materials have to be used, the roof pitch etc.

In addition to the local plans there is the official Danish Building Regulation, which is applicable all over Denmark. Among other things the Building Regulations specify the maximum amount of primary energy, new houses can use per year. Buildings can include and deduct negative primary energy, if energy is produced on site, to fulfill the energy frame.

The development of this energy frame for new houses is as follows:

Year	Energy frame for new houses in Denmark
2006	Maximum energy use: 70 kWh/m²/year
2010	Maximum energy use 52 kWh/m²/year
2015	Maximum energy use: 30 kWh/m²/year
2020	Maximum energy use: 20 kWh/m²/year (expected)
2025	Maximum energy use: 0 kWh/m²/year (expected)

Table 12: Development of energy frame for new houses in Denmark in general.

Financing of building constructions

Privately owned buildings are normally financed by mortgage institutions, who are allowed to finance 80% of the assessment value of the house. The owner must finance 5% with own funds, while 15% can normally be financed with regular bank loans.

Public housing associations for renting can finance new buildings by 10% support from the local municipality, 2% from resident deposits and 88% by mortgage institutions, where the Danish Government guarantees the annuities.

In addition, certain building retrofitting measures of social housing buildings can be financed through the national foundation, “Landsbyggefonden”, where all social housing companies in Denmark are contributing with a share of all housing rent income.

Figure 18: Sonderborg harbor front (Photo: ProjectZero)

5.3.2 Fact box: Buildings in Sonderborg in numbers

Area	Field	Indicators		Value	Units	Data source	Comments
Energy supply network	Energy uses in building typologies	Total buildings energy consumption per year	Heat	615,500	MWh/year	Geographical Energy Balance 2015	End-use consumption (excl. industry)
			Electricity	179,500	MWh/year	Geographical Energy Balance 2015	End-use consumption (excl. industry. 'Electricity' incl. electricity for heating and heat pumps)
		Residential buildings energy consumption per year	Heat	537,000	MWh/year	Geographical Energy Balance 2015	End-use consumption
			Electricity	102,000	MWh/year	Geographical Energy Balance 2015	End-use consumption ('Electricity' incl. electricity for heating and heat pumps)
		Total building energy consumption in the city per capita	Heat	8,210	kWh/year per inhabitant	Geographical Energy Balance 2015	End-use consumption (excl. industry)
			Electricity	2,390	kWh/year per inhabitant	Geographical Energy Balance 2015	End-use consumption (excl. industry. 'Electricity' incl. electricity for heating and heat pumps)
		Residential buildings energy consumption per capita	Heat:	7,170	kWh/year per inhabitant	Geographical Energy Balance 2015	End-use consumption
			Electricity	1,360	kWh/year per inhabitant	Geographical Energy Balance 2015	End-use consumption ('Electricity' incl. electricity for heating and heat pumps)
		Public lighting energy use per year		4,332,300	kWh/year	Geographical Energy Balance 2015	End-use consumption
		Public lighting energy use per capita		58	kWh/year per inhabitant	Geographical Energy Balance 2015	End-use consumption
		Portion of households connected to the district heating and cooling		Ca. 40	%	Statistics Denmark	Data is not accurate

Table 13: Buildings. All data is for the municipal area of Sonderborg (if nothing else stated). For information about Geographical Energy Balance 2015 see chapter 4.

5.4 Mobility

5.4.1 Mobility in Sonderborg in text

Motorized private transportation

Compared to number of inhabitants, the Sonderborg municipal area is characterized by a relatively large number of private cars and vans. There are about 37,500 cars and vans in Sonderborg Municipality. Hence, there are more than 0.5 cars per citizen in Sonderborg, (3.4% higher than the national average of cars pr. citizen in Denmark). The reason for the high number of cars might be the rather rural characteristics of the municipality where towns are spread and people need a car in order to get around.

Type of vehicle	Average traffic amount (trips) per day (24 hours)	Average traffic work (1,000 KM) per day (24 hours)
Cars	139,678	1,226
Small vans	10,769	203
Big lorries buses	6,819	132
Totally	157,266	1,561

Table 14: Status (2012) for the transport situation of Sonderborg (Source: COWI).

Electric Vehicles

In 2015, there were 100 electric vehicles in Sonderborg. After the government chose to impose taxes on electric vehicles (EV), the number of EV's sold has drastically decreased. In Sonderborg, there were in 2015 nine public charging locations with multiple EV chargers at each location giving a total of 29 EV charging points.

Ferry lines

Sonderborg has three ferry lines. The first one is connecting the otherwise water-separated eastern and western parts of the municipality by a 10-minute crossing. This line is popular because of the low price, and the possibility to save a lot of time and distance. Truckers who like to take advantage of the low prices and the high fuel saving potential frequently use this particular ferry line.

The second ferry line connects Sonderborg with the island Fyn. This line is often used to transport cars, bikes and walking passengers. The ferry has 7-8 departures every day, one trip takes about 50 minutes.

The third line is connecting Sonderborg with the small island Ærø. Tourists frequently visit this island during summer, which leads to varying passenger numbers during summer and winter.

Figure 19: Three of Sonderborg Municipality's fleet of electric vehicles (Photo: Municipality of Sonderborg)

Figure 20: Ferry line connecting two otherwise water-separated areas of Sonderborg Municipality by a ten-minute crossing (Photo: ProjectZero).

Aviation

The airport in Sonderborg has a regular route connecting Sonderborg to Copenhagen. Approximately 56,000 passengers per year use this route. Compared to the train, the plane is time saving, as it only takes 45 minutes to fly to Copenhagen. With its five departures on weekdays and two departures on weekends the plane is used mainly by business people.

Railway

There is only train station in Sonderborg city. The station is connected to the national (and international) rail network, and from the train station a city bus departures every 30 minutes to carry passengers to the main bus station in the center of Sonderborg city. From early morning to late night, every other hour there is a direct train to Copenhagen, which takes appr. 3.5h.

It is possible to get to the major cities in Denmark by train, even though it requires some train changes during the trip. Furthermore, trips to the rest of Europe are possible by train.

Public transport

Besides the train, busses characterize public transportation in Sonderborg Municipality. Sonderborg has 27 local bus routes that are transporting 1,300,000 passengers through the entire municipality every year. Furthermore, there are six city busses in the city of Sonderborg, transporting 528,600 passengers every year.

Since 2009 schoolkids get free bus passes, which is making bus transportation attractive, especially for the younger generation.

Cycling

In Sonderborg there are 268 km cycle path, and further 60 km are planned to be implemented. Studies show that 22 % of the citizens in Sonderborg are using the bike every day making an average distance of 10.5 km.

In 2016 the politicians in Sonderborg agreed on a green transportation strategy. This strategy aims to reduce CO_2 emissions by 80 % toward 2029 compared to 2014. The strategy contains 27 initiatives, which are focused on public transportation, private transportation, heavy transportation and sustainable transportation (walking and bicycling).

5.4.2 Fact box: Mobility in Sonderborg in numbers

Area	Field	Indicators	Value	Units	Data source	Comments
Transport and mobility	Mobility City Profile	Total number of vehicles in the city per capita	0.57	Number/inh	Geographical Energy Balance 2015	
		Total number of private cars per capita	0.45	Number/inh	Geographical Energy Balance 2015	
		Total number of commercial vehicles per capita	0.05	Number/inh	Geographical Energy Balance 2015	
		Total number of taxis per capita	0.0005	Number/inh	Geographical Energy Balance 2015	
		Total number of trucks per capita	0.004	Number/inh	Geographical Energy Balance 2015	
		Total number of public	0.0005	Number/inh	Geographical	

		buses per capita			Energy Balance 2015	
		Total number of public bicycles per capita	0	Number/inh		
		Number of two-wheel motorized vehicles per capita	0.05	Number/inh	Geographical Energy Balance 2015	
		Kilometers of bicycle paths and lanes per population	0.0036	Km/inh	ProjectZero	
		Daily average length by bike trip	10.5	km/ vehicle ·day	ProjectZero	
	City Statistics for Mobility	Percentage of electric private cars	0.3	%	ProjectZero	
		Percentage of electric taxis	N/A	%		Data not available
		Percentage of electric motorcycles	N/A	%		Data not available
		Percentage of electric public buses	0	%		
		Percentage of biogas public buses	0	%		
		Number of public EV charging stations	9 charging areas with 29 charging points in total	Number	www.ladekortet.dk	
		Total number of recharges per year	N/A	Number		Data not available
		Total kWh recharged in the EV charging stations	N/A	kWh		Data not available
		Cost of a monthly ticket for public transport in relation to the national minimum wage or average wage	0.36%	%	Sydtrafik, Statistics Denmark	6 zones monthly ticket (valid in full municipal area), average income in municipality.
	Environmental impact with mobility	Transport energy use per capita	10,025	kWh/year per inhabitant	Geographical Energy Balance 2015	Gross final energy consumption
		Transport greenhouse gas emissions per capita	2.5	t /(pers.·a)	Geographical Energy Balance 2015	
		Percentage of renewable energy use in public transport	4.1	%	Geographical Energy Balance 2015	

Table 15: Mobility and transportation. All data is for the municipal area of Sonderborg (if nothing else stated). For information about Geographical Energy Balance 2015 see chapter 4.

5.5 ICT infrastructures and services

5.5.1 ICT infrastructures and services in Sonderborg in text

Smart City Services

Sonderborg Municipality has a website for residents in the municipality. The website consists of both information and self-service to improve availability and flexibility of services to the citizens. Furthermore the municipality offices have self-service counters in addition to staffed counters which are open to residents whom do not have computer and internet access at home.

Street lights are being upgraded to LEDs, and are turned on automatically at dusk and turned off at dawn. Several intelligent parking information signs make navigating the city for free parking spaces smooth and reduce congestion.

There were 29 public electrical vehicle chargers in the municipality before SmartEnCity started divided between 9 locations. The chargers are operated by either Clever or E.On and all are linked to the online portal Ladekortet.dk which shows information about the availability, location and operator name.

Monitoring and communication infrastructure

The level of fiber optic internet availability is continuously increasing due to a conscious effort to bring fast internet to the Danish country side. Cell phone coverage and 3G/4G is available across the municipality. The majority of café's and stores provide free wi-fi access and the library has PCs and printers available for free as well as online media services like free newspapers, movies and music.

Buildings, and apartments, have full control over central heating and ventilation, either manually or by electronic means. The majority of homes have utility meters that can be read by the utility companies automatically from afar. The utility companies have had the exchange of old meters to new, smart, meters on their agenda for years and do this gradually. Many apartment buildings and houses have installed motion detectors on outdoor- and staircase lighting.

Policies and regulations

All data collected is legally required to follow the Danish law regarding data collection and use; Persondataloven. This law is applicable to all national, regional and local authorities as well as private companies and individuals. Personal data collected on any topic may only be used as aggregated and only if the data has been anonymized.

Standards (extract from D2.2)

Standardization in the ICT field has become complex with the exponential growth of data, services and technical developments. The following is a sample of standardization activities developed by ISO; ISO, ITU, OGC, ETSI, IEEE and BSI.

Besides these, the three EC initiatives; ESPRESSO, CITYkeys and The Smart Cities Information System cover the Smart City field and industry groups implementing those approaches. For more information on this topic reference is made to D2.2 Recommendations for updating standards or generating new ones.

Business model and funding (extract from D2.3)

Smart Cities need to be economically feasible without public subsidies in the near future, and meanwhile, public and private funding should be better balanced in order to draw a sustainable roadmap for urban retrofitting. If all stakeholders involved in the process of city transformation are able to identify added value of the changes, investments will follow.

Public and private collaboration and a stronger integration of the value chain matching city needs with industrial solutions is a strategy to leverage public and private investments. For more information on this topic reference is made to D2.3 New business models procurement schemes and financing mechanisms for smart city projects.

5.5.2 Fact box: ICT infrastructures & services in Sonderborg in numbers

Area	Field	Indicators	Value	Units	Data source	Comments
Urban infrastructure	Existing city monitoring infrastructure	Number of parking information panels	22 electronic and 7 non-electronic	Number		
		Number of air quality stations	0	Ratio	[13]	
		Number of weather stations	1 in the city, 2 in the municipality	Ratio	[14]	
		ICT citizen oriented platforms	YES	YES/NO		
	Communication infrastructure in the city	Percentage of the population covered by a mobile-cellular network	99	%		
		3G Mobile network cells	59	Number of 3G mobile network cells	[15]	
		4G Mobile network cells	58	Number of 4G mobile network cells	[16]	
		Number of cell phone connections per capita	1+	Connections/inh		More than inh., many have separate work/private cell phones
		Number of internet connections per capita	0.92	Connections/inh		Average for southern Denmark

Table 16: Urban infrastructure. All data is for the municipal area of Sonderborg (if nothing else stated).

[13] http://www2.dmu.dk/1_Viden/2_miljoe-tilstand/3_luft/4_maalinger/5_maaleprogrammer/oversigtskort.asp
[14] http://www.vejrcentral.dk/da/vejr/vejrstationer.html
[15] http://www.mastedatabasen.dk/VisKort/PageMap.aspx
[16] http://www.mastedatabasen.dk/VisKort/PageMap.aspx

5.6 Stakeholder engagement

5.6.1 Stakeholder engagement in Sonderborg in text

ProjectZero is the vision for transitioning the territory of Sonderborg Municipality into a zero CO_2 community by 2029. Within this transition, priority is given firstly to energy efficiency and secondly to using energy only from the areas' own renewable resources.

The execution is based on strong citizen participation, and is oriented on actions and the opportunity to grow new green jobs as part of the implementation. Sonderborg´s ProjectZero transition was established in 2007 as a public private partnership by the Sonderborg city council, local business and utility companies and national partners.

