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TOWARDS SMART ZERO CO_2 CITIES ACROSS EUROPE
VITORIA-GASTEIZ + TARTU + SONDERBORG

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Table of content:

0 Publishable Summary ... 8
1 Introduction ... 11
1.1 Purpose and target group ... 12
1.1.1 D 4.3 Building retrofitting completed ... 12
1.1.2 D4.4 District heating and cooling system commissioned and deployed ... 13
1.1.3 D4.5 Street lighting commissioned and deployed ... 13
1.1.4 D4.7 Gas buses purchased and in operation ... 13
1.1.5 D4.8 Mobility infrastructure set up and in operation ... 13
1.1.6 D4.9 Bike-sharing system set up and in operation ... 14
1.1.7 D4.11 ICT infrastructure commissioned and deployed ... 14
1.1.8 D4.14 PV installations in use ... 14
1.2 Contributions of partners ... 15
1.3 Relation to other activities in the project ... 15
2 Objectives and expected Impact ... 17
2.1 Objective ... 17
2.1.1 D 4.3 Building retrofitting completed ... 17
2.1.2 D4.4 District heating and cooling system commissioned and deployed ... 17
2.1.3 D4.5 Street lighting commissioned and deployed ... 17
2.1.4 D4.7 Gas buses purchased and in operation ... 17
2.1.5 D4.8 Mobility infrastructure set up and in operation ... 17
2.1.6 D4.9 Bike sharing system set up and in operation ... 18
2.1.7 D4.11 ICT infrastructure commissioned and deployed ... 18
2.1.8 D4.14 PV installations in use ... 18
2.2 Expected Impact ... 18
2.2.1 D 4.3 Building retrofitting completed ... 18
2.2.2 D4.4 District heating and cooling system commissioned and deployed ... 18
2.2.3 D4.5 Street lighting commissioned and deployed ... 19
2.2.4 D4.7 Gas buses purchased and in operation ... 19
2.2.5 D4.8 Mobility infrastructure set up and in operation ... 19
2.2.6 D4.9 Bike sharing system set up and in operation ... 20
2.2.7 D4.11 ICT infrastructure commissioned and deployed ... 20
2.2.8 D4.14 PV installations in use ... 21
3 Demo implementations in Tartu ... 22
3.1 Building retrofitting ... 22
3.2 District heating and cooling system ... 33
3.3 Street lighting ... 36
3.4 Gas buses ... 40
3.5 Mobility infrastructure ... 43

3.6 Bike sharing system ... 48
3.7 ICT infrastructure ... 54
3.8 PV installations ... 57
4 Lessons Learned ... 58
4.1 Building retrofitting ... 58
4.2 District heating and cooling system ... 59
4.3 Street lighting ... 59
4.4 Gas buses ... 59
4.5 Mobility infrastructure ... 60
4.6 Bike sharing system ... 60
4.7 ICT infrastructure ... 61

Table of Tables:

TABLE 1 ABBREVIATIONS/ACRONYMS.......7
TABLE 2: CONTRIBUTION OF PARTNERS.......15
TABLE 3: RELATION TO OTHER ACTIVITIES IN THE PROJECT.......16
TABLE 4: DIFFERENCES OF SCOPE AND TARGETS OF RENOVATION.......24
TABLE 5: SUMMARY OF RESULTS OF RENOVATION SO FAR.......25
TABLE 6: INSTALLED PV-PANELS AND EXPECTED ELECTRICITY PRODUCTION.......26
TABLE 7 ENERGY PRODUCTION 2021.......36

Table of Figures:

FIGURE 1 LOCATION OF TARTU CITY.......... 11
FIGURE 2 LOCATION OF THE PROJECT PILOT AREA IN TARTU.......... 12
FIGURE 3 PROCESS MODEL OF RETROFITTING.......... 22
FIGURE 4 RENOVATION INTERVENTIONS IN TARTU.......... 23
FIGURE 5 SUMMARY OF RENOVATION RESULTS IN TARTU.......... 25
FIGURE 6 SMART HOME INSTALLATION SCHEME.......... 27
FIGURE 7 SMART HOME SYSTEM APPLICATION VIEW.......... 27
FIGURE 8 PUBLIC OPEN-AIR EVENT FOR INHABITANTS OF PILOT ÁREA.......... 29
FIGURE 9 MEETING WITH REPRESENTATIVES OF HOUSING UNIONS OF PILOT AREA.......... 30
FIGURE 10 SMART HOME TRAINING SESSION.......... 30
FIGURE 11 SMART HOME TRAINING SESSION.......... 31
FIGURE 12 AWARDING AMBASSADORS.......... 31
FIGURE 13 SMART CITY PLATFORM.......... 32
FIGURE 14 ENERGY DATA ON THE PLATFORM (RENEWABLE ELECTRICITY PRODUCTION IN LUTSU 16 BUILDING) 32
FIGURE 15 PRINCIPAL FLOW DIAGRAM OF COOLING PLANT.......... 33
FIGURE 16 FACADE OF COOLING PLANT WITH SOLAR PANELS.......... 34
FIGURE 17 SOLAR PANELS ON THE COOLING PLANT ROOF.......... 35
FIGURE 18 INSTALLATIONS IN TARTU LH PILOT AREA (TARTU LIGHTING MANAGEMENT SYSTEM).......... 37
FIGURE 19 VIZULO LUMINAIRES INSTALLED IN TARTU LH PILOT AREA.......... 37
FIGURE 20 INSTALLATION IN TARTU LH PILOT AREA.......... 38
FIGURE 21 SMART CONTROLLER.......... 38
FIGURE 22 SENSORS FROM PILOT AREA.......... 39
FIGURE 23 THE CONTROL SYSTEM.......... 39
FIGURE 24 NEW FILLING STATION.......... 41
FIGURE 25 BUS LINE NETWORK.......... 42
FIGURE 26 NEW VALIDATOR.......... 42
FIGURE 27 EV-CHARGING STATION INSTALLED IN TARTU.......... 43
FIGURE 28 LOCATIONS OF CHARGERS IN TARTU.......... 44
FIGURE 29 EV-BATTERY RE-USE SYSTEM.......... 45
FIGURE 30 SCHEME OF EV-BATTERY RE-USE SYSTEM.......... 45
FIGURE 31 USED BATTERIES.......... 46
FIGURE 32 SOLAR COMBINED BOX.......... 47
FIGURE 33 NISSAN CHARGER.......... 47
FIGURE 34 OPENING OF TARTU BIKE SHARE.......... 49
FIGURE 35 DATA FROM MOBILE POSITIONING (DAILY MOVEMENTS OF CITIZENS).......... 50
FIGURE 36 PROPOSALS FROM CITIZENS.......... 50
FIGURE 37 FINAL LOCATIONS (69) FOR BIKE SHARE STATIONS.......... 51
FIGURE 38 ELECTRIC BICYCLE.......... 51
FIGURE 39 SCHEME OF DOCKING STATION.......... 52
FIGURE 40 VIRTUAL STATION TECHNOLOGY.......... 53
FIGURE 41 DIGITAL SINGLE MARKET FOR CITY SERVICES.......... 54
FIGURE 42 CIOP MODULES.......... 55
FIGURE 43 CITY PORTAL LANDING PAGE.......... 56
FIGURE 44 MY DATA SOURCES.......... 56
FIGURE 45 DAL - MAPPED DATA SOURCES.......... 57

Abbreviations/Acronyms

Abbreviation/Acronym	Description
SmartEnCity	Towards Smart Zero CO2 Cities across Europe
SEC	SmartEnCity
WP	Work package
TAR	Tartu City Government
TREA	Tartu Regional Energy Agency
IBS	Institute of Baltic Studies
UTAR	Tartu University
ET	Telia
TAKSO	OÜ Takso
FTAR	Fortum Tartu AS (Gren AS)
PV	Photovoltaics
RES	Renewable energy source
DH	District Heating
DC	District cooling
DHC	District Heating and Cooling
RES	Renewable Energy Sources
DHW	Domestic Hot Water
SEC	SmartEnCity
WP	Work package
PV	Photo voltaic
FTAR	Fortum Tartu
HP	Heat pump
CHP	Combined Heat and Power
DCS	Distributed Control System
CH	Chiller
Gas buses	CNG buses
CNG	Compressed Natural Gas
AC	Alternate current
DC	Direct current
PV	Photo voltaic
CHAdeMO	Quick charging method for battery electric vehicles (Japan)
EV-charger	Quick charger for electric vehicles
EV-battery	Used batteries of electric vehicles
DAL	Data Access Layer
ESCO	Energy Savings Company
EC	European Commission
EU	European Union
EV	Electric Vehicle
GDPR	The EU General Data Protection Regulation
GIS	Geographic Information Systems
GUI	Graphical User Interface
ICT	Information and Communication Technology
KPI	Key Performance Indicator
PI	Performance Indicator

Table 1 Abbreviations/Acronyms

0 Publishable Summary

The main idea of the Tartu lighthouse project is to turn Hrustsovkas into 'smartovkas' with accompanying innovative solutions in integrated infrastructures, public transport, street lighting and monitoring. The aim of the investments is to create a high-quality living environment that inspires the pilot area community to make environmentally aware decision s and change their patterns of behavior.
In the field of **retrofitting**, the project seeks to tackle one of the greatest challenges of Europe's existing building stock – quickly deteriorating precast panel apartment buildings that were quickly produced in response to housing shortages. In case of Tartu, hrustsovkas make up a panel building type that was designed in the end of 1950's during the reign of Nikita Khrushchev and which were constructed in the 50's - 70's. With an average life cycle of 30-40 years, many of these buildings have already outlived their time, meaning that the shortcomings in quality are becoming increasingly evident and might even pose a threat to their residents. The main idea of Tartu's lighthouse project is to turn old Soviet-era panel buildings (khrushchyovkas or hrustsovkas) into smartovkas i.e. high-quality living environments with a drastically reduced energy consumption. Building retrofitting is the most complex and expensive task of Tartu demo area and has represented the biggest share from the all preparation activities. The complexity comes from the fact that the houses are owned by their residents (approximately 2000) through housing associations (22 organizations) which are the targets in the SmartEnCity project. As the residents are basically project partners in SmartEnCity it means the retrofitting task is, more than the others, a combination of technical, communicational and sociable variables. The objective of building retrofitting is to implement the 'smartovka' retrofitting model in the demo area of the Tartu Lighthouse based on the procedures developed within the project. The main aim of the retrofitting model is to significantly increase the energy efficiency of the buildings, provide a stable interior climate through temperature control and ventilation, increase the aesthetic appeal of panel buildings and thus create a sustainable and healthy living environment for citizens.

The new **district cooling system** in Tartu city Centre area was commissioned in 2016. New heat pump with thermal capacity of 1.4 MW cooling and 1.9 MW heating was installed as part of cooling plant. The installed HP is capable to produce 6-degree water for District cooling and 63 degrees water for DH system utilizing surplus heat from DC as heat source for DH system. The HP could reduce consumption of fuels in heat production and reduce CO_2 emissions. Also, there are significant indirect savings in CO_2 emissions because the efficiency of central cooling plant has 50…70% higher than local building base systems.
Also solar panels at the walls and roof of cooling station were installed to support CO_2 reduction.
Tartu has made a long-term commitment towards developing a smart city environment, acknowledging that smart solutions are mainly related to the fast growth of ICTs.
Smart city goals for deployment of **smart street lighting** is to rise energy efficiency and to reduce carbon emissions and socio-economic costs. To achieve these goals, the newest technology and ICT solutions have been used. The main result is the energy efficient public lighting with intelligent control system. The information from the installed sensors also serves a wider meaning in addition to lighting control, as it is possible to develop different services for residents in the future based on this information (N: based on the information of the environmental sensors, it is possible to design a running track with the cleanest air, etc.).

The installation of luminaires was completed in December 2017. Sensors were installed in the second part of 2018 and the intelligent control system is in continuous development.

The new biogas buses started operation in Tartu city bus lines on 1st of July of 2019. In total 64 new buses, manufactured in the Scania factory, started travelling along the routes, equipped with air conditioning, low bottoms and running on an environmentally friendly source of fuel.

As of 1 July 2019, the City of Tartu also switched over to a new bus route network, which differs significantly from the recent network in terms of itineraries, the number of lines, as well as the frequency of departures. New bus line network consists 13 regular bus lines (formerly 26 lines) along with two night lines. Company AS GoBus is operating new gas buses.

The new bus line network will raise the service level of public transport in Tartu - shortening bus intervals and increasing the speed of connections. The fastest connections make it possible to increase the attractiveness of public transport and bring drivers of private cars to use the public transport. This fact, combined with the reduced environmental impact of gas buses, will allow the maximum environmental benefits of public transport reorganization to be achieved. Tartu´s public transport is 100% carbon neutral as of January 2020.

One important part of Tartu city transport policy is the promotion of the use of alternative fuels in the city transport system. The city itself sets a good example here - public transport in the city was recently completely converted to gaseous fuel, at the disposal of city government officials (mainly social workers) are 26 electric cars, etc. As of November 2018, there are 5 **electric car chargers** available to the public, which were installed in the city center area of Tartu as part of the SmartEnCity project. What makes the installation of these chargers special is the fact that they are the first public electric car chargers in Estonia that can use both the CCS and CHAdeMO charging modes. The chargers have been already subjected to 5566 charging sessions since they were installed.

In addition to installing electric car chargers, OÜ Takso, a partner in the SmartEnCity project, created an **electric car battery re-use system** for charging electric taxis. The system allows to use old electric car batteries to store electricity and then charge the electric car. Solar panels are also integrated into the system, so that mostly renewable energy is used for charging. Only a small part of the electricity from grid is needed to charge vehicles (usually in the night-time and in winter when solar energy is scarce).

On 8th of June of 2019 Tartu City launched a city-wide **bike-sharing** (450 bicycles + 69 parking stations initially) and electric bike rental system (300 electric bicycles) consisting in total 750 bicycles and 69 parking stations. Since launching within the systems is made about 2 458 000 rides and the total distance traveled by the bicycles is about 6 560 000 kilometers. Bike sharing has been extremely popular in Tartu.

Developing a bike sharing system has been one of the mobility priorities of the City of Tartu. A respective feasibility analysis was carried out in 2014 and a business model was developed based on the findings. The aim of setting up a public bike sharing system aimed to encourage the use of bicycles and make this a considerable alternative to cars. It is expected that the bike sharing system will bring about decreased environmental problems (noise, air quality), parking issues and problems with traffic intensity. Bike sharing is considered a part of the public transport system of the City of Tartu.

