TOWARDS SMART ZERO CO_2 CITIES ACROSS EUROPE

VITORIA-GASTEIZ + TARTU + SONDERBORG

Deliverable 4.4: District heating and district cooling system is commissioned and deployed

WP4, Task 4.5

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Abbreviations and Acronyms

Abbreviation/Acronym	Description
SmartEnCity	Towards Smart Zero CO2 Cities across Europe
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 voltaics
FTAR	Fortum Tartu
HP	Heat pump
CHP	Combined Heat and Power
DCS	Distributed Control System
CH	Chiller
GWP	Global Warming Potential

Table 1: Abbreviations and Acronyms

0 Publishable Summary

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 ^{0}C water for District cooling and 63 ^{0}C hot 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 CO2 emissions about 373 T per year. Also there will be significant indirect savings in CO2 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. Total capacity of panels is 67kW and production of PV panels was 49 MWh, which is 8,3% of total power consumption used for cooling production in 2018.

The leading partner of cooling project was FTAR. Design has been made by Capital Cooling from Sweden. The tender for chillers and HP won AcRef OÜ who delivered HP produced by Carrier. PV panels were installed by Naps Solar Estonia OÜ. The SmartEnCity partners had less prominent roles.

Figure 1: Internal view of cooling plant

1 Introduction

Fortum Tartu (FTAR) is the energy company who providing the energy services in the Tartu area. FTAR is owner of the bio CHP plant, boiler plants, district heating networks and DC production and distribution system. The share of RES fuels was 75% in 2018.

All new public and business buildings have systems for comfort cooling which was initiated the idea to create district cooling system in the city center area. The district cooling service area is partially overlapping with pilot area of SmartEnCity project, which was the reason to install the heat pump as heat source for pilot area. Technically the HP will use the excess heat from buildings situated in pilot area and lead it via DH net to retrofitted buildings inside of pilot area for heating of hot water.

Objective was to produce hot water for demo buildings by heat pump using residue heat from pilot area.

1.1 Purpose and target group

The purpose of this deliverable is to document the details and processes made by FTAR related to district heating and cooling in SmarEnCity project. The details include a description of the technical details process and also first results and lessons learned so far.

Target group include other partners of SEC project but also target groups interested in implementation of new DC system..

1.2 Contributions of partners

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

Participant short name	Contributions
FTAR	Overall & general content
TAR	Particular content

Table 2: Contribution of partners

1.3 Relation to other activities in the project

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

Deliverable Number	Contributions
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	This deliverable connects all demo actions into ICT platform. Data will be easily used for evaluation and replication purposes
D7.8	This deliverable provides the overall description of the KPI's and therefore the measurements to be implemented in DHC

Table 3: Relation to other activities in the project

2 Objectives and expected Impact

Deployment of district heating and district cooling system was one part of Tartu Lighthouse Demonstrator tasks in the SmartEnCity project. Installation of HP and PV panels was supported by the project. The district heating and cooling system is based on a heat pump that, installed to return the flow of the district cooling system, will produce heat for the district heating system by using residual heat from cooling. The district cooling system is using free solar energy from PV panels to cover a part of the cooling system's energy demand. The solution will meet consumer demands for thermal indoor comfort and domestic hot water while retaining high energy efficiency and share of renewable energy. In essence, the current situation whereby hot water is produced locally with electric boilers will be replaced with a system whereby hot water is supplied from the district heating network.

2.1 Objective

The main objective of this deliverable was to implement innovative and environmental 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.

2.2 Expected Impact

The expected 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 373t, when DC system will be fully developed and sufficient amount of DC clients have been connected to the system.

Production of cooling energy 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 lead to higher energy efficiency and therefore to remarkable reduction of CO2 emissions.

Important aspect of the current cooling system deployment that reduction of leakages of F-gases from cooling has been expected. In case of centralized production there is only few industrial cooling equipment installed and the total amount of F-gases used is much less compared to private cooling solutions. F-gases have significant impact to global warming and therefore the reduction of F-gas leakages has positive impact on environment. In addition in case of centralized 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 be as lighthouse for other new developments.

