TOWARDS SMART ZERO CO_2 CITIES ACROSS EUROPE

VITORIA-GASTEIZ ✣ TARTU ✣ SONDERBORG

Deliverable 5.9: Sonderborg Demo intervention summary report

WP5

30/11/2021 (M 70)

Deliverable Version:	D5.9 REV1.0
Dissemination Level:	PU[1]
Author(s):	Nicolas Bernhardi (ZERO), Torben Esbensen (ZERO), Kristina Bozhkova (ZERO), Peter Rathje (ZERO)

[1] PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691883

Document History

Project Acronym	SmartEnCity
Project Title	Towards Smart Zero CO2 Cities across Europe
Project Coordinator	Francisco Rodriguez Tecnalia francisco.rodriguez@tecnalia.com
Project Duration	1st February 2016 - 31st July 2022 (78 months)

Deliverable No.	D5.9 Sonderborg Demo intervention summery report	
Diss. Level	Public	
Deliverable Lead	*ZERO*	
Status		Working
		Verified by other WPs
	X	Final version
Due date of deliverable	30/11/2021	
Actual submission date	29/11/2021	
Work Package	WP 5 - Sonderborg Lighthouse deployment	
WP Lead	*ZERO*	
Contributing beneficiary(ies)		

Date	Version	Person/Partner	Comments
27/11/2019	REV00	Nicolas Bernhardi	Initial template/structure
14/11/2021	REV01	Peter Rathje	update document
20/11/2021	REV02	Peter Rathje	update document
24/11/2021	REV03	Kristina Bozhkova, Peter Rathje, Torben Esbensen	update
28/11/2021	REV04	Per Alex Sorensen, Simon Sorensen	external review
28/11/2021	REV1.0	Peter Rathje	Update, completion, Final version
29/11/2021	REV1.0	Silvia Urra (TEC)	Submission to the EC

Copyright notice

contained herein is error-free, or up to date, nor makes warranties, express, implied, or statutory, by publishing this document.

Table of content:

Table of Tables:

Table of Figures:

Abbreviations and Acronyms

Table 1: Abbreviations and Acronyms

Abbreviation	
B42	Boligforeningen af 1942 (Housing association)
CEO	Chief Executive Officer
COIP	City open information platform
DEM & Esbensen	Danish Energy Management & Esbensen (Company) A/S
DH	District Heating
EV	Electrical Vehicle
F.U.	Functional unit
GA	Grant Agreement
ICT	Information & Communication Technology
IoT	Internet of Things
LCA	Life Cycle Analysis
LHC	Lighthouse city
PLAN	PlanEnergi Fond
PSO	Public Service Obligation
PV	Photo Voltaic
RES	Renewable Energy Sources
SAB	Sonderborg Andelsboligforening (Housing association)
SCIOSS	ICT backend system developed by VG
SEAP	Strategic Energy Action Plan
SmartEnCity	Towards Smart Zero CO2 Cities across Europe
SEC	SmartEnCity
SOBO	Sonderborg Boligforening (Housing association)
SONF	Sonderborg Forsyningsservice A/S (Municipal owned utility company)
VG	Vikingegaarden
VMS	Vikingegaarden's Management System
WP	Work package
ZERO	Project Zero A/S (Company)

0 Publishable Summary

Sonderborg created in 2007 the public private partnership ProjectZero to catalyze and drive the climate-transitions toward a ZEROcarbon Sonderborg by 2029 based on an integrated energy system approach with priority given to

#1 energy efficiency by smart use of energy

#2 sector couplings

#3 energy from renewable sources

#4 resource efficiency by Power-to-X production

In 2009, Sonderborg was awarded the EU Commissions “Energy Award” and in 2017 the Commissions “Cities in the Spotlight”.

Sonderborg’s ambition is to achieve the ZEROcarbon vision by 2029 and show the world, how a small and medium sized city can combat the climate challenge by co-creating ambitious goals, collaboration, planning and stakeholder- & citizen engagement.

The SmartEnCity Sonderborg demo action projects have included

- Demonstration of building retrofitting of 51 buildings with 815 apartments saving 1,428 MWh energy by implementing multiple measures including façade insulation, low energy windows, building integrated solar cells, new ventilation systems with heat recovery, new outdoor LED-light etc. Residents from seven house association departments have been engaged in the process and continue their climate journey with further climate actions.
- Demonstration of solar cell battery solutions for another 1,639 house association apartments with 2,500 residents. The project is demonstrating how residents can harvest their own renewable solar energy and store it later use in order to maximize their own self supply. The expected electricity purchase saving amounts to 1,433 MWh.
- Demonstration of how Sonderborg municipality replaced old diesel busses by 44 modern municipal biogas-busses, creating not only more carbon friendly and environmental clean bus-services, but also more reliable and citizen/user friendly public transport.
- Demonstration of new EV-charging infrastructure enabling a faster penetration of e-cars based on establishing both smart and conventional EV-chargers at strategic locations across Sonderborg center city.
- Demonstration of a new energy-data based City Information Open Platform with more than 700 data collection points across the city is already supporting Sonderborg’s transition to become a smart city by understanding the power of data. Students, businesses and citizens have been involved in the CIOP since 2019, but the CIOP-journey will continue and achieve new ambitious goals until the SmartEnCity project terminate in summer 2022.

The EU SmartEnCity demo project has helped Sonderborg, create and demonstrate robust and integrated climate actions towards a “smart and integrated energy system”, engage stakeholders and citizens in smart city data actions, achieve its ambitious milestone 2020 with 50% carbon reduction and create the next Roadmap2025 targeting 75% carbon reduction by 2025.

1 Introduction

Since 2016, smart city interventions were implemented in the city of Sonderborg. Majority of the interventions were part of the initial SmartEnCity Grant agreement. However, some of the interventions implemented, were added to the project scope due to unexpected challenges in implementing the demo actions or changes in the partner structure, documented and approved in the amendments.

In general, majority of demo interventions in Sonderborg are focused on hardware installations throughout the center city. Therefore, the Demo intervention report will in a wide range relate to deliverable D5.2 (Sonderborg integrated planning report).

Interventions that were added to the project later, will be shortly described and approaches, challenges and solutions found during the implementation will of course be part of the report as well.

1.1 Purpose and target group

The purpose of the Sonderborg Demo intervention summery report is to follow up on the integrated interventions as an embedded implementation task. The overall goal of Sonderborg´s energy transition is to implement an integrated energy system, that gradually integrates the fluctuating renewables in the Sonderborg area through an energy efficient and smart demand side management using advanced energy appliances and smart ICT systems. These SmartEnCity actions aim towards a 100 % Renewable Energy Sources (RES) system in the future.

The complexity of the task-execution ranges from securing strong citizen engagement in the district intervention tasks, to secure those synergies between the individual tasks are seen and embedded in the overall planning, to maximize outcome/results including unlocking new “domino” opportunities by the actions.

Action 1 - Sonderborg Building retrofitting complete (D5.3)

This Deliverable contains information about the process of energy retrofitting 51 buildings with 815 apartments and 66.181 m2 build area in Sonderborg. The main target audience of the implemented actions are the three housing associations (B42, SAB, SOBO) and their tenants. The municipality as a building authority and the engaged private sector companies are also beneficiaries of the implemented actions.