Bike sharing- and electric bike rental systems are connected into one combined Smart bike sharing system to ensure efficient management and both have been set up within the SmartEnCity project. The system is mainly targeted at people who need to travel ca. 2-5 km to work, school, home etc. Broadly speaking, the bike sharing system consists public city bikes, parking lots with safety locks and a software system that enables to manage rides, rent out a bike in one of the parking locations and redock it in another. The service users are identified through Tartu's smart card (also used for other modes of transport) or mobile app. Visitors and tourists can join temporarily with their credit cards. The system is operated by the substructure of the Tartu City Government – Tartu Linnatransport.

Tartu has a long tradition of using smart solutions to enhance its citizens' quality of life. Various **ICT solutions** are an integral part of this approach and the reason for incorporating them also into the Tartu SmartEnCity project. ICT solutions will not only boost the development of Tartu as a smart city but also offer comfort, security and an enhanced quality of life for its pilot area citizens.

The reasons for including ICT solutions in the Tartu SEC project are numerous as they:

- enhance automation and thus also increase optimization.
- gather all city-wide data relevant into one innovative platform.
- enable to freely monitor all the data both on a city, building and apartment level.
- enable to monitor the functioning of systems and prevent and detect errors.
- increase residents' awareness of their energy consumption and thus allow the residents to make better informed consumption decisions.
- increase both the residents' and Tartu citizens' awareness of the potential of ICT solutions and how they can benefit their everyday life (i.e. the smart home systems that will be installed in the pilot area smartovkas).

To this end, the ICT infrastructure and the CIOP that has been deployed in Tartu includes an integration of several city-wide smart solutions: district heating, smart city lighting, smart buildings and apartments, traffic and public transport etc.

Tartu City Government owns a number of different buildings - schools, kindergartens, social houses, sports buildings, administrative buildings etc. With support of SmartEnCity Project there will be installed **solar panels** on 4 buildings with total capacity of 210 kW. The installation of solar power plants will significantly reduce the environmental impact of electricity generation and increase energy autonomy in public buildings.

1 Introduction

Tartu, with its population of 100,000 is the second largest city in Estonia. Lying 185 kilometers south of Tallinn, Tartu is also the centre of South-Estonia. Tartu is known as a green, innovative and environment-friendly city. The slogan of Tartu is "The City of Good Thoughts". Tartu is a city of education and well known for the University of Tartu founded in 1632.

Figure 1 Location of Tartu City

The aim of the environmental policy of Estonia and of Tartu is to reach climate neutrality at latest by 2050. According to Tartu´s Energy and Climate Action Plan "Tartu energia 2030" the vision of Tartu City is:

Tartu is a smartly developing community with good energy, and a green pioneer.

Pilot area

According to statistics, ca. 6,500 people lived in the city center of Tartu, making up ca. 7% of all citizens. The pilot area includes a part of the city center with about 4,000 citizens. The population density of the city center is about 3,600 people/km2. The pilot area includes the University of Tartu Library, the Vanemuine Theatre, a big shopping mall, offices as well as several residential areas.

In the city centre, there are 42 hrushchyovka-type apartment buildings which were mostly built in the 1960´s. The inhabitants are socially mixed and diverse. The apartments are privately owned and, in many cases, rented out (e.g. for students).

The pilot area makes up the part of Tartu that was completely destroyed in World War 2 bombing. This left the city center of Tartu empty and under the Hrushchev housing scheme, it was decided that the area be filled with panel buildings. With little aesthetic appeal and low construction quality, the city has now taken the aim to renovate and smarten up these 'relics' of the past.

There are 42 panel buildings in the pilot area, out of which 18 are smartened up with help of the project. The total area of these panel buildings in the pilot area is 79,000 m2, out of which 35,216 m2 is renovated. Altogether, ca. 1,620 residents of the pilot area (out of ca. 4,000) have been affected by renovation activities.

Figure 2 Location of the project pilot area in Tartu

1.1 Purpose and target group

1.1.1 D 4.3 Building retrofitting completed

The objective of the retrofitting plan was to drastically reduce the energy usage of the demo area hrustsovkas. The average energy consumption of these buildings was before the retrofitting about 270 kWh per m2 annually and the target level is 90, reducing energy consumption by more than 66%. This ambitious goal is not achievable by only using regular insulation technologies. A combination of different measures are needed, including ventilation with heat exchangers, and using local energy production. All of the technical solutions are accompanied with modern ICT technologies for the best outcome.
Target group include other partners of SEC project but also citizens and other interested groups in retrofitting of existing buildings into low energy buildings.

1.1.2 D4.4 District heating and cooling system commissioned and deployed.

The solution introduced in Tartu is meeting consumer demands for thermal indoor comfort and domestic hot water while retaining high energy efficiency and share of renewable energy. In essence, the situation in the pilot area apartment houses whereby hot water is usually produced locally with electric boilers have been replaced with a system whereby hot water is supplied from the district heating network. The new district heating and cooling system created in Tartu is using residual heat from cooling for producing hot water, which will be supplied through the existing district heating network. As Tartu uses wood chips in its district heating, the system is already almost 100% renewable (only top load will be covered from natural gas). Installed heat pump is thus increasing the RES share in district heating system.
Target group include other partners of SEC project but also target groups interested in implementation of new district heating and – cooling systems.

1.1.3 D4.5 Street lighting commissioned and deployed.

The public lighting systems in cities are often based on HPS luminaires, which consume a lot of energy. New LED technologies in streetlighting allow significant energy savings to be achieved immediately after implementation. The lifetime of these LED lights is expected to reach 100,000 hours in a few years. During the entire lifetime of the lighting systems, the smart control paradigm will save an additional 42% of energy (reducing an equal amount of carbon emissions compared to the same streetlights working on a static regime).
Target groups include, SEC partners, municipalities, NGOs, and activist groups working for sustainable living environment and carbon free future.

1.1.4 D4.7 Gas buses purchased and in operation

Transport is one of the biggest polluters in Europe and a threat to a healthy urban environment. In order to improve the situation, it is necessary to quickly find environmentally friendly solutions for the transformation of public transport systems in cities. The City of Tartu decided to switch 100% on compressed gas buses and start to use biomethane in buses.
Target group include other partners of SEC project but also target groups interested in implementation of carbon neutral public transport systems.

1.1.5 D4.8 Mobility infrastructure set up and in operation

In the beginning of the project 11 public fast charging points for electric vehicles existed in Tartu, In order to meet the increased demand of charging infrastructure as a result of rising numbers of EVs in the city 5 fast charging points have been installed in public locations in the city center area to provide the needed energy for the new EVs.
One of the central ideas of the project in the field of mobility is to reuse EV batteries for storing energy. As electric vehicles are gaining popularity everywhere, solutions for

repurposing their deteriorating, but still valuable batteries (delivering 70-80% of their original output at end of life) have become essential and will yield many environmental benefits.
Target group include other partners of SEC project but also users of electrical vehicles and companies offering charging services.

1.1.6 D4.9 Bike-sharing system set up and in operation

The establishment of an electric bike rental system and public bike-sharing allows for the best possible result in environmental sustainability and public good in mobility activities within the set budget. Experiences in other cities shows that the implementation of electric bike-sharing systems increases the duration of cycling sessions and the distances covered compared to regular bikes. Bikes in an electric bike rental system are used more often and the system is more efficient.
Target group include other partners of SEC project but also citizens and other cities interested in implementation of bike-share systems.

1.1.7 D4.11 ICT infrastructure commissioned and deployed

Without high-quality data, it is very difficult to make sustainable decisions in the city management. It is becoming increasingly clear that decision-making processes must be data-driven. To ensure this, it is necessary to set up appropriate ICT infrastructure in cities, which will enable data to be collected, processed, presented and also made available to all parties. In Tartu was introduced the ICT infrastructure (City Information Open Platform-CIOP) that is needed for data harvesting, monitoring and evaluation.
Target group include other partners of SEC project but also citizens and other cities interested in implementation of ICT infrastructures.

1.1.8 D4.14 PV installations in use

Currently, the most of electricity in Estonia is generated from the oil shale, making the national energy mix the most carbon intensive in the EU. It is therefore necessary to find on-site opportunities for electricity generation. In addition to reducing environmental impact, local solutions also help to achieve independence and autonomy. Within the project will be installed solar power plants in 4 municipal buildings having high energy consumption.
Target groups include SEC partners, citizens, municipalities, NGOs, and activist groups working for sustainable living environment and carbon free future.

1.2 Contributions of partners

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

Participant short name	Contributions
TAR	Overall & general content
IBS	Engagement and Smart Home system
TREA	Retrofitting, monitoring
UTAR	Social innovation, monitoring
ET	ICT and monitoring
TAKSO	EV battery re-use
SCL	Building retrofitting, ICT and monitoring
FTAR	Integrated infastructures
CTEL	Public lighting

Table 2: Contribution of partners

1.3 Relation to other activities in the project

The following Table 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
D4.1	This deliverable provides the overall description of the current state of the lighthouse city area and will provide a comparison in future after demo actions have been implemented
D4.11	ICT platform
D4.12	Citizen engagement and replication
D7.8	This deliverable provides the overall description of the KPI's and therefore the measurements to be implemented in building retrofitting
D4.3	Building retrofitting

D4.4	District heating and cooling system commissioned and deployed
D4.5	Street lighting commissioned and deployed
D4.7	Gas buses purchased and in operation
D4.8	Mobility infrastructure set up and in operation
D4.9	Bike sharing system set up and in operation
T4.2	Citizen engagement actions. This task seeks to develop and test social innovation models for changing citizen behaviour and their adaptation to new technologies in Tartu. The sub-tasks include studying socio-economic conditions, consumption levels and community behaviour (e.g. databases, ICT solutions and sensors, questionnaires); the theoretical and methodological development of social innovation models (e.g. theoretical work, focus groups, experimental research, development of motivation schemes) as well as testing and evaluating social innovation models, followed by data analysis and improving the overall citizen engagement model.
T4.3	District integrated intervention. This task will develop detailed management procedures and deployment plans for implementing the demo actions in all of its pillars (building retrofitting (i.e. the 'smartovka' model), integrated infrastructures and sustainable mobility) and carrying out the ICT deployment in a coordinated way so that synergies and economies of scale can be harnessed, coordination problems can be solved and the underlying potentials can be fully exploited.
T4.4	Building retrofitting. The objective of task 4.4. is to implement the 'smartovka' retrofitting model in the demo area based on the procedures developed under T4.3.
T4.5	Integrated infrastructures . Following the procedures developed under T4.3, task 4.5. is about introducing a district cooling system that produces heat for the district heating system by using residual heat. This solution will be accompanied by smart meters so to collect real-time data on consumption (cf. T 4.7) and a smart street lighting system with intelligent controlling. In addition, PV panels will be installed in a number of public buildings.
T4.6	Smart mobility. Following the procedures developed under T4.3, the aim of task 4.6. is to implement a set of smart mobility activities that cover different means of transport. Combining the benefits of biogas and electricity, the aim is to introduce 100% biogas buses accompanied by new charging points for public use. In the field of light transportation, electric bikes will also be available in EV rentals and a general bike-sharing system will be set up. Finally, a system for re-using EV batteries for storing renewable energy will be set up.
T4.7	ICT´s. Under this task, the deployment of the ICT infrastructure that is needed for data harvesting, monitoring and evaluation in Tartu's Urban Management System will take place. Also, the specific infrastructure needed for the deployment and operation of the City Information Open Platform (CIOP) will be set up.

Table 3: Relation to other activities in the project

2 Objectives and expected Impact

2.1 Objective

2.1.1 D 4.3 Building retrofitting completed

The main objective of this activity is a deep renovation of high-energy consuming apartment buildings into energy-efficient, near to zero energy buildings. The further goal is to achieve zero carbon urban environment.

2.1.2 D4.4 District heating and cooling system commissioned and deployed

The main objective of this activity was to implement innovative and environmentally friendly solution where district cooling, district heating and solar PV panels are integrated as one effective production unit. Monitoring of performance of the installation and summary of final results will reflect the effect of investments made.

2.1.3 D4.5 Street lighting commissioned and deployed

The unique combination of field-proven wireless technology, which has been previously applied in security and Smart City applications, and smart energy management enables massive and low-cost smart street lighting installations for reducing energy consumption. The aim was to bring intelligence and data processing to the device level and build networks of locally collaborating self-aware devices – sensors and luminaire controllers.

2.1.4 D4.7 Gas buses purchased and in operation

Across Europe transport accounts for about 20 % of all greenhouse gas emissions, nearly half of it is related to passenger transport. To reduce the carbon footprint of mobility, public transport has to be strengthened, especially in rural and suburban regions that represent bottlenecks in public transport networks. To meet the challenges of the era, the city of Tartu decided to use in the public transport system only biogas buses for next 10 years and to re-organize the public bus network.

2.1.5 D4.8 Mobility infrastructure set up and in operation

The main objective of this activity was to strengthen the usage of alternative fuels (electricity) and RES in transport sector and create an innovative EV-battery re-use solution. Interventions will reduce CHG emissions from transport sector and make the city more livable place.

2.1.6 D4.9 Bike sharing system set up and in operation

Implementation a city-wide bike sharing- and electric bike rental system that complements the existing public transport system ultimately helps to reduce CHG emissions and car traffic in the city.

2.1.7 D4.11 ICT infrastructure commissioned and deployed

Under this task the deployment of the ICT infrastructure that is needed for data harvesting, monitoring and evaluation in Tartu's City Information Open Platform (CIOP) was set up. This infrastructure deployment was planned and carried out in close coordination with other activities of WP4. As the most tangible outcome for the pilot area residents, all apartments in retrofitted buildings received a smart home system equipped with software that enables to monitor their energy consumption and control the functioning of their new smart homes.

2.1.8 D4.14 PV installations in use

With support of SmartEnCity Project installation of solar parks on 4 public buildings with total capacity of 210 kW will be deployed. The activity will reduce CO2 emissions from electricity use by 213 tonnes per year.

2.2 Expected Impact

2.2.1 D 4.3 Building retrofitting completed

The impact of building retrofitting is quite wide, and it appears in several areas as reduction of CO2 emissions, as boosting a production of green electricity, as benchmark for future retrofitting in building sector and as a role model of sustainable living environment. Building retrofitting is offering for society many benefits and opportunities on the way to climate neutrality - cleaner city environment, change of energy consumption patterns of citizens, better health of citizens etc. The reduction of usage of fossil fuels and thus reduction of CO2 emissions is the main expected impact. The estimated annual reduction of energy is about 6 000 000 kWh and CO2 emissions about 922 t.
The retrofitting activities will contribute to the city climate policy targets – increasing the total capacity of privately owned PV power plants and consumption of locally produced electricity.