DC system could solve a lot of problems for end users. Buildings having local cooling equipment generate a lot of problems like need for stronger power supply system, licensed maintenance staff, more space for equipment and high noise level. Usually DC will solve all those problems with smaller environmental impact.

3 Overall Approach

Ambition of FTAR in SEC project was to produce heat to DH network by using residue heat from DC system. FTAR started with DC project from “green field” which means no DC plant, DC network and DC customers were existing before the project started. Plan was to create new DC system with final cooling capacity of 13MW and expected winter load of 10% from summer load which is 1,3MW. Preliminary idea was to produce all cooling by using electrical chillers and free cooling from river. The excess heat from coolers was planned to lead in river Emajõgi. This solution was most profitable because of the lowest life cycle costs. When preparations for SEC project started, the new idea of usage the surplus heat from DC as heat source during heating season arise. Usage of surplus heat in DH enable to reduce fuel consumption in DH and thus CO2 emissions. Even 75% of primary energy in DH production is RES in Tartu, there is need for usage of fossil fuels like natural gas or peat during winter period.

The heat pump with capacity of 1,9MW heat and 1,4MW cooling has been installed as part of cooling plant. The design and tendering process was done in cooperation with Swedish company Capital Cooling. The project management and tendering of subsystems was made by own staff of FTAR. The commissioning of plant was in summer 2016.

When designing of cooling plant started, the idea of using PV panels arised. The main reason was architecture of the building of cooling plant. We were looking for the nice look of plant and PV panels as solution were selected. First idea was to cover walls fully with PV panels at south and east side. This plan was not feasible, because cooling plant is situated at city centre area and new 4-6 floor buildings were planned around the plant in near future and shadows of those buildings will reduce the sun radiation to panels. That is the reason why only 20kW of PV panels were installed at the walls instead of planned 70kW. To cover missing but preliminary planned capacity, extra 47kW of PV panels was installed at the roof in summer 2017.

FTAR is delivering DH service for buildings of the SEC project pilot area. Our promise was to deliver hourly base remote metering system for demo buildings. Those meters measuring overall heat consumption of demo buildings. Our standard remote metering solution was installed for demo buildings.

The successful implementation of this deliverable has been based on good collaboration between FTAR and municipality of Tartu. As creation of new district cooling system require a lot of piping works, municipality helped as to apply all necessary permits for construction works.

4 Task 4.5 / District heating and cooling commissioned and deployed

District cooling

The idea to create DC system in Tartu rised in 2013. The investment decision was done in 2014. According to business plan no heat pump was initially planned at cooling plant. According to feasibility study, the production with electrical coolers and free cooling was planned. The cooling of coolers 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.

During the implementation of the project, the heat pump as part of cooling plant was integrated into production system. Idea was, 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 maximum 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 coolers with capacity of 2,3MW and 4,7MW and one HP with capacity of 1,4MW cooling energy installed today. If market demand will increase, next compressor cooler with capacity of 4,7MW will be installed.

