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Resource Efficient Cities Implementing Advanced Smart City Solutions – READY

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Scope of deliverable

This deliverable summarizes the activities and the results of the monitoring of the installations and buildings in Aarhus/Denmark and Växjö/Sweden within READY.
Monthly monitoring data have been collected and analysed for all READY Demonstration Projects (RDP) regarding the energy consumption, production and the environmental and financial impact.

Context of deliverable

The report is based on the READY demonstration activities in Aarhus and Växjö.

Perspective of deliverable

The perspective of the deliverable is to present the monitoring results and disseminate the activities and solutions to achieve a higher degree of energy from Renewable Energy Sources (RES) in the energy utilization in cities, especially the building sector.

Involved partners

AIT, COWI, ESS-SE, VEAB-SE, HOUSE-DK, MUN-DK et al.

Executive summary

This deliverable describes the monitoring results for the READY Demonstration Sites in Aarhus in Denmark and Växjö in Sweden. The monitoring includes the measurement of energy consumption in the buildings and the energy production from Renewable Energy Sources (RES) at the READY Demonstration Sites (RDS) in order to assess the energy demand resp. production, in a normalised year. Further READY Demonstration Projects (RDP) regarding district heating/cooling and electric mobility were monitored as well.

The buildings were refurbished by means of Building Envelope Improvement (BEI) including new windows. These passive means are a requirement for achieving low energy consumption. The buildings are further equipped with active elements in the form of efficient balanced ventilation with a high degree of heat recovery, Photovoltaic (PV) and Photovoltaic Thermal (PVT) systems on roofs as well as Waste Water Heat Recovery (WW-HR) facilities and a Battery Energy Storage System (BESS) for self-consumption optimisation of the PV yield.
The measures regarding district heating were performed by lowering the system's temperatures with the aim of reducing pipe heat losses and by installing a 1 MW sea water-fed heat pump increasing the share of renewable heat in the district heating network (Aarhus).
Further READY Demonstration Projects are the innovative district cooling project "energy used three times" (Växjö) and the installation of charging stations for electric vehicles (Aarhus).

In READY, the normalised average Final Energy consumption of all buildings is 64 kWh/m^2yr, which meets the corresponding target value according to Building Energy Specification Table (BEST, see DOW) very well. Due to deviations from original planning regarding the installation of RES facilities (PV(T) systems, etc.), the monitored on-site RE production (at the sites of the refurbished buildings) of 5.9 kWh/m^2yr does not in itself meet the corresponding target value.
Nevertheless, this shortcoming is (over)compensated by the contribution of the above mentioned 1 MW sea water-fed heat pump in Aarhus harbour. This large heat pump can contribute with up to 6 GWh renewable heat to the district heating system per year.
READY's total environmental impact is a reduction of greenhouse gas (GHG) emissions of approx. 70 thousand tons $CO_{2,eq}$ within a 30 years timeframe.
As READY's 30 years GHG emission saving target was 57 Thousand tons, the corresponding achieved GHG emission savings of 62 Thousand tons (excluding the contribution of further measures), speaks for READY's success.
The project and the results can be used as model for other construction projects. Furthermore, the results are disseminated and discussed in various fora.

Acknowledgment

This project has received EC support from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. ENER/FP7/609127/READY.

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JULY 2020

READY - RESOURCE EFFICIENT CITIES IMPLEMENTING ADVANCED SMART CITY SOLUTIONS

D.7.3 Evaluation of the operational monitoring data of the demonstration projects

REPORT

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List of Abbreviations

an.	Annual
AC	Alternating current
AIT	AIT Austrian Institute of Technology
Approx.	Approximately
AW HP	Air/water heat pump
BEI	Building Envelope Improvement
BESS	Battery Energy Storage System
BOPS	Electricity consumption for building operation
CA-SE	CA-Fastigheter AB
CA-SE2	CA I Växjö AB
CHP	Combined Heat and Power
CO_2	Carbon dioxide
$CO_{2,eq}$	CO_2 equivalent (emissions)
COP	Coefficient of performance
COWI	COWI A/S
D.	Deliverable
DANF-DK	Danfoss
DC	District Cooling
DC	Direct Current
DDHA	Danish District Heating Association, Grøn Energi
DH	District Heating
DHC-LT	Kauno Energija AB
DHW	Domestic Hot water
DK	Denmark
DK1	Code of the READY Demonstration Site in Aarhus with reference number 1
DK2	Code of the READY Demonstration Site in Aarhus with reference number 2
DK3	Code of the READY Demonstration Site in Aarhus with reference number 3
DK4	Code of the READY Demonstration Site in Aarhus with reference number 4
DK-Ch	Code of the READY Demonstration Project in Aarhus regarding the Charging Stations for Electric Vehicles
DKK	Danish Kroner
DK-PVT	Code of the READY Demonstration Project in Aarhus regarding a Photovoltaic Thermal System
DK-ST	Code of the READY Demonstration Project in Aarhus regarding a Battery Energy Storage System
DK-WW	Code of the READY Demonstration Project in Aarhus regarding a Waste Water Heat Recovery (WW-HR) System
DNU	The New University Hospital (Aarhus)
DONG-DK	DONG Energy
DOW	Description of Work
DTI	Danish Technological Institute