2.2.2 D4.4 District heating and cooling system commissioned and deployed

The impact of solution is quite wide, and it appears in several areas as reduction of CO2 emissions, as benchmark for future DHC developments, as customer friendly service for society with many different aspects. The reduction of usage of fossil fuels and thus reduction

of CO2 emissions in DH is the main expected impact. The estimated annual reduction of CO2 emissions will be 373 t,
Production of cooling in industrial plant have significantly higher efficiency compared to small local solutions. It has estimated that industrial cooling application using 50…70% less electricity compared to local solution. It led to higher energy efficiency and therefore to remarkable reduction of CO2 emissions. Important aspect is that in the smaller usage and leakages of F-gases has been expected. In case of central production there is only few industrial cooling machines installed and the total amount of F-gases used is much less compared with sum of usage in customer's solution. Also, leakages of F-gases from cooling plant are much smaller compared to sum of leakages at customer's solution. F-gases have impact to global warming and therefore the reduction of F-gas usage has positive impact. Also, in case of industrial solutions it is much easier to change the used F-gas with more environmental friendly gases like CO2, ammonia or HFO which have GWP value close to 1.
Fuel free solutions in heating sector is the future. HP solution, where surplus heat from DC is used as heat source together with PV panels is interesting case for benchmark. The solution could by as lighthouse for other new developments.

2.2.3 D4.5 Street lighting commissioned and deployed

The features provided by the technology provide a clear business advantage, improving the rate of adoption of the smart streetlight control technology, thereby resulting in reduced power consumption, carbon footprint and light pollution.
On the wider level, the proposed smart streetlight control solution has the potential to change the market in a big scale, allowing municipalities to start saving right from the moment of the installation. Furthermore, as savings are instant, it will also reduce the payback period of the LED street luminaire, which will lead to much wider market uptake of saving energy in streetlight installations. The lifetime of these LED lights is expected to reach 100,000 hours in a few years. During the entire lifetime of the lighting systems, the smart control paradigm will save an additional 42% of energy (reducing an equal amount of carbon emissions compared to the same streetlights working on a static regime). Expected annual reduction of carbon emissions (CO^2) is 164 t. Expected energy efficiency (energy saving) is 138 729 kWh in year.

2.2.4 D4.7 Gas buses purchased and in operation

The impact of deployment of biogas buses is multiple. Main impact is a reduction of CO^2 emissions, but there are several side impacts, which are significant in terms of city environment and sustainability – cleaner city environment, reduction of private car traffic, change of movement patterns of citizens, better health of citizens etc.

The reduction of usage of fossil fuels and thus reduction of CO^2 emissions in transport system is the main expected impact. The estimated annual reduction of CO^2 emissions is 5280 tons.

2.2.5 D4.8 Mobility infrastructure set up and in operation

The main impact of this deployment is a reduction of CO^2 emissions from car usage, but there are several side impacts, which are significant in terms of city environment and sustainability – cleaner city environment, better health of citizens etc. The reduction of usage of fossil fuels and thus reduction of CO^2 emissions in transport system is the main expected impact.

This activity has great impact on future trends. As part of the activities, public EV-chargers for electric cars were installed in the downtown area of Tartu, which enables the use of chargers in addition to the CHAdeMO charging standard for CCS charging standard vehicles. Thanks to the new possibilities, new electric vehicles have already appeared in the cityscape.

However, the re-use system for old electric car batteries developed by OÜ Takso helps solve the problem of batteries that have become obsolete - to give them a new life as energy storage devices.

2.2.6 D4.9 Bike sharing system set up and in operation

The impact of this activity is multiple, but main impact is a reduction of CO^2 emissions from city transport system. In addition, there are several side impacts, which are significant in terms of city environment and sustainability – cleaner city environment, reduction of private car traffic, change of movement patterns of citizens, better health of citizens etc.

The estimated annual reduction of CO^2 emissions is 1079 tons in case of bike sharing and 711 tons in case of electric bike rental system. In total is annual expected reduction of CO^2 in Tartu transport system at minimum 1890 tons from implementation of Smart bike sharing system.

2.2.7 D4.11 ICT infrastructure commissioned and deployed

Tartu has a long tradition of using smart solutions to enhance its citizens' quality of life. Various ICT solutions are an integral part of this approach and the reason for incorporating them also into the Tartu SmartEnCity (SEC) project. ICT solutions will not only boost the development of Tartu as a smart city but also offer comfort, security, and an enhanced quality of life for its pilot area citizens.

There are numerous positive impacts of ICT deployment:

- enhancement of automation and thus also increase optimization of energy use.
- city-wide data gathering into one innovative platform.
- data both on a city, building and apartment level is gathered and available for future analysis.
- possibility for monitoring the functioning of systems and prevent and detect errors.
- increase residents' awareness of their energy consumption and thus allowing the residents to make better-informed consumption decisions.
- increase both the residents' and Tartu citizens' awareness of the potential of ICT solutions and how they can benefit their everyday life (i.e. the smart home systems).

2.2.8 D4.14 PV installations in use

The activity will reduce CO_2 emissions from electricity use by 213 tonnes per year. Currently, most of electricity in Estonia is generated from the oil shale, making the national energy mix the most carbon intensive in the EU. As a side effect the local renewable electricity production will have a positive impact on energy security.

3 Demo implementations in Tartu

3.1 Building retrofitting

The main idea of Tartu's lighthouse project was to turn hrushchyovkas (a type of panel buildings that were constructed during the reign of Nikita Hruschchev starting from the 1950s) into smartovkas (i.e. high-quality living environments that inspire the community to make environmentally aware decisions and to change their patterns of consumption behavior) with a drastic reduction in the energy use of the buildings. With an average life cycle of 30-40 years, many of the hrushchyovkas have been already outlived their time, meaning that the shortcomings in quality are becoming increasingly evident and might even pose a threat to their residents. Hereby, the SmartEnCity approach proceeds from an understanding that new buildings are constructed according to high contemporary standards and are thus energy-efficient anyways – the true challenge was how to retrofit the old panel buildings that have great energy saving potential.

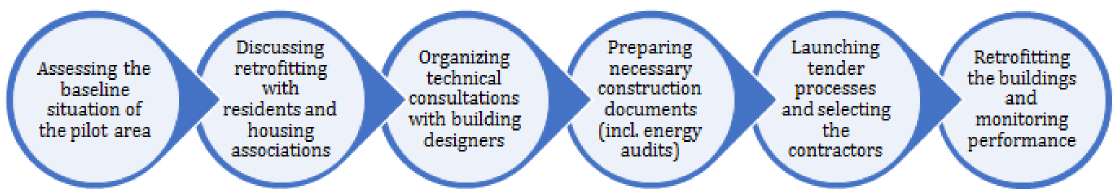

Figure 3 Process model of retrofitting

Tartu piloted a series of retrofitting solutions in 18 hrushchyovkas in the city center. Increasing the energy performance of the demo area's housing stock through the smartovka renovation package reduced energy consumption from the ca. 270 kWh/m2y to 90 kWh/m2y (i.e. meeting class A requirements). The solutions included:

- Insulating all outer walls of the buildings (weighted average level U≤0.22 W/(m2*K));
- Replacing all windows with triple-glazed windows (integrated thermal transmittance level U≤1.10 W/(m2*K)) and adding an insulation layer;
- Replacing all front doors to reduce heat loss;
- Insulating and reconstructing the roofs (heat transfer coefficient U≤0.12 W/(m2*K));
- Installing a ventilation system with heat exchangers;
- Reconstructing the central heating system and installing thermostatic valves that allow to adjust room temperature in the range of 18-23°C;
- Adding low-temperature cooling systems to complement the district heating system;
- Installing PV panels to provide additional energy for the buildings;
- Applying art solutions on the facades to increase the aesthetic appeal of the buildings;
- Setting up a smart home system

Renovation activities have been funded in combination of Commission funding, a national support scheme (KREDEX) and additional loans taken by the dwelling owners.
Retrofitting activities have been the most complex and time consuming for the Tartu pilot project. Renovations with such an approach and scope have not been carried out in Estonia

before, which is why in some cases the methodology and technical solutions had to be created during the operation. The project team and other Estonian partners made significant contributions to the development of various technical solutions (especially building ventilation solutions and smart home solutions) and to the involvement of residents in the renovation process.

Renovation process

Renovation process was started from rising awareness among potential beneficiaries in pilot area by info days, announcements and meetings with citizens and building associations. All together 42 buildings were defined to be eligible as beneficiaries.

The aim was to retrofit buildings mostly from 1960ś -1970´s and had certain type - called „hrushchyovkas". Selection of that type was chosen by several practical reasons - the energy consumption of such type buildings is very high and replication potential is huge. There has a lot of same type buildings in Tartu, in Estonia and even in whole Eastern Europe.

During the pilot was tested a deep renovation and mixed financial models, to break the barriers of renovation wave in Tartu and how to achieve high energy efficiency targets (more ambitions then national) through deep (and smart) renovation. Renovation model was worked out by the Estonian project consortium.

Thank to project activities was boosted a development market of renovation and especially in technical designing and construction works processes. For this reason, the procurements for technical design and construction works was made separately by every apartment association (apartment association is legal body formed by apartment owners in every multiapartment buildings in Estonia).

The retrofitting works in Tartu covered practically all parts of the buildings. The largest part in terms of volume was the insulation of various parts of buildings and the renovation of heating and ventilation systems. The following illustration shows the main construction works in the renovation process:

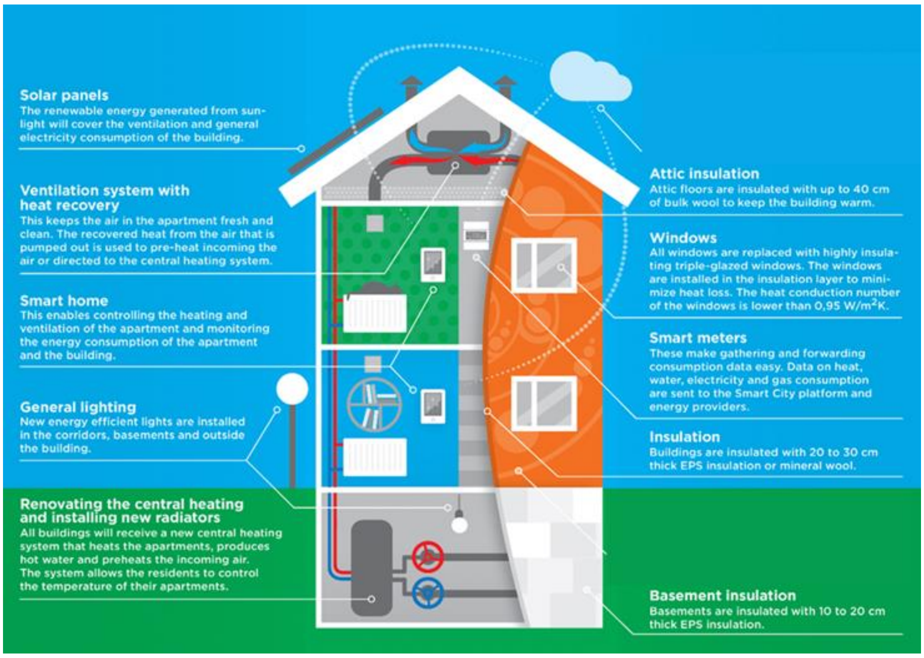

Figure 4 Renovation interventions in Tartu.

Measure/	National requiremets	SmartEnCity requirements
Energy performance label	< 150 kWh/m^2 a, „C“	<90 kWh/m^2 a, „A“
Windows	U= 1,1	U= 1,0
Wall insulation		Ca 10% better of „C“
PV	Not obligatory	Installed 24-50 kW on each building
Ventilation	with heat recovery	with heat recovery demand based (CO2)
Smart home	not obligatory	Installed
work of art on exterior walls	not obligatory	installed
Training for residents	not obligatory	Done, several meetings and info days (twice a year)

Table 4: Differences of scope and targets of renovation

Summary so far

The renovation of the buildings has been successful on the example of the Tartu pilot. According to monitoring data, the target (at least 60% energy savings) in energy use was met and the target for on-site production of renewable electricity was exceeded. The amount of renovated m^2 was somewhat smaller (less than 10%) than originally planned. However, the project is likely to exceed its CO^2 reduction target. The project convincingly proved that the renovation of similar apartment buildings into a high "A" energy class is completely feasible and the renovation practice in Tartu can be transferred to other European regions as well.
The figure and tables below illustrate the results so far of the renovations.

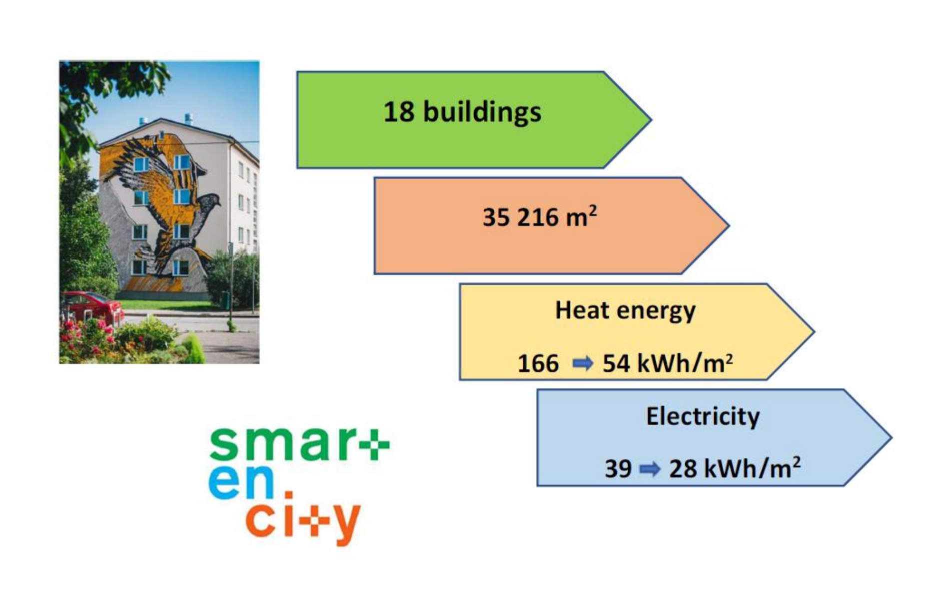

Figure 5 Summary of renovation results in Tartu.

The table below shows the monitoring results by building. As the renovations were completed at different times, unfortunately not all data are fully comparable, but we can still make a preliminary summary. It should be noted that in most cases the energy impact of renovations will not be felt until the second year after the end of the renovation. This is mainly due to the moisture stored in the structures during construction work.