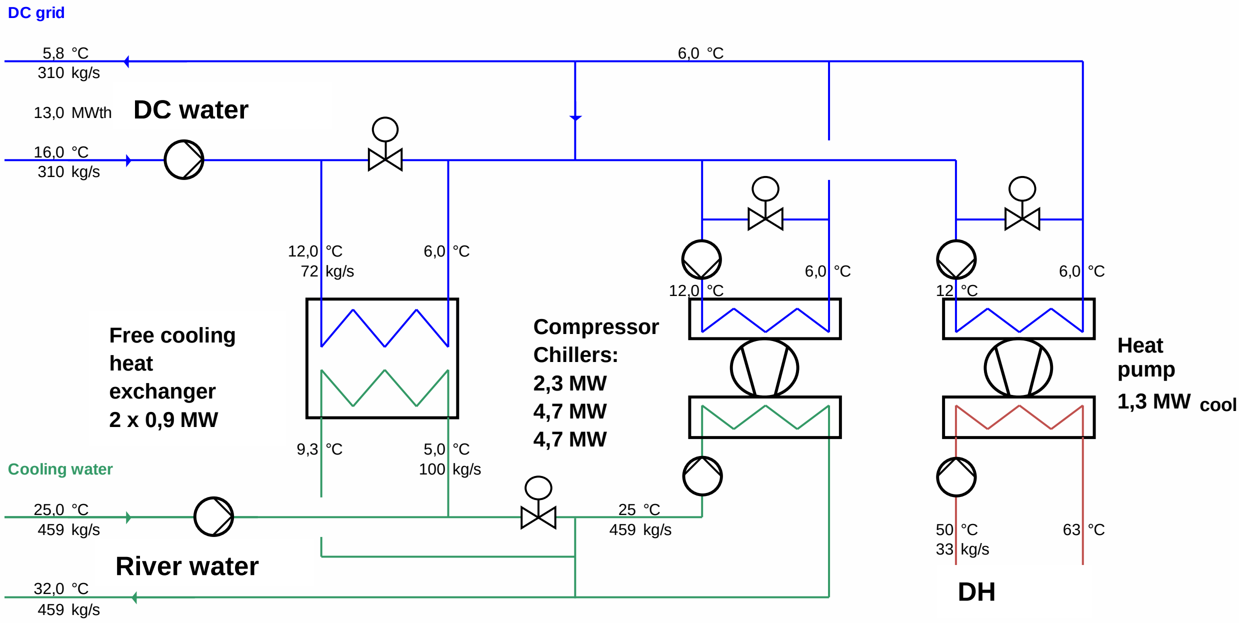

Figure 2: Principal flow diagram of cooling plant

Heat pump which is installed in cooling plant has been delivered by Carrier and it works with HFC refrigerant R134A which has GWP value 1430. HP is capable to produce 6 ^{0}C water for DC and up to 63 ^{0}C hot water for DH system. It is able to lead heat whether to supply or return line of DH network. 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 energy and 3,5kW of heat energy 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 DC plant was commissioned in summer 2016. There is 8,3MW of cooling capacity installed today. The contracting and connecting of new cooling customer's takes time therefore we have not reached the expected cooling demand yet. About 25% of installed cooling capacity was in use during the hottest days in summer 2018.

The length of DC network is 3,9km today and there is 6 customers connected to the network today. Unfortunately the amount of cooling customers is not big enough by now to run HP continuously during winter period.

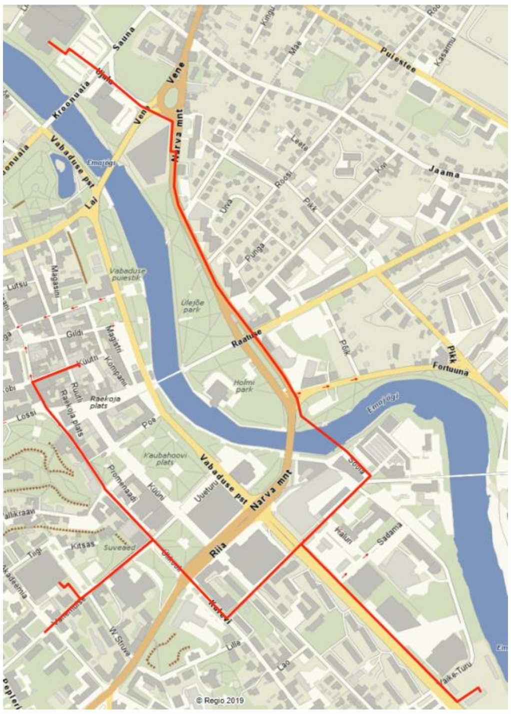

Figure 3: District cooling network inTartu

The tendering of HP was one part of coolers tender. All coolers and HP were purchased by one contract. The tendering process was made by Swedish consultancy company Capital Cooling. The main criteria of evaluation was lowest life cycle cost of equipment. The coolers and HP was delivered by AcRef OÜ. Heat pump is produced by Carrier and compressors-coolers by York.

Solar panels

As DC production needs a lot of electrical power, the PV panels 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.