The demo-action 1 has also been published in the SmartEnCity Booklet:
https://www.smartencity.eu/outcomes/final-publication/

Action 2 - Solar cell storage in operation (D5.5)

This Deliverable contains information about the process of designing and implementing PV-solar battery storage systems in SOBO and SAB housing departments in Sonderborg. PV-solar battery systems will help the tenants save/accumulate energy generated during the day,

for use during the night. The main target audience of the implemented actions are other housing associations in Sonderborg, across Denmark and EU. Other larger building owners might also be beneficiaries of the implemented actions.

Action 3 - 38 biogas-buses in operation (D5.4)

This Deliverable contains information about the process of replacing old diesel busses by 44 new biogas-busses in Sonderborg. The busses are servicing not only citizens in the Sonderborg center city, but also providing a network of public transportation across the 497 km2 geographic area of Sonderborg municipality – and further exploitation of biogas-technology opportunities. The main target audience of the implemented actions are other municipalities in Denmark and abroad.

The demo-action 2 has also been published in the SmartEnCity Booklet:
https://www.smartencity.eu/outcomes/final-publication/

Action 4 - EV charging infrastructure in operation (D5.6)

This Deliverable contains information about the process of installing 24+ EV-chargers across the Sonderborg geography. Choosing location, overcoming installation challenges/barriers and promoting the charging opportunities are part of the project scope. The main target audience of the implemented actions are private companies and other municipalities in Denmark and abroad.

Action 5 - ICT Sonderborg platform in operation (D5.7)

This Deliverable contains information about the process of replicating the Telia/Tartu City Information Open Platform solution and having it “up running” and used by main target groups in Sonderborg. The main target audience of the implemented CIOP system/concept actions are municipalities in Denmark and abroad.

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
ZERO	Overall content of D5.9
PLAN	Final external critical review of content.
ET	Contribution to ICT content

TEC	Overall review and comments to this document

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
D2.5	Integrated Management models for large scale Smart City transformation projects
D2.6	Citizen Engagement Strategy and deployment plan
D2.7	Integrated and systemic SmartEnCity urban regeneration strategy_v1
D2.8	Integrated and systemic SmartEnCity urban regeneration strategy_v2
D5.1	Sonderborg Diagnoses and Baseline
D5.2	Sonderborg Integrated Planning report
D5.3	Sonderborg building retrofitting complete
D5.4	38 biogas-buses in operation
D5.5	Solar cell storage in operation
D5.6	EV charging infrastructure in operation
D5.7	ICT Sonderborg platform in operation
D5.8	Sonderborg SmartEnCity Stakeholder Platform Report on citizens and stakeholders' involvement strategy
D5.9	Monitoring reports

D7.3	Definition of the evaluation protocols used for the baseline generation
WP8	Replications to followers and Smart Cities Network. Including creation of the ProjectZero Roadmap2025 for Sonderborg using the SEC EIP methodology and involving more than 100 local experts and stakeholders. SmartEnCity Bulletin newsletters and www.SmartEnCitynetwork.eu website mentioning the Sonderborg solutions.
WP9	Exploitation, Dissemination & Communication The SmartEnCity Booklet.

Table 3: Relation to other activities in the project

2 Objectives and expected Impact

2.1 Objective

The objective of the Sonderborg Demo intervention is to demonstrate the planned demo actions and achieve the results.

This includes building retrofitting, smart mobility and EV charging infrastructure development, as well as the ICT deployment in a coordinated way so synergies and economies of scale could be taken advantage of, coordination problems could be solved, and further potentials can be fully exploited.

The purpose is to develop a strong robust SmartEnCity demo city and inspire other municipalities across Europe to implement coordinated energy actions towards a ZEROcarbon community.

2.2 Expected Impact

Action 1: Building retrofitting impact (task 5.4)

Seven departments in three Sonderborg housing associations (SAB, B42, SOBO) have implemented energy retrofitting in 51 buildings with 815 apartments and 66,181 m2 build area.

The energy demand before retrofitting varied between 114 kWh/m²/year and 139 kWh/m²/year.

The energy retrofitting measures were expected to reduce the energy demand with between 21% and 47% in the different departments.

The expected total energy saving was 1,866 MWh/year. Actual measured energy savings (M49-M60) was 1,428 MWh/year, an average deviation of 23% from the expected savings. Deviations from target at department level are both above and below expectations. See table below for specifics.

The [2]Rebound-effect, defined by changed user behavior, might cause this unexpected difference.

[2] https://blog.ucsusa.org/peter-oconnor/energy-efficiency-what-is-the-rebound-effect-946/

Department	Street	Energy Demand before retrofitting kWh/m²/year	Expected energy demand after retrofitting kWh/m²/year	Measured energy demand after retrofitting kWh/m2/year	Measured energy savings kWh/year
SAB-22	Kløvermarken	139	118	120	616,000
SOBO-11	Borgmester And.	139	92	118	96,000
B42-10	Skriverløkken	114	89	102	83,000
B42-12	Sundquistgade	120	61	82	87,000
B42-13	Ringbakken	120	73	70	216,000
B42-21	Morbaerhegnet	114	93	85	278,000
B42-28	Vissingsgade	122	86	98	52,000
In total					1,428,000

Table 4: Building retrofitting impact

Action 2: Solar cell storage in operation (task 5.5)

11 housing association departments across SAB and SOBO were part of the Solar cell battery storage project. 86 buildings with 1,639 apartments and 2,500 residents were engaged in this task.

The PV Battery storage project was part of Amendment 2 + 3. Implementation, therefore, were not completed until summer 2021 and actual savings will not be reported until 2022.

Below is a list of the 11 department-projects implemented.

Department	Apartments No.	Investment Euro	Saved electricity (expected) kWh	Saved electricity (expected) Euro	ROI Years
SAB – 13:	93	340,000	105,000	30,000	11.3
SAB – 15:	105	360,000	125,000	35,000	10.3
SAB – 18:	114	410,000	120,000	34,000	12.0
SAB – 20:	94	295,000	105,000	30,000	9.8
SAB – 21:	72	385,000	85,000	24,000	16.0
SAB – 22:	432	345,000	65,000	18,000	19.1
SAB – 24:	324	925,000	330,000	93,000	10.0
SAB – 27:	52	170,000	55,000	15,000	11.3
SAB – 30:	232	420,000	250,000	70,000	6.0
SAB –Byg 2	Common	90,000	23,000	7,000	12.9
SOBO – 12:	72	325,000	110,000	30,000	10.8
SOBO – 21:	49	206,000	60,000	17,000	12.1
	1,639	**4,271,000**	**1,433,000**	**403,000**	**10.6**

Table 5: PV Battery storage - investment and feasibility survey

Average investment per apartment: 4,271,000 / 1,639 = 2,610 Euro.