e.	Energy
EC	European Commission
EE	Energy Efficiency
electr.	electricity/electric
EMZI	Emanuele Zilio
EON-DK	E.ON Denmark
ESS-SE	Energy Agency for Southeast Sweden
EUR	Euro
EV	Electric Vehicle
FP7	Seventh Framework Programme (EU)
GWh	Gigawatt hours
h	hour
h^{-1}	per hour
HOUSE-DK	Boligforeningen Ringgården
HP	Heat Pump
IKEA	IKEA – Industry
KAM-DK	KAMSTRUP
kEUR	Thousand EURO
kWh	Kilo Watt hours
kWp	Kilo Watt peak
LB-DK	Lithium Balance
LEI-LT	Lietuvos Energetikos Institutas
LGI	LGI Consulting
LIBs	Lithium-ion Batteries
m^2	Square metre(s)
MEUR	Million EURO
MUN-DK	Aarhus Municipality / AffaldVarmeAarhus
MUN-SE	Växjö Municipality
MW	MegaWatt
MWh	MegaWatt hours
N/A	Not Applicable
no.	Number
O&M	Operating and Maintenance (costs)
POC	Point of Connection
PV	Photovoltaic (system)
PVT	Photovoltaic Thermal (system)
q50	Design air permeability at 50 pascals pressure in h^{-1}
RDP	Ready Demonstration Project
RDS	Ready Demonstration Site
R&D	Research & Development
RAC-DK	RAcell- SME – Industry (original partner from proposal)
RE	Renewable Energy
READY	Resource Efficient Cities Implementing Advanced Smart City Solutions
ren	Renewable
RES	Renewable Energy Sources

resp.	Respectively
RMH	Reto Michael Hummelshøj
SBEH	Smart Building Energy Hub
SCF	Self-consumption fraction
SCIS	Smart Cities Information System
SCOP	Seasonal coefficient of performance
SE	Sweden
SE1	Code of the READY Demonstration Site in Växjö with reference number 1
SE1.1	Code of the READY Demonstration Site in Växjö with reference number 1.1
SE3	Code of the READY Demonstration Site in Växjö with reference number 3
SE-DH	Code of the READY Demonstration Project in Växjö regarding the District Heating Network in Alabastern
SEK	Swedish Kroner
SE-PVT	Code of the READY Demonstration Project in Växjö with a Photovoltaic Thermal System
SE-WW1	Code of the READY Demonstration Project in Växjö "Energy used three times" (district cooling project)
SE-WW2	Code of the READY Demonstration Project in Växjö with a Waste Water Heat Recovery (WW-HR) System
SPETS	Peak consumption supplied with primary district heating (Swedish term)
SPF	Seasonal Performance Factor
ST	Solar Thermal (system)
TN	Thomas Natiesta
UNI-DK	Aarhus University
UNI-SE	Linnaeus University
U-value	Thermal transmittance
VEAB-SE	Växjö Energy
VENT	Balanced domestic/office ventilation with efficient heat recovery
VFAB-SE	VÖFAB
vs	Versus
VXH-SE	Växjobostäder
WP	Work Package
WW-HR	Waste Water Heat Recovery (system/facility)
yr	Year(s)

1 Summary

This report, *D.7.3 Evaluation of the operational monitoring data of the demonstration projects* is a deliverable of the EU-funded project called READY. It contains monitoring data and analyses of the demonstration activities conducted in Aarhus/Denmark and Växjö/Sweden.

The monitoring data covers energy consumption of refurbished buildings, heat losses of energetically optimised district heating networks, the heat production and electricity consumption of heat pumps, the electricity (and heat) production of photovoltaic (thermal) systems and others. Some buildings and facilities were commissioned after 2018. Therefore, reliable monitoring data of a full calendar year (i.e. 2019) were not available for all buildings and facilities. Eventually, missing, implausible or non-representative measurement data were replaced by reliable data from other months and further input values (e.g. heating degree days).

Based on this data, comprehensive analyses concerning the environmental and economic impact of the undertaken measures was performed. In this report, the aggregated monitoring results and the outcome of the analyses are presented. Where applicable, the results from the monitoring data were compared with the energy consumption and production values stated in the Building Energy Specification Table (BEST) which is part of the Description of Work (DOW) of the READY project. This report proves that the BEST Targets are met and therefore, the READY project has been successful.

Energy consumption

In 2019 resp. 2020, the monitoring data[1] from the READY Demonstration Sites (RDS)[2] in Växjö resulted in a Final Energy consumption[3] of 72 kWh/m², which is 10 kWh/m² below the BEST Target Value of 82 kWh/m².

In 2019 respectively 2020, the monitored Final Energy consumption of the buildings at the RDS in Aarhus was 59 kWh/m²per year which is even 13 kWh/m² below the BEST Target Value of 72 kWh/m².

In **READY**, the average Final Energy consumption at all Demonstration Sites of the whole project was 64 kWh/m²yr, which is 12 kWh/m² below than the BEST Target Value of 76 kWh/m².