Why citizen engagement – purpose and scope

Strong citizen participation is necessary to achieve the ProjectZero energy efficiency goals for Sonderborg, where 43% of the scheduled carbon reductions by 2029 is expected to be created as energy savings across all sectors and with active participation from citizens, businesses, schools etc.

Strong citizen participation is also important for changing the current society thinking through new society learning activities.

The ProjectZero Company has been allocated the necessary resources to plan and drive the ProjectZero roadmap implementation and the stakeholder engagement.

Figure 21: Among other means, local businesses in Sonderborg are engaged through awareness creation about their participation. The figure is a sticker saying: "ZEROcompany – We work actively to make the Sonderborg area CO_2 neutral by 2029" (Photo: ProjectZero).

The Change model and participatory platforms

The ProjectZero change-model is based on a traditional s-curve for acceptance of new innovation, where there will be Innovators, Early Adapters, Early Majority, Late Majority and Laggards. Each segment needs to be addressed differently in a staged model creating segmented participatory platforms.

Several platforms for stakeholder participation has been developed since 2007. The most important will be described further below. Each of them has been refined and developed further based on feedback, learning and progression.

Addressing the value-proposition to the segment (outside in), on-going adjustment for progression (along the s-curve) and value based communication to the segment seems to be in common across all segments and platforms.

Citizen participation platforms

In 2008 Sonderborg created the House of Science learning program, where kids and youth from Kindergarten to PhD will learn and participate in Sonderborg´s transition. In pre-school the focus is nature and waste as a resource. In school the green teaching plan hold the curriculum for energy in buildings and society. Kids are visiting local sights and assist Sonderborg´s energy transition. In high school more complex themes in energy, society and sustainability is being addressed.

The House of Science platform creates good citizenship and challenges assumptions around the local neighborhoods by a young group of climate ambassadors.

Figure 22: Local ambassador showing a ProjectZero badge (Photo: ProjectZero).

The ZEROfamily program – the starting point for Citizen engagement

In 2009, ProjectZero created the ZEROfamily program, enabling more than 100 families to join a one-year learning journey in energy. The families were exposed to energy saving potentials in their every-day life and motivated to monitor their consumption meters on a monthly basis – and address the consumption in the family daily discussions.

During one year the families reduced power and heat consumption by almost 25% and water by 40% by attitude and changed behavior. The families requested an energy advisor (a person) to visit them in their private homes, but the ZEROfamily program had no resources for doing this.

The ZEROhome platform

With financial support from the Danish government and local partners, the ZEROhome platform was launched mid-2010. During 2.5 years an energy advisor visited more than 1,200 families, performed an energy check and motivated the families to implement the suggested initiatives/investments in new appliances, heat sources, windows, LED, installations etc. More than 65% of the families implemented one or more initiatives and created thereby a documented craftsmen turnover of app. €14 mio.

Furthermore, other 1,400 families were inspired by the communication and supportive events to install PV-panels at their roofs and more than 1,000 families have replaced their oil burners with district heating or heat pumps (rural areas).

Based on learning from the EU Refurb project, the ZEROhome (now version 4.0) is being developed based on a commercial platform addressing the young families and empty nesters segments.

Tenants is the next wave

Citizen engagement was in 2013 segmented further by the ownership of their homes into home-owners (ZEROhome), tenants in house associations and tenants in private flats.

The tenants in private flats are addressed as part of the ZEROlandlord-platform, which was created in 2014 as a partnership with the national landlord association.

Tenants living in Sonderborg´s six house associations are to be addressed in the SmartEnCity project, where the three major house associations are partners. More than 1,000 families will benefit from energy retrofit of their homes, co-financed by EU as part of the Sonderborg Lighthouse project.

Core activities so far, has been to secure a strong tenant (citizen) participation in the house association decision making process. This has involved information meetings, engagement workshops, coordination meetings at all decision levels from tenant to department board to house association board of directors along with the house association administration. All house associations have with strong majority committed the requested additional local funding.

New tenant initiatives include car-sharing of electrical cars, developing local prototype families, display of community smart energy data, further learning initiatives and the implementation of Sonderborg as a new UNESCO sustainable learning City.

Monitoring and evaluation

The citizen participation is currently monitored directly as part of the platform progress monitoring. This has limitations as the indirect participation of citizens not being part of the specific program/platform is not included.

New ways of monitoring progress based on big data (energy consumption, transport use, etc.) will be explored further as part of the SmartEnCity project.

5.6.2 Fact box: Stakeholder engagement in Sonderborg in numbers

Area	Field	Indicators	Value	Units	Data source	Comments
Citizens	Existing actions related to citizen engagement	Recycling rate	74% for all segments 61% for households	%		Data from 2012
		Voter turnout in last municipal election	74	%		
		Number of local associations per capita	N/A	Number of consultations / inhab.		Data not available
	Channels for citizen engagement	Number of awareness raising campaigns	N/A	Number		Data not available
	Current scenarios of citizen engagement	Citizens participation in smart city projects	N/A	Number		Data not available
		Professional stakeholder involvement	N/A	Likert scale Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree		Data not available

Table 17: Citizen engagement. All data is for the municipal area of Sonderborg (if nothing else stated).

6 City needs definition and prioritization

The needs in the Sonderborg municipal area has (and still is) continuously been analyzed and updated through a variety of plans, each addressing parts and connections in relation to the total conversion of Sonderborg to reach the goal of becoming a zero CO_2 emission community by 2029.

These plans identify priority areas and bottlenecks and include several economic analyses, spatial analyses, and other analyses that compose an important basis for identifying and updating needs as well as prioritizing the actions in Sonderborg. A selection of the most recent plans are:

- **ProjectZero Masterplan 2029:** Roadmap to reach zero CO_2 emissions for all activities in the Municipality area of Sonderborg by 2029.
- **ProjectZero Roadmap 2020:** A specific proposal for how the Sonderborg area can achieve a sub-goal of 50% reduction by 2020 (compared to the 2007-baseline).
- **Strategic Energy Plan 2015:** Strategic Energy Plan for Sonderborg using the EnergyPLAN calculation tool for Sonderborg reaching zero CO_2 emissions in 2029.
- **Heat Plan 2015:** Analysis of the (socio-economic) potentials for converting supply and consumer side to renewable energy based heating solutions.
- **Idea catalogue for green mobility solutions 2016:** Transportation strategy recently agreed on by Sonderborg politicians with the aim to reduce CO_2 emissions from transport in Sonderborg by 80 % by 2029 compared to 2014.

Figure 23: A selection of recent plans for the transition of Sonderborg (left to right: ProjectZero Masterplan 2029, Heat Plan 2015, ProjectZero Roadmap 2020, Idea catalogue for green mobility solutions 2016 and Strategic Energy Plan 2015).

6.1 Sonderborg SWOT analysis of action-oriented strategy

To explain needs and prioritization in Sonderborg, the following section – based on the above plans – briefly describe Sonderborg's overall approach followed by a short review of some of the action-oriented content in relation to four focus areas in SmartEnCity:

- Energy efficient building refurbishment action
- District Heating with RES action
- Sustainable mobility action
- ICT cross-action.

Each of the sections are summarized in the form of a SWOT-analysis, identifying strengths, weaknesses, opportunities and threats related to the implementation of the actions.

Sonderborg's overall approach

Local as well as national goals for fossil-free renewable energy based communities demand a significant expansion of renewable energy capacities. In many cases this entails increasing integration of fluctuating production from renewable energy sources, which requires a dynamic and intelligent energy system that efficiently uses the energy when it is available by making it attractive for the end-user to have a flexible and smart energy consumption.

Thus, demonstration projects and business cases that can ensure an intelligent and locally based expansion of renewable energy capacity as systems, concepts and solutions for realizing a dynamic and intelligent energy system is considered to contain great potentials for creating growth locally in Sonderborg and nationwide.

This connects to an important link between Sonderborg's ambition to become a zero CO_2 emission community and promote local growth potentials. Identifying, testing and refining systems, concepts and solutions that can ensure an intelligent expansion of the renewable energy capacity while creating added value to all stakeholders, is seen as a key strategy for ProjectZero as a potential green growth engine.

In addition, enhancing integrated approaches is an important strategy. In Sonderborg and in Denmark in general, electricity production and district heating production as combined heat and power (CHP) production have historically connected the electricity and heat sectors. Similarly, a focus for Sonderborg is to increasingly integrate the sectors, and strategically identify and exploit efficiency potentials. In all of the energy producing and consuming sectors, approaches for intelligent integration of renewable energy sources are needed locally as well as nationwide in Europe.

Strengths: Strong carrier of goal (ProjectZero). Broad political, citizen and business support for green transition. Thoroughly analyzed alternatives to implement green transition. Accepted common strategy as basis for actions to achieve goal.
Weaknesses: Declining population. Lack of integration between sectors.
Opportunities: Demonstrator of future solutions at national and international context contain growth potential. Connecting business cases to demonstration projects to increase growth potentials.
Threats: Changing framework conditions create uncertainty about demonstration projects. Shift in support against green transition actions (political, citizens, businesses).

Energy efficient building refurbishment action

For Sonderborg to reach the goal of being a zero CO_2 emission community by 2029 energy efficiency of buildings (as well as in general) is a major strategic item – rather than only increasing RES supply. Energy efficiency in buildings contain a large potential in Sonderborg since almost a third of all buildings are built before 1950.

For Sonderborg's strategy to be a sustainable community, it is also important to maintain and develop residential areas into attractive housing areas. A decreasing population in Sonderborg Municipality – partly due to the outsourcing of industrial working places – meaning a reduction of potential residents, is generally challenging this.

Thus, in the SmartEnCity demonstration project of building refurbishment in Sonderborg, retrofitting activities that enhance energy efficiency and attractiveness of buildings will be in focus.

Figure 24: Energy retrofitting action in Sonderborg (Photo: Sonderborg)

The buildings for the demonstration project are owned and selected by different social housing companies, and the refurbishment actions are formed by the building retrofitting plans of the different social housing companies, making implementation and financing more feasible.

The buildings represent typical and therefore replicable social housing building types and energy retrofitting measures. Around 35% of Sonderborg's population lives in similar cooperative owned residential buildings so the potential for energy savings is substantial.

During the implementation of the building retrofitting actions, possibilities for cooperation will be investigated, in order to have a potential effect of scale. This is considered a replicable situation in a large part of Europe.

Strengths: Commitment from social housing companies, connection to refurbishment plans increase financing potentials. Integrated (coordinated) effort between consumption side (energy efficient buildings) and supply side (mainly district heating) increase possible solutions.
Weaknesses: Declining population, ageing building stock
Opportunities: Combine (necessary) retrofitting energy measures with creation of attractive housing areas. Promote completed retrofitting measures to other (similar) building owners in Sonderborg. Homogenous building stock increase potential to replicate energy solutions.
Threats: Difficult to obtain mortgage loans for energy renovations in some areas (typically intensifies the further you go from the city center).

District Heating with RES action

The ambition is to develop and demonstrate the future integrated smart energy system solution at city-level in Sonderborg. The goal is to develop a full-scale demonstration that strategically connects the energy demand and supply, based on electricity as leading future energy source, combined with green district heating and green gas from renewable sources.

On the supply side, Sonderborg´s renewable energy production capacity must be expanded with about 25 MW by 2020 through a combination from 15 MW wind and 10 MW of solar energy. Furthermore, before 2029 an additional 120 MW RES should be installed. Current plans include a near shore wind park.

The challenges will be securing a strong community support to the establishment of large renewable installation facilities, such as wind farms, securing value creation for all parties involved in the expansion of renewable energy capacity and managing changing frames and policy conditions provided at national- and EU-level.

This covers only parts of the overall strategy for converting Sonderborg's heating sector in the future. Other heating and district heating actions to be completed from 2013-2020 can be mentioned:

- 1.5% annual heat savings
- Converting individual oil- and natural gas fired boilers to district heating and connecting new customers to district heating: 8,700 buildings. This number especially include existing plans for new buildings and conversion of areas to district heating
- Conversion of individual oil- and natural gas fired boilers to individual heat pumps: 400 buildings
- Conversion of individual oil- and natural gas fired boilers to biomass-fired boilers: 100 buildings.
- Solar thermal is set to cover 20% of the district heating demand in 50% of the district heating networks in Sonderborg corresponding to about 64,000 MWh.