Building	EPC before, kWh/m2 a	EPC after, kWh/m2*a	EPC reduction, %
1	227	128	44%
2	254	122	52%
3	267	89	67%
4	279	91	67%
5	244	162	34%
6	259	82	68%
7	237	103	57%
8	254	101	60%
9	234	97	59%
10	264	X	X
11	269	75	72%
12	300	65	78%
13	272	141	48%
14	246	91	63%
15	239	X	X
16	245	80	67%
17	271	103	62%
18	257	81	68%
Average	**257**	**101**	**60%**

EPC - Energy Performance Certificate

Table 5: Summary of results of renovation so far

The project originally planned to install 253 kWp of solar power plants on the buildings to be renovated. Largely due to the fact that the capacity of solar panels has increased over time and newer technical solutions were used in the renovated buildings (especially in the case of ventilation) it was possible to install solar power plants with higher capacity than planned. A total of 554 kWp. The table below shows the installed capacity of the solar power plants by buildings.

Building	Installed PV-panels (ETA), kW	Expected production (ETA), MWh/y
1	51,6	43,0
2	25,0	19,2
3	30,0	23,0
4	20,0	17,3
5	23,9	17,8
6	25,0	22,7
7	30,0	23,0
8	30,0	27,6
9	25,0	19,2
10	33,6	33,5
11	27,1	25,1
12	27,1	25,1
13	23,4	19,8
14	46,5	35,7
15	67,0	54,7
16	15,0	19,8
17	24,0	18,4
18	30,0	25,9
TOTAL	554,2	471,0
AVERAGE	30,8	26,2

Table 6: Installed PV-panels and expected electricity production

Smart home system

The smart home system for Tartu apartment buildings was procured by public international tender in 2018. The best offer was made by a local company EnLife OÜ, whose bid was the only one within the budget limit. The system and devices were installed to all 18 buildings and each of the 691 apartments. The house associations could choose between radio (11 buildings) and cable (7) installations. From the project perspective it was important to test out different solutions and bring them to the market – at the time, there were no existing smart home solution providers for retrofitted apartment buildings.

Smart home installation scheme:

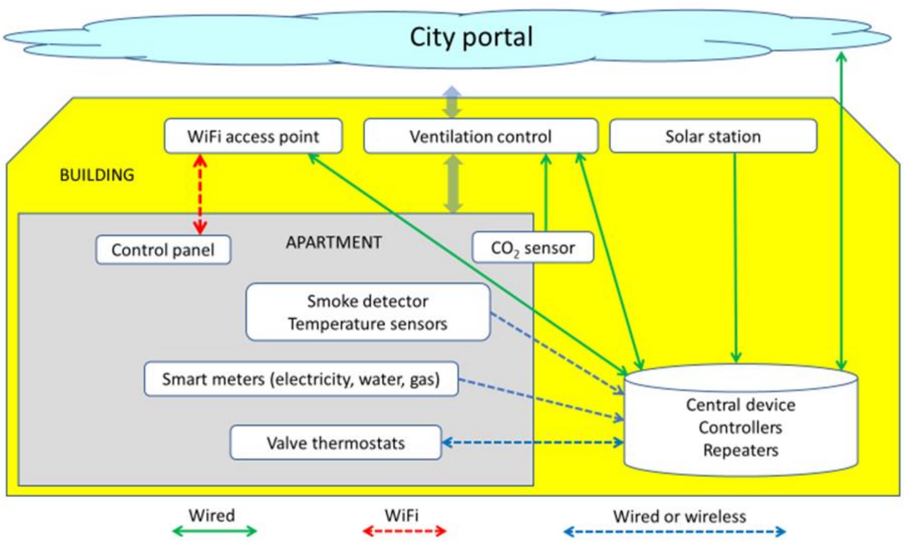

Figure 6 Smart Home installation scheme

Every apartment was equipped with smart electricity-, water- and gas meters, temperature and smoke sensors, CO2 sensors and valve thermostats (to control the rooms' temperature). On the wall close to the apartment entrance door was mounted a tablet to allow the residents to monitor their energy consumption and building's PV panels production, apply energy saving rules, control ventilation and temperature in rooms and open the building's front door to visitors. In addition, the system allows to use videocall with visitors at the building's front door.

In every building, there is a central device which stores sensors data, controls rooms temperature, communicates with the ventilation device and PV inverters, provides information for home tablets and mobile apps. The aggregated energy data is sent to the central city portal. Hardware and software for central device, controllers, repeaters, access points, cable sensors and impulse meters were developed by EnLife OÜ.

The smart home system can be used both via the smart home tablet in the home or a mobile app.

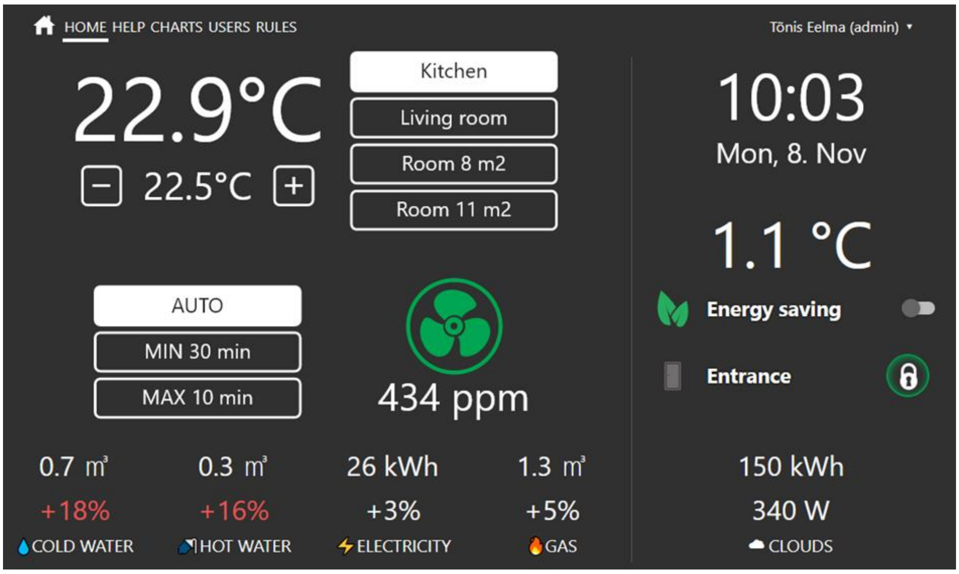

Figure 7 Smart Home system application view

Smart home printed user manual was delivered to all apartment residents and made available also on web https://tarktartu.ee/nutikodu-juhend .
As a result, building residents got a tool to control and optimize their everyday energy consumption. The house associations can gather consumption data (this was done manually before) and make billing automatic, also they have better general view of the energy consumption of the building. Individual temperature and ventilation control was enabled for residents, and separated ventilation system and CO2 level monitoring was especially useful and welcome during the COVID period.
Some problems were encountered in terms of technology - radio devices had connection problems in several places and extra efforts had to be made to get the system to work properly.

Engagement activities in Tartu during renovation

There were three main goals on engagement in the pilot area in Tartu:

1. To motivate the housing associations to join the SmartEnCity project and renovate their buildings;
2. To introduce the project and its activities to both the pilot area and other citizens, and to get them engaged and active;
3. To conduct social innovation experiments and offer educational events and programs in order to increase acceptance and awareness of new technologies, solutions and smart living.

To engage residents and housing associations in renovation, the engagement working group was formed in Tartu of key local partners who had the most tasks related to engagement and who were most necessary for the regular coordination and implementation of engagement activities. These partners are:

- The Institute of Baltic Studies (IBS; working group leader);
- Tartu City (TAR);
- The University of Tartu (UTAR);
- Tartu Regional Energy Agency (TREA);
- Smart City Lab (SCL).

The engagement working group started working and regularly meeting every two to three weeks once the project was officially launched. The first and foremost goal of the engagement target group was to reach out to housing associations to introduce the new renovation opportunity.
The engagement working group also compiled the Communication and Engagement Plan, an internal working document that includes the local goals and actions of communication and engagement, a description of the pilot area, project milestones, social innovation goals, indicators and a risk assessment. This document has been important in guiding and recording engagement activities in the pilot area.

The engagement process to introduce the new renovation opportunity and to help housing associations in reaching a decision to renovate in Tartu had five stages:

1. In the initial stage, the housing associations were contacted to introduce the renovation possibilities.
2. In the second stage, the housing associations had an internal discussion and made the final decision about renovation.
3. In the third stage, the associations together with building designers designed the building plan.
4. In the fourth stage, the building companies contracted by the contractors renovated the buildings.
5. In the fifth and final stage, the associations started using the renovated buildings.

Numerous different communication and engagement tools were used during and after the renovation period to 1) stay in touch with the residents, 2) inform them of upcoming events and activities, 3) to gather feedback, 4) to raise awareness of the project.
The most important of these were:

- Local project webpage and Facebook page
- Public information events for pilot area residents on project progress and renovation
- Information events for housing association representatives on project progress and renovation, and more specific topics, e.g. ventilation, the smart home, etc.
- Smart home trainings for pilot area residents
- Public art tours and art exhibition on the pilot area murals and artworks
- “Smart house resident’s handbook” and a smart home system instruction manual
- Flyers, stickers
- Illustrated map of the pilot area which shows the locations of all the renovated houses
- Regular newsletters and emails via the mailing lists
- Local project videos
- Articles in local media (newspapers, magazines, radio and TV)

Figure 8 Public open-air event for inhabitants of pilot área

Figure 9 Meeting with representatives of housing unions of pilot area

Figure 10 Smart Home training session

Social innovation – Ambassador program

Peoples' everyday life practises are difficult to alter, however, the technical transformations of the buildings and apartments may affect occupants' everyday life practices. For example, in non-renovated hrushchyovkas, a common practice is to open windows when ventilation is insufficient. In fact, according to a pre-renovation survey of residents in the pilot area, three-quarters of residents opened their windows at least once a day (SmartEnCity pre-renovation survey report, 2018). However, once the new ventilation systems were installed, this practice has to change to enable the normal functioning of the sensor-based ventilation system. Research has shown that social interaction, namely communication and dialogue, is crucial in adapting to interventions to retrofit buildings (Chiu et al., 2013; cit. Lowe et al., 2018) and social learning, i.e. learning from others (Bandura, 1977) can help to diffuse knowledge, competence, and therefore affect the technology and retrofit acceptance rates in general.

Based on social learning concept, Ambassadors program was developed as a social innovation experiment. This program aimed to raise awareness about retrofitted buildings, indoor climate, smart home system and consumption among pilot area residents. The training program was developed to encourage pilot area residents to learn from each other by training so-called Ambassadors in every pilot area building who would be able to help and support their neighbours in various aspects of smart house and smart city living.

The program consisted of five face-to-face trainings, each focusing on an important smart living area: home expenses and how to live in a smart apartment; indoor climate, ventilation and environmentally friendly interior design solutions; waste, recycling and sustainability; smart home system and the rights of an apartment owner and green mobility solutions. The trainings took place every other Monday from 8 April to 29 May. All in all, nearly 40 people attended the trainings with 8 people attending at least 4 out of 5 trainings. These eight

Ambassadors were awarded with a diploma and practical prizes at the pilot area summer event on 29 May 2019.

Figure 11 Smart Home training session

Figure 12 Awarding Ambassadors

Monitoring

Building retrofitting interventions will be monitored with help of smart city platform (Cumulocity) developed within the project by company Telia Eesti AS.

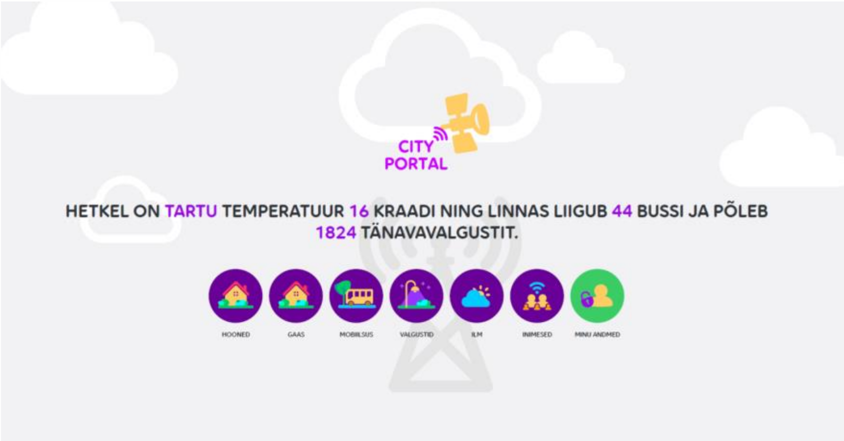

Figure 13 Smart City platform

Data on the energy use (heat, electricity, water consumption, gas consumption) and renewable energy production of all renovated apartment buildings have been collected on the city platform. There is both pre-renovation and post-renovation data on the buildings. The illustration below shows an excerpt from the data on the platform.

Figure 14 Energy data on the platform (renewable electricity production in Lutsu 16 building)

Awards received so far

The project activities have received active attention in Estonia since the beginning of the project. In addition to active media coverage, the project's activities have won various awards. In the field of building renovation, Tartu objects have been awarded by the Estonian Union of Co-operative Housing Associations twice:

Most successful retrofitting project – Tähe 2 apartment building
Special prize for roof solution (PV panels) and renewable energy production in heritage protected area – Lutsu 16 apartment building

3.2 District heating and cooling system

District cooling

The idea to create DC system in Tartu started in year 2013. According to business plan no heat pump was planned at cooling plant. According to plans, the production with electrical chillers and free cooling was planned. The cooling of chillers condenser side was planned by water from river. The designed capacity of cooling plant was 13 MW of cooling and designed DC supply water temperature is 6 ^{0}C.

With support of SmartEnCity project, the heat pump as part of cooling plant was integrated into production system. Idea is that during winter it is able to produce heat and reduce consumption of fossil fuels. The capacity of heat pump is 1,4MW$_{cool}$ and 1,9MW$_{heat}$. The size of heat pump was selected according to cooling load in winter which was estimated to be 10% from maximal summer load. One reason for installing of HP was higher reliability of plant. Technically, if the river water system is under maintenance, it is possible produce cooling by HP. All together there is 8,3MW of cooling capacity installed today. There is two compressor chillers with capacity of 2,3MW and 4,7MW and one HP with capacity of 1,4MW cooling installed today. If market demand will increase, next compressor chiller with capacity of 4,7MW will be installed.