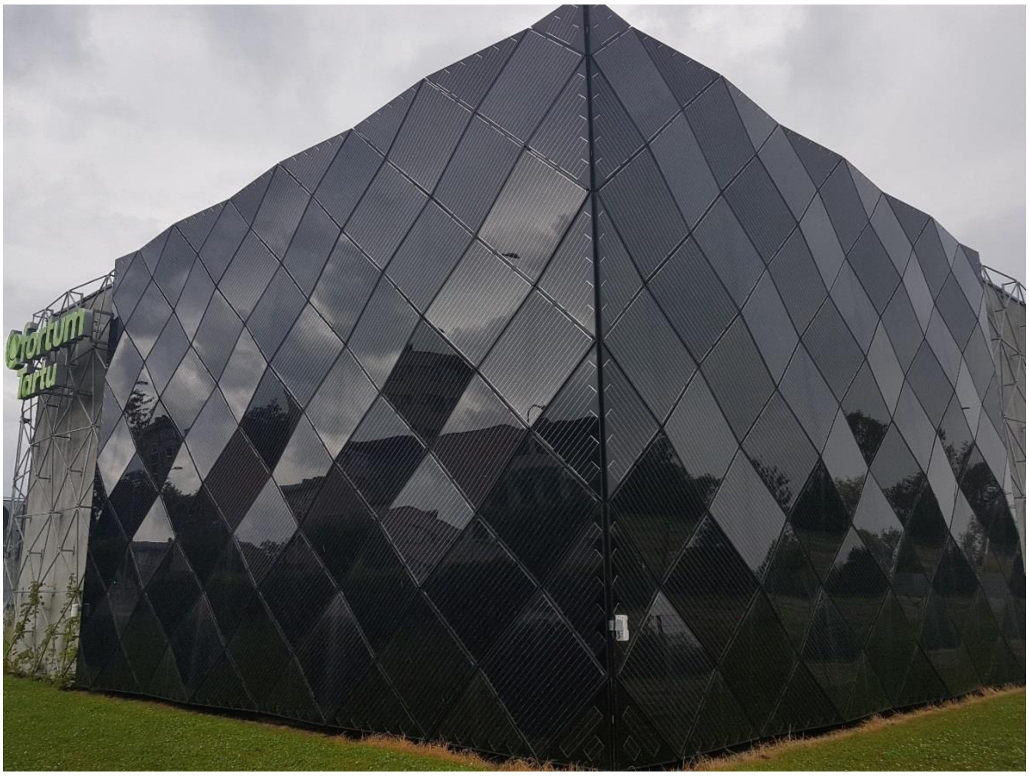

Figure 4: Facade of cooling plant with solar panels

Figure 5: 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 was about twice more expensive compared to standard solution. Additionally there was cost of steel frame.

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 solar-edge inverters.

The solar system was designed and constructed by Naps Solar Estonia OÜ.

The PV panels system is connected with power grid. When the production of PV panels is bigger than consumption, the excess power is directed 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 DH area are connected to the DH network. DH network is in good technical condition today and around 80% of DH network has been renovated in last 20 years. Together with the SEC project all demo buildings will be renovated by house owners. Renovation of buildings in Tartu LH pilot area consist different construction activities including district heating solutions. The role of FTAR is to ensure a connection to DH network for every building and deliver remote heat metering system.

All renovated buildings have heat metering which measuring the total consumption of consumed heat energy with commercial accuracy. Standard heat meters produced by Kamstrup are used today (type Multical 601 or 602). FTAR will change all heat meters with new Multical 603 type heat meters. 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 will have data delivery system via GSM link. The installation of new type meters is planned to be according to progress of renovation of the buildings.

FTAR will install heat meters only in building level. Heat meters for apartments will be delivered in together with installation of smart home solution.

Monitoring

District cooling plant has modern Distributed Control System (DCS) which is mainly used in industrial applications. DCS system is delivered by Siemens and it works on S7 controller. 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 database for external users. The generation of different reports for SEC project is possible by technical persons of FTAR.

All measurements needed for SEC project have described in Deliverable 7.8 “Integrated Infrastructures action monitoring program”. All measurements needed for fulfilling monitoring program are implemented.