Average investment per m2 apartment area: 4,271,000 / 127,600 = 33.5 Euro

Average electricity purchase saving from grid per m2 apartment: 403,000 / 127,600 = 3.2 Euro

Action 3: 38 biogas-busses in operation (task 5.6)

Replacement of 38 old diesel busses by 44 biogas-busses took place in June 2017. Additional 6 busses were purchased to cover the transport need. The replacement/investment was part of the SmartEnCity project, however the measurement criteria defined were soft criteria focused on reliability and accuracy of departure/arrival of the busses.

The data collection includes vehicle fuel efficiency.

Period	Total km	Total gas consumption (m^3)	Km per m^3-gas consumption
M61-M67	1.231.144	494,631	2.49
M55-M60	1.223.291	461,000	2.65
M49-M54	1.109.117	420.532	2.64
M43-M48	1.310.723	444.640	2.94
M37-M42	1.201.255	447.297	2.68

Table 6: driven km and fuel efficiency for the biogas-busses since 2017

Action 4: EV-charging infrastructure in operation (task 5.6)

Seven smart Evergreen chargers were installed as part of the first implementation phase. Additional 24 EON charging-points were installed in the second roll-out.

The initial seven chargers never functioned, and the supplier was changed to EON to secure the implementation of a well-functioning EV-charger solution.

Figure 1: EON EV-charger at the 1864 historic center in Sonderborg

The below table shows how the use of the EON chargers has evolved during the last 1½ year.

			M49-M54		M55-M60		M61-M67	
GID	Physical address	Number of charging points	Number of charging sessions	Average charging (kWh)	Number of charging sessions	Average charging (kWh)	Number of charging sessions	Average charging (kWh)
45.0.0.6400.17	Grundtvigs Allé 195, 6400 Sønderborg, (Bilka Sonderborg)	6	139	17,9	576	3,6	358	8,6
45.0.0.6400.12	Ellegårdvej 8, 6400 Sønderborg, (Sonfor)	4	147	5,8	173	6,4	168	6,3
45.0.0.6400.19	Rønhaveplads 1, 6400 Sønderborg, (public parkingspace)	2	40	8,4	51	4,4	46	11,3
45.0.0.6400.22	Stationsvej 10, 6400 Sønderborg, (The Court, Sonderborg)	2	3	18,8	58	7,5	13	8,5
45.0.0.6400.21	Dybbøl Banke 16, 6400 Sønderborg, (1864 Museum)	2	38	9,6	65	5,3	75	12,0
45.0.0.6400.20	Aabenraavej 25, 6400 Sønderborg, (Skansen, sportsfacility)	2	4	11,7	24	9,6	36	30,7
45.0.0.6400.18	Martin Nyrupsplads 2, 6400 Sønderborg, (Sønderborghus, culture center)	2	18	16,1	69	7,6	35	27,9
45.0.0.6400.23	Langbro 7, 6400 Sønderborg (Danish Crown)	4	15	24,1	158	16,3	139	18,0
			404	**11,9**	**1.174**	**6,2**	**870**	**11,8**
	Total charge (kWh)			4.796		7.307		10.232

Table 4: EV-charging statistics from the 24 EON charging-points in Sonderborg

Action 5: ICT Sonderborg platform in operation (task 5.7)

The Sonderborg CIOP is a direct clone of the Tartu CIOP. Therefore, the architecture of both platforms is the same and contain:

- Cumulocity
- The data sources
- The Data Access Layer
- The DAL mapping tool
- The City portal

The Sonderborg platform was implemented in summer 2019 with information collected by more than 700 sensors. A CIOP 2.0 ambition based on upload of available energy-data from citizens and companies is being implemented during M67 – M78, as part of amendment 3 actions. Ultimately with the goal to establish and demonstrate the integrated energy system.

Several data/digitalization events organized are ramping up Sonderborg's transition to become a smart city.

3 Demonstration actions completed

The implemented demonstration actions in Sonderborg consist of the following action-tasks described in the Grant Agreement number 691883 (AMENDMENT Reference No AMD-691883-61) - Towards Smart Zero CO2 Cities across Europe (SmartEnCity).

WP5 – Sonderborg Lighthouse deployment Actions

- task 5.4 Building Retrofitting
- task 5.5 Integrated Infrastructures (Solar cell storage)
- task 5.6 Smart Mobility
- task 5.7 ICT

The Diagnosis and Baseline (described in task 5.1) created the implementation strategy and District Integrated Intervention (described in task 5.3). The Sonderborg stakeholder alliance-platform, and the Citizen Engagement Actions (described in task 5.2) enabled the mobilization of citizen engagement either for approving the actions (task 5.4, 5.5), supporting the implementation (task 5.6, 5.7) or adapting/using the implemented actions (task 5.6, 5.7).

3.1 Action 1 - Building Retrofitting (task 5.4)

In task 5.4, the building cooperative owners of SAB, SOBO and B42 planned and implemented specific building retrofit actions. ZERO coordinated the activities between the 3 housing associations involved.

Seven housing association departments with 51 buildings and 815 apartments together 66.181 m2 build area in Sonderborg have been retrofitted as part of this task.

Department	Street	No. Buildings	No. Apartments	Built area m²
SAB – 22	Kløvermarken	19	432	32.421
SOBO – 11	Borgmester And.	8	88	8.420
B42-10	Skriverløkken	5	87	6.960
B42-12	Sundquistgade	3	16	2.300
B42-13	Ringbakken	4	48	4.320
B42-21	Morbaerhegnet	10	120	9.600
B42-28	Vissingsgade	2	24	2.160
___		51	815	66.181

Table 5 - Survey of retrofitted departments

Department	Street	Energy demand Before Retrofitting kWh/m²/year	Energy demand after retrofitting kWh/m²/year	Energy savings kWh/m²/year
SAB-22	Kløvermarken	139	118	21 (15%)
SOBO-11	Borgmester And.	139	92	47 (34%)
B42-10	Skriverløkken	114	89	25 (22%)
B42-12	Sundquistgade	120	61	59 (49%)
B42-13	Ringbakken	120	73	47 (39%)
B42-21	Morbaerhegnet	114	93	21 (18%)
B42-28	Vissingsgade	122	86	36 (30%)

Table 6 - Expected energy savings by department

The seven departments have implemented different energy retrofitting measures, including: Insulation of facades, airtight constructions, new low energy windows and doors, new ventilation systems with heat recovery replacing traditional exhaust air ventilation systems, new outdoor LED street lighting in the surrounding ground areas and in stairwells, automatic heating control systems in district heating supply of the buildings, improvement of indoor climate, installation of in total 6.000 m² of building integrated solar photovoltaic plants for electricity supply with focus on good architectural integration of the solar panels in roofs.

The average energy savings in the seven departments was expected to be 30%.

Below are pictures of typical samples of the implemented actions from all three housing associations.

Figure 2: SOBO Department 11, Building integrated solar cells

Figure 3: SOBO Department 11: New heat exchangers for district heating

Figure 4: SOBO Department 11: New low-energy windows

Figure 5: SAB Department 22: seen from above with solar cells

Figure 6: SAB Department 22 with building integrated solar cells, in total on 19 buildings

Figure 7: B42 Department 10, solar cells on the roof

Figure 8: B42 Department 13, new facade insulation

Figure 9: SOBO Department 11: New outdoor LED lamps

Figure 10: B42 Department 21: New ventilation system with heat recovery

The different retrofitting works in individual buildings was carried out according to the process developed in T5.3. PV systems were designed to deliver 80% of the power production to consumption hour by hour and max 20% to the grid. Workshops were organized for board-members in the three housing associations and all department tenants took part in discussions (coordination actions as defined in T5.2) including voting for the implemented actions.