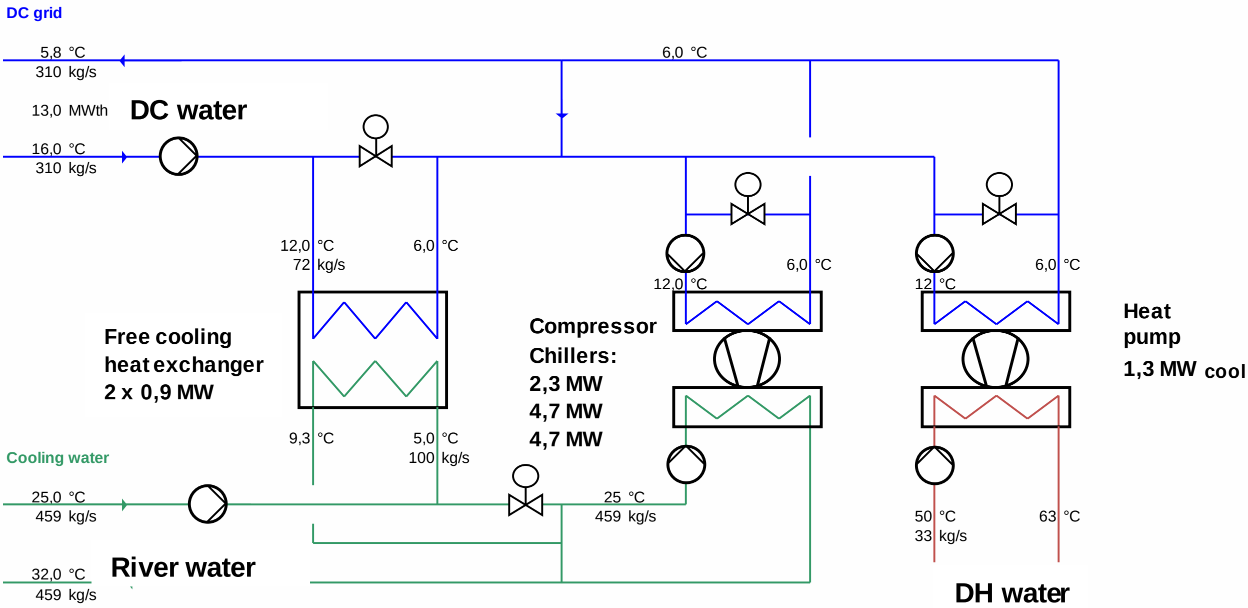

Figure 15 Principal flow diagram of cooling plant

Heat pump which is installed in cooling plant is capable to produce 6 degree water for District cooling and up to 63 degrees water for DH system. It is able to lead heat whether to supply or return line of DH net. The COP value of HP is 3,5 for heating and 2,5 for cooling which means that by 1 kW electricity it is able to produce 2,5kW of cooling and 3,5kW of heating and total COP is 6. The cooling plant is fully automated and no staff needed for operation. The remote control from CHP plant was established.
The contracting and connection of new cooling customer's takes time therefore we have not reached the expected cooling demand yet. About 25-35% of installed cooling capacity was in use during the hottest days in last summer.

Solar panels

As DC production needs a lot of electrical power, the PV panels with support of the SmartEnCity project at the walls and roof of plant were installed. Total electrical capacity of panels is 67 kW. There is 20kW of panels installed at the walls and 47kW on the roof.
The position on PV panels at walls was designed by architect. It was challenge to find technical solutions for implementation of this architectural design. The panels at walls are not with standard dimensions therefore the panels were ordered as special product. Also fixing of panels at walls was challenge, as every panel had different fixing angle. The steel frame under panels was designed and constructed. The construction of PV panels at wall was complicated task but the final result was very good. The cooling plant with "solar wall" is situated beside of main road of Tartu therefore we have got lot of positive attention from citizens.

Figure 16 Facade of cooling plant with solar panels

Figure 17 Solar panels on the cooling plant roof

The panels at wall had much higher investment cost per installed kW than normal solution. The cost of wall PV panels is about twice more expensive compared to standard solution.
The PV panels on the roof had standard installation solution. The panels were installed with angle of 15 degrees. The installed capacity of roof panels is 47kW and they are connected via 25kW and 17kW inverters.
The PV panels system is connected with power grid. When the production of PV panels is bigger than consumption, the excess power goes to grid. The produced electricity is measured by one overall energy meter. Metering data is collected remotely in every hour.

District heating at pilot area

All demo buildings in Tartu pilot area are connected to the DH net. DH net is in good shape today and around 80% of DH net has been renovated in last 20 years.
All renovated buildings have heat metering which measuring the total consumption of consumed heat energy with commercial accuracy. This change will give better data quality for hourly readings. Old type heat meters do not have data logger functionality inside of the device therefore there could be the situation, when readings from certain period could miss because of bad quality of internet or GSM link. All new meters have data delivery system via GSM link.

Monitoring

District cooling plant has modern Distributed Control System (DCS) which is mainly used in industrial applications. All together there is about 60 measurements implemented and saved

into archive database continuously. Almost all measurements are visible online via WinCC application by technicians and engineers of FTAR. Reports of measured readings could be made for different time intervals. All measurements needed for commercial use have separate measurement device which have certificate of approval for commercial use according to regulations.
Because of high security level, there is no access to this data base for external users. The monitoring data for SmartEnCity project is generated by technical persons of FTAR.

Energy produced		2021
Electricity by PV panels (solar)	MWh	48.29
Cooling by heat pump	MWh	79
Heat by heat pump	MWh	109

Table 7 Energy production 2021

3.3 Street lighting

The framework

Tartu has been a pioneer in the development of street lighting among Estonian cities. Tartu was one of the first who had larger amounts of mercury luminaires exchanged for sodium luminaires and similarly one of the first who installed of LED luminaires in larger volumes. Now Tartu is the first city developing smart street lighting solution. Reduction of costs on energy and energy efficiency is a cross-cutting issue in the city's development strategy and development documents.
The deployment of smart street lighting in Tartu pilot area was a voluminous and diverse process where other project partners also played an important role: CTEL (sensors and control system) and ET (data collection and CIOP). All engaged partners also contributed to the development of technical requirements. Specific issues (light calculations, technical aspects of luminaires) were also assisted by external experts.
The tendering process was a responsibility of TAR. The whole deployment process lasted 28 months.

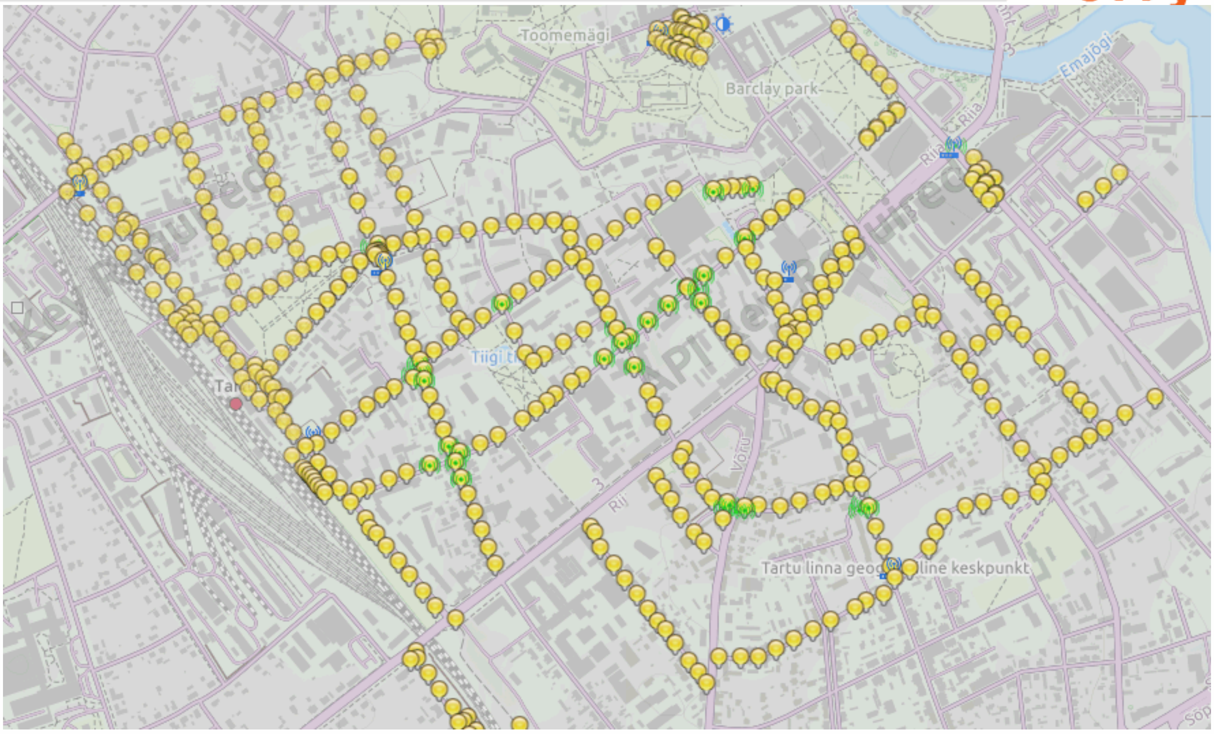

Figure 18 Installations in Tartu LH pilot area (Tartu lighting management system)

The LED luminaires

Modern LED luminaires are characteristic because of their high luminous efficiency, long life time, reliability and high color rendering index. Maintenance-free exploitation, high quality of production and possibility of easy lighting control makes LED luminaires a highly recommended choice. LED lighting provides incredible energy efficiency without sacrificing light quality.

The LED lighting allows to achieve significant energy savings right after installation and, combined with a smart control system, increases your savings even further. The lifetime of LED lights is expected to reach 100,000 hours in a few years. Deployment of LED lighting consists several benefits:

- No need for engineering personnel for deployment and maintenance;
- Dynamic control of luminaires based on real-time local situational information;
- Real-time feedback from luminaire on operation;
- Accurate power consumption measurement;
- Very reliable operation;
- Future proof - easy to add other devices providing Smart City Services into the same network;
- Reducing the energy consumption and carbon footprint of street lighting installations.

As a result there was installed altogether 322 LED-luminaires in Tartu LH pilot area from company Vizulo.

Figure 19 Vizulo luminaires installed in Tartu LH pilot area

Procurement was initiated in March 2017 and all the works was finished in-time in December 2017. Installation work was carried out by company Leonhard Weiss Energy AS.

Figure 20 Installation in Tartu LH pilot area

The sensors and controllers

322 streetlight controllers were produced and installed in Tartu for this project. Controllers were produced by CTEL and installed into luminaires by the luminaire producer (Vizulo). Necessary software developments were mostly made by CTEL employees. The controllers communicate with each other in a flat self-configurable mesh network. According to the rules saved in each controller, they can dim the streetlight and switch it on and off. Rules can be based on the specific time, sunset and sunrise time and data from sensors. Some problems with the controller software occurred after installation of the luminaires but Cityntel was able to fix the bugs and update the software.

Figure 21 smart controller

Eight sensor units were developed and produced in cooperation with Thinnect OÜ. First two of them were added to the system at the beginning of 2018. Later in 2018 other sensor units were installed. Sensors measure ambient temperature, air pressure, relative humidity, particles, CO_2, NO_2, traffic intensity, road temperature and noise. Motion sensors and part of noise- and camera based sensors are installed separately.

Figure 22 sensors from pilot area

The control system

The solution developed by Cityntel is based on a wireless mesh technology. Smart controllers, capable of in-network and in- device decision-making, are installed in every street light and rely on wireless communication for communicating information between the controllers and sensors. Unlike competing solutions, where all control commands are sent from a server or network controller, this smart control solution requires no permanent server connectivity as operational rules are stored directly in the luminaire controller, improving greatly the resilience of the solution. The features provided by the technology provide a clear business advantage, improving the rate of adoption of the smart street light control technology, thereby resulting in reduced power consumption, carbon footprint and light pollution. Web based user interface Lumoflex was developed based on the experience from previous projects of CTEL. Software developments were made by CTEL in cooperation with company Thinnect. User interface enables to manage the streetlights and sensors, create groups and rules, receive alarms and manage users. API for third party applications was developed by CTEL. The City Portal developed by Telia uses API for receiving streetlight and sensor data from Lumoflex central management UI.

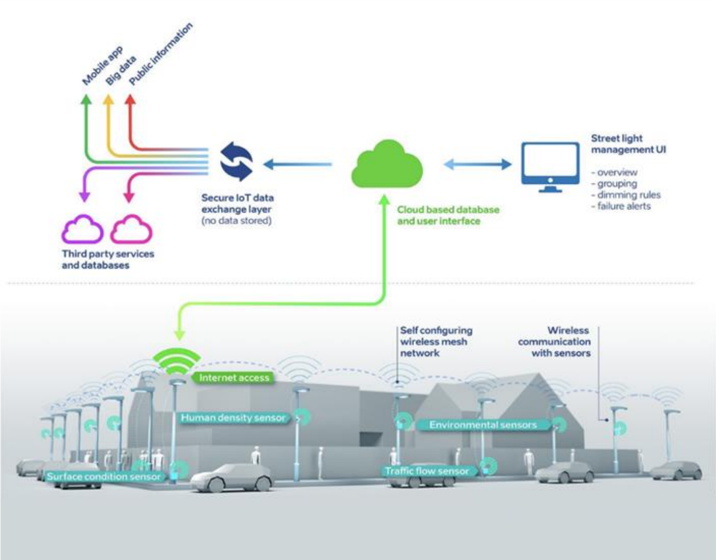

Figure 23 The control system

Monitoring and evaluation

The monitoring and evaluation of the smart street lighting deployment is done by the TAR in cooperation with ET and CTEL. Data of the performance of the smart street lighting is directed into CIOP. The main indicator reflecting the system performance is - energy consumption.

On the City Information Platform will be presented some visualization for public. Specialists will have access to the all dataset gathered from the system for monitoring and analysis.

Energy efficiency

Smart lighting has already provided significant energy savings in the first year. With further development of the management system, savings are likely to increase even further. Considering the rapid development of LED technology in the last decade, it can be quite certain that in the future it will be possible to achieve greater energy savings under the same prerequisites than in the present project.

Consumption of HPS (2017)	196673
Nominal consumption of LED (kWh)	71480
Real consumption (including dimming) (kWh) 2021	54364
Saving from dimming (kWh)	17116
Total saving (kWh) (HPS vs. Dimmed LED)	142309
Saving (%)	**73**

Table 8: Energy consumption of street lighting in Tartu LH pilot area

3.4 Gas buses

As of 1 July 2019, the City of Tartu switched over to a new gas buses and new bus route network. The new network differs significantly from the recent network in terms of itineraries, the number of lines, as well as the frequency of departures. In total 13 bus lines will begin to travel along the route, along with two night lines. New gas buses will begin serving the routes, with AS GoBus providing service on the route network. From January of 2020 the Tartu´s public transport is 100% carbon neutral as only biogas is used in the buses as fuel.