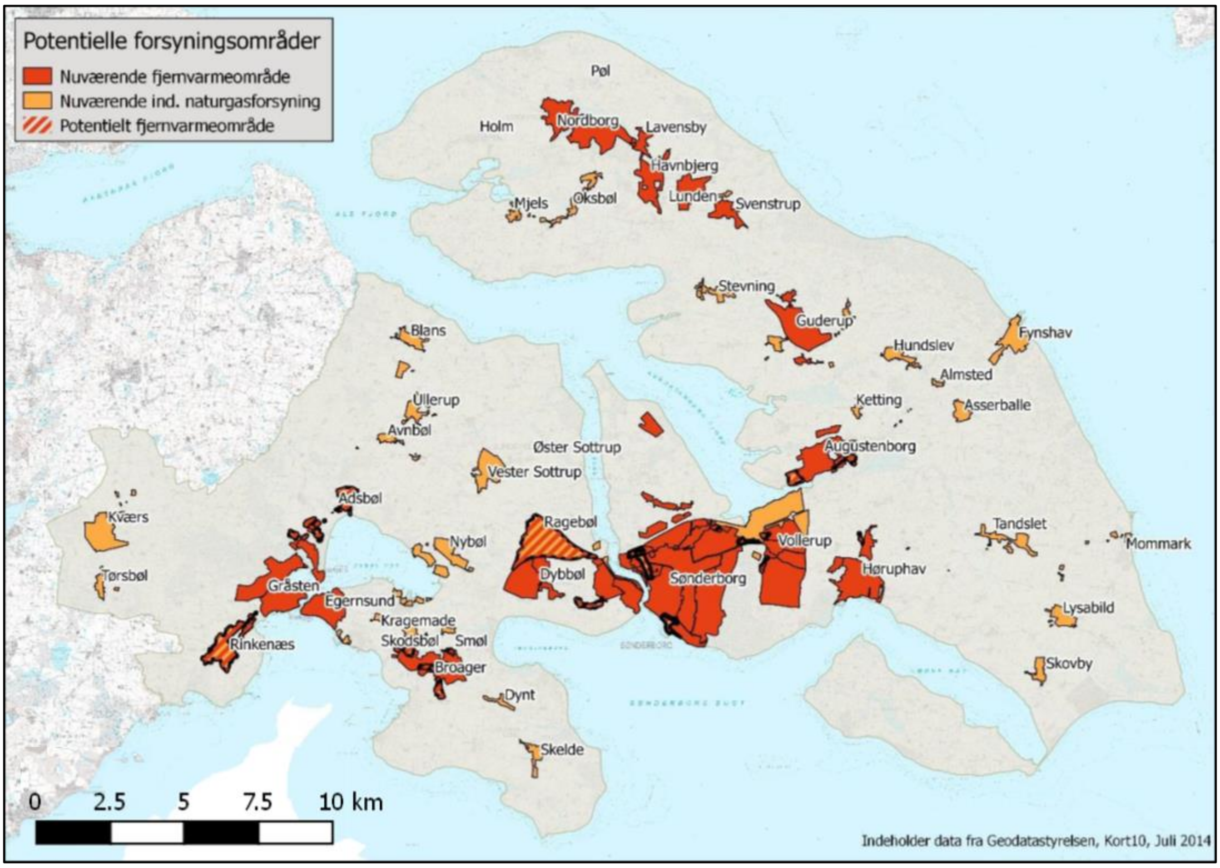


Figure 25: Extract of spatial analysis from Heat Plan 2015 for Sonderborg of potential new areas for district heating, converting areas currently supplied by heating from individual natural gas fired boilers (red: existing district heating, orange: existing natural gas area, striped: potential new district heating area) (Municipality of Sonderborg, 2015).

Strengths: Extensive existing district heating system and integration between heat and electricity sectors increase possibility to integrate large-scale renewable energy. Existing strategic plan for expanding renewable energy capacity.
Weaknesses: Installation of large-scale renewable energy facilities could depend on private investors. Large-scale renewable energy facilities require suitable areas.
Opportunities: Effort in SmartEnCity project increase potential to create business cases for large-scale renewable energy projects. Demonstration of large-scale heat pump in district heating increase replication potential in Sonderborg.
Threats: Changing frames and policy conditions provided at national- and EU-level. Lack of community support for large-scale renewable energy facilities.

Sustainable mobility action

Sonderborg Municipality and ProjectZero recently finished an analysis and mapping of the transport in Sonderborg. The work included engagement of mobility experts and the result is a catalogue of initiatives to promote transition of the transport sector. The solutions in the catalogue are focused on:

- Public transport
- Private cars

- Sustainable transport (cycling, walking, running, etc.)
- Heavy duty transport

Main conclusions from the analysis are that public transportation forms should be strengthened anywhere this is suitable. Transport done by private cars in Sonderborg today should initially be converted from conventional internal combustion engine vehicles to vehicles based on renewable fuels (e.g. electricity or gas), but the amount of private cars should also be reduced through the introduction of car-sharing initiatives and a modal shift towards increased biking and walking.

To achieve a modal shift from cars to bikes, it will be important that the conditions for biking in Sonderborg is improved, as well as enhancing a new culture of cycling for the next generations of citizens in Sonderborg already during their early education years.

Heavy duty transportation is a complex challenge, and includes vehicles which Sonderborg can have little or no direct impact for. However, converting this part of the transport system is still an important challenge to address, which initially should be supported by creating awareness about – and access to – alternative fuel types. In this light, Sonderborg Municipality as well as the major businesses within the municipal area should pursue to influence this transition by their procurement politics and logistics systems.

Figure 26: Extract of the analysis of transport in Sonderborg focusing on mobility needs of the citizens (Municipality of Sonderborg, 2016).

The first big step in Sonderborg towards significant savings in CO_2 emissions from the transport is related to the tender of bus transportation in the municipality in 2017, for which it has been decided that all the buses must be bio methane fueled. This is supported by installing a local bio methane plant along with bio methane fueling infrastructure in the city of

Sonderborg. This could potentially be accompanied by a smaller bio methane fueling station in the town of Nordborg, the second largest urban area in the municipality located in the northern part, to increase the service level for busses to depart from there in the morning.

Strengths: Political support for introducing alternative fuel types in public transport system (bio methane buses and fueling infrastructure). Existing mobility strategy connected to mobility needs of local citizens.
Weaknesses: Transition of private transport system highly dependent on individual citizen. Heavy duty transport
Opportunities: Recharging stations and bio methane fueling infrastructure in Sonderborg increase potential for replacing conventional vehicles (e.g. heavy duty transport). Transition of public transport system can campaign a general transition of transport system to increased renewable fuels. Demonstrating car-sharing system for social housing residents can pave the way for similar solutions in Sonderborg.
Threats: Increasing national registration fee for EVs. Transition of transport system (especially heavy duty transport) depend on technological development.

ICT cross-action

ICT is a tool in the process for Sonderborg's transition to a zero CO_2 emission community. Not only through intelligent management tools, but also through data collection and visualization of demand and supply in the municipality.

Data loggers installed in buildings pre- or post-retrofitting works can show exact data for the reduction of electricity, heat or water demand and manifest the anticipated savings via an energy management system. Data loggers connected to RES facilities can show current and accumulated RES supply over any given period of time.

Installing data loggers and linking them to an energy management system, Sonderborg as a community can solidify the findings with numbers and data. A visualization from the data can be used as infographics for the residents and in education throughout various levels of school.

Data loggers in zero emission vehicles can show on-road data which could help in the transition from conventional internal combustion vehicles to alternative vehicles and to map what the needs for transportation are and solve those by other means than individual conventional car ownership.

Strengths: Installation of data loggers accepted by residents in building retrofitting demonstration project.
Weaknesses: Data logging unwanted by some citizens (e.g. in private cars)
Opportunities: Visualize activities in Sonderborg to increase the possibility for citizens to understand Sonderborg's green transition. Measured data increase data quality and enhance basis for updating Sonderborg's plans for transition. Connecting RES supply to E-mobility recharging strategy increase possible of RES integration in Sonderborg's energy system.
Threats: Lack of interaction possibility between the intelligent rechargers and the EV car sharing service.

6.1.1 Demarcation of areas of intervention

As the ambition for Sonderborg is to become a zero CO_2 emission community considering all activities in the Sonderborg Municipality area, several interventions (e.g. the integrated energy interventions) are not concentrated within a strictly demarcated area, but broadened out to include the whole municipal area. This regards ICT actions, district heating actions and mobility actions.

However, the energy efficient building refurbishment actions will be concentrated within Sonderborg as the main city in the municipality. The layout of the demonstration area has been defined by:

a) Having demonstration buildings from 1950-1980’s, including older buildings from central and more “outer ring” parts of Sonderborg
b) Building retrofitting shall fit into the retrofitting time schedules of the social building companies.

A total of 45 buildings will be retrofitted, all buildings are supplied with heat from Sonderborg District Heating Company.

6.2 Pre-definition of the district integrated intervention

Potential barriers for Sonderborg’s demonstration projects presented in this section are analyzed in SmartEnCity D2.1: Review of regulatory gaps and recommendations to facilitate city transformation processes.

6.2.1 Energy efficient building refurbishment action

In Sonderborg the aim is that 66,000 m^2 of social housing building blocks will be energy efficient retrofitted including installing of PV-facades/roof. This demonstration action is focused on 45 buildings owned by the three leading social housing companies of Sonderborg:

- Sonderborg Andelsboligforening – 12 buildings
- Boligforeningen Sobo – 9 buildings
- Boligforeningen B42 – 24 buildings.

The buildings contain a total of 844 dwellings with about 1,700 residents. Heating consumption is more or less the same in all demonstration buildings independent of the building year, reflecting that the social housing companies in energy retrofitting of their buildings carry out the same energy saving measures in their regular building retrofitting programs.

The involvement of all three social housing companies of Sonderborg will secure a strong dissemination of results and a stronger local commitment to the overall implementation of the demonstration project.

Building retrofitting measures addressing electrical energy consumption are oriented towards limiting consumption in the weakest areas with measures like LED lighting substitution and implementation of lighting controls. Additionally, electric consumption will also be addressed from the supply side, through installation of PV generation in each building.

Thermal energy consumption will be addressed with various measures including insulation and installation of new heat control systems.

As cost-effective balancing between energy efficiency measures in buildings and increasing RES-supply is a major focus of the Sonderborg demonstration project. Thus, related to the demonstration project of buildings in Sonderborg, the increase of RES-supply is applied as a cost efficient strategy to reduce the CO_2 emissions related to energy consumption in buildings – in contrary to a strategy exclusively focusing on energy savings, reaching very low energy consumption, but at a higher cost.

The joint implementation of all these measures will significantly decrease the energy consumption and carbon emissions of the retrofitted buildings.

Figure 27: One of 45 demonstration buildings in Sonderborg where retrofitting actions are to be carried out (Photo: ProjectZero).

Financing

Financing for the energy saving measures of the demonstration project will be made from the social housing companies' real estate financing sources. The "ordinary building retrofitting measures are financed through the national foundation, "Landsbyggefonden", where all social housing companies in Denmark are contributing with a share of all housing rent income. This means that there is a financing source available for regular building retrofitting measures.

The total investment of the three housing associations is 4,227,960 EUR. EU-support is expected to cover about 33% of the total investment for each association.

Technical approach

In general, the existing energy condition of the demonstration buildings in Sonderborg can be described as follows:

- Cavity between the double walls is filled out with mineral wool insulation.

- Older double thermo glazing windows and outer doors, which need to be replaced with energy thermo glazing and frames with lower U-value (in some buildings this has already been implemented).
- Roof insulated with a relatively thin layer of mineral wool insulation (in some buildings this has already been implemented).
- No solar thermal or PV systems installed.

The retrofitting actions of the building blocks is tailored to the need of each building block. All in all the actions for the 45 building blocks will include:

- PVs will be installed (all building blocks)
- New heating control systems
- New ventilation systems
- New windows
- Attic insulation
- Facade insulation
- LED public lighting

6.2.2 District Heating with RES action

To support the goal in Sonderborg of increasing the renewable energy share in the district heating production, the aim during the SmartEnCity project is to install a large-scale heat pump as a demonstration project in the district heating system. The demonstration heat pump is set to use seawater as heat source, and is planned with a heat effect of 3.1 MW. The demonstration heat pump project in SmartEnCity will be the first step towards implementation of additional heat pumps in the district heating system in Sonderborg[17].

Although the additional heat pumps are to be realized beyond the scope and timeline of the SmartEnCity project, part of the demonstration project will be to calculate and analyze how the future system of integrated infrastructures in Sonderborg should be designed, using operation data and experiences from the demonstration heat pump.

An addition to this is the preparations of a wind park to be located near the shore of Sonderborg municipal area. These preparations will also be part of the analysis of the future system of integrated infrastructures in Sonderborg.

Financing

Financing of the installations on the district heating systems will be covered by municipal guarantees for bank loans. The decision on investment in a large-scale heat pump for RES-district heating supply will be made by SONFOR with the acceptance from the Municipality of Sonderborg and in cooperation with district heating companies of the overall Sonderborg district heating system.

[17] The long-term conversion of the district heating system of Sonderborg to 100% renewable energy sources is undertaken in several phases that go beyond the scope of SmartEnCity. Regarding heat pumps, the future system could consist of a total capacity of 5.75 $MW_{electricity}$ heat pumps, that can be operated in periods with electricity production from a nearshore wind park and thus be part of a future integrated infrastructure. As the system is integrated, the actual design of the future system will depend on how other parts can be implemented, e.g. the implementation of the nearshore wind park, which at the moment is pending government incentive changes and external project developers.

The EU funds obtained through this project are set to cover approximately 50% of the demonstration heat pump implementation.

Technical approach

The seawater heat pump for the district heating system in Sonderborg will have an effect of 0.75 $MW_{electricity}$ with COP of 4 corresponding to a heat effect of 3.1 MW with a preliminary estimated annual heat production of about 12,400 MWh (4,000 hours of operation).

A feasibility study due in December 2016 will show the optimal location of the demonstration heat pump. This could be in either Sonderborg, Augustenborg or Nordborg district heating networks. In the future, these district heating areas are to be connected, although this is beyond the scope and timeline of the SmartEnCity project.

The demonstration heat pump will be an integrated part of one of these existing local district heating networks, e.g. if located in Sonderborg district heating network potentially delivering heat to all 37,000 citizens living in Sonderborg city.

Establishment of the heat pump will take place in a close cooperation with Sonderborg District Heating Company, Augustenborg District Heating Company or Nordborg District Heating Company, and other major stakeholders connected to the overall district heating system.

The heat pump is expected to be established in phases being modular units that can be added gradually as the grid is connected between the areas of the three aforementioned district heating companies.

6.2.3 Sustainable mobility action

In 2016 the politicians in Sonderborg agreed on a green transportation strategy. This strategy aims to reduce CO_2 emissions by 80 % by 2029 compared to 2014. The strategy contains 27 initiatives, which are focused on public transportation, private transportation, heavy transportation and sustainable transportation (walking and bicycling).