Innovative financing and public tendering were part of the implemented actions. Specific building documentation validation and quality control was carried out to ensure individual interventions were aligned with the defined ambition levels and put in place.

This task has also concluded the construction works and gathered construction certificates to ensure measures have been put in place and correctly commissioned.

For more information:

For full D5.3 Report: Sonderborg Building retrofitting complete:
https://emdesk.eu/cms/?p=334&hash=ajY4Nw||ZG93bmxvYWQ7bGF0ZXN0OzIyN2

The Sonderborg demo action 1 has also been published in the SmartEnCity Booklet:
https://www.smartencity.eu/outcomes/final-publication/

See the SmartEnCity video explaining the importance of building retrofitting to citizens here:
https://www.youtube.com/watch?v=B6edi1RBFtc

During the Sonderborg Climate Conference 2021 a “Seeing is Believing tour” LIVE stop was made at the SAB housing association in Sonderborg. The video and discussion between the chairperson of SAB and Torben Esbensen can be viewed here: https://youtu.be/bPNyivMZuG0 (view from 08:35 minutes)

3.2 Action 2 - Integrated Infrastructures (solar cell storage task 5.5)

SAB and SOBO, two of the Sonderborg housing association partners have implemented the solar cell storage task.

SAB had 9 of their housing departments with 1,518 apartments involved in the project. SOBO had 2 departments with 121 apartments involved. The 11 departments have in total 1,639 apartments with 2,500 residents. A total of 86 buildings have been retrofitted with solar PV and battery solutions.

Department	Location	No. Buildings	No. Apartments	Built area m²
SAB - 13	Borgmesterløkken	5	93	7.500
SAB - 15	Klosterløkken	4	105	8.500
SAB - 18	Ryttervænget	9	114	9.100
SAB - 20	Vølundsgade	8	94	7.600
SAB - 21	Rådmandsløkken	6	72	5.800
SAB - 22	Kløvermarken	19	432	32.000
SAB - 24	Søstjernevej	12	324	25.500
SAB - 27	Primulavej	4	52	3.600
SAB - 30	Stenbjergparken	10	232	18.500
SOBO- 12	Grundtvigs Alle	6	72	6.000
SOBO – 21	Udsigten	3	49	3.900
		86	**1.639**	**127.600**

Table 7: list of Sonderborg house association departments implementing the Solar cell storage solution

The purpose of this task is to gain knowledge about these new energy systems, inform and inspire other housing associations and other house owners in Europe to reduce purchase of electricity from the grid.

Figure 11: SAB department 24, 1,870 m2 solar PV panels integrated in roof combined with 200 kWh battery capacity. Each of the 10 buildings has one solar PV panel-system and a battery in the basement. Department 24 has 324 apartments.

A battery storage solution is an interesting solution for apartment buildings, because solar electricity produced during the day can be stored until the late afternoon or evening, when the electricity consumption is higher than during the day, and thereby also contribute to reducing the peak load demand on the public grid.

Figure 12: SAB Department 18, 730 m2 solar PV panels integrated in the roof combined with 75 kWh battery capacity

The solar PV and battery systems are designed, so that a minimum of 80 % of the produced electricity can be used directly via the batteries to the apartments. A maximum of 20 % will be submitted and sold to the public grid.

Figure 13: SAB Department 21, The batteries are installed in technical rooms outside the buildings

The solar electricity is expected to cover 45 – 50 % of the total electricity consumption in the housing departments.

Department	*Apartments No*	*Solar PV area m2*	*Solar PV kW*	*Battery capacity kWh*	*Solar contribution kWh/year*
SAB – 13:	93	600	110	60	105,000
SAB – 15:	105	750	140	80	125,000
SAB – 18:	114	730	135	75	120,000
SAB – 20:	94	600	110	60	105,000
SAB – 21:	72	500	110	50	85,000
SAB – 22: *	432			290	65,000
SAB – 24:	324	1,870	345	200	330,000
SAB – 27:	52	350	65	30	55,000
SAB – 30:	232	1,650	295	80	250,000
SOBO – 12:	72	670	120	70	110,000
SOBO – 21:	49	350	70	55	60,000
	1,639	**8,070**	**1,500**	**1,050**	**1,410,000**

Table 8: design survey for the 11 solar cell storage systems

* SAB 22 already had an existing solar PV system, to which battery plants have been added. Electricity purchase saving of 65.000 kWh is additional saving due to the batteries.

The deliverable describes the following actions taken to implement and complete the solar PV and storage systems:

- Decision making process to approve the solar PV and battery systems
- Design phase including defining design criteria
- Tender and contract processes
- Approval from public authorities
- Implementation phase including description and photos of the systems
- Approval of construction work and handover to housing associations
- Start of monitoring period

The total investment of the 11 systems corresponds to 4,271,000 Euro (table 6). The expected saved electricity purchase from the Grid is 1,410 MWh – with an estimated saving of 403,000 Euro. The pay-back period is 10 years.

For more information:

D5.5 Report: Solar cell storage in operation, available for download from EMDESK from November 2021 (M 70).

3.3 Action 3 & 4 - Smart Mobility (task 5.6)

Task 5.6 consist of two key actions:

- Integrating the replacement of existing diesel busses with 38 biogas busses into the project, being part of the measurement and evaluation program
- establishing a new E-recharger infrastructure for e-mobility

Action 3: Replacement of old diesel busses with 38 biogas busses

Figure 14: Biomethane busses parked for the night

The objective of converting from conventional diesel buses to biomethane buses in Sonderborg was mainly based on reduction of carbon emissions, although also sulphur emissions, NOx and PM pollutants are significantly reduced. The reduction of carbon emissions from public transport is part of the ambitious and prominent goal of Sonderborg area becoming carbon neutral by 2029.

The city transport administration created the tender-specs for the new busses. Apart from being fuelled by biogas, they should also

- make it easy for handicapped and elderly people to enter the buss
- support up to 4 bicycles to be taken into the buss
- support electric charging of phones during the drive

The implementation of the public transport zero emission biomethane buses went according to plan. Although, including the preparatory work leading up to the successful implementation was ongoing for more than 3 years and necessitated at least one committed traffic planner at the municipality as well as attention and commitment from the Sonderborg city council as the ultimate decision maker. As part of the process, biogas as fuel, instead of electricity, was challenged and discussed taking into consideration the driving distance of the busses, technology maturity and the business/investment case.

Figure 15: picture of new biomethane fueling station and service location established in Ragebøl

Not only, was it necessary to launch a tender for 44 biomethane buses, a separate tender was launched to construct the filing/service area with a comprehensive distributed biomethane fuelling station for the buses since there were no such existing facilities in the municipality. Furthermore, the research and planning team discovered the benefits by adding a small fuelling station at the terminal stop furthest away (in Nordborg) from the main fuelling station (in Ragebøl) to avoid empty passenger bus-drives to refuel.