The buses

In total 64 new gas buses, manufactured in the Scania factory, equipped with air conditioning, low floors and running on an environmentally friendly source of fuel. There are two types of buses: normal buses (12 m in length, 27 seats, and standing room for 52) and articulated buses (18 m in length, 41 seats and standing room for 96).

Filling station and biogas

Public transport service provider GoBus AS constructed a new filling station in Tartu (Ringtee 25) for gas buses. New filling station have slow-filling equipment for 42 buses for overnight filling and 3 units of equipment for fast filling. The filling station was constructed by company Nordic Gas Solution.

Figure 24 New filling station

From January 2021, 100% locally produced renewable fuel biomethane will be used in Tartu city buses. The fuel is produced in the Ilmatsalu biogas plant on the territory of the city of Tartu. Around 2,279,500 kg of biomethane used in 2021 by Tartu buses.

Bus network

The new bus route network differs significantly from the existing route network in terms of itineraries, the number of lines, as well as the frequency of departures. The new route network has fewer total routes, although these routes are more direct, better connected to one each other and operate at more frequent intervals. Timetables with a uniform frequency of service ensures that buses serving the same routes will not arrive simultaneously at the same stop. An important principle in the new route network is also the reduction in the number of circular routes and their replacement with pendulum routes, which leads to a simpler route network. The routes travel in both directions along the same itinerary, and are therefore better understood by users. Taking into consideration feedback collected from residents of Tartu, an entirely new circular route (No. 9/9a) was created alongside the pendulum routes, which passes through all of the most important points of interest.

The new bus line network was created in close cooperation with finish company WSP Finland. In course of the process more than 1 000 comments and proposals from citizens were gathered.

Figure 25 Bus line network

All of the new gas buses have also new smart validators enabling to pay for a ride using contactless bank card, bus card or QR-code.

Figure 26 New validator

Monitoring

This activity is monitored by TAR with help of smart city platform (CIOP) developed within the project by company Telia Eesti AS. GPS data from buses will be analysed and based on this information will be defined accuracy of timekeeping of buses.

3.5 Mobility infrastructure

EV-chargers

Quick chargers are in general referred to as min 50kW direct current (DC) chargers, which allow you to charge for example Nissan Leaf electric car batteries (24 kW) for approximately 30 minutes. Significantly cheaper AC (Alternating current) chargers with a lower power rating (typically 11-22 kW) for public use are also available on the market, which can charge for example Nissan Leaf batteries for approximately 8 hours.

In 2012 was established national quick charging network - ELMO consisting 167 50-kW chargers all-around of Estonia and 11 of them are located in Tartu. ELMO network is available for cars using CHAdeMO standard.

Due to the fact that the ELMO network chargers are located not in the centre part of Tartu and are not easily accessible to SmartEnCity pilot area residents and only allow charging according to CHAdeMO standard, it was decided to install 5 new electric car quick chargers enabling charging also according to CCS standard in the Tartu city centre area.

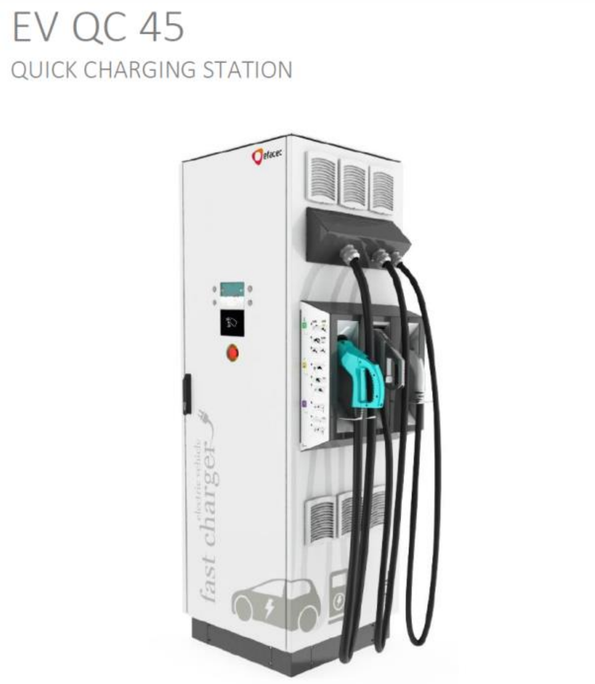

Figure 27 EV-charging station installed in Tartu

The process of installation of quick chargers started at the beginning of 2016 when the most suitable locations for chargers was determined. The choice of locations based on the precondition that the chargers have to be located in easily accessible locations and where electric vehicle users move on a daily basis. In total of 4 locations was selected, with one charger to be installed in 3 locations and two chargers in one location.

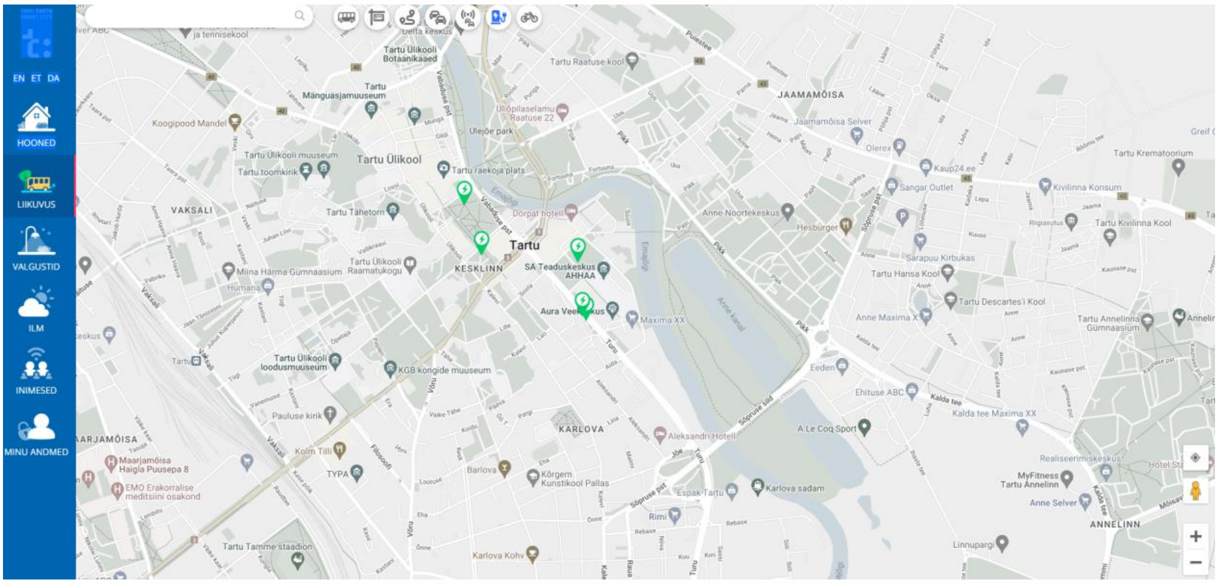

Figure 28 Locations of chargers in Tartu

After the appointment of the locations, contracts were signed with the network service provider for electricity connection and equipment was installed in October of 2018.

The most difficult part of this intervention was securing of operations. As in the National ELMO network the cost of electricity was subsidized by the state, it was very difficult on a commercial basis to compete with the ELMO network. In order to ensure the most attractive way for consumers to recharge their electric car, a call for tenders was organized and evaluation of tenders was on the basis of the fixed price of electricity for small consumers.

EV battery re-use

One of the new ideas of the project in the field of transport was to re-use of EV batteries for storing energy. As electric vehicles are gaining popularity everywhere, solutions for repurposing their rather quickly deteriorating, but still valuable batteries (delivering 70-80% of their original output at end of life) have significant market potential and could yield many environmental benefits. Tartu – having built up a considerable electric taxi fleet was a suitable test site for piloting these solutions.

Figure 29 EV-battery re-use system

The objective of the activity is to use in sustainable way EV batteries giving them a second life. Re-use of old batteries will benefit the protection of environment as there is needed to use less resources in production of energy storages and in the same time will be used renewable energy from sun to charge EV-s.

The EV taxis of the private company OU Takso are partially recharged based on renewable energy that is produced on-site with PV panels and stored in used EV batteries.

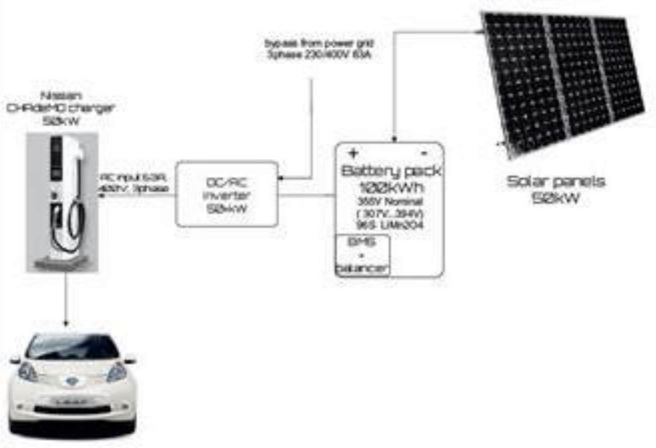

Figure 30 Scheme of EV-battery re-use system

The battery re-use system allows to charge in the sustainable way around 30 EV-s during the day (depending on location of the system). For the system is needed up to 6 EV used batteries. As a lifetime of the EV battery is around 5 years (in case of taxis) then it is needed around 30 EV-s to supply the solution with needed used batteries. In this way the solution is autonomous and suitable for fleet of 30 EV-s. Depending on climate conditions supernumerary electricity produced by PV-panels can be used for other purposes on site (lighting) or sold to grid.

The system consists 100 kW of used batteries. Battery have 26 modules series, each module have 4 elements in parallel and in total of 424V. Batteries have over voltage, overheat and under voltage protection circuits, and also emergency OFF button. Every module have individual BMS module manufactured in Estonia. Batteries will be re-charged during the day-time with Solar power. If the car is charged during the day-time it will get power from PV panels and from batteries as well. During the night-time when the power of batteries is almost used and battery voltage is low inverter will switch charging on grid power.

Figure 31 Used batteries

The power of installed solar panels (PV) is in total 50kW. Panels are installed in 2 sections - 6x20 panels in series and 3x20 panels in series. In total 180 panels. Total voltage of PV-panels is over 700V.

The most complex part of the solution is the management of the Nissan electric vehicle battery system and re-converting of current (from AC to DC and from DC to AC) OÜ Takso had a good cooperation with Tallinn University of Technology for the development of the equipment. The rest of the system components (solar panels, charger, inverters) are freely available on the market.

Solar combined box – is connector box where solar cables is connected in parallel and protected each line with double breakers. Solar converter – is converting solar 760 voltage power to 430 voltage power what is suitable for inverter for charging.

Figure 32 Solar combined box

Inverter used in the system is a 60VA rated to 48kW off-grid inverter, with backup input from grid and is isolated from the grid by transformer. Each line is protected with automatic fuse and with ordinary fuse as well.

Figure 33 Nissan charger

Car Charger - Nissan CHADEMO charger with rated 44kW

The EV-battery re-use system have many benefits:

- Decarbonizing the electricity supply
- Increase of grid stability
- New business opportunities
- Increased resource efficiency
- Independence in energy supply
- Batteries lifespan extended (environmental impact from manufacturing of batteries reduced)
- System is able to work in off-grid mode (autonomy)

As the EV market continues to grow and manufacturers are announcing more and more models that are affordable to the end users, the market for second-use EV batteries can be expected to increase remarkably as well. Besides offering a solid business opportunity as replaced batteries are expensive to discard and recycle while still having most of their capacity, reusing batteries reduces waste and adds another 5-10 years of effective lifetime. Several automakers are already experimenting with alternative uses for these second-life batteries in stationary energy storage, so the solution that is developed and piloted in Tartu could considerably contribute to these efforts. Solution can be easily replicated everywhere.

Monitoring

Intervention is monitored within the project and will be carried out with help of smart city platform (Cumulocity) developed within the project by company Telia Eesti AS.

3.6 Bike sharing system

Development of a Smart bike sharing system has been one of the mobility priorities of the City of Tartu. A respective feasibility analysis was carried out in 2014 and a business model was developed based on the findings. The aim of setting up a public Smart bike sharing system is to encourage the use of bicycles and make this a considerable alternative to cars. Smart bike sharing system will bring about decreased environmental problems (noise, air quality), parking issues and problems with traffic intensity. Smart bike sharing is considered a part of the public transport system of the City of Tartu.

Tartu Smart bike share has acquired next generation electric assist bikes, which can communicate with the IoT-system in real-time. This gives us information about the bike's location and in case there is some problem, we can react quickly. Software installed in the bikes collects data for statistics about your rides, speed, distances etc.

Launch of bike share system

From June of 2019, Tartu has a brand new Smart bike system including bike share and electric bike rental system, comprised of 750 bikes in (initially 69) bike share stations across the city. A total of 510 bikes are electric and the remaining 240 are regular bikes. Tartu Smart bike share system is included into city's public transportation network which gives the city a modern and integrated public transportation network, where users will be able to combine bicycle riding with bus rides.

Figure 34 Opening of Tartu bike share

Planning of the bike share

Various bike sharing systems have been successfully set up in many cities all over the world. In most of the cases, these systems have been established by large cities that have taken a strategic goal to increase the use of bikes and bring down the use of private cars. A considerable decrease in the cost of respective technologies has also brought cities closer to the point from which the implementation of bike sharing systems is attractive. However, as cities mostly set up bike sharing systems partly, e.g. in the central area or between major attractions, the comprehensive approach taken by Tartu to cover the entire city can serve as a good practice. After all, it is more likely that people will use the system if they can get to their exact destinations, not just the approximate neighborhood.

As such, the main factors that determine the success of the bike sharing solution are the following:

- Coverage of the system/number of parking lots
- Availability of bikes and docking stations
- Safety (e.g. requirement to wear a helmet)
- Simplicity of the solution
- Weather conditions (e.g. whether the service can be used in wintertime)
- Affordability Population and density

Creation of a Tartu´s Smart bike sharing system was started in 2017 when a survey (including public survey) was carried out to determine the location of bicycle parking lots. The survey was conducted by Positium LBS, which used more than 15 different data layers to determine potential parking locations (including mobile positioning data). In addition, a public web survey was organized. Over 2,000 proposals for parking lots were received from public. Finally, 84 of the most suitable locations were choosed out of which 69 were also deployed within the SmartEnCity project.