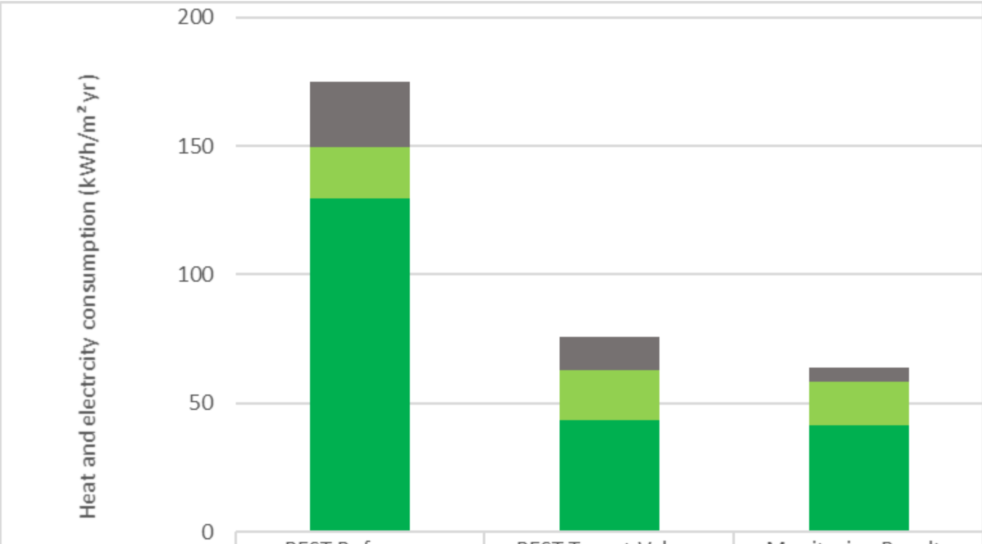
[1] In this report, unless otherwise noted, area-based values, representing a group of buildings, are floor area-weighted average values. When applicable, energy consumption/production values were normalised to reference conditions (e.g. heating degree days of a reference year see 3.3). For the definition of floor area see 3.2.1.

[2] In this report, READY Demonstration Projects regarding building refurbishment are hereafter referred to as READY Demonstration Sites.

[3] Heat consumption from district heating network for space heating and domestic hot water (DHW) preparation and electricity consumption for building operation (BOPS, lighting in common areas and centralized ventilation systems).

Hence, the monitoring data proves that the reduction in Final Energy consumption as targeted by the READY project is met.

Figure 1 shows the BEST Reference, the BEST Target Values and the Monitoring Results of the heat consumption for space heating and Domestic Hot Water (DHW) as well as the electricity consumption for building operation (BOPS) of the multi-family and for office buildings in READY.



	BEST Reference	BEST Target Values	Monitoring Results
Electricity (BOPS)	25	13	6
DHW	20	19	17
Space heating	129	44	41

Figure 1: *BEST Reference, BEST Target Values and Monitoring Results (2019 resp. 2020) of heat consumption for space heating and DHW and electricity consumption (BOPS) in READY (floor area-weighted average)*

RE production

The BEST Targets concerning the on-site[4] Renewable Energy (RE) production in Växjö was on average 3.4 kWh/m²yr and 24 kWh/m²yr in Aarhus. The BEST target Value of on-site RE production at the RDS in Växjö and Aarhus together was 16 kWh/m²yr.

In 2019 resp. 2020, the monitored on-site RE production in Växjö was 3.2 kWh/m²yr and 7.7 kWh/m²yr in Aarhus. The floor area-weighted average value of all RDS was 5.9 kWh/m²yr.

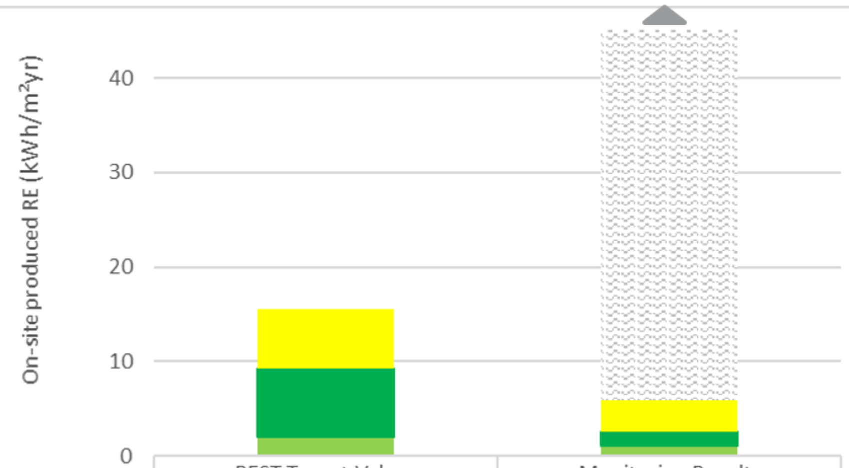
The monitoring values show that the target regarding on-site RE production was not completely fulfilled, but a 1 MW heat pump in Aarhus harbour more than compensates these shortfalls with a potential heat production of 6 GWh/yr.

Figure 2 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the solar heat (ST yield) and electricity (PV yield) production from roof-

[4] Hereafter "on-site" refers only to RE production (e.g. of a PV system) at READY Demonstration Sites with a corresponding "target value" in the BEST (see DOW).

top Photovoltaic (PV) and Photovoltaic Thermal (PVT) systems as well as from Waste Water Heat Recovery (WW-HR) facilities (WW-HR yield) at the READY Demonstration Sites in Växjö and Aarhus.

The contribution from the 1 MW sea water-fed heat pump is indicated. The energy savings in the improved district heating network in Växjö and the other measures, not mentioned in this section, were not included.



	BEST Target Values	Monitoring Results
1 MW heat pump		72.63
PV yield	6.30	3.41
ST yield	7.22	1.35
WW-HR yield	1.95	1.13

Figure 2: BEST Target Values and Monitoring Results (2019 resp. 2020) of on-site RE production (heat and electricity) in READY (floor area-weighted average). The contribution from the 1 MW heat pump is indicated.