Nature Energy decided to establish a publicly available gas-filling station right outside the municipal filling/service-area, enabling also other vehicles to be charged by gas.

Figure 16: Nature Energy public gas-filling station established next to the municipal filling station in Ragebøl/Sonderborg

The lead partner in implementing this action was the city transport administration and the city council. Other core stakeholders engaged were the private sector biomethane producing company Nature Energy, Umove, the private sector bus operating company that won the tender process and Sydtrafik, the regional public transport service provider. The bus-fleet ended up consisting of 44 Scania Citywide LE gas busses.

ProjectZero helped the municipality create a Strategic Green Transport plan in 2016, supported discussions about alternative fuel vehicles and assisted with informative research and lessons learned from elsewhere. SONF collaborated and supported the process with

project management resources and an educational and informative video for the general public regarding the benefits of the biomethane buses.

Figure 17: the biogas-busses in operation at the main bus-station in Sonderborg

The construction of the main fuelling station was completed in May 2017, less than 6 months after the site development started. The biomethane buses started operating on 25. June 2017 as planned, only 10 months after the announcement of the winner of the public tender. The contract for Umove to operate the buses is 10 years with the possibility of extending for another 2 years.

For more information:

Deliverable D5.4: 38 biogas-buses in operation:

https://emdesk.eu/cms/?p=334&hash=6GF0ZXN0OzE3NtcwOQ||ZG93bmxvYWQ7b9

The Sonderborg demo action 3 has also been published in the SmartEnCity Booklet: https://www.smartencity.eu/outcomes/final-publication/

A SmartEnCity video was produced to explain the features of the new biogas busses: BioBus EngSub - YouTube

During the Sonderborg Climate Conference 2021 a “Seeing is Believing Tour” LIVE stop was made at the biogas buss-charging station. The busses and fueling station video presentation can be seen here: https://youtu.be/bPNyivMZuG0 (view from 1 hour and 43 minutes into the video).

Action 4: EV charging infrastructure in operation

Denmark has a national ambition of having 750,000 E-cars on the road in 2030 despite a slow adoption of EVs, when the vision was created in 2019. To enable this transition from conventional vehicles to EVs, it is important to create a supporting charging-infrastructure in key locations.

The leading partners in implementing this demonstration action were Sonderborg Forsyning (SONF) and ProjectZero (ZERO), the coordinating partners of the Sonderborg Lighthouse City demonstrator, the private sector EV-charging developer E.ON as well as supervisors at stores and cases.

The initial plan was to buy especially tailor-made “Evergreen” EV-chargers from Vikingegaarden (VG partner), to support a smart charging when green power was available and cheap. The initial 7 installations all failed, and the additional 24 chargers was purchased/installed by the market leader E.ON who won the public tender.

Figure 18: E.ON electric vehicle charger

The 24 EV charging-point locations in Sonderborg have been carefully chosen based on accessibility, tourist attractions, shopping areas and busy intersections:

- 2 x 2 with 22 kW Ellegaardvej 8, Sonfor HQ in an industrial area
- 3 x 2 with 22 kW Bilka, main shopping center in Sonderborg center
- 2 x 2 with 22 kW Danish Crown, major destination for work commuters
- 1 x 2 with 22 kW Rønhaveplads, a very central public parking spot for getting to the pedestrian street
- 1 x 2 with 22 kW Vingården/Sønderborghus, next to Sonderborg’s culture house (Sonderborg hus)
- 1 x 2 with 22 kW Retten i Sønderborg, next to the public Courthouse, visited by many guests from nearby and abroad every day

- 1 x 2 with 22 kW Historiecenter 1864 at Dybbøl Banke, a famous historic museum center in the outskirt of Sonderborg attracting tourist visitors from abroad
- 1 x 2 with 22 kW Skansen, next to a main sports/event facility in Sonderborg

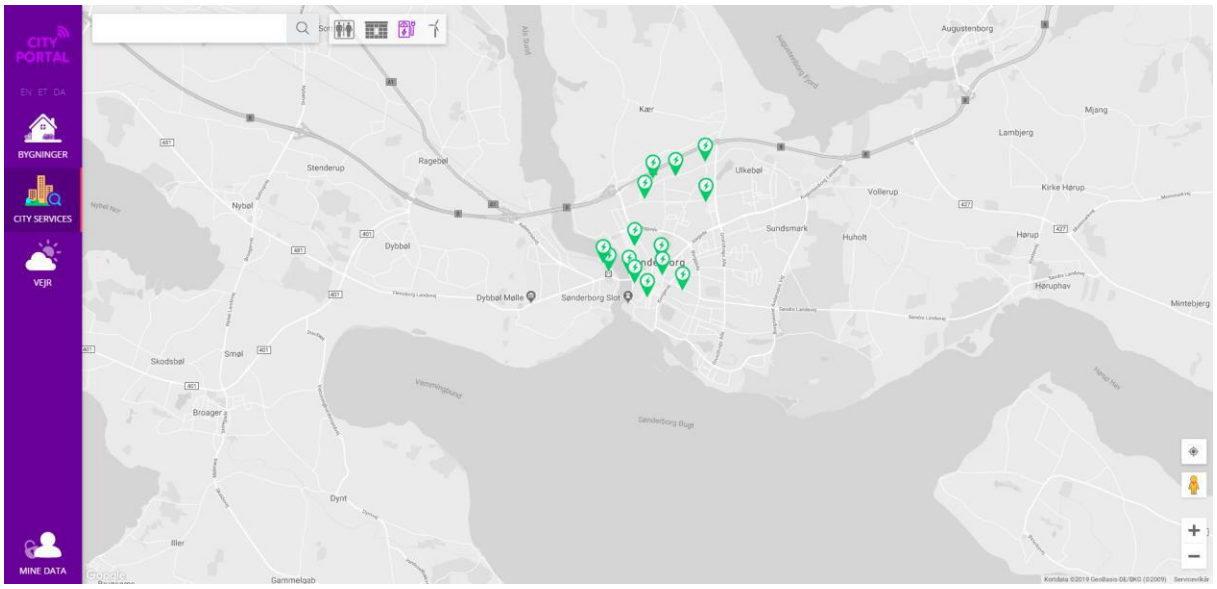

Figure 19: Sonderborg CIOP screen print showing EV-chargers in the center of Sonderborg

Monitoring of the seven Evergreen EV-chargers was not possible but monitoring of the 24 E.ON EV-chargers frequently made and reported as part of WP7.

The Danish government changed late 2020 tax structures for electrical cars. Surveys are showing that electrical cars are cheaper to operate per km-driven than traditional fossil fueled cars – based on 15,000 km driven per year. Car-owners need to understand and adapt the business model of electrical cars. Banks will support electrical cars as an economic safe choice due to pressure from EU policies and regulations.

BEV (Battery Electrical Cars) and PHEV (Plug-in Hybrid Electrical Cars) are now growing rapid in numbers in Sonderborg. Almost 50% of all new registered cars during Q4/2021 are either BEV or PHEV cars and the figure is expected to continue growing until 2030, mainly affected by supply delays from the car manufactures.