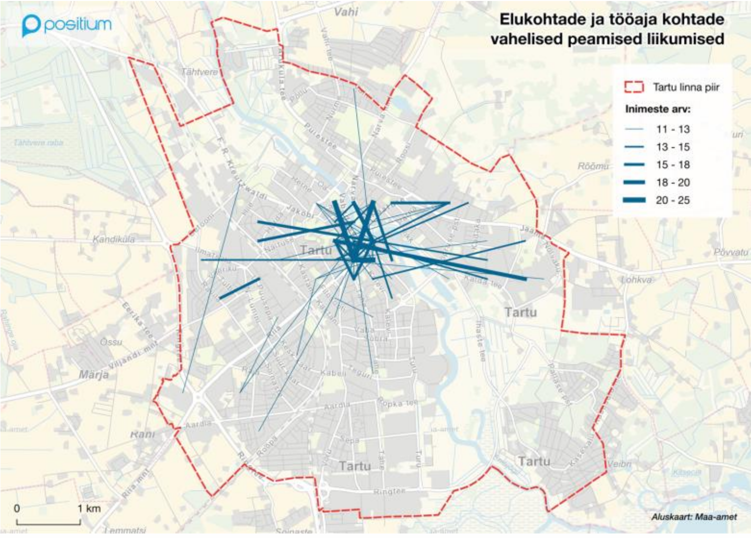

Figure 35 Data from mobile positioning (daily movements of citizens)

Results of online survey

During the planning phase was also conducted a survey among citizens and inhabitants of neighbouring areas of the city in order to find out how residents view cycling and what is their willingness to use bike share in the future. The main results from survey shows that 28% of respondents who is using private car for daily movements agree to give up on car rides In favour for bike sharing system. Respondents find that the bike station could be an average of 536 meters from their place of residence or work and 25% of respondents are ready to use the bike sharing system year-round if the system is well-accessible.

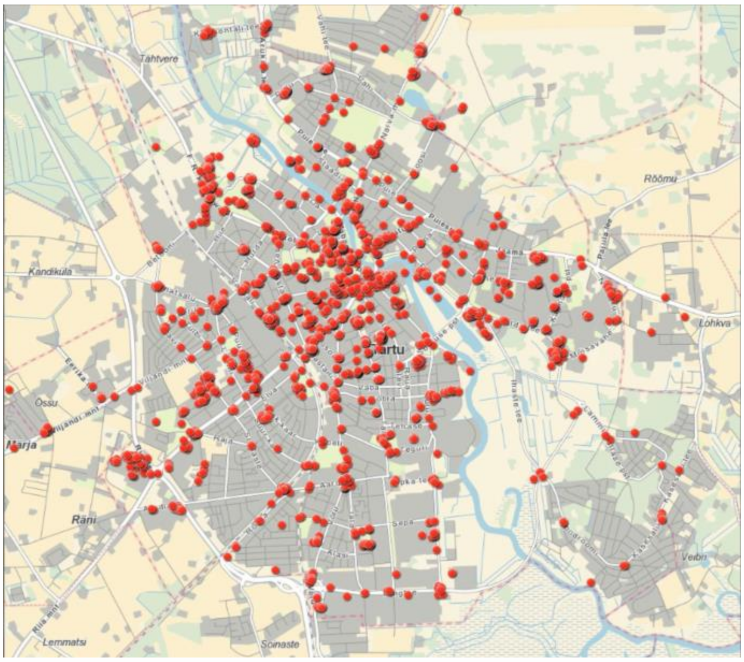

Figure 36 Proposals from citizens

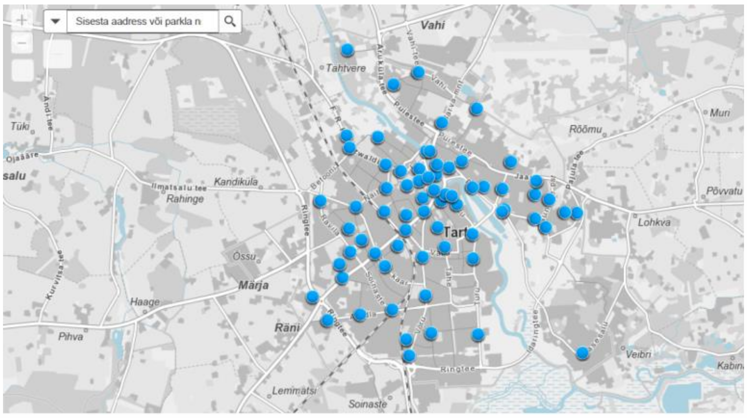

Figure 37 Final locations (69) for bike share stations

Use of bicycles

Electric assist bikes within the Smart bike share system are easy to use, with the electric motor starting when pedalling and the bike being free of any additional control devices. Electric assist bikes will remain in circulation until temperatures fall below freezing, and during cold periods only regular bikes will remain in circulation.

The bike share and electric bike rental systems were being supplied by the Canadian company Bewegen Technologies Inc, who won the public procurement organised in spring of 2018.

Figure 38 Electric bicycle

In order to rent a bike, the user must purchase a season ticket (one day, week or year) for the bike share network or must have a valid period ticket for Tartu city's urban lines. The user must create a bike share account, either on-line or via the Tartu Smart Bike mobile app, and connect it to a credit card. User can use a bus card or mobile app to unlock the bicycle. When returning the bike, the bike should be left in any bike share station, making sure that the bike has been properly locked. If there are no available spaces in the station, the bike can be secured with an additional lock near the station.

Bicycles

Another characteristic of the bicycles used in the Tartu bike sharing system is that all the smartness is installed on the bicycles. All bicycles have SIM cards for data communication and GPS sensors. This allows you to get an accurate overview of the current state of the system (where the bicycles are, what their current technical condition, etc.) and to provide the necessary maintenance work as well as bicycle logistics.

Stations

Bike sharing station prioritizes adaptability and flexibility. The stations require minimal anchoring, making them easy to install, remove and reconfigure. The lightweight design eliminates the need for large vehicles for installation. The anchor system is thin and can be assembled onsite, with the informational board and docks being mounted directly to the rail. This provides additional flexibility by eliminating requirements for excavation or trenching works. Station technology enables configuring of stations in a variety of manners that respond to the needs of each location. Stations can be configured continuously, discontinuously, curved, or customized. Individual docking points can be straight facing, double sided, right-oriented, or left-oriented.

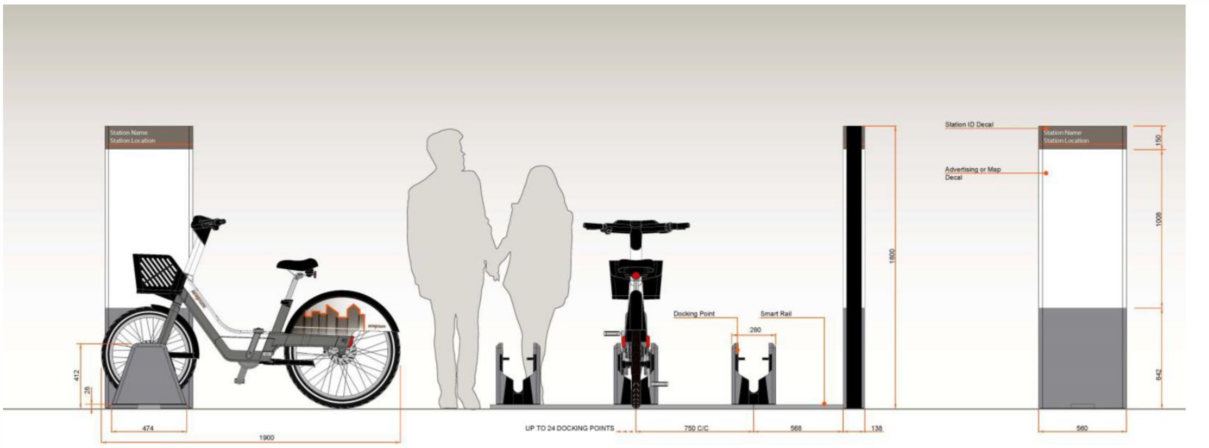

Figure 39 Scheme of docking station

Tartu´s Smart bike share station technology have also a virtual or “dockless“option which is revolutionizing bike sharing. GPS technology enables dockless bike sharing. The system operator may create virtual stations within seconds. Geo-fenced area that is GPS designated to match clearly marked region. Secondary lock of the bicycle and double-sided kickstand are used for parking. Hybrid systems using both virtual and physical stations Temporary virtual station is ideal solution for special events (concerts, gatherings etc.).

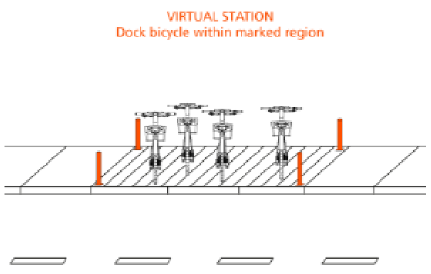

Figure 40 Virtual station technology

Citizen engagement:

The residents of Tartu have been involved in the implementation of the Smart bike sharing system already from the beginning of planning the solution and they have several roles in this process. First of all, the residents were involved in deciding on the locations of the docking stations and drafting the service pricing policy (e.g. length of free driving time, daily and monthly pass prices). After the launching of the Smart bike sharing system, residents are involved in improving the service quality. More specifically, questionnaires will be conducted to identify user expectations and needs, and the design of the service will be adjusted accordingly.

Citizens are also engaged through awareness-raising – citizens are informed of how the system operates, how they can register as users, use the system and pay for it, how they can ensure their own and others' safety etc. Similar content is communicated to visitors and tourists. The main communication messages include the following aspects:

- Smart bike sharing is convenient, practical, safe, healthy, fast, flexible and affordable;
- Smart bike sharing will make the urban environment more human friendly and approachable;
- Users need to make sure that they take care of the safety of themselves, others and the bike sharing equipment.

Monitoring

Bike sharing and electric bike rental system is monitored within the project and monitoring will be carried out with help of smart city platform (Cumulocity) developed within the project by company Telia Eesti AS. GPS data from bikes will be analysed.

As of March 2022, there is made in total about 2 460 000 rides within the system and about 6 566 000 kilometres covered since launching.

3.7 ICT infrastructure

Tartus' long term vision is to build a Digital Ecosystem for city data and services by integrating various data inputs and sensor systems together into one city ICT platform, where anyone could build their own Value Adding Services on top of city provided platform. The City Information Open Platform (CIOP) concept was introduced by Telia, within SmartEnCity project.

Tartu CIOP is a direct outcome of WP6 studies and is built on top of foundation described in WP6 deliveries, where a state-of-the-art study of available platforms and technologies was performed to find the best data and services integration solution for the city.

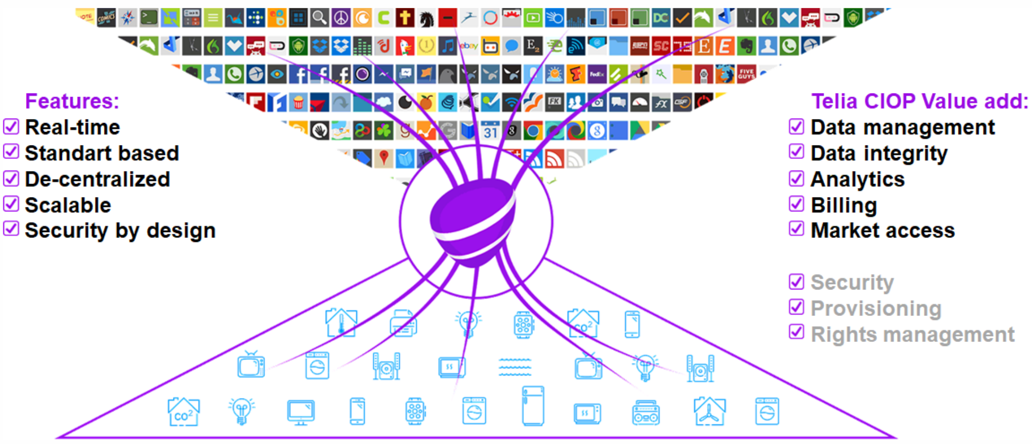

Figure 41 Digital Single Market for city services

The challenge was high due to the nature of data that had to be collected - City Level, Building Level and personalized Apartment Level data all in one platform. Whereas City-level data had to be open for anyone to use and at the same time personalized data had to be protected on the GDPR level.

To best address the above-described challenge, the CIOP was designed with multiple separate modules:

1) IoT platform Cumulocity for easy integration of any sensor systems,
2) Data Access Layer (DAL) for Authentication and Consent Management. This layer also introduces an API for Third Party Access to the data,
3) Data Mapping Tool as a technical service for describing and allocating data for end-users,
4) City Portal for end-user access to City and personal data.

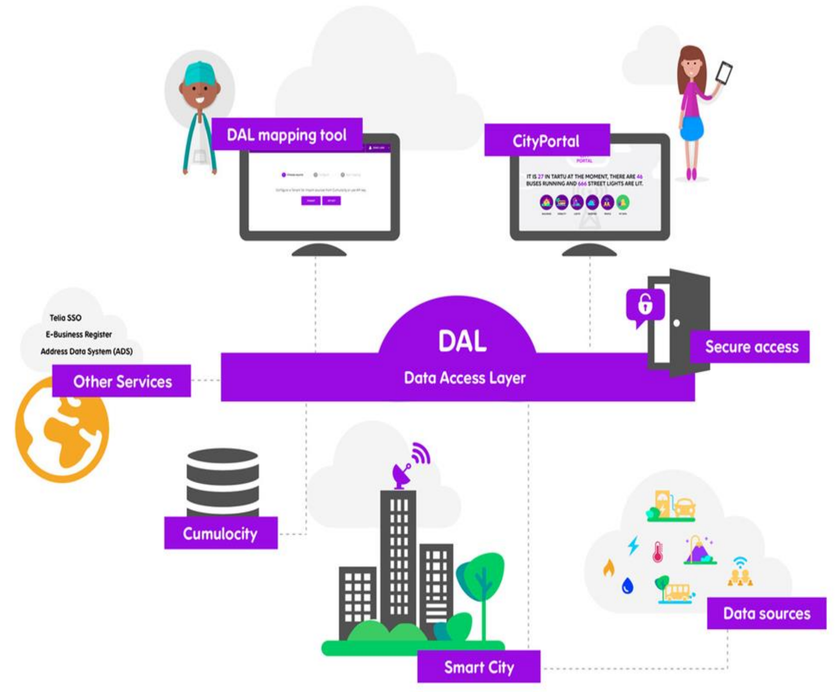

Figure 42 CIOP modules

After business and technical requirements were identified, the state-of-the-art study was performed and 54 smart-city, IoT and/or similar platforms were listed. After benchmark testing against above-mentioned requirements, Cumulocity was the one to outperform other similar platforms and was implemented as the first part of the CIOP.