Sonderborg's sustainable mobility actions comprise three major elements:

- Bio methane buses in the Municipality of Sonderborg from 2017 (incl. bio methane filling station to be in operation)
- E-mobility, establishing 30 intelligent recharging stations
- EV car sharing services through TADAA (currently under re-development)

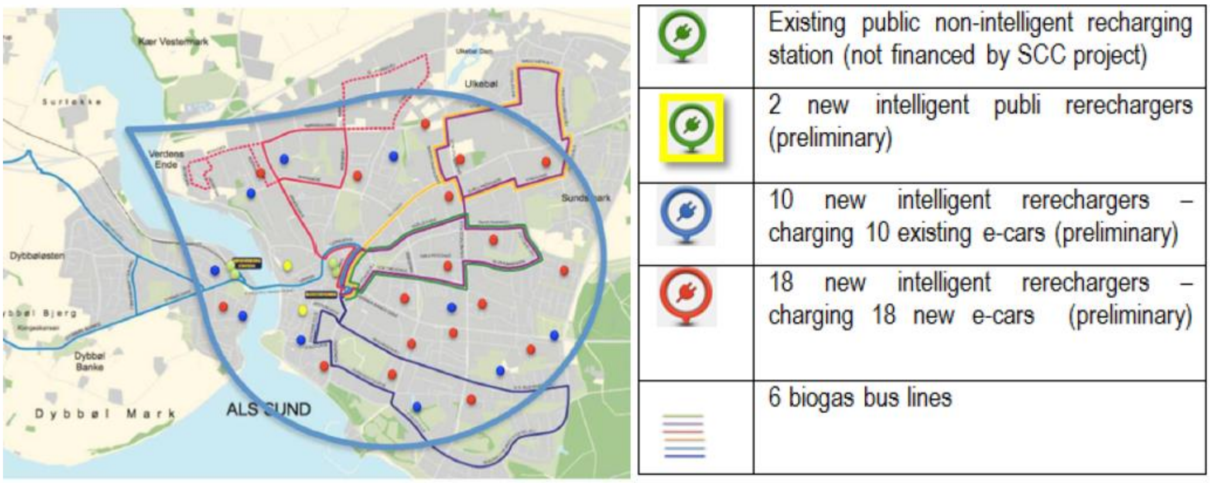


Figure 28: Potential locations for intelligent recharging stations in Sonderborg.

A part of the demonstration project will be to evaluate the effect of CO_2 emission savings from an intelligent E-mobility recharging strategy.

Another part of the demonstration will be to specifically evaluate the interaction between the intelligent rechargers and the EV car sharing service. This will be done by installing up to 18 of the intelligent rechargers at the home stations of the EV car sharing cars. The home stations for the EV car sharing services will be in various central locations of parking lots directly connected to the housing associations in Sonderborg.

Finance

SONFOR owns and finances the 30 charging stations. Total cost for rechargers is: 206,664 EUR. Vikingegaarden will operate the charging stations.

Extra costs for operating the bio methane buses compared to a reference of diesel buses is annually 400,000 EUR, for 4 years: 1,600,000 EUR, financed by Municipality of Sonderborg.

Technical approach

On 1st January 2016 a 20% increase of a onetime registration fee was introduced to EVs from which they have been exempt until this date. The fee is introduced gradually with a 20% annually until the full national registration fee has been reached. As this poses a potential challenge for EV introduction in Sonderborg, a car-sharing is approach (TADAA) is currently being developed.

For electric vehicles (E-mobility) there will be installed 30 intelligent rechargers. The rechargers are for e-cars and backend system to remote control recharging. A web-service is used to interface with Energy Manager (see section 6.2.4 ICT cross-action). Rechargers can run as stand-alone and will be remote controlled from Energy Manager to equalize charging peaks and move charging to times of the day with lower demand in the grid.

Implementation of bio methane buses for Sonderborg bus lines has been decided by the municipality and is not dependent of change of regulations etc.

6.2.4 ICT cross-action

The ICT actions in Sonderborg will be focused in the deployment of the Urban Management System for Sonderborg (UMS-S) based on the common definition of the City Information Open Platform (CIOP) for all three lighthouse cities.

Sonderborg Open ICT Urban Management System within the framework of the overall SmartEnCity City Information Open Platform CIOP is structured:

1. **VMS** – overall data collection from Sonderborg and provide data to all other partners using an open web service XML platform. Collects data from all partners in Sonderborg and manages the frontend and backend, feeding the CIOP.
2. **Energy Manager** – provides information to balance production and consumption. The goal is not directly to control devices (e.g. heat pump), but to inform devices when most optimal to run depending of the load on the electricity network and RES production.

Figure 29: Cabinet where electricity data logger will be installed (Photo: ProjectZero).

VMS (established by Vikingegaarden)

VMS is the base of the Sonderborg Urban Management system to collect data from all parties in Sonderborg and integrates with the CIOP. VMS is a web-based system, which will be upgraded within the project, with the original mission to manage data and alarms with access from any PC with internet access. There is a series of GSM based data loggers to collect data to the VMS system to be extended in the project.

Energy Manager

Balancing consumption and production.

- Connects to EV charging stations and VMS and indirect remote controls chargers and devices.
- Needs production information from RES-supply to be able to calculate how to share load between devices.
- Overall reporting.
    - Current load.
    - Analyses of logged data.

7 SmartEnCity Evaluation Framework for intervention baseline

In this chapter some ideas will be shown as starting point for detecting how the baseline must be evaluated. In a later step, baseline will be calculated (D3.2, D4.2, D5.2) taking into account the protocols to be developed in D7.3.

Each of the phases, which cover the evaluation of intervention performance are introduced:

7.1 Technical definition of the integrated intervention
7.2 Evaluation plan
7.3 Data collection approach for the evaluation of intervention performance
7.4 Installation of monitoring equipment
7.5 Data collection
7.6 Performance evaluation

SmartEnCity aims to develop an urban regeneration model towards the Smart and Zero Carbon City concept to be implemented in three lighthouse cities, Vitoria-Gasteiz (Spain), Tartu (Estonia) and Sonderborg (Denmark) for improving energy efficiency in main consuming sectors in cities, while increasing RES supply.

The three cities will develop a number of coordinated actions to progress towards the goal of Smart and Zero Carbon Cities:

- Reducing the energy demand of residential building stock through cost-effective low energy retrofitting actions at district scale,
- Increasing the RES share of energy supply through extensive leveraging of local potentials,
- Enhancing the use of clean energy in urban mobility by means of extensive deployment of green vehicles and infrastructure
- Using ICTs for the integration and consistency in demo planning and implementation
- Engagement activities to secure the involvement of citizens.

In this regard, SmartEnCity will demonstrate that the interventions performed in the cities as well as the strategies addressing non-technical barriers (business models, citizen engagement strategies and public procurement among others) meet the foreseen ambitious objectives in the three LH. Given the complexity of the project, a common and holistic methodology will be defined in order to assess the interventions performance from multiple points of view based in the comparison of the **post-retrofit period** (called as final performance) against the period before the intervention, which is named as **baseline**.

The definition of this holistic methodology for the assessment of the performance of interventions in the three LH cities will be deployed in D7.3. In D7.3 different protocols will describe how to evaluate the presumed benefits of SmartEnCity and will also include how to address the process for data collection, adjustment required to estimate the baseline model and measurement requirements for the post-intervention period.

These protocols will be based in a complete set of KPIs which should be useful during the entire renovation project because, both in the baseline and final performance, the evaluation should be carried out through well-established indicators in order to compare the before and after of the demoarea.

Five protocols will take part of the methodology for evaluating SmartEnCity interventions in terms of energy consumption and greenhouse gas emissions savings, efficiency, social acceptance, economic performance and citizen engagement. During the next months, partners will be working in defining such protocols.

7.1 Technical definition of the district integrated intervention

Technical definition of the district integrated intervention consists of the description of the main characteristics of the demoarea where the implementation plans will be executed. Information included below would be needed to be compiled in order to make the evaluation plan compatible with the demoarea.

For whole interventions, it is required to know the definitive technical solutions, the citizen engagement strategies, partners and stakeholders which will take part and their responsibilities, financial schemes as well as the periods where they will be implemented. For the evaluation of district intervention, it is also recommended to count with the constructive characteristics of buildings and the current energy system of the district as well as the type of residents.

All these issues must be considered for defining the baseline evaluation approach.

7.2 Evaluation plan: definition of KPIs

7.2.1 KPIs for the intervention evaluation

The framework for the evaluation of interventions was defined in D7.2 where potential KPIs was identified to be used in the project by each type of intervention/action (district renovation, sustainable mobility and citizen engagement) to measure the objectives to be met according with the information collected from the DoA.

Thus, four types of objectives and KPIs were proposed taking into account the expectative of the project.

- Technical
- Environmental
- Social
- Economic

Figure below shows the framework of evaluation described in D7.2.

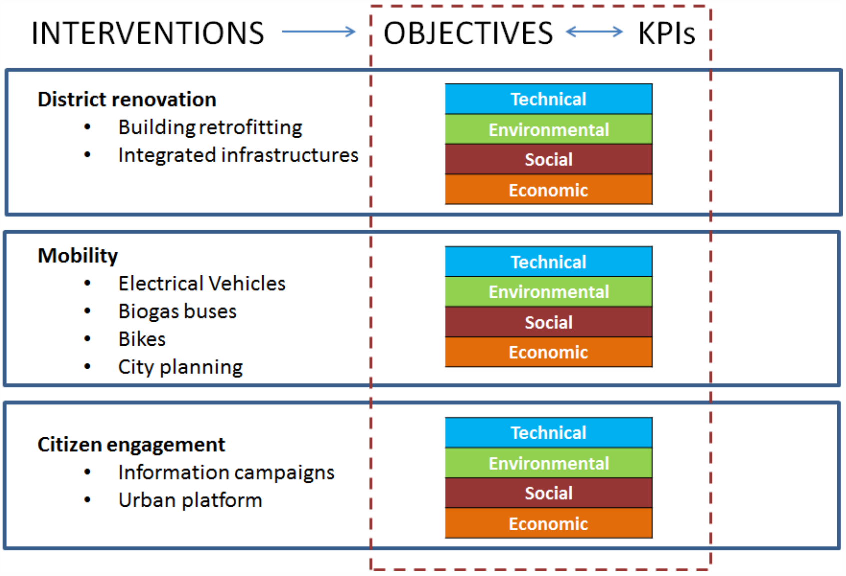


Figure 30: Types of interventions, objectives and KPIs.

Table below compiles the KPIs proposed in D7.2 grouped by categories.

	Technical KPIs	Environmental KPIs	Social KPIs	Economic KPIs
District renovation	18	7	26	8
Mobility	9	3	13	8
Citizen engagement	23	3	10	3

Table 18: KPIs proposed in D7.2

These KPIs will be validated by the partners involved in the LH cities and later merged in the different Protocols to be deployed in D7.3.

- Energy Assessment Protocol
- ICTs Protocol
- Life Cycle Analysis (LCA) Protocol
- Mobility Protocol
- Protocol for cross cutting issues which covers the social acceptance, citizen engagement and economic performance.

7.2.2 Protocols for the intervention evaluation

Each of the protocols will be deployed by small groups with representative partners from the three LH cities which will collaborate in the definition of the scope, approach and set of KPIs to be included in these protocols taking as reference the evaluation framework described in D7.2.

Foreseen scope of each Protocol is described below, which will be defined in D7.3.

- *Energy Assessment Protocol* to cover the energy savings achieved with the implementation of energy performance solutions in the districts, the associated CO_2 avoided and the thermal comfort achieved.
- *ICTs Protocol* in order to carry out the evaluation of the efficiency gained and the higher use of RES in the district due to the implementation of ICT strategies during the intervention.
- *Life Cycle Analysis (LCA) Protocol* to determine the reduction of environmental impacts due to the district intervention.
- *Mobility Protocol* to calculate the energy and CO_2 emissions avoided with the implementation of mobility actions in the cities as well as the affections in the traffic and journey delays.
- *Protocol for cross cutting issues* which covers the social acceptance, citizen engagement and economic performance to be measured through different tools.
  - Social acceptance protocol could aim to evaluate the perception of potential target groups: residents, drivers/vehicle owners and citizens about the project and the life quality improvements achieved.
  - Economic protocol could deal with the cost effectiveness of the solutions and the return of the investments for potential target groups: residents, drivers/vehicle owners and municipality.

Citizen engagement protocol could cover the influence of the information campaigns and the urban platform in potential target groups (residents, drivers/vehicle owners and citizens) as engagement activities carried out in the cities and the improvement of the Urban ICT infrastructure. It will measure the success of interventions, the use of web and other ICT applications and the attendance to information campaigns. Regarding KPIs, common indicators will be used for whole process of evaluation but it is thought about the possibility to use only few KPIs for baseline for the case of some Protocols (e.g. ICT, social and citizen engagement) where it could not have any sense to deploy all the set of KPIs but only the most representative.

Table below introduces the foreseen scope, approach and KPIs for each Protocol according with the current working plan defined in WP7.