Sonderborg and ProjectZero have a strong commitment to support the transition to electrical cars. The SmartEnCity Energibyerne.dk network of Danish cities – part of the EU SmartEnCity Network – recently applied for EUCF-funding for a joint e-car journey and the application was approved for 12 months implementation funding.

Figure 20: Map of the seven Energibyerne.dk cities across Denmark

For more information:

D5.6 deliverable: EV charging infrastructure in operation:

https://emdesk.eu/cms/?p=334&hash=fYWQ7bGF0ZXN0OzI4ODE1MQ||ZG93bmxv6

E-car article at ProjectZero website: http://brightgreenbusiness.com/news/archive/2021/tips-for-those-considering-an-electric-car

3.4 Action 5 - ICT (task 5.7)

Task 5.7 aimed at deploying the necessary ICT infrastructure needed for management, data harvesting, monitoring and evaluation of the Sonderborg ICT System, as well as implementing the specific infrastructure needed for the deployment and operation of the City Information Open Platform (CIOP).

As the Danish ICT partner (Vikingegaarden) withdraw their participation in the SmartEnCity project per 31.08.2018 a solution had to be found in order to make sure that Task 5.7 could be fulfilled by the partnership in Sonderborg.

During the screening for a suitable solution, it soon became obvious that a collaboration with the other partner cities, where similar systems had to be implemented, would be most favorable.

Therefore, a collaboration with the Estonian IT partner Telia Esti was decided by the WP5 management group focused on the implementation of a Sonderborg CIOP.

This collaboration was written into the second amendment of the SmartEnCity project which was approved in May 2019.

Right after the amendment was approved the implementation of the CIOP was started.

Furthermore, the planning for the first Sonderborg Smart ZEROHACK was started, as the organization of a hackathon also was part of the amendment.

Technical design

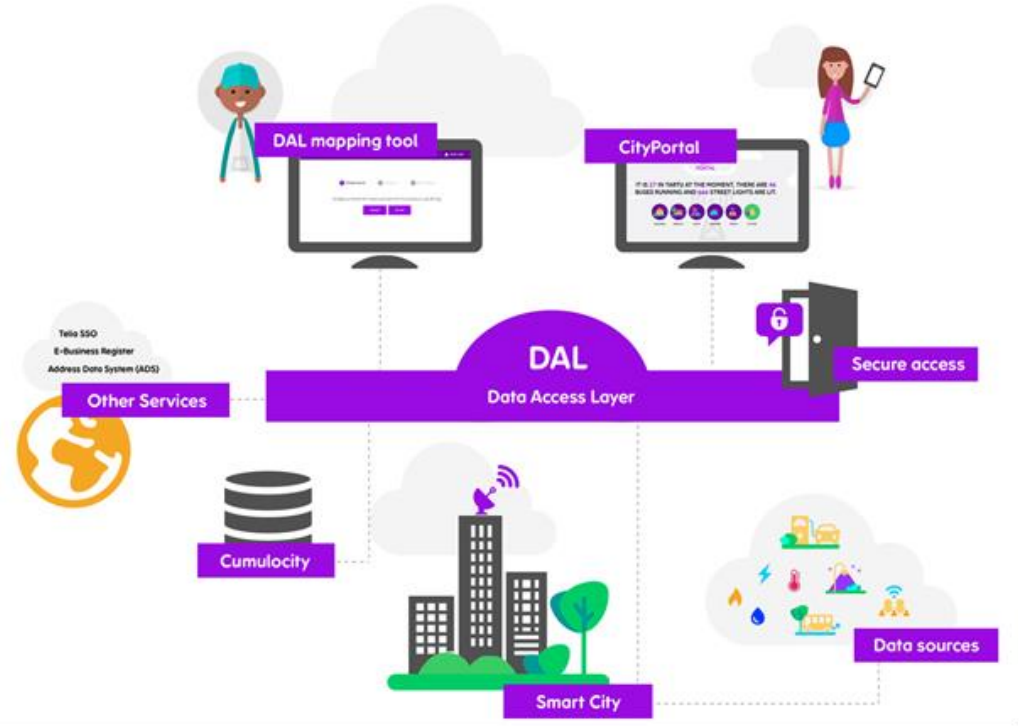

Figure 21: the CIOP

The Sonderborg CIOP is a direct clone of the Tartu CIOP. Therefore, the architecture of both platforms is the same and contain:

- Cumulocity
- The data sources
- The Data Access Layer
- The DAL mapping tool
- The City portal

Porting of the platform to Denmark - challenges

As the platform initially was developed for the Estonian market some aspects had to be changed for making the platform work in Sonderborg. The following section will describe the adjustments that had been made.

Translation

The language is of course a very important aspect when talking user experience and adoptability of the platform. Therefore, translating the platform was one of the first tasks that had to be accomplished. In order to translate the platform, the crowdin platform was chosen (https://crowdin.com/).

Through this cloud-based solution the single buttons and information boxes were translated one by one.

As the Estonian team already from the beginning had worked on an English version of the platform, the Danish version is based on the translation of the English platform to Danish.

This task was accomplished by SONF during June/July 2019.

NemID

Initially the platform used Estonian login methods (ID-card, Mobile-ID or Smart-ID). As the Danish citizens obviously don't have any of the Estonian login methods another solution had to be implemented.

NemID is the Danish standard for authentication at bank accounts and public services. As all Danish citizens already use this authentication method and it is considered to be very secure the project team choose to implement NemID.

In order to do so, ZERO had to order the NemID solution at nets, as nets requires that the company ordering this solution is located in Denmark.

After this a test environment was set up, which made it possible for the development team to implement NemID on the platform.

Data measurements from the local housing associations

As the former IT partner (Vikingegaarden) had developed proprietary gateways and protocols it was cheaper and easier to switch out the existing installations with new measurement equipment. Through this the Danish partnership also had a first use-case to show how easy the measurement equipment could be installed and mapped, so the first data came up to the platform.

To get the data from the housing associations new gateways that are compatible with cumulocity were purchased.

Furthermore, some Kamstrup Modbus modules, output top modules, antennas and some other installation supplies were purchased.

After the installation of this new hardware the data could be sent directly to the CIOP platform.

The collected data from VG has been uploaded to the new platform.

ZEROhack hackathon

As part of the amendment 1, a Sonderborg hackathon was added to the project. As the concept of hackathons was new to ZERO, the development of the concept started with some research in Sonderborg and some initial brainstorming on how a hackathon could look like in the local context, taking both the CIOP and additional data into account.

One of the main focusses was to gain more local knowledge on this type of events and to make sure that hackathons would be held more regularly in Sonderborg.

Therefore, the local universities were engaged in planning and holding the hackathon.

Furthermore, local utilities provided their (data) challenges for the participants in order to make sure the found solutions would benefit the citizens in Sonderborg.

Figure 22: Student group at workstation students at their ZEROhack-workstation

Figure 23: Participants at the ZERO hackathon

The hackathon concluded a need for continuing Sonderborg's smart city and data journey, including upload of more data from citizens and companies and special citizen data-driven engagement actions.