On top of Cumulocity and other data inputs, one of the most important parts of the CIOP is **Data Access Layer (DAL)**. This is a secure gatekeeper module between data producers and consumers. All authentications are controlled by DAL, also sharing, delegation information and consent management is handled in this module. These are the components to secure the data and ensure the GDPR compliance.

City Portal includes two strictly separate parts - **Open Data** portal and My Data portal. Under the Open part of the portal, everyone can see, free of charge, the data that has been published by the city or building owners.

CIOP is the main tool for monitoring Tartu's activities and interventions in the project. Data on all main activities are collected here and the calculation of project indicators is partly based on this application. The maximum amount of data is collected automatically (sensors, APIs). However, some data must also be entered into the system manually.

Value-Added Services on top of CIOP

Tartu Smart City Portal

In the menu, you can choose between different pages: Buildings, Mobility, Lights, Weather, People, My data. The first five pages are open for exploring for everyone and My Data is secured for your personalized data

Figure 43 City Portal landing page

My Data Portal

This part of the portal is secured and holds more detailed data than the previous open data part. To see your data, you have to be logged in the system.

After logging in you'll be taken to the "Sources "page. This page shows your data groups or data groups shared with you.

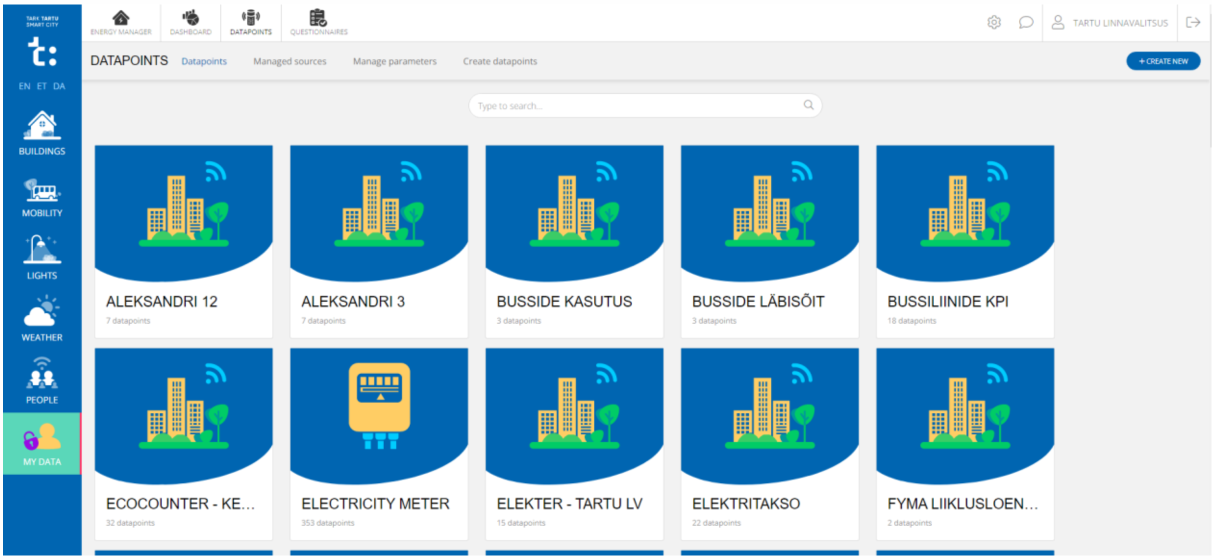

Figure 44 My data sources

DAL Data Mapping Tool

This tool is designed to describe already connected data or to connect new data sources. Also, ownership of data will be defined in this module.

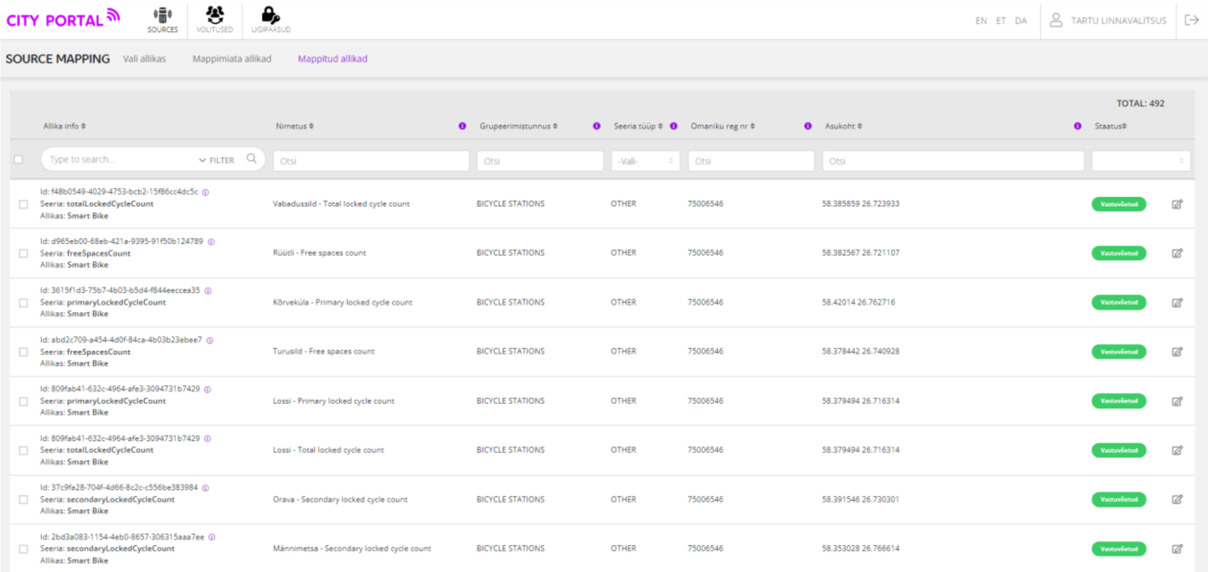

Figure 45 DAL - mapped data sources

3.8 PV installations

Tartu City Government owns a number of different buildings - schools, kindergartens, social houses, sports buildings, administrative buildings etc. With support of SmartEnCity Project will be installed solar panels on 4 buildings with total capacity of 210 kW.

Intervention will reduce CO2 emissions from electricity use by 213 tons per year. Currently, most of electricity in Estonia is generated from the oil shale, making the national energy mix one of the most carbon intensive in the EU.

To date, the Department of City Property has mapped 19 buildings that could be fitted with solar panels. An expert assessment has been carried out to determine the possible capacity of a solar panels to be installed on each of these buildings, taking into account the roof area of the buildings and their position relative to the weather charts. Based on this research determined 4 most suitable buildings in terms of energy production and own electricity consumption.

4 Lessons Learned

4.1 Building retrofitting

Retrofitting of buildings in Tartu has been a rather long and complex process. When we started with planning of renovations at that time, there was no experience in Estonia of renovating similar apartment buildings to energy class "A". In particular, there was a lack of knowledge on how to deal with ventilation and other technical systems and ensure in the same time a minimum energy consumption. The introduction of a smart home solution on this scale was also innovative. Both the designers and the residents lacked knowledge and experience.
On the renovation process, it becomes increasingly important the prior in-depth planning by owners (apartment association, inhabitants) in cooperation of technical consultants and technical designers. Great help in the preparation phase was from the side of KredEx (national grant provider) who carried out comprehensive expertise of the technical projects of renovated buildings.
During the renovations, a number of modern integrated technical systems were installed in the buildings (ventilation, heating system, smart home solution, etc.). The perfect integration of these systems is essential to ensure a high-quality indoor climate in buildings and to optimize energy use. Experience after renovations shows that such systems require constant monitoring and maintenance and thorough tuning. Qualified assistance is needed here and the corresponding requirements must also be laid down in construction contracts in order to avoid future problems.

While engagement was very successful in a sense that the required number of housing associations made the decision to renovate.
There were several good practices that helped achieve the goals of engagement in Tartu:

- Regular working group meetings and dedicated members are key, i.e. the engagement working group has been meeting regularly every 2 to 3 weeks, which has been important in having an overview and the planning of all engagement processes in the project.
- Consistent and personal communication are crucial for success, e.g. TREA’s personal approach and technical support for housing associations; personal communication during the choosing of artwork, etc.
- Negative attitudes are not permanent, i.e. at first the project seemed too ambitious for local housing associations; however, attitudes quickly changed thanks to constant encouragement and awareness raising.

Although we estimated that a social innovation measure implemented in the renovation process - energy ambassadors, was a successful project. nearly half of the retrofitted buildings did not end up with an Ambassador.
In general, it can be added that modern renovation processes can be much more complex than it first appears. In order to achieve a high-quality end result, it is necessary to thoroughly plan activities and involve a wide range of parties.

4.2 District heating and cooling system

Long term planning needed for establishing the new district cooling network. Starting DC services from the “zero” requires very good understanding about market, business model, investment and operation costs of services. The development of DC network together with connected customers takes time.
The expected winter load of HP was 10% from summer peaks but actual load is 7-8%. Also we learned, that HP is working with the highest efficiency at 80…100% load. If the load is smaller, the efficiency will drop dramatically and therefore the feasibility of HP is not the best. Connection of new customers take time and therefore achieving enough load for HP takes longer time than expected.
PV panels solution at walls got a lot of positive attitude from citizens. It is good example where decoration and solar panels together will have positive impact. As the free space for panels in urban city area is limited, the facade solar solutions is the future. It is good benchmark for replication in other sites.

4.3 Street lighting

Deployment of smart street lighting was in itself a complicated and time-consuming process. The main problems were related to the technical characteristics of the luminaires, controllers and sensors. As technology in this field develops very quickly, there must always be a very good lighting expert in the team, or it must be possible to find a competent external expert. Preliminary work - making light calculations and drafting technical specifications is crucial. Thorough preparation allows to save time in the procurement process and achieve the desired result. The technical requirements for luminaires must be fairly precise and sufficiently rigorous. Current experiences show that overly flexible requirements bring financially affordable but technically very low-quality luminaire offers. The situation is similar with controllers and sensors. On the market, the supply is high and often very low quality sensors or electronic components are offered from which sensors to produce. In the case of the Tartu project, there were for example problems with microphones in production of noise sensors, where microphones had to be replaced because they were of poor quality.

4.4 Gas buses

The experience gained from the previous procurement period regarding the use of gas buses and optimization of the bus network formed the basis for the reorganization of the public transport system in Tartu.
The introduction of gas buses was once rather risky as neither municipalities nor public transport service providers had experience in operating and using gas buses. There were also no filling stations of compressed gas available at this time. The risk taken by Tartu paid off and, as it has become clear over time, gas buses justify themselves. Thus, in preparing for the new procurement period, it was decided that within the framework of the SmartEnCity project only gas buses will be introduced in Tartu in next period.

In the case of gas buses, it is very important to have the necessary fueling infrastructure in place. I is more complex and time-consuming to build gas filling station than filling station for liquid fuels. The necessary requirements must be reflected in the procurement document.
In connection with the re-designing of the bus network, we experienced the importance of involving high-level experts/professionals into process. We also experienced how important it is for the citizens to be involved in such processes. In the planning phase was used about 20 different data-layers (mobile positioning data, data from ticketing system, POI´s, schools, workplaces, living places etc.) to identify movement patterns of citizens and create efficient public transport network in Tartu. At last we got for same amount of money a public transport system with much higher quality and significantly lower environmental impact in comparison to existing system.

4.5 Mobility infrastructure

When implementing this deliverable, we experienced two main problems that should be considered in implementing similar activities:
- finding the right development partner to create a recycle system for electric car battery re-use system proved difficult. Innovation is often a situation where market players are uncertain and not always ready to contribute enough. There is a high chance of failure and therefore thorough preliminary work to involve a trusted and competent partner is crucial.
- in case of installation of quick chargers for electric cars, we had to carry out more than one procurement in order to reach a satisfactory final result. Our experience shows that market participants need to be consulted in order to obtain similar low-profile and innovative solutions. It´s crucial to identify the technical nuances that will affect the later operation of the solution as well as the business model.
As a positive experience we would like to point out that, as a result of the installation of innovative quick chargers, the private sector has invested in environmentally friendly vehicles and several electric cars have appeared in the city in recent months.

4.6 Bike sharing system

Establishing a Smart bike sharing in Tartu has been a rather long and complicated process. When we started with planning of Smart bike share our understanding was that about 200 bicycles and free-floating system could be built in Tartu. 5 years later after the launch of the Smart bike sharing, we can say that the current system with 750 bicycles and 69 parking stations will need to be expanded in the coming years. The system may be up to 2 times larger in the future. The opening of the Smart bike share showed that the interest of the city residents in this kind of transportation option is extremely high and during the first month, proposals have been made by the residents as well as the companies for the additional bicycle parking stations.
The phase of active implementation of the Tartu Smart bike share lasted about 2 years. Based on our experience, we also recommend those cities who plan to create a bike share system to take a time for at least 2-3 years. Planning of locations for bicycle parking stations alone and building their bases and electrical connections takes at least 1.5-2 years. It is a long-term process, but thorough preparatory work will also ensure success later.

Since cycling and walking are the foundations of the Tartu transport system and the development of these modes of movement has been a political priority in Tartu for the last two decades, it was easier for us to get political support for a bike share project than in some other cities. It is obvious that without active political support it can be quite difficult to say that it is impossible to successfully implement the bike share.

At the time of the report, the Smart bike share has been in operation in Tartu for 2,5 years, and some weaknesses have also come to light during this period - information systems may go out of line in active use, people tend to use bicycles unintentionally and also vandalize. In order to reduce the impact of possible problems, it is advisable to have different operational strategies in the start-up phase for a flexible response. It is very important to pay attention to security (IT systems, traffic, general security) and to inform the public proactively.

In conclusion, it can be said that the implementation of the Smart bike share is definitely very positive and undoubtedly has a healing effect on the city traffic and the urban environment as a whole.

4.7 ICT infrastructure

As predicted at the beginning of the CIOP implementation phase, most of the delays and/or kickbacks have been on a human and agreement side – not on technical implementation. Thus, there were no deviations to the planned work.

The implementation of Tartu CIOP directly feeds into the Sonderborg LH demo actions as the same technology will be also implemented as Sonderborgs' CIOP.

All in all, the planning and launch of the systems have been successful. In Tartu, the CIOP is functional and in the demo houses, the smart home systems are currently being installed.