Protocol	Scope proposed	Approach *	Type of KPIs
Energy assessment protocol	Energy and emissions savings & thermal comfort in district due to renovation	Deployment of IPMVP Protocol and adaptation to the district scale. Selection of options defined in this protocol according to the possibilities: data gathered from meters or from energy bills or simulation of the energy use of the whole facility	Technical and environmental indicators for district intervention from D7.2
ICT protocol	Energy efficiency & share of RES/self-energy supply in district due to the use of ICT	Tailored protocol for evaluating the data collected in meters	Technical indicators for district intervention from D7.2

LCA protocol	Reduction in the environment impact due to the intervention in the district	Tailored and simplified procedure for evaluating the data collected from the energy systems and materials of construction used in the district (before and after SmartEnCity). The LCA should be calculated through software SIMAPRO or GABI and the Life cycle inventory database ECOINVENT	Environmental indicators for district intervention from D7.2
Mobility protocol	Energy and emissions savings & traffic and journey delays reduction by mobility actions	Tailored protocol for evaluating the data collected in meters to be installed in vehicles and questionnaires to be distributed	Technical and environmental indicators for mobility action from D7.2
Social acceptance protocol	Social acceptance of project and interventions & quality life gained with interventions/actions in residents, drivers/vehicle owners and citizens	Tailored protocol for evaluating the data collected from the potential target groups selected	Social indicators for district intervention, mobility action and citizen engagement from D7.2
Citizen engagement protocol	Success of citizen engagement strategy implemented in the cities by the achievements in workshops/information campaigns and ICT platform (e.g. number of attendees and users from each potential target group (residents, drivers/ vehicle owners and citizens) anddeployment of the urban ICT platform	Tailored protocol for evaluating the information collected from the potential target groups selected	Technical and environmental indicators for citizen engagement from D7.2
Economic performance protocol	Cost, economic savings & payback associated to the interventions for residents, drivers/vehicle owners and municipality	Tailored protocol for evaluating the data collected from the potential target groups	Economic indicators for district intervention, mobility action and citizen engagement from D7.2

Table 19: Protocols: scope and KPIs

In addition, in this report is included some details for each Protocol approach in order to be considered as an introduction for the baseline definition.

Energy Assessment Protocol

Measurement and Verification (M&V) is a well-defined process which reliably verifies the savings in terms of energy and greenhouse gas emissions achieved by an Energy Conservation Measure (ECM).

Since energy savings cannot be directly measured because this concept represents the absence of energy consumption, the savings have to be determined by comparison of the consumption between the periods before and after renovation, implementing adjustments, when needed. With the aim of drawing the concept graphically, Figure below depicts the stages in the M&V plans, where the baseline is the period before the intervention, reporting period represents the post-retrofit period and dividing both the refurbishment itself.

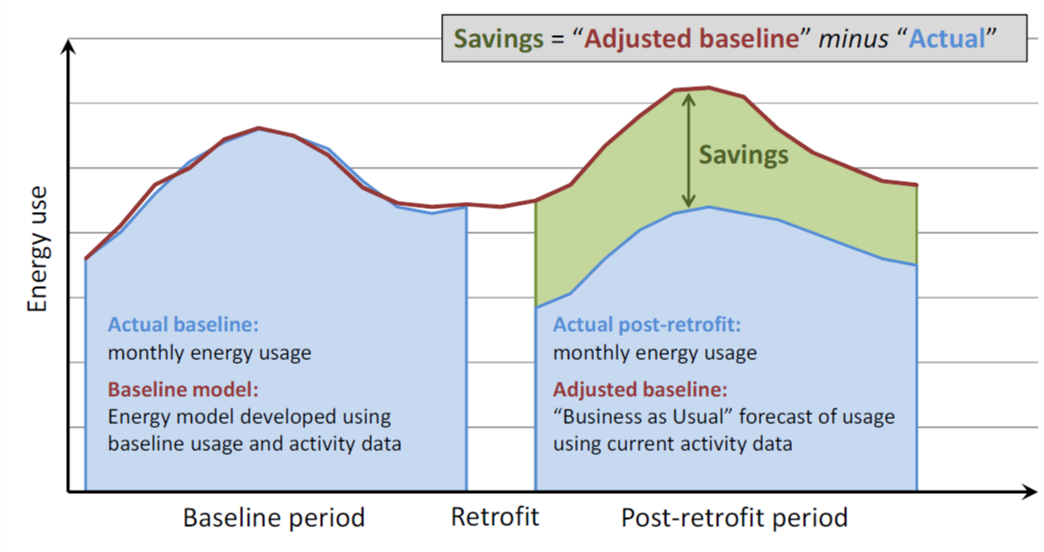


Table 20: Measurement & Verification stages

IPMVP is the protocol selected at proposal stage for measuring the energy performance in SmartEnCity, being also the protocol implemented in other projects focused in energy renovations of districts. Each LH must establish its own specific Measure & Verification plan (M&V plan) based in the four options defined in IPMVP: (A) individual ECM with measured and estimated parameters (B) single ECM, but all the values are metered (C) whole facilities through measurements (D) entire or partial installation by means of simulation.

In any case, the energy savings are calculated by means of a key-condition for long-term success. That is to say, the equation below that represents the baseline measurements, the actual energy and the adjustments which are used to re- formulate the baseline consumption under the same conditions than the reporting period.

Energy savings = Baseline energy – Post retrofit energy +/- Adjustments

Regarding the measurement periods, these ought to be selected to determine all the operational modes of the installation. Thus, they must cover a complete operational cycle from the minimum energy consumption to the maximum one. In a lot of projects, IPMVP recommends one year taking into consideration the climate conditions affect the energy consumption.

About the adjustments, IPMVP presents two possibilities [1]: routine and non-routine. The first group describes the parameters that influence the energy and they vary along the life cycle. The second one considers those variables that remain almost constant during the renovation project.

Finally, an important part within IPMVP is the definition of the boundary. The protocol offers a certain freedom degree for the selection of the boundary, but always considering the facilities involved in the renovation project inside it. In fact, the objective is to reduce the efforts in the independent variables metering. Thus, the boundary can cover an individual element (for instance, a pipe), a group of elements (for example, a boiler with its distribution circuit) and/or the whole building or group of buildings. Within this boundary, the metering equipment is in charge of taking the samples which have to apply with quality assurance concept. In this way, IPMVP establishes the electricity consumption must be measured in the same way than the company (i.e. similar equipment, poll rate, demand peak and so on). As well, a calibration procedure is set up according to the law procedures so as to decrease the error percentage in the equipment measurements and/or simulation software.

For baseline evaluation a selection between the four options must be made and applied taking into account that this scenario is proposed to be quantified in an early stage of the project (M18).

(A) Individual ECM with measured and estimated parameters
(B) Single ECM, but all the values are metered
(C) Whole facilities through measurements
(D) Entire or partial installation by means of simulation

Protocols for Social Acceptance, Economic Performance and Citizen Engagement

Tailored protocols must be defined according to the possibilities to be implemented in the LH cities. D7.2 introduced the potential evaluation which includes the target groups (residents, drivers/vehicle owners, citizens and municipality) and the tools (questionnaire or interview to be launched via workshops, telephone calls, door to door or urban platforms).

Questionnaires are proposed to be launched to residents (tenants or owners), drivers/vehicle owners, citizens and the municipality in order to know information related to social acceptance to the project and economic savings and payback reached with the project as well as the success achieved through the project. They can be distributed in workshop/information campaigns already foreseen in the project, but it is also possible to arrange anotherspecific action for collecting this information. Furthermore, with the aim to know if it has produced a change in the opinions due to the implementation of actions/interventions, it is – to the extent possible – thought to launch them in two occasions (before interventions for evaluating the baseline and after the intervention for evaluating the final performance). For an accurate evaluation, the same people/people profile must participate in both stages. Finally, it has to remark that an only questionnaire will be designed for each target group dealing with all the previous issues.

During the protocol definition, agreement will be made about whether all these groups can be involved as well as the most suitable tools to be used. These decisions must be taking for the whole process of evaluation: baseline and final performance and must be aligned with the citizen engagement strategies established in the cities since to involve citizens in this type of activities is not easy.

Different situations can occur:

- No established citizen engagement strategy resulting in no easy collaboration with of citizens. In addition, they do not have the knowledge to reply certain questions.
- A well citizen engagement strategy has been established, but it is considered that this type of actions can difficult the implementation of the intervention since for example residents can feel annoyed with this type of actions.

For the final performance, in which a continuous communication with residents, drivers/vehicle owners and citizens has been reached along the project, this type of evaluation should not suppose any problem. However, for the case of baseline, which is intended to be evaluated at the beginning of the Project (M18), these difficulties can be found.

Mobility Protocols

Unlike in the building and district evaluation case, for which there is a well-known and established protocol, there is no standard protocol to evaluate the impact of the mobility actions to be implemented in the SmartEnCity. Nevertheless, the core concepts provided by the IPMVP can still be applied (setting a baseline, measuring, computing and reporting savings) with some limitations regarding the scope of the monitoring or the boundaries, given the differences between the studied systems.

As in the case of building retro-fitting, the baseline period should represent all operating models of the energy systems with a period length sufficient to represent all situations of energy consumption (e.g. different travel habits, weather conditions, holiday seasons, etc.). For the mobility case, this makes a period of at least a year desirable, since it is the minimum period that contains all the periodic holiday seasons and also contains the different weather conditions for all seasons.

Also, data should be gathered at the period immediately before the actions introduced, since periods further back in time would not reflect the starting conditions existing before so accurately.

The scope of the baseline in terms of energy savings could be an equivalent number and typology of internal combustion vehicles to the ones introduced by the different measures funded by the SmartEnCity project, although other indicators should be taken at the city level/demo site for those measures not directly related with clean vehicles introduction, such as the usage of public transport or average travel times.

<u>ICTs Protocol</u>

The assessment methodology for the ICT tools aims at ensuring that the monitoring system implemented is able to manage all variables and parameters and must do it in a reliable and efficient way. Specifically, through this protocol is expected to know the energy consumption profile of buildings which allows to manage the energy demand of each substation and adjust the power delivered by the generator of heat, the reliability of the system based in power interruptions, the ratio of energy produced at local level over the energy consumption, the share of renewable energy in energy consumption/demand of buildings, among other information.

A specific procedure, which includes the selection of only few KPIs, will be defined for baseline evaluation taking into account that the information that can be gathered at the beginning of the project is related with the existing monitoring tools implemented in the demosite.

<u>Life Cycle Analysis (LCA) Protocol</u>

SmartEnCity intends to deploy a simplified environmental assessment of the renovation actions, undertaking a Life Cycle Assessment (LCA) study, one of the most internationally recognized and accepted methods to investigate the environmental benefits of the life cycle of products, processes and services. Environmental impacts include those from emissions into the environment and through the consumption of resources, as well as other interventions (e.g. land use) associated with providing products that occur when extracting resources, producing materials, manufacturing the products, during consumption/use, and at the products' end-of-life (collection/sorting, reuse, recycling, waste disposal). These emissions and consumptions contribute to a wide range of impacts, such as climate change.

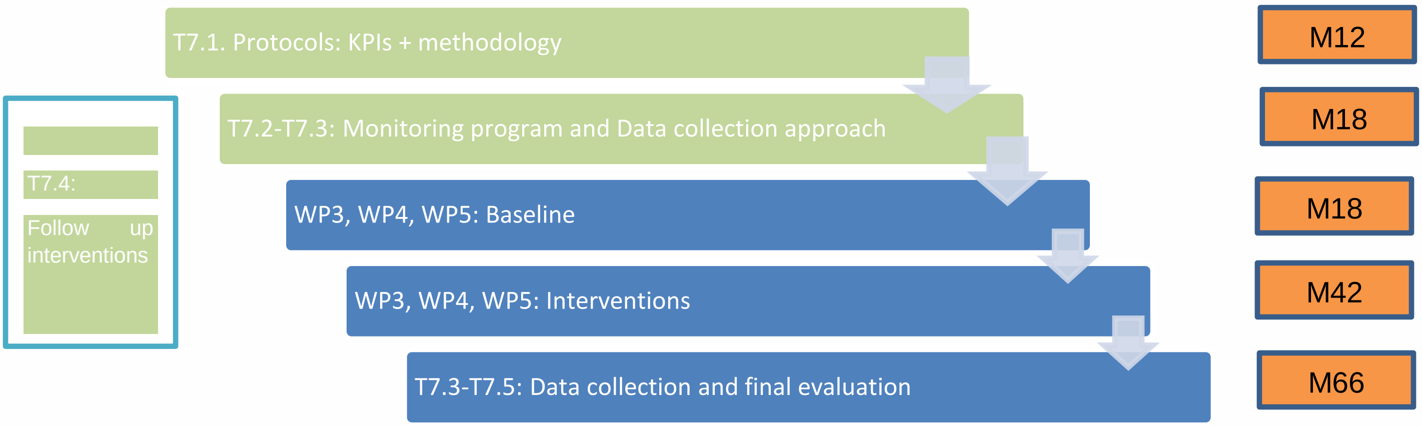
The main objective of this study in our SmartEnCity project is to assess the environmental impact associated with the current situation in the district (baseline) in comparison with a future scenario in which efficient energy solutions will be implemented in the districts. The final performance will also include the affections in the environment during the retrofitting activity. Therefore, the aim is to consider the changes that will be incorporated in the districts throughout the project development for comparing with respect to the baseline scenario, characterizing, by this way, the environmental burdens associated with the demonstrative intervention. Finally, LCA will permit to evaluate and identify critical points of the stages or subsystems of the renovation actions, from extraction of raw materials to the end of life of the involved products.

7.3 Data collection approach and monitoring program

Once the protocols are developed, it will be needed to define the programs which compiling the monitoring requirements for metering data from interventions (e.g. variables and frequency) and the approach which allows to collect data and store them in urban platforms or other storage source (e.g. questionnaires fulfilled). Monitoring program and data collection approach will include the specifications for baseline and post-intervention period.

These tasks correspond with T7.2 (monitoring program) and T7.3 (data collection approach) which have M18 as deadline. A coordination with the partners involved in the definition of evaluation protocols, monitoring programs, execution of interventions and actions and performance evaluation must be done in order to align all these issues. There is a room in the project for that, so that it will establish the procedure to start such collaboration (T7.4).

The figure below represents the stages until to make the final performance evaluation of the interventions.



For the case of baseline to be evaluated at M18, monitoring programs and collection approach will be defined as follow.