Creating a CIOP landing page

In cooperation with a local company, ProjectZero launched in June 2020 a CIOP landingpage. www.CityPortalSønderborg.dk enabling citizens to learn more about the ProjectZero vision and journey before they "arrive/land at the CIOP platform. The CIOP-platform was also extended with tools to help citizens and small medium sized companies to improve energy efficiency.

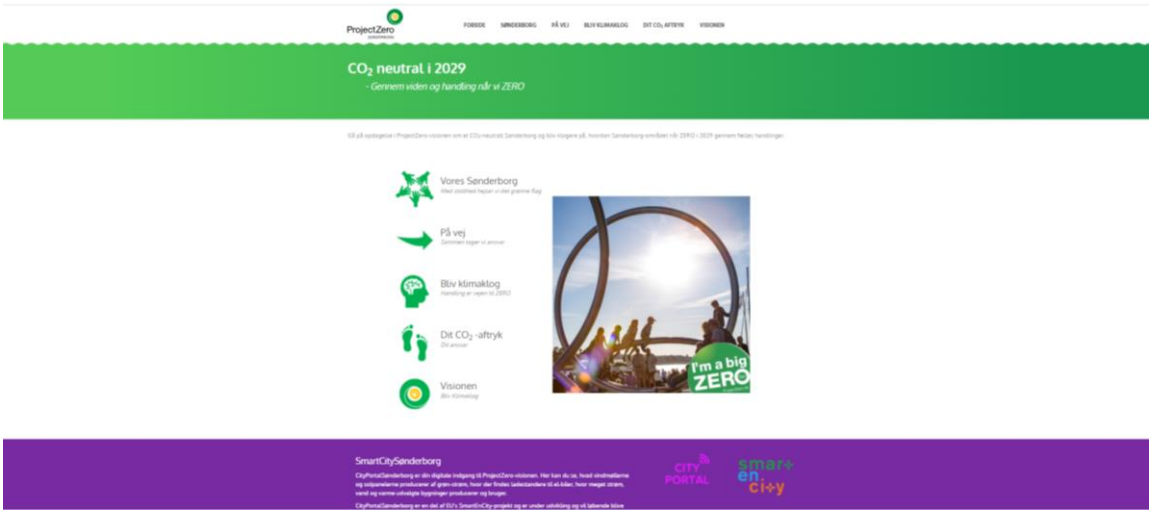

Figure 24: A Citizen engagement CIOP landing page was created

How can data help companies become more innovative?

A joint data-workshop with Danish Energinet.dk authority was organized in September 2020, with participation from companies across Sonderborg and specialists from energinet.dk and the Danish Association of Industry confederation. The workshop concluded that energinet.dk was already collecting electricity data and a frequent supply of data would be possible to the CIOP platform, respecting the GDPR-rules.

Figure 25: group discussion during the SmartCity Sonderborg data-workshop

The next step: CIOP 2.0 vision is being implemented

As part of the Amendment 3, resources were made available for ZERO to continue add multiple data to the CIOP-platform based on citizen and company participation to the platform. The additional data will be based on data available in the energy system, but never before presented to the citizens nor the companies, ultimately with the goal of demonstrating a smart integrated energy system in sonderborg. The ambition will also help Sonderborg migrate its annual progress monitoring and reporting to progress potentially during 2022 to quarterly and monthly reporting.

The CIOP 2.0 vision/system is under implementation by ZERO using also resources from outside the organisation to ramp up and secure the completion before the SmartEnCity project ends in July 2022.

For more information:

D5.7 Report: ICT Sonderborg platform in operation

https://emdesk.eu/cms/?p=334&hash=40OzMxMjEwOQ||ZG93bmxvYWQ7bGF0ZXN8

Visit/review the CIOP landing-page (in Danish): www.CityPortalSønderborg.dk

Go direct to the CIOP website: www.SmartcitySonderborg.dk

4 Deviations to the plan

4.1 Action 1 – Sonderborg building retrofitting complete

The action and the measures were implemented according to the scope defined in the original Grant Agreement.

4.2 Action 2 – Solar cell storage in operation

The originally scheduled action of a heat pump was changed as part of Amendment 2 because the planned heat pump integration in the Sonderborg district heating system was not possible to implement. Instead, the solar cell battery storage demo concept was developed and approved as part of Amendment 2.

Due to COVID-19, residents' approval of the business- and investment case was delayed. Amendment 3, however, secured additional 12 months monitoring before the end of the project.

4.3 Action 3 – 38 biogas-busses in operation

The action and the measures were implemented according to the scope defined in the original Grant Agreement. The replacement ended up with 44 new busses instead of 38.

4.4 Action 4 – EV charging infrastructure in operation

The originally scheduled action was changed as part of Amendment 1 due to legal barriers for implementing the originally scheduled motivation grant to citizens buying e-cars.

4.5 Action 5 – ICT Sonderborg platform in operation

As the ICT-partner Vikingegaarden (VG) decided to exit the project during 2018, it was decided to replicate the successful implementation of the Telia ESTI City Information Open Platform in Sonderborg. The redefined action, the change of partner and economics were defined and approved as part of Amendment 2 and successfully implemented by the partners.

5 Lessons learned

5.1 The importance of having a strong city climate vision, a robust masterplan and roadmaps

Sonderborg created in 2007 the public private partnership ProjectZero to catalyze and drive the climate-transitions toward a ZEROcarbon Sonderborg by 2029 based on an integrated energy system approach with priority given to

#1 energy efficiency by smart use of energy

#2 sector couplings

#3 energy from renewable sources

#4 resource efficiency by Power-to-X production

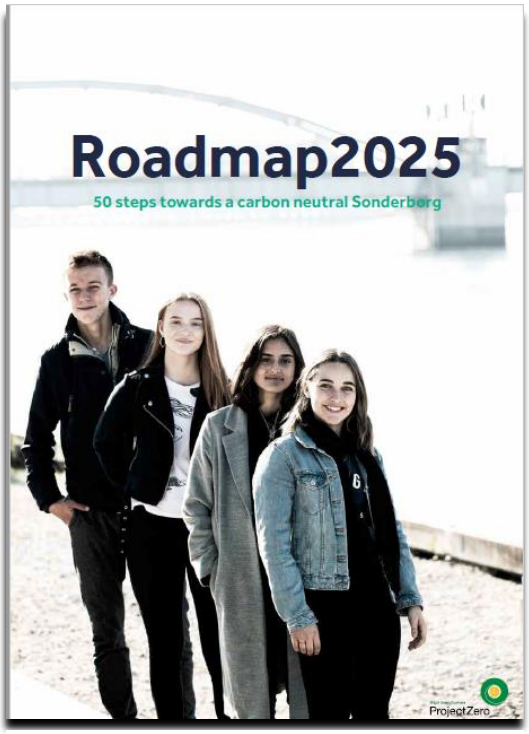

Figure 26: Roadmap2025 created as part of SEC WP8

The ProjectZero-vision was created by a local think-tank seeing the opportunity for Sonderborg to become a global front-runner in combatting the climate challenge by implementing the ZEROcarbon by 2029 vision (21 years ahead of Denmark), based on strong political commitment, citizen engagement, business innovation and green job creation.