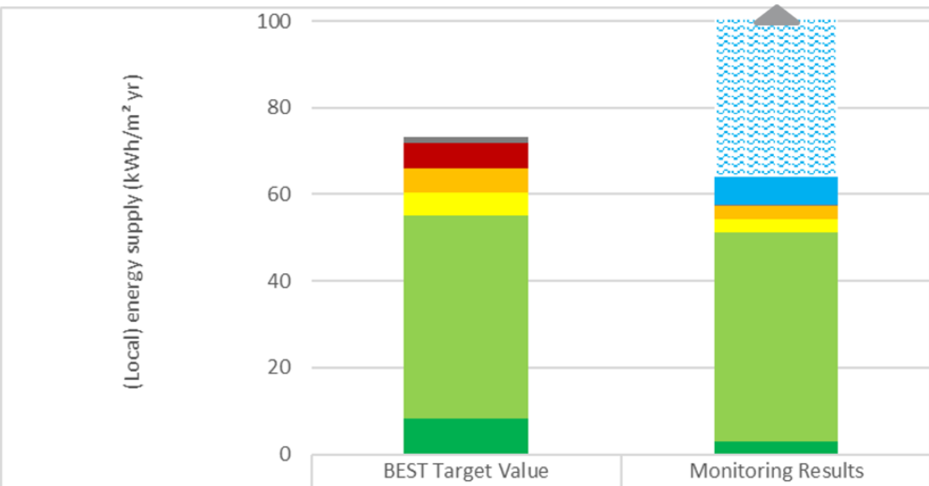
RE supply to buildings

Additional BEST Targets refer to the heat and electricity supply to the READY Demonstration Sites by the local district heating networks and the electricity grids from centralized renewable heat and electricity production.

At the time when the DOW was established, the use of waste heat from The New University Hospital (DNU) and the electricity production from additional common wind turbines (both in Aarhus) were suggested. These measures were not implemented within READY but in Aarhus resp. Växjö the renewable share in both, district heating (80% resp. 95%) and electricity (66% resp. 90%) is high.

Therefore, the total renewable contribution from on-site RE production and grid supply is remarkable. Additionally, the above mentioned 1 MW (first of 12 MW planned) sea water-fed heat pump at Aarhus harbour displaces the non-renewable share in READY's district heating supply.

Figure 3 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the renewable[5] and non-renewable energy supply to the RDS in Växjö and Aarhus and the on-site RE production in READY. The surplus heat production of the 1 MW sea water-fed heat pump is indicated.
The energy savings in the improved district heating network in Växjö and the other measures, not mentioned in this section, were not included. The graph confirms that on an annual, project-wide view, almost no non-renewable energy is required to supply the RDS with heat and electricity.



	BEST Target Value	Monitoring Results
1 MW heat pump (surplus)		81.1
1 MW heat pump		6.5
non-ren electr. supply	1.4	0.1
non-ren heat supply	5.9	0.0
ren electr. supply	5.6	3.1
local ren electr. prod	5.1	3.1
ren heat supply	47.0	48.3
local ren heat prod	8.2	3.0

Figure 3: BEST Target Values and Monitoring Results (2019 resp. 2020) of the total renewable and non-renewable energy supply to buildings in READY from on-site RE production resp. grids (floor area-weighted average). The surplus heat production of the 1 MW sea water-fed heat pump is indicated.

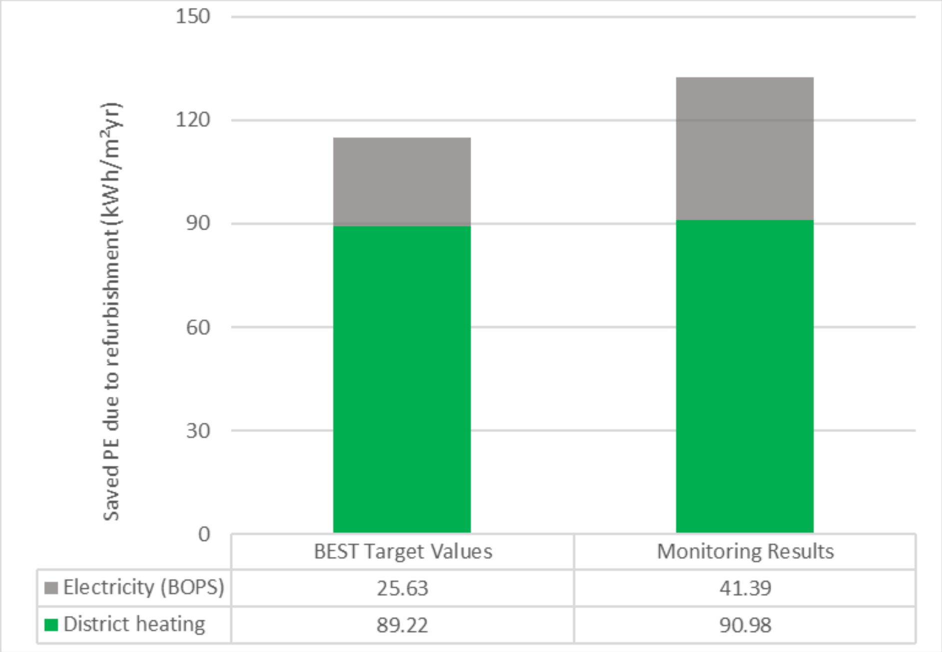
Further energy savings

The optimised district heating network in Alabastern/Växjö achieves a reduction in pipe heat losses of 106 MWh per year. The innovative district cooling project "energy used three times" in Växjö reduced the cooling energy consumption by 1 GWh by means of efficiency in the cooling system of the servers at a data centre and save 600 MWh cooling energy as it is provided by the heating of the football turf. As the cooling energy is provided by free cooling (from lake water), and by an absorption cooling machine (COP=0.65) which is powered by heat from the district heating network, the total saved heat is 2.5 GWh. Including the free cooling waste heat used for the football turf the total heat savings are approx. 3.1 GWh.