- *Energy Assessment Protocol*: Simulation seems the best way to evaluate the energy behavior of district since it seems that there is not possibility to implement meters with time enough to evaluate the energy consumption before the retrofitting works. If this is the scenario, monitoring metering will not be defined for baseline and data collection approach will refer to collect the data from the district which allows to simulating the buildings.
- *ICTs Protocol*: Since this protocol is related to the information compiled through the ICT solutions (meters), the monitoring program and data collection for the baseline evaluation

will be established according to the available information at the beginning of the project and the monitoring systems previously implemented in demostrators.

- *Life Cycle Analysis (LCA) Protocol*: The own protocol could define all the aspects of data collection approach and monitoring requirements for evaluating the environmental impacts.
- *Mobility Protocol*: It is not well-known how monitoring and collection approach will be defined for measuring the performance of mobility action since it will be related with the tailored procedure to be designed.
- *Protocol for cross cutting issues* which covers the social acceptance, citizen engagement and economic performance. The data collection approach and monitoring requirements is supposed to be part of the own Protocol.

7.4 Installation of monitoring equipment

Once the monitoring program and collection approach is defined, monitoring equipments will be selected and installed according to them in district and vehicles.

The implementation of the monitoring systems has to be developed in parallel to the construction works in districts, whereas for the mobility action, it will define a specific strategy for the implementation of monitoring equipment in the vehicles. Then, once the monitoring equipment is available, it is needed a commissioning phase to ensure that the implementation plan has been properly deployed in the three demo sites and that all the data acquisition systems work as expected, to assure that monitoring is performed in an appropriate manner. For the case of baseline, all these aspects must be considered.

7.5 Data collection

Concerning the period considered for collecting data, it will depend on the type of intervention. For the case of district renovation and mobility, it is important to meter all energy consumption data of the building and vehicles before the retrofitting works and mobility actions start during at least one year. Once the works have been concluded, it is recommend monitoring the energy generation, supply and consumption for at least two years in order to guarantee a consistent evaluation.

For the protocols which does not require a continuous collection of data through meters (LCA, Social acceptance, Economic performance, Citizen engagement), the data collection will finish once all the data expected has been gathered.

7.6 Performance evaluation

The evaluation of the intervention performance must be done according to the protocols established. All the details about how to implement them in baseline will be defined in D7.3.

Consequently, deliverables from WP7 will detail all the aspects related to how to evaluate baseline, dealing this section with some starting descriptions about how to deal with this issue.

8 Deviations to the plan

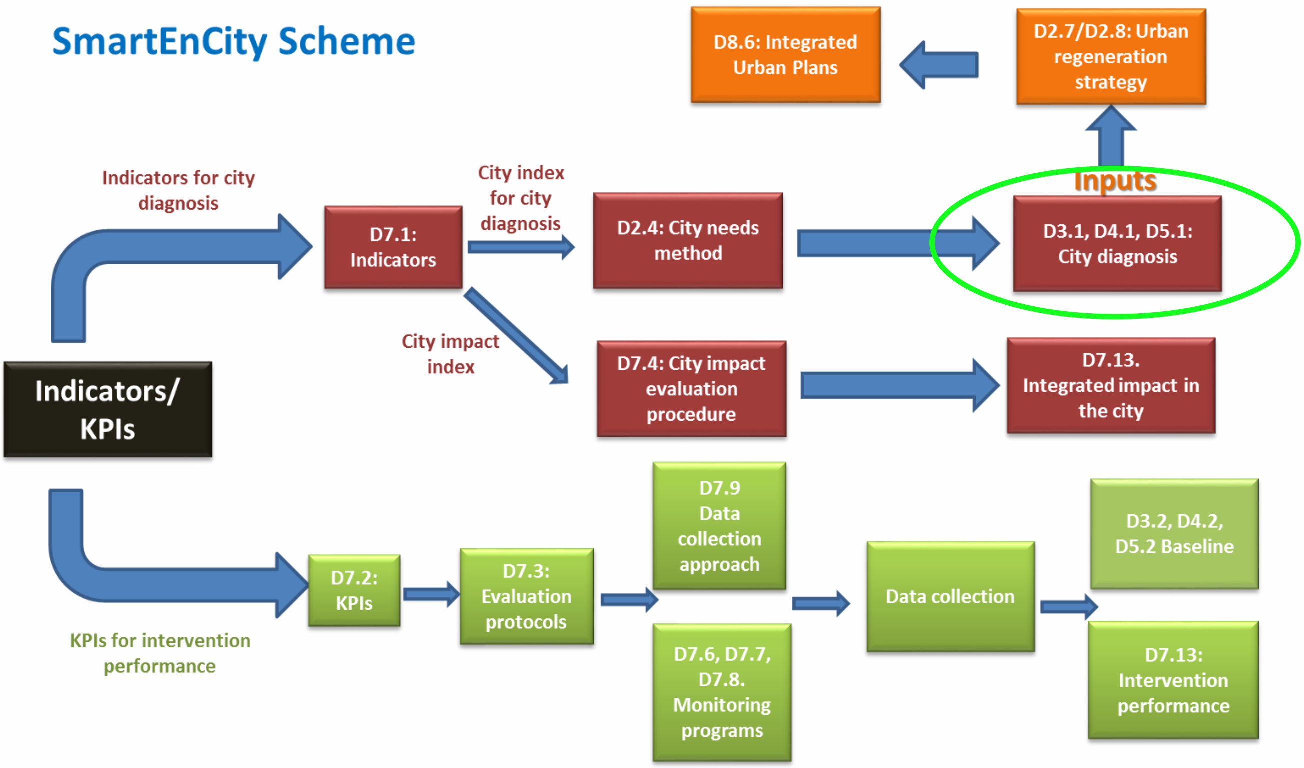
Intervention baseline definition was originally intended to be included in D5.1 due to a "mistake" in the DoA, stating that baseline should be done in D5.1 (M9) before the development of protocols at M12. As this is not possible, baseline will instead be evaluated at M18 once the protocols are designed

In the Sonderborg characterization process (Chapter 5) there are a few missing indicators which were identified as *mandatory*. After reviewing the proposal for the three cities, those indicators were identified as relevant, but after a hard gathering and calculating process, some were still unavailable. Main reasons were lack of management time to request and receive data from the different responsible bodies, and data availability.

The difficulty of this task has been useful to identify potential barriers any city can face in the search, selection and calculation of indicators. This reflection will be a relevant output to include and develop in further generic urban regeneration strategies (D2.7/D2.8).

9 Outputs for other WPs

This figure shows the connection of City Diagnosis from each LH with the next deliverables, being the Urban Regeneration Strategy the most immediate report where to take into account the conclusions obtained in the audit carried out to the cities of Vitoria-Gasteiz, Tartu and Sonderborg. Finally, Integrated Urban Plans can incorporate all the outputs.



The city diagnosis will define the city needs and therefore it is an output for defining Integrated Urban Plans (WP8, D8.6). In addition, the city diagnosis will be the starting point for the city impact evaluation to be done at WP7 (D7.13).

Finally, diagnosis and baseline definition of D5.1 sets the common ground for the remaining WP5 deliverables, which will deal with LH intervention in Sonderborg.

Annex A1. List of final indicators for city diagnosis

The indicators agreed with cities as mandatory (green cells) and optional (yellow cells) have been included in these tables, with updated definitions for those indicators which were classified as optional due to be unfamiliar for some partners. There are also few changes with mandatory indicators regarding previous versions. All changes in definitions/units have been marked in red.

For optional indicators, it is up to the city if they want to include them in the city diagnosis. Also, the city can incorporate (or not) data from other scales (e.g. regional or national) in case there are not data at city level.

All these indicators were introduced in D7.1 with the definitions. Then in D2.4, a further selection was developed, taking into account the opinion of the cities.

List of indicators for city diagnosis				
Area	*Field*	*Indicators*	*Description*	*Unit*
City characterization	***Key features of the city***	Size	Land area of city (total city surface)	km^2
		Population	Total number of persons inhabiting a city	Inhabitant (inh)
		Population density	Population per unit area in the city	$Inh./km^2$
		Annual population change	Change in the number of inhabitants in the last year	%
		Median population age	Median age is the age that divides a population into two numerically equal groups	Years
		% of population > 75	Number of persons older than 75 years	%
		Land consumption	Formula: *Total built surface/Total city surface* This indicator measures the land use intensity and urban areas density	Km^2/Km^2
	Socio-economic features of the city (Current economic performance of the city)	GDP per capita	The gross domestic product is the monetary value of all the finished goods and services produced within a city's borders in a specific time period considering the number of inhabitants	M€/inh
		Median disposable income	Median disposable annual household income	€
		Energy intensity of economy	Formula: *GDP value of the city /total energy consumption* This indicator is the ratio between the gross inland consumption of energy and the gross domestic product (GDP) for a given calendar year. The gross inland consumption of energy is calculated as the sum of the gross inland consumption of five energy types: coal, electricity, oil, natural gas and renewable energy sources. It measures the energy consumption of an economy and its overall energy efficiency and will serve to understand the energy consumed in relation with the economic situation of the city	MWh/M€
	Socio-economic features of the city (City prosperity)	New business registered per population	Number of births of enterprises in a city per the number of inhabitants (or by region in the case) In can be found in EUROSTAT as Employer business demography by size class and NUTS 3 region in this link: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=bd_esize_r3&lang=en Alava can be found for the case of Vitoria. In the case of Denmark, I don't know if the regions that appear in the list include the city of Sonderborg.	Number
		Proportion of working age population with higher	Proportion of working age population (18-65 years) qualified at level 5 or 6 ISCED (Short-cycle tertiary education or bachelor's or equivalent level)	%

		education		
	Socio-economic features of the city (Equity)	City unemployment rate	Unemployed citizens in relation to employed and unemployed who are legally eligible to work	%
		Youth unemployment rate	Percentage of youth labor force unemployed	%
		Percentage of the stock reserved for social housing	*Formula: Number of dwellings built dedicated for social housing/number of total dwellings built in a city* It a measure of the governmental action to improve housing accessibility	%
		Energy poverty level	Share of average energy expenses relative to the average disposable income (income minus taxes). The energy poverty can be understood as a lack of access to "modern" energy services and to goods comfort conditions. There are a lot of definitions for energy poverty but we will consider this ratio: It is considered that families belongs to energy poverty level if this ratio is higher than 10%.	%
	Environmental features of the city	Waste generated per capita	The amount of municipal solid waste generated per capita annually. It includes all economic activities and in addition waste generated by households.	Ton/inh
		Nitrogen dioxide emissions	Average annual nitrogen dioxide emissions per capita collected by environmental stations located in the city. It will also be reported the maximum amount allowed	µg /m^3
		Fine particulate matter emissions	Average annual fine particulate matter emissions (PM 2.5) per capita collected by environmental stations located in the city. It will also be reported the maximum amount allowed	µg /m^3
		Air quality index	Average annual concentration of relevant air pollutants (NOx and fine particles). It will also be reported the maximum amount allowed. This index represents the city's general air quality conditions throughout the year and compare to European air quality norms. This index is based on the pollutants year average compare to annual limit values, and updated once a year.	ppp or µg /m^3
		Days PM10 > 50 µg/m3	Number of days in a year in which the concentration of particles in the city is higher than 50 µg/m^3.	days/year
		Noise pollution	Share of the population affected by noise >55 dB(a) at night time	%
		Green space	Percentage of preserved areas/reservoirs/waterways/parks in relation to total city surface.	ha/ha

Energy supply network	***City energy profile***	Primary Energy Consumption in the city per year	Gross inland consumption of the city excluding non-energy uses	MWh/year
		Final Energy produced in the city per year	This indicator refers to the renewable & non-renewable energy generated in the city. The energy generation shall be expressed independently by type of energy produced.	MWh/year
		Public lighting energy use per year	Final energy consumption in the city for public lighting uses. The energy consumption of public lighting represents usually an important portion of the costs and of the energy consumed in the service sector of cities and it will be useful to evaluate the impact of investing in the public lighting	kWh/year
		Total buildings energy consumption per year	Final energy consumption of energy in whole buildings of the city (it includes residential and non-residential buildings) for heating and electricity uses Consider to split this in two: 1. Buildings heat consumption 2. Buildings electricity consumption.	GWh/year
		Public building energy consumption per year	Final energy consumption of energy in public buildings of the city for heating and electricity uses Consider to split this in two: 1.Public buildings heat consumption 2. Public buildings electricity consumption. It will be useful to evaluate the importance/impact of investing in the retrofitting of public buildings	kWh/m^2
		Residential buildings energy consumption per year	Final energy consumption of energy in residential buildings of the city for heating and electricity uses Consider to split this in two: 1.Residential heat consumption 2. Residential electricity consumption. It will be useful to know the share of energy consumption in heat and electricity in the buildings	GWh/inhab.year
		Primary Energy Consumption in the city per capita	Primary Energy consumption in the city per year and considering the number of inhabitants It will be required the data per capita in order to compare the three cities	MWh/year per inhabitant
		Final Energy produced in the city per capita	Final Energy produced in the city per year and considering the number of inhabitants It will be required the data per capita in order to compare the three cities	MWh/year per inhabitant
		Public lighting energy use per capita	Public lighting energy use in the city per year and considering the number of inhabitants It will be required the data per capita in order to compare the three cities	kWh/year per inhabitant
		Total building energy consumption in the city per capita	Residential + non-residential consumption in the city for heating and electricity uses considering the number of inhabitants It will be required the data per capita in order to compare the three cities	kWh/year per inhabitant
		Public buildings energy consumption per capita	Energy consumption by public buildings considering the surface of public buildings It will be required the data per capita in order to compare the three cities	kWh/m^2
		Residential buildings energy consumption per	Residential consumption in the city for heating and electricity uses considering the number of inhabitants	GWh/inhab.year per inhabitant