In 2009, Sonderborg was awarded the EU Commissions “Energy Award” and in 2017 the Commissions “Cities in the Spotlight”.

Sonderborg’s ambition is to achieve the ZEROcarbon vision by 2029 and show the world, how a small and medium sized city can combat the climate challenge by co-creating ambitious goals, collaboration, planning and stakeholder- & citizen engagement.

A ProjectZero Masterplan2029 was created in 2009, followed by a Roadmap2015 (2009) and a Roadmap2020 (2014). The Roadmap2025 was created as an integrated part of the SmartEnCity project WP8 (during 2018), engaging more than 100 local experts and stakeholders.

ProjectZero helped Sonderborg municipality co-create the Sonderborg Green Transport strategy (2016), which became an important political strategy for approving the phase out of old diesel busses in the public transport system in 2017.

The ProjectZero-vision, being a political lighthouse of Sonderborg (city council), helped the WP5-partners implement the five demo actions.

5.2 Citizen engagement

Citizen engagement has been key to the success of all demo actions. Citizens (residents) are the real decisionmakers in the Sonderborg housing association, as the residents by a formal voting have to agree to the implemented actions and measures. Residents' behaviour also plays a vital role in securing that expected energy savings become real and not partly converted into a more comfortable indoor temperature and better living.

To secure a long-term strong citizen engagement at all housing association levels, Energy and Sustainable Strategies for all Sonderborg house associations were created and approved by the over all housing association boards in 2020. The creation process was part of the EU H2020 Happi project, which also supported a further engagement of all six Sonderborg housing associations in creating a joint Green Ambassador program.

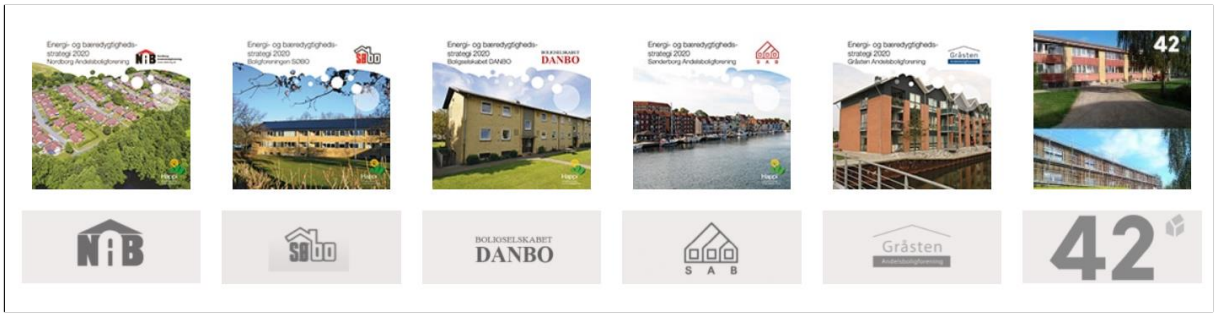

Figure 27: Energy & sustainability Strategies, created by the six house associations as part of the EU Happi-project

The developed strategies have helped the housing associations time and plan new initiatives (in time), in order to secure approval at the annual department investment meetings. For 2021 EV-charging infrastructure became a discussion point at all department meetings.

5.3 Technology readiness

Technology readiness can normally be scored on a scale from 1 – 10. But when it comes to making investment decisions including new technologies, a low score can be painful, even the technology might appear promising.

Also, in the Sonderborg demo-cases, technology readiness has been considered as part of the action planning and implementation.

Busses: Phasing out Sonderborg's old diesel busses sounded like a safe choice, but what would be the new safe choice - electrical or biogas busses? Electricity busses were considered, but biogas busses were chosen due to driving distance, charging time and maturity of electrical busses back in 2016, when decision was made. Today (2021), majority of busses are replaced by electrical busses, but still mainly when driving distance is short.

Batteries: In the PV solar storage task, new developed type of Lithium batteries are used for demonstration together with solar PV panels. Materials used for manufacturing lithium batteries are in the category “products with low sustainability”. Therefore, it was investigated to use so called “flow batteries” based on more sustainable materials instead of lithium batteries. However, flow batteries are still in a development phase, and the investment would be more than double compared to lithium batteries.

EV-chargers: the original plan was to implement smart EV-chargers, allowing the charging based on high availability of wind-energy. Unfortunately, the planned use of Evergreen chargers turned out not to function with no alternative option being available at the market (2019). Today such smart solutions are available.

ICT platform: The plan was for Vikingegaarden to create a city platform based on their proprietary ICT-system, which turned out would not function. Instead, the Telia Esti CIOP platform became a safe (investment) opportunity to replicate the Tartu CIOP solution in Sonderborg and allow the two cities to learn from each other. However, as ICT platforms continue to progress/develop and Telia mainly market the CIOP solution in Estonia, there is in future a risk, that the current advanced CIOP platform will be overtaken by new university open data platforms.

5.4 How SmartEnCity actions have catalysed other actions

A decision to replace Sonderborg’s old diesel busses by modern biogas-busses were taken by the Sonderborg city council in 2016. The replacement also required creating a new parking/fuelling facility for the 44 biogas busses. The contract was won by the Nature Energy biogas production company - and the biogas buss shift also catalysed the following additional climate actions in Sonderborg

- Nature Energy establishing a public gas-fuelling station, allowing new heavy-duty vehicles to be fuelled
- Nature Energy decision in 2017 to establish two large biogas production plants in Sonderborg, enabling the bus fuel to be locally produced

Figure 28: the biogas Glansager/Sonderborg plant

- Sonderborg municipality decision to implement new waste manage polity, demanding household waste to be sorted in 9 fragments – one of them being organic waste, feeding the biogas plant
- SONF-partner being the Sonderborg waste management operator, implementing electrical and gas-driven waste collection vehicles in 2020, has closed the circular economy loop, as SONF in 2020 also presented a new company sustainability report and company profile.
- and Sonderborg Municipality based on ProjectZero´s success implemented a municipal commitment to the UN Global goals – including a comprehensive benchmark report.

5.5 Availability of competencies

The SmartEnCity project has benefitted from strong competences in Sonderborg/Denmark to design solar PV and battery systems. However, still only little experience by Danish construction companies to implement and to maintain battery systems connected to solar PV. The SmartEnCity has helped local companies gain stronger system-knowledge in such new systems.

5.6 Change of national political framework

Denmark have undergone a major change in national framework since the SmartEnCity project started in 2016. A new climate Law was approved by the Danish Parliament in 2020 and retrofitting of housing association buildings became part of a boost green economy restart same year.

Stronger political frame-setting will increase citizen awareness of the importance of the green transition and green solutions, as demonstrated in the Sonderborg demonstration project and its five climate actions.

6 Outputs to other WPs

The D5.9 Report is completing the SmartEnCity WP5 demo action reporting. However, data collection and monitoring of the implemented actions will continue as part of WP7.

ZERO and partners will continue disseminate the solutions and results as part of WP8 and WP9, including further editions of the SmartEnCity Bulletin News.

ZERO will continue realize the CIOP 2.0 visions as defined in the Amendment 3 until the end of the SmartEnCity in summer 2022.