[5] In this approach no distinction between renewable and nuclear energy was made

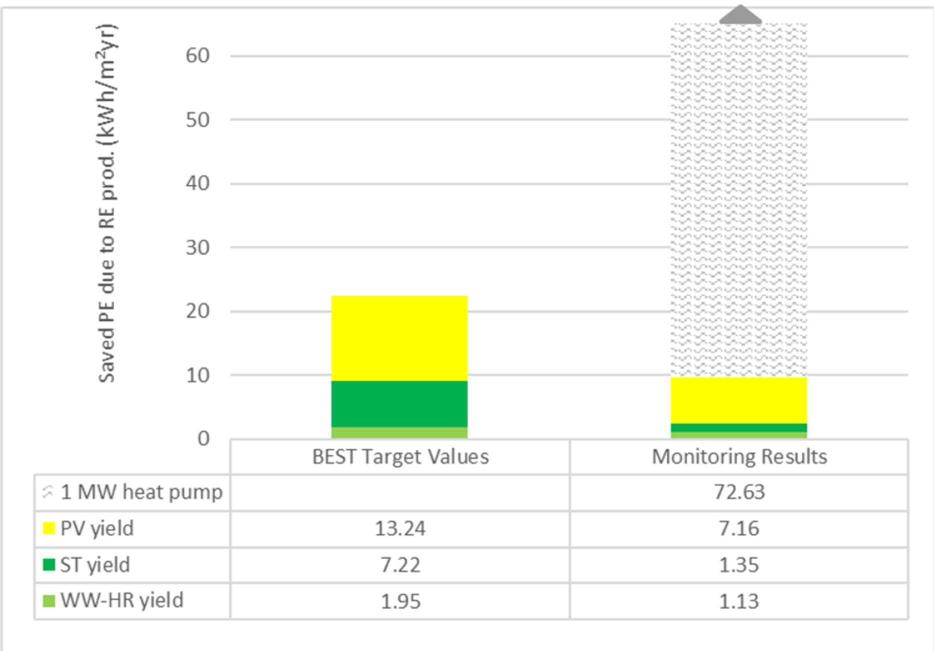
Primary Energy

In READY, building refurbishment leads to PE savings of 91.0 kWh/m²yr regarding heat and 41.4 kWh/m²yr regarding electricity. Figure 4 and Figure 5 show the BEST Target Values and Monitoring Results (2019 resp. 2020) regarding PE savings due to building refurbishment resp. due to on-site RE production (1 MW heat pump indicated).



	BEST Target Values	Monitoring Results
Electricity (BOPS)	25.63	41.39
District heating	89.22	90.98

Figure 4: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding PE savings due to refurbishment in READY (floor area-weighted average)



	BEST Target Values	Monitoring Results
1 MW heat pump		72.63
PV yield	13.24	7.16
ST yield	7.22	1.35
WW-HR yield	1.95	1.13

Figure 5: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding PE savings due to on-site RE production in READY (floor area-weighted average). The contribution from the 1 MW heat pump is indicated.

https://cowi.sharepoint.com/sites/A064318-project/Shared Documents/03 Deliverables/04 Reporting/07 WP7/D.7.3/04 Final Documents/D7.3 Evaluation of the operational monitoring data of the demonstration projects_v2.4 final.docx

CO_2 emission savings

In READY, the annual CO_2 emission savings regarding building refurbishment is approx. 1,668 tons[6]. Figure 6 illustrates the specific CO_2 emission savings (per m² gross floor area) due to building refurbishment.

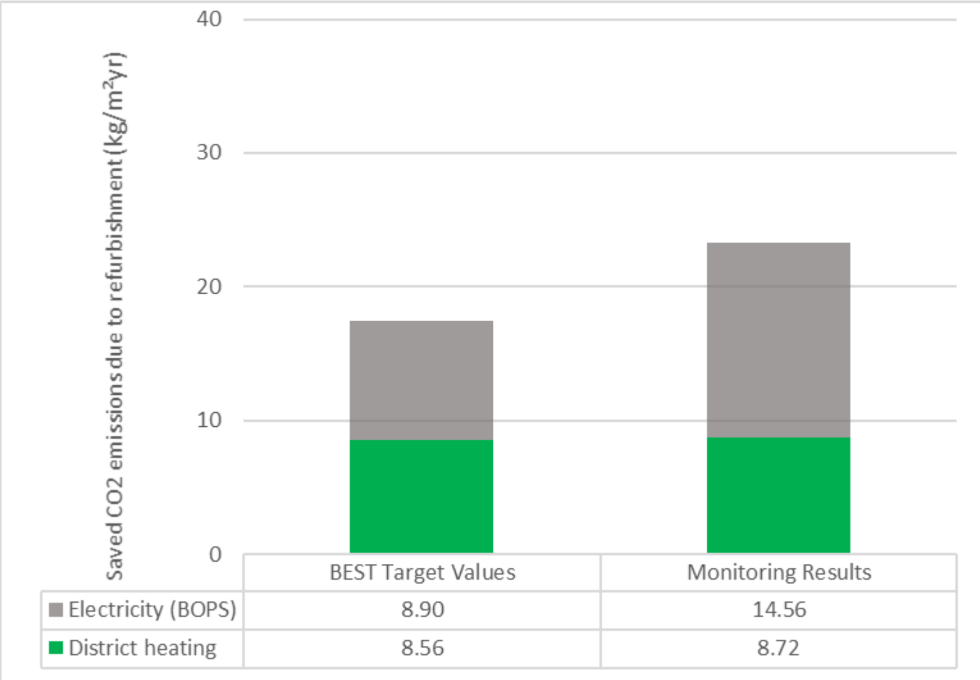


Figure 6: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding the CO_2 emission savings due to building refurbishment in READY (floor area-weighted average).