		capita		
		Portion of households connected to the district heating and cooling	*Formula: Number of households connected to the district heating and/or cooling network / total number of households* The existence of decentralized energy generation in a city is in many cases linked to renewable energy generation. The district networks help to integrate the renewable energy and low carbon energy technologies in the energy mix.	%
	Energy uses in building typologies	Total residential natural gas energy use per capita	Total annual residential natural gas use / Total city population It will be required the data per capita in order to compare the three cities	kWh/hab·year
		Total residential oil energy use per capita	Total annual residential oil use / Total city population It will be required the data per capita in order to compare the three cities	kWh/hab·year
		Total residential biomass energy use per capita	Total annual residential biomass use / Total city population	kWh/hab·year
		Percentage of the energy consumption by end use in residential buildings: space conditioning	Measure of the total energy consumption of heating and cooling in residential buildings. Formula: [Energy consumption in the domestic sector related to heating and cooling over a calendar year / Total residential buildings energy consumption] x100	%
		Percentage of the energy consumption by end use in residential buildings: domestic hot water	Measure of the total energy consumption of DHW in residential buildings Formula: [Energy consumption in the domestic sector related to domestic hot water over a calendar year / Total residential buildings energy consumption] x100	%
		Percentage of energy consumption by end use in residential buildings: lighting and appliances	Measure of the electricity consumption in residential buildings Formula: [Energy consumption in residential buildings related to lighting and appliances over a calendar year / Total residential buildings energy consumption] x100	%
		Percentage of the energy consumption by end use in public buildings: thermal and cooling uses	Measure of the electricity consumption in public buildings Formula: [Energy consumption in public buildings related to heating, DHW and cooling over a calendar year / Total public buildings energy consumption] x100	%
		Percentage of the energy consumption by end use in public buildings: electrical uses	Measure of the electricity consumption in public buildings Formula: [Energy consumption in public buildings related to lighting and appliances over a calendar year / Total public buildings energy consumption] x100	%
	Potential local renewable energy resources	Percentage of total energy derived from renewable sources	Total renewable energy consumption in the city /gross inland consumption in the city	%
		Energy use from District Heating	Total energy supplied by district heating sources in the city/ Total energy consumption in the city	kWh/year
		Energy use from Biomass	Total energy supplied by biomass sources in the city/ Total energy consumption in the city	kWh/year
		Energy use from PV	Total energy supplied by photovoltaic sources (photovoltaic plants or distributed photovoltaic elements) in the city/Total energy consump-	kWh/year

			tion in the city	
		Energy use from Solar Thermal	Total energy supplied by solar thermal sources/Total energy consumption in the city	kWh/year
		Energy use from Hydraulic	Total energy supplied by water sources (hydraulic plants)/ Total energy consumption in the city	kWh/year
		Energy use from Mini-Eolica	Total energy supplied by wind sources/ Total energy consumption in the city	kWh/year
	Potential local renewable energy resources	Energy use from Geothermal	Total energy supplied by geothermal sources/ Total energy consumption in the city	kWh/year
		Budgets devoted to renewable energies and Energy Efficiency	Public Budget (from the city council) of the projects related to Renewable Energy and Energy Efficiency /population	Euros / Persons
	Environmental impacts of the energy consumption	Global Warming Potential (GWP) per capita	Emissions of residential and non residential sectors / city population	Tn equi. CO_2 / year capita

City plans and regulation & Governance	**City plans and strategies**	Existence of plans/programs to promote energy efficient buildings	Is there any specific document promoted by the municipality which details a set of intended actions for promoting energy efficient buildings in the city?	YES/NO
		Existence of plans/programs to promote sustainable mobility	Is there any specific document promoted by the municipality which details a set of intended actions for promoting sustainable mobility in the city?	YES/NO
		Existence of local sustainability action plans	Is there any specific document in the city which provides direction on common management issues associated with water, waste, energy, biodiversity and pollution in the city?	YES/NO
		Signature of Covenant of Mayors	Has the municipality signed the Covenant of Mayors?	YES/NO
		Existence of Smart Cities strategies	Is there any specific urban development vision to improve quality of life by using technology to meet residents' needs and improve the efficiency of services (e.g. government services, transport and traffic management, energy, health care, water, innovative urban agriculture and waste management)?	YES/NO
		Existence of public incentives to promote energy efficient districts	Are there any specific public incentives for promoting the energy efficient districts in the city coming from the municipality (e.g. grant, tax exemptions and special loans)?	YES/NO
		Existence of public incentives to promote sustainable mobility	Are there any specific public incentives for promoting sustainable mobility in the city coming from the municipality (e.g. grant, tax exemptions and special loans)?	YES/NO
	Public procurement procedures & Regulations and normative	Existence of regulations for development of energy efficient districts	Is there any specific official rule or law performed by the municipality that says how to develop energy efficient districts in the city?	YES/NO
		Existence of regulations for development of sustainable mobility	Is there any specific official rule or law performed by the municipality that says how to develop sustainable mobility in the city?	YES/NO
		Existence of local/national Energy Performance Certificate (EPC)	Is there any specific EPC for buildings in the city?	YES/NO
		Share of Green Public Procurement	Percentage of annual procurements in the city administration (public transport, construction, health services and education) that include environmental criteria	%

	Governance	Involvement of the administration on smart city projects	The extent to which the smart city strategy has been assigned to one department/director and staff resources have been allocated. The valuation will be made by working team working in the city diagnosis	Likert scale Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree
		Involvement of the administration on smart city projects	What extent to which the local authority is involved in the development of smart city projects, other than financial? The valuation will be made by working team working in the city diagnosis	Likert scale Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree
		Multilevel government	The extent to which the city cooperates with other authorities from different levels. The valuation will be made by working team working in the city diagnosis	Likert scale Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree
		Paperless governement (incl e-signature)	The extent to which the Information and Communication Technologies (ICTs), and other web-based telecommunication technologies have been deployed in the city to enhance the efficiency and effectiveness of service delivery in the public sector. The valuation will be made by working team working in the city diagnosis	Likert scale Strongly disagree Disagree Neither agree nor disagree Agree Strongly agree
Transport and mobility	Mobility City Profile	Total number of vehicles in the city per capita	Number of public and private vehicles registered in the city divided by the number of inhabitants	Number/inh
		Total number of private cars per capita	Number of private cars registered in the city divided by the number of inhabitants	Number/inh
		Total number of commercial vehicles per capita	Number of vehicles used for the delivery of goods and services divided by the number of inhabitants	Number/inh
		Total number of taxis per capita	Number of taxis registered in the city divided by the number of inhabitants	Number/inh
		Total number of trucks per capita	Number of trucks registered in the city divided by the number of inhabitants	Number/inh
		Total number of public buses per capita	Number of buses registered in the city for public services divided by the number of inhabitants	Number/inh
		Total number of public bicycles per capita	Number of available bicycles in public initiatives divided by the number of inhabitants	Number/inh
		Number of bicycles per capita	Number of private bicycles registered in the city divided by the number of inhabitants	Number/inh
		Number of two-wheel motorized vehicles per capita	Total number of two-wheel motorized vehicles (including scooters and motorcycles, but no bicycles), related to the total number of inhabitants	Number/inh
	City Statistics for Mobility	Average age of motor vehicles for public transport	Mesure of the average age of motor vehicles for public transport	years
		Kilometers of high capacity public transport system per population	Length of high capacity public transport network (heavy rail metro, subway and commuter rail systems)	Km/inh

		Kilometers of light passenger public transport system per population	Length of light capacity public transport network (light rail streetcars, tramways, bus, trolleybus and other)	Km/inh
		Kilometers of bicycle paths and lanes per population	Length of bicycle paths (independent roads or parts of a road designated for cycles and signed-posted as such) and lanes (part of carriageways designated for cycles and distinguished from the rest by longitudinal road markings)	Km/inh
		Total annual number of trips	Total annual number of trips in the city	Number of trips
		Total annual number of trips by private car	Total annual number of trips by private car	Number of trips
		Total annual number of public transport trips	Total annual number of trips in public transport	Number of trips
		Total annual number of trips by bike	Total annual number of trips by bike	Number of trips
		Total annual number of trips by motorbike	Total annual number of trips by motorbike	Number of trips
		Total annual number of trips by taxi	Total annual number of trips by taxi	Number of trips
		Total annual number of trips on foot	Total annual number of trips on foot	Number of trips
		Annual number of public transport trips per capita	No. of trips made by public transport per year / Total city population	Number trips /inh
		Daily average time by trip	Annual time of total trips / total number of vehicles / 365	min / vehicle ·day
		Daily average length by trip	Annual length of total trips / total number of vehicles / 365	km/ vehicle ·day
		Daily average length by private car trip	Annual length of total trips by private car/ total number of vehicles / 365	km/ vehicle ·day
		Daily average length by public transport trip	Annual length of total trips by public transport/ total number of vehicles / 365	km/ vehicle ·day
		Daily average length by bike trip	Annual length of total trips by bike/ total number of vehicles / 365	km/ vehicle ·day
		Daily average length by motorbike trip	Annual length of total trips by motorbike/ total number of vehicles / 365	km/ vehicle ·day
		Daily average length by taxi trip	Annual length of total trips by taxi/ total number of vehicles / 365	km/ vehicle ·day
		Daily average length by foot trip	Annual length of total trips on foot/ total city population / 365	km/ vehicle ·day
		Percentage of electric private cars	Number of electric vehicles related to total number of private cars	%
		Percentage of electric commercial cars	Number of electric vehicles related to total number of commercial cars (vehicles for delivery goods)	%
		Percentage of electric taxis	Number of electric vehicles related to total number of taxis	%
		Percentage of electric motorcycles	Number of electric vehicles related to total number of motorcycles	%
		Percentage of electric public buses	Number of electric vehicles related to total number of public buses	%
		Percentage of	Number of biogas vehicles related to total number of public buses	%

		biogas public buses		
		Number of public EV charging stations	Total number of public EV charging stations in the city	Number
		Total number of recharges per year	Total number of recharges during a year in the public EV charging stations	Number
		Total kWh recharged in the EV charging stations	Number of estimated kWh recharged during a year in the public EV charging stations	kWh
		Parking facilities per capita	[No. of public and private parking facilities / Total city population] Measure of the facility to park vehicles.	Number/inh
		Number of public parking areas per capita	Total public parking areas in the city/Total city population	Number/inh
		Number of available parking slots per capita	Total number of public parking slots in the city	Number/inh
		Pedestrian area per capita	Surface in the city reserved for pedestrians related total surface in the city. It is a measure of the facility for pedestrian movement.	Km^2/km^2
		Cost of a monthly ticket for public transport in relation to the national minimum wage or average wage	[Price of a monthly ticket for public transport in the city / National minimum or average wage)] x 100. It is a measure of the weight of public transport in the household economy.	%
		Transportation fatalities per capita	[No. of transportation fatalities in the city over a calendar year / Total city population]. It is a measure of the overall safety of the transportation system.	Number/inh
	Environmental impact with mobility	Transport energy use per capita	Transport energy use over a calendar year / Total city population. Measure of the total energy use per capita due to public and private transport.	kWh /pers.·a
		Transport greenhouse gas emissions per capita	Transport GHG emissions, in equivalent CO_2 units, generated over a calendar year / Total city population Measure of the total greenhouse gas emissions per capita due to public and private transport.	t /(pers.·a)
		Percentage of renewable energy use in public transport	[Renewable energy use in public transport over a calendar year (kWh) / Public transport energy use over a calendar year (kWh)] x100 Measure of the use of renewable energy in public transport.	%