At least following measurements could be used for SEC project:

System	Measurement	unit	Meter	Remark
DC plant	Cooling energy delivered	MWh	Heat meter	Direct measurement
	Overall electrical consumption	MWh	Electric Wh-meters	Calculated from balance
	Outdoor temperature	^{0}C	Thermometer	Direct measurement
HP	Heat energy produced and delivered	MWh	Heat meter	Direct measurement
	El. current and voltage consumed by HP	A, V	Multimeter of protection device	Energy to be calculated
	Cooling energy produced	MWh	Heat meter	Direct measurement

	Working hours	hour	No direct measurement	Data from database
	Inlet and outlet DH water temperatures	^{0}C	Electrical thermometer	Direct measurement
Coolers	El. current and voltage consumed by cooler	A, V	Multimeter of protection relay	Energy to be calculated
PV panels	Electricity produced by PV panels	kWh	Electrical meter	Hourly readings to database

Table 4: Measurements for monitoring programme

The solar radiation data is available from public web page http://meteo.physic.ut.ee/. This page has created by Tartu University and it is collecting weather data in Tartu. According to web page data it is possible to estimate the efficiency of solar panels.

First outcomes and results

PV panels installed at walls are working surprisingly well during winter season. As the angle of sunshine is quite low in Estonia during winter and the panels are not covered by snow, the panels at walls working relatively well. The panels at roof do not produce electricity at all if they are covered by snow.

Heat pump has been in operation only few hours. There is two main reasons:

1. The cooling capacity of HP is relatively big compared to cooling load. There are only few customers connected to the network by now and we have not reached the expected cooling demand. During winter season our cooling load has been much smaller than expected. It is quite difficult to run HP with load which is many times smaller than minimum load of HP.
2. Production of cooling with free cooling from river is more feasible compared to HP production.

We are still positive and we believe HP will have more working hours in the future. Today all heat for DH is produced by CHP plant which run at nominal load almost around the year. There is no need for additional heat for DH network during summer time. From 2021 the subsidies for electricity production in CHP plant will end. There will occur situation where in case of lower power prices the run of HP instead of electrical coolers will be feasible. Also we believe, the winter load will be rise in the future ant it will be able to run HP.

Energy produced		**2017**	**2018**
Electricity from PV panels (solar)	MWh	20.1	49.0
Share of solar from total power consumption	%	6	8.3
Cooling energy from coolers and heat pump	MWh	1539	3010
Heat energy from heat pump	MWh	31,2	0

Table 5: Energy production 2017 and 2018

5 Lessons Learned

Long term plans is needed for establishing the new district cooling network. Starting DC services from "zero" require very good understanding about market, business model, investment and operation costs of service. The development of DC network will take time. Generally starting-up the DC service has gone according to plans but due to the small amount of customers we do not have reached enough efficiency for HP. We shall be patient as DC service is long term activity and start-up takes time.

The expected winter load of the installation was 10% from summer peaks but actual load is lower - 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. Connecting of new customers will take time and therefore achieving optimal workload for HP takes longer time than expected.

Preliminary the HP was planned to operate during the winter-time. Analyses are showing that HP might be feasible also during the summer. After subsidies for CHP production will end, the HP could be the base load production unit in cooling plant. We believe, instead of burning fuels it becomes more environmental friendly and more feasible to run HP all around the year. If there will be enough cooling load, the HP could cover almost 10% of total heat demand in DH network during summer period.

District cooling system has very long life time period. During last years the environmental and global warming issues has become more important, new CO2 reduction targets has been agreed and CO2 prices have gone up. Therefore the importance of using residue heat from cooling has been increased. We see, that even HP do not works as much as foreseen, it is feasible in long-term.

DC is long term service and we have learned, that energy sector is in continuous change. More and more solar and wind power is coming to market. Power price will be much more volatile and new HP gives more possibilities for flexible energy production. If there is too much RES power available at the market, we can use HP as power consumer and vice versa in case of lack RES electricity we can use other energy sources, like biofuels for heat production.

On future there might be positive scenario, that there is too much solar and wind power on the market, we are using HP as heat source utilizing surplus energy from cooling. It will be totally renewable heat production without burning fuels and without CO2 and pollution from flue gases.

PV panel 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.