The on-site RE production (heat and electricity) lead to annual CO_2 emission savings of approx. 231 tons per year. Additionally, the 1 MW sea water-fed heat pump in Aarhus harbour (Denmark) saves CO_2 emissions of approx. 648 tons per year.

Figure 7 illustrates the floor area-weighted average CO_2 emission savings due to on-site RE production. The contribution from the 1 MW sea water-fed heat pump is indicated. The CO_2 emission savings in the improved district heating network in Växjö and the other measures, not mentioned in this section, are not included in this graph.

[6] CO_2 emissions calculated with CO_2 emission factors defined in the DOW

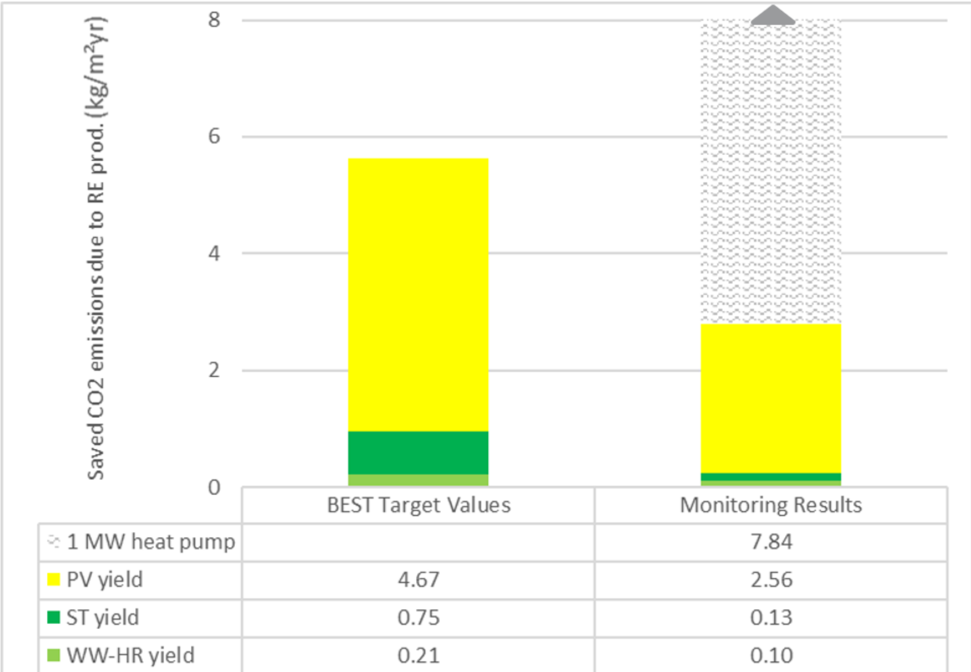


Figure 7: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding the CO_2 emission savings due to on-site RE production in READY (floor area-weighted average). The contribution from the 1 MW heat pump is indicated.

The further READY Demonstration Projects not included above contribute to CO_2 emission savings as well. The optimised district heating network in Alabastern/Växjö achieves CO_2 emission savings of approx. 7.9 tons per year. The CO_2 emission savings of the innovative district cooling project "energy used three times" in Växjö are at least 230 tons per year.

Economic analysis

The share of investment costs required to achieve the energy savings presented above was approx. 13 MEUR (166 EUR/m²) just regarding building refurbishment. The total investment costs of all facilities for on-site RE production (hereafter also referred as RES facilities) was approx. 1 MEUR excl. VAT.

The total cost of refurbishment is significantly higher, e.g. approx. 1,500 EUR/m² for Demonstration Sites in Aarhus, as this figure includes cost for new bathrooms, new kitchens, balconies, surfaces, gardening etc. These non-energy relevant cost shares are not part of READY and hence, not investigated in WP7.

The EC Support for building refurbishment measures was 50% of the share of investment costs required to achieve energy savings (max. 50 EUR/m²). The EC Support for RES facilities was 50% of eligible costs of RES facilities (PVT and WW-HR systems). Standard PV systems were not supported.

In READY, the simple payback time for the energy-related investment in building refurbishment is on average 34 years resp. 25 years if the EC Support is taken into consideration. The simple payback time for the investment in all on-site RES facilities in READY is on average 24 years resp. 15 years if the EC Support is taken into consideration.

A suitable way to analyse the cost effectiveness of energy-saving measures is to calculate the costs for the reduction of CO_2 emissions (e.g. by building refurbishment). These include costs for all (additional) measures that must be performed in order to achieve CO_2 emission savings: investment costs, reinvestment costs, O&M costs, etc.

As energy savings and CO_2 emission savings often come along with energy cost savings, this characteristic number may become negative, which means that the total costs to achieve CO_2 emission savings are lower than the energy cost savings. Positive values on the other hand mean that the total costs to achieve CO_2 emission savings are higher than the energy cost savings.

In READY, the CO_2 emission saving cost of the measures regarding building refurbishment is on average -77 EUR/ton and -84 EUR/ton regarding on-site RE production. If EC Support for energy-saving measures was taken into consideration, these values would be even better. As these values are negative, on average, cost effectiveness of the READY measures could be confirmed, although this is not the case for each measure in particular.

2 Introduction

The objective of WP7 is to monitor the overall energy and carbon impact of the READY project as well as to monitor the energy performance of all READY Demonstration Projects.

The aim of deliverable D.7.3 is to report the results, findings and conclusions from the monitoring activities related to the READY project in Aarhus and Växjö communities, presented in Figure 8.