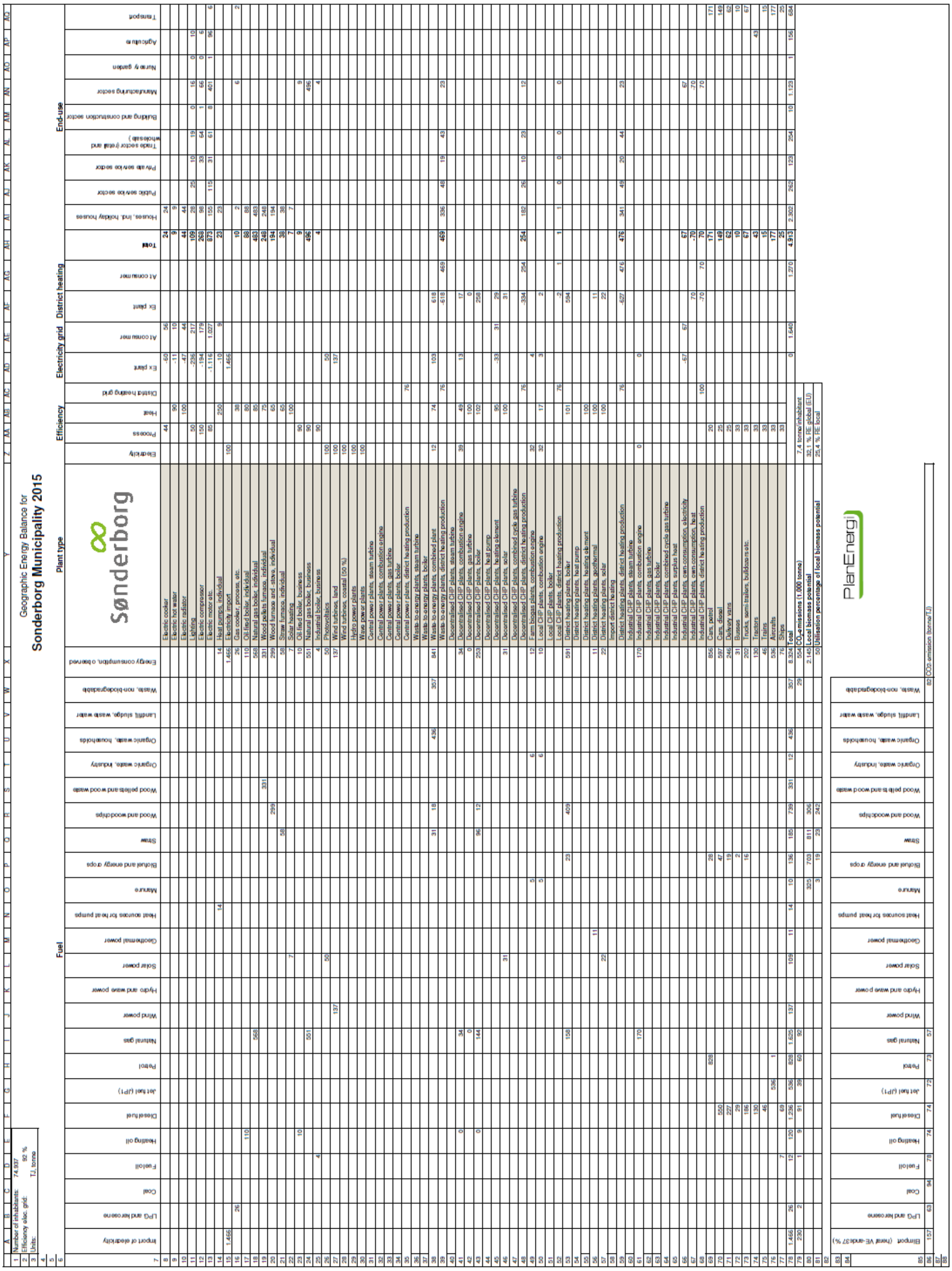
Urban infrastructure	Existing city monitoring infrastructure	Number of parking information panels	Total numbers of panels in the city with availability information in public parkings	Number
		Number of air quality stations	Total number of air monitoring stations/points located in the city related to the minimum stations required by the law	Ratio
		Number of noise stations	Total number of noise monitoring stations/points located in the city related to the minimum stations required by the law	Ratio
		Number of weather stations	Total number of weather stations/points located in the city related to the minimum stations required by the law	Ratio
		Number of loan point for public bicycles	Total hire-points in the city to enable users to pick up and return public bicycles related to the number of public bikes	Ratio
		Number of smart-meters installed	Total number of smart-meters installed in the city related to the number of inhabitants	Ratio
		ICT citizen oriented platforms	Is there any public ICT global platform available for citizen offering general information about the city and including iinstitutional mechanisms which allow to provide to the managers or policy makers of the city the problems identified by the citizens in order to trigger administration action?	YES/NO
		Data privacy	The level of data protection by the city is defined as how the ownership of the data has been clearly defined and accepted by the residents	Likert scale: Strongly disagree/Disagree Neither agree nor disagree/Agree/ Strongly agree
	Communication infrastructure in the city	Percentage of the population covered by a mobile-cellular network	Number of persons who own a mobile cellular related to the city population	%
		Percentage of the population covered by at least a 3G mobile network	Number of persons who own a mobile cellular at least 3G related to the city population	%
		3G Mobile network cells	Total number of 3G (UMTS & CDMA2000) mobile network cells to cover the land area of the city from a mobile phone perspective	Number of 3G mobile network cells
		4G Mobile network cells	Total number of 4G (WiMAX) mobile network cells to cover the land area of the city from a mobile phone perspective	Number of 4G mobile network cells
		Number of cell phone connections per capita	Total number of cell phone connections in the city in relation to the population of the city	Connections/inh
		Number of internet connections per capita	Total number of internet connections in the city in relation to the population of the city	Connections/inh
		Number of landline phone connections per capita	Total number of landline phone connections (excluding cellular connections) in the city in relation to the population of the city	Connections/inh
		Smartphone penetration	Number of smartphones in relation to total mobile phones	%
		Free Wi-Fi zones	Total number of free Wi-Fi zones offered to citizens	Number of free Wi-Fi zones identified in the city
		Cable Network	Is there any network cable system deployed in the city?	YES/NO
		Cable Network Types	Different types of networks deployed in the city	Types of cable network available in the city (twist-

				ed pair cable, coaxial cable, fibre optic,…)
Citizens	**Existing actions related to citizen engagement**	Recycling rate	Amount of solid waste recycled/amount of municipal solid waste generated	%
		Voter turnout in last municipal election	Voter participation level: [Number of persons that voted in the last municipal election /Total city population eligible to vote] x 100	%
		Number of local associations per capita	Total number of citizen associations in the city: Number of associations / Total city population	Number of consultations / inhab.
	Channels for citizen engagement	Number of information contact points for citizens	Total number of information contact points for energy efficiency, sustainable mobility, environment, etc in the municipality	Number
		Number of municipal websites for citizens	Total number of available websites for informing citizens about the city	Number
		Number of websites consultation per capita	Total number of visits in the websites related to total city population	Number
		Number of interactive social media initiatives	Total number of municipality links in social media channel as Facebook, Twitter, YouTube, etc (It is required to mention the channels) as well as total number of followers of each initiative related to the population of the city	Number
		Number of discussion fórums	Total number of internet discussion site dedicated to the citizens	Number
		Number of awareness raising campaigns	Average number of awareness raising campaigns carried out in the city yearly for energy, mobility and environmental	Number
		Number of thematic events	Number of thematic events dedicated to citizens in the topics energy efficiency, sustainable mobility and environment. Previous term (awareness campaigns) tries to provide information about a topic to improve understanding as well as mobilising the society to bring about the necessary change in attitudes and behaviour. In this case, the purpose is only to inform about a topic	Number
		Number of newspaper columns	Number of columns addressed to topics related to energy efficiency, sustainable mobility, environment which appear in local newspapers each week	Number
	Current scenarios of citizen engagement	Citizens participation in smart city projects	The number of projects in which citizens actively participated as a percentage of the total projects executed	Number
		Professional stakeholder involvement	What extent to which professional stakeholders are involved in planning and execution of urban strategies in your city?	Likert scale: Strongly disagree/Disagree Neither agree nor disagree/Agree/ Strongly agree

Table A1. Common and optional indicators

Annex A2. Geographical Energy Balance 2015: Sonderborg Municipality

The Geographical Energy Balance consists of a large variety of data calculated in 16 appendixes to the Geographical Energy Balance, before applied to a common data model in Excel that summarizes and calculates energy performance and interactions in the area. A screenshot of this data model is shown below.



A short summary of the appendixes used for the Geographical Energy Balance is provided below.

At the time of deadline of this report, updated data from DEA on production composition of residual electricity and Energy Statistic 2015 (for example used to allocate non-road energy use and individual solar heating) is still awaited, which is why latest data available for both (2014) is used instead.

Appendix 1 – Energy Producer Count consists of data on all energy producers in Sonderborg. The "Energy Producer Count" ('Energiproducenttælling') provides an overview of all the energy producers' production of electricity and heat, fuel type, fuel consumption, plant type etc. (data collected by ProjectZero).

Appendix 2 – LPG and kerosene consists of data regarding consumption of LPG (liquefied petroleum gas) and kerosene in the Geographical Energy Balance, which are relatively limited in Denmark, see Energy Statistics 2014 (DEA 2015[18]). The consumption in the municipality is found by allocating the national consumption by the population of the municipality.

Appendix 3 – Diesel, petrol, and fuel oil for ships and trains consists of data regarding consumption of diesel, petrol and fuel oil. Fuel oil is mainly used for marine transport. Diesel consumption is from trains and ships, incl. fishing. Petrol consumption, incl. avgas (aviation gasoline) is from aviation. The consumption in the municipality is found by allocating the national consumption found in the Energy Statistics 2014 (DEA 2015[18]) by the population of the municipality.

Appendix 4 – Jet fuel (JP1) consists of data regarding consumption of jet fuel (JP1). The consumption in the municipality is found by allocating the national consumption found in the Energy Statistics 2014 (DEA 2015[18]) by the population of the municipality.

Appendix 5 – Fuel for road transport consists of data regarding consumption of diesel and petrol for road transport. The fuel consumption is based in on statistics of the stock of vehicles in Sonderborg (Statistics Denmark), the total consumption for road transport measured in Energy Statistics 2014 (DEA 2015[18]), national data for mileage per vehicle type (Danish Road Directorate, 2016[19]) and average fuel consumption norm per vehicle type (Danish Centre for Environment and Energy 2014[20]).

According to the Energy Statistic 2014, 3.3 % of the petrol consumption consists of bioethanol and 7.8 % of the diesel consumption consists of biodiesel in 2014. There is therefore in the Geographical Energy Balances allocated 3.3 % for bioethanol and 7.8 % for biodiesel of the fuel consumption for each road transport.

Appendix 6 – Wind power consists of data regarding wind power production and is based on data from the DEA's central data register for wind turbines ('Master data register for wind turbines')(DEA 2016[21]). The register provides data on all wind turbines and their placement in all municipalities in Denmark.

[18] **Danish Energy Agency. 2015**: https://ens.dk/sites/ens.dk/files/Statistik/tab2014_web.xlsx
[19] **Danish Road Directorate. 2016**: http://www.vejdirektoratet.dk/DA/viden_og_data/statistik/trafikken%20i%20tal/Noegletal_om_vejtransport/Documents/Statistikkatalog.xlsx
[20] **Danish Centre for Environment and Energy. 2014**. *Normforbrug for køretøjer*. Received by mail on 1st of October 2016.
[21] **Danish Energy Agency. 2016**: https://ens.dk/sites/ens.dk/files/Statistik/anlaegprodtilnettet.xls

Appendix 7 – Photovoltaic systems consists of data regarding electricity production from photovoltaic systems. The electricity production in the municipality is calculated based on the Danish TSO Energinet.dk's database on photovoltaic (Energinet.dk, 2016[22]). Annual production per kWp is set to 800 kWh/kWp (DEA 2012[23], p. 96; International Energy Agency 2006[24], p. 117).

Appendix 8 – Biogas consists of data regarding the total production of biogas within the municipality from the "Biogas Statistics" from DEA (2015[25]). Biogas contained in the DEA's "Energy Producer Count" is not included in this appendix.

Appendix 9 – Biomass potential consists of data regarding biomass potentials within each municipality. Aarhus University has produced a dedicated and updated inventory of local biomass in 2012. The inventory consists of energy crops, straw, wood and wood chips, and biogas. For further details of the method, see "Energy from biomass - Resources and technologies assessed in a regional perspective" (Aarhus University 2008[26]).

Appendix 10 – Electricity consumption consists of data regarding the electricity consumption within the municipality. The local electricity distribution companies in the municipalities provide the data. Electricity consumption in the Geographical Energy Balance is allocated to the consumer categories on the right side of the Geographical Energy Balance. The allocation of end-use is based on data from "Technology Catalog, potentials for energy savings" (DEA 1995[27]). The DEA estimates that electricity consumption has remained fairly stable since 1995, with an increase in consumption for IT and a decrease for lighting (Sparenergi.dk 2014[28]).

Appendix 11 – District heating networks consists of data regarding grid losses in the district heating networks in the municipalities. The grid losses is based on data from the Danish District Heating Associations (2016[29]) benchmarking statistics for 2015.

Appendix 12 – Diesel consumption in agriculture consists of data regarding the consumption of diesel in agriculture tractors etc. Diesel consumption is calculated based on fuel consumption for different crop types based on "Energy Consumption and input-output relations of field operations" (Nielsen, 1989[30]). Crop distribution for the municipalities can be found in Statistics Denmark (n.d.).

Appendix 13 – Gas sales consists of data regarding natural gas consumption for residential, commercial and industry. The data is based on gas sales figures delivered by the natural gas

[22] **Energinet.dk. 2016**: https://www.energinet.dk/.../El/Solceller%20Pr.%20Kommune.xlsx
[23] **Danish Energy Agency. 2012**. *Technology Data for Energy Plants. Generation of Electricity and District Heating, Energy Storage and Energy Carrier Generation and Conversion*.
[24] **International Energy Agency. 2006**. *Renewable Energy RD&D Priorities. Insights from IEA Technology Programmes*.
[25] **Danish Energy Agency. 2015**. Biogasproduktion 2000-2014.
[26] **Aarhus University. 2008**. *Energi fra biomasse – Ressourcer og teknologier vurderet i et regionalt perspektiv*. Tjele: Det Jordbrugsvidenskabelige Fakultet.
[27] **Danish Energy Agency. 1995**. *Teknologikatalog, potentialer for energibesparelser*. København K: Energistyrelsen
[28] **Sparenergi.dk. 2014**: http://sparenergi.dk/forbruger/el/dit-elforbrug
[29] **Danish District Heating Association. 2016:** http://www.danskfjernvarme.dk/~/media/danskfjernvarme/videnom/aarstatistik/06112015%20benchmarking%202015%20nogletal%20til%20web.xlsx
[30] **Nielsen. 1989**. *Energy Consumption an input-output relations of field operations*.

distribution company DONG Energy A/S. These figures consist on data included in Appendix 1 "Energy Producer Count" and these consumptions for e.g. industry and district heating plants is therefore subtracted.

Appendix 14 – Chimney weeper data consists of data regarding number of combustion units in the municipalities and consists of oil-fired boilers, wood stoves, wood furnaces, wood pellet boilers, and straw boilers etc. These data is based on the chimney sweeper records which are always up-to-date.

Appendix 15 – Energy consumption of industry consists of data regarding the consumption of energy in the industries within Sonderborg. The data is from Statistics Denmark for the year 2014. The statistics only relates to industrial workplaces with more than 20 employees.

Appendix 16 – Energy production from solar collectors consists of data regarding the energy production from solar collectors ('Energy Statistics 2014'). The production is allocated based on the number of buildings with individual heat supply in each municipality, derived from Statistics Denmark (n.d.).