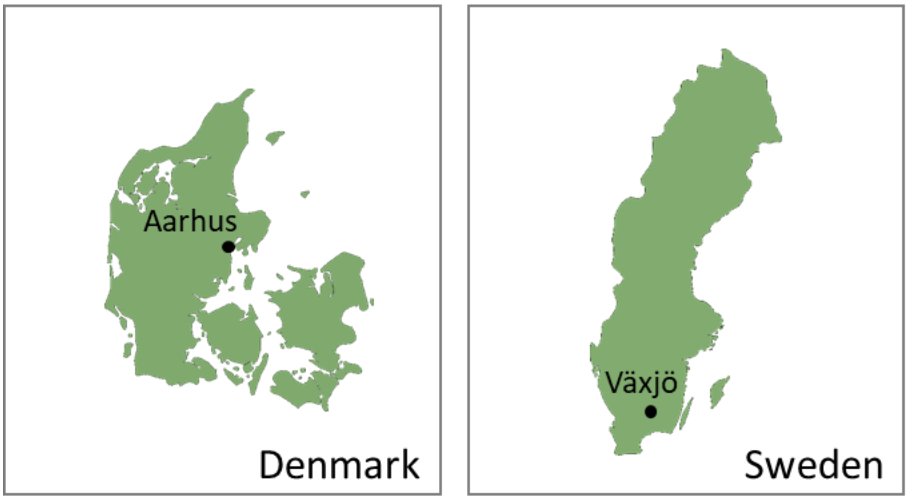


Figure 8: Map representing the two demonstration communities, Aarhus in Denmark and Växjö in Sweden

2.1 READY Demonstration Projects

In Växjö and Aarhus, three resp. four READY Demonstration Projects regarding building refurbishment of residential and office buildings and eventually further energy saving measures have been monitored (see Table 1).

Table 1: READY Demonstration Sites in Aarhus and Växjö where building refurbishment and eventually further measures were performed

Code	District	Building type	Measures	Gross floor area (m²)
SE1	Alabastern, Växjö	Multi-family buildings	BEI[7], VENT[8]	26,853
SE1.1	Alabastern, Växjö	Multi-family building	BEI, VENT, WW-HR[9], PVT	3,361
SE3	Arabygatan 9, Växjö	Office building	BEI, VENT	3,340
DK1	District 21 Phase 1: Rydevænget, Aarhus	Multi-family buildings	BEI, VENT, PV, WW-HR	12,028
	District 21 Phase 2: Rydevænget, Aarhus			2,123
	District 21 Phase 3: Fjældevænget, Aarhus	Multi-family buildings	BEI, VENT, PV	4,528
	District 21 Phase 4: Fjældevænget, Aarhus	Multi-family buildings	BEI, VENT, PV	9,623
DK2	District 20 Trigeparken, Aarhus	Multi-family buildings	BEI, VENT, PVT, WW-HR,	19,140
DK3	Dybedalen 1A, Aarhus	Office building	BEI, VENT, PV	1,446
DK4	Hasle/Skejby, Aarhus	Single family house	BEI	174
Sum				**33,554**
Sum				**49,062**
Total				**82,616**

[7] Building envelope improvement

[8] Balanced domestic/office ventilation with efficient heat recovery

[9] Facility for Waste Water Heat Recovery (WW-HR)

[10] Battery Energy Storage System (BESS)

Additionally, READY Demonstration Projects regarding district heating/cooling (RDP SE-DH[11] and SE-WW1 in Växjö), public charging stations for electric vehicles (RDP DK-Ch in Aarhus), and a 1 MW sea water-fed heat pump (RDP DK-WW1 in Aarhus) were established (described in 2.2).

RDS DK1 in Aarhus

The first READY Demonstration Site in Aarhus is a multi-family block composed by 2 x 6 buildings called Rydevænget/ Fjældevænget, where the impact of Building Envelope Improvement (BEI), Balanced domestic ventilation with efficient heat recovery (VENT) and the performance of a PV installation have been monitored (RDS DK1).

Figure 9 and Figure 10 show the buildings in Rydevænget before and after refurbishment.

Figure 9: Buildings in District 21 Rydevænget/Fjældevænget, Aarhus (RDS DK1) before refurbishment[12]

[11] The READY Demonstration Sites (RDS) have the identification codes SE1, SE1.1, SE3, DK1, DK2, DK3 and DK4 as defined in the DOW. For READY Demonstration Projects not (directly) related to building refurbishment (RDP), e.g. RES facilities, no identification codes had been defined in the DOW, hence, new identification codes, e.g. SE-PVT, were defined within WP7.

[12] See https://www.bf-ringgaarden.dk/se-vores-boliger/vores-afdelinger/afdeling-21/om-afdelingen.aspx)

Figure 10. Buildings in District 21 Rydevænget/Fjældevænget, Aarhus (RDS DK1) after refurbishment[13]

RDS DK2 in Aarhus

The second monitoring site in Aarhus (RDS DK2) is a multi-family block in Trigeparken with six buildings (see Figure 11 and Figure 12), the monitored measures are the BEI, VENT an PVT system (RDP DK-PV), a Battery Energy Storage System (RDP DK-ST) and a WW-HR facility (RDP DK-WW2).

Figure 11: Buildings in District 20 Trigeparken, Aarhus (RDS DK2) before refurbishment

[13] Ibid.

Figure 12. Buildings in District 20 Trigeparken, Aarhus (RDS DK2) after refurbishment[14]

RDS DK3/4 in Aarhus

The other two READY Demonstration Sites in Aarhus are an existing office building in Dybedalen 1A (RDS DK3, see Figure 13) and a single-family house in Hasle/Skejby (RDS DK4, see Figure 14). The office building was refurbished with BEI and VENT. Furthermore, the building was equipped with a roof-top PV system (RDP DK-PV). The single-family house in Hasle/Skejby (RDS DK4) was refurbished only with BEI.

Figure 13: Office building located in Dybedalen 1A (RDS DK3)

[14] See https://www.bf-ringgaarden.dk/se-vores-boliger/vores-afdelinger/afdeling-20/om-afdelingen.aspx

Figure 14: Single-family house in Hasle/Skejby (RDS DK4)

Further READY Demonstration Projects in Aarhus are a public charging facility (RDP DK-Ch), initial steps for a low-temperature district heating project in Harlev district (RDP DK-DH)[15] and a 1 MW sea water-fed heat pump at the Aarhus harbour (RDP DK-WW1).

RDS in Växjö

In Växjö, there are three RDS where several energy saving/RE production measures, similar to those applied in Aarhus were applied: building refurbishment including BEI, balanced ventilation with heat recovery (VENT), installation of a PVT system (RDP SE-PVT) and a facility for WW-HR (RDP SE-WW2).

RDS SE1/1.1

The first two RDS in Växjö are a compound of 14 multi-family buildings in Nydalavägen/Hjalmar Petris väg (RDS SE1, see Figure 15) and another multi-family building in Nydalavägen 22 (RDS SE1.1, see Figure 16).

Both RDS are located in Alabastern district. The applied measures are the BEI and the installation of centralized ventilation systems with energy efficient heat recovery (RDS SE1 and SE1.1), a PVT system at the READY Demonstration Site SE1 (RDP SE-PVT) as well as a WW-HR system at SE1.1 (RDP SE-WW2).

[15] Representative monitoring data not yet available

Figure 15. Monitored buildings in Alabastern, Växjö (RDS SE1) after refurbishment

Figure 16: Monitored building in Nydalavägen 22, Alabastern (RDS SE1.1)

RDP SE3 in Växjö

Another READY Demonstration Site is located in Tvinnaren 4 (RDS SE3, see Figure 17). The building was constructed in 1945-1946 and used as a clothing factory. Today, the building is used as an office building. 3,340 m² of the second floor has been refurbished in 2017.[16]

Figure 17: Monitored office building located in Tvinnaren 4 (RDS SE3)[17]

Further RDP in Växjö

A conventional district heating network was upgraded to a low-temperature district heating network (RDP SE-DH) and an innovative project with district cooling, where by means of an cascading approach (each user uses the return from the previous user) back-cooling is performed by heating a football turf. (RDP SE-WW1, see 2.2.3)

2.2 Energy saving and RE production measures

2.2.1 Building refurbishment

In the course of building refurbishment, the thermal insulation of facades, roofs, ground floors, etc. of the buildings at the RDS in Aarhus and Växjö were enhanced, the existing windows were replaced by well insulated windows with triple-layered glazing and balanced ventilation systems with heat recovery installed in almost all buildings.

Façade insulation

The U-values of the building components of the refurbished buildings in Aarhus and Växjö before and after the building refurbishment are listed in Table 2.

[16] See D.6.2

[17] Ibid.

Table 2: U-values of building components before and after building refurbishment

	Code:	SE1/SE1.1		DK1		DK2		DK3		DK4	
Building component	**Unit**	**bef.**	**now**	**bef.**	**now**	**bef.**	**now**	**bef.**	**now**	**bef.**	**now**
External walls	W/m²K	0.36	0.33	0.70	0.22	0.70	0.15	0.70	0.15	0.70	0.10
Roof	W/m²K	0.24	0.11	0.50	0.51	0.50	0.12	0.50	0.10	0.40	0.10
Ground floor	W/m²K	0.41	0.38	0.75	0.60	0.75	0.30	0.75	0.24	0.75	0.12
Windows	W/m²K	2.50	0.90	2.90	0.56	2.90	0.80	2.90	0.80	2.90	0.90

Air tightness

Another crucial aspect of thermal building quality is the air tightness of buildings that is improved significantly in the course of building refurbishment, as performed in READY. The air tightness can be determined by means of a so-called Blower-Door test. The tested q50-values of the buildings at the Växjö RDS lie in a very good range between 0.31 h^{-1} and 0.51 h^{-1}. For the RDS in Aarhus, these values are not available.

Ventilation

The buildings at the RDS in Aarhus and Växjö (except RDS DK4) were equipped with balanced ventilation systems with energy efficient heat recovery.

Figure 18 shows a decentralised ventilation device at READY Demonstration Site DK2 in Aarhus.

Figure 18: Ventilation heat recovery device in Building at RDS DK2

Table 3 lists the efficiency of the heat recovery and the resulting ventilation heat losses of the buildings at the RDS after building refurbishment. The ventilation heat losses in the former building situation were not investigated, but a good rough estimate is five times the current value.

Table 3: Ventilation efficiency values of the buildings after building refurbishment

Code	ventilation rate (h^{-1})	efficiency of heat recovery (%)	ventilation heat losses (kWh/m², yr)
SE1 and SE1.1	0,764-0,799	81,3-86,0	unknown
SE3	5.8	74.8-78	unknown
DK1	0.3	85-88	2.7
DK2	0.3	86	2.7
DK3	0.6-1.7 (VAV)	85	6.1
DK4	0.3	no balanced ventilation	7

2.2.2 On-site RE production (heat and electricity)

At most of the READY Demonstration Sites facilities for the production of renewable heat and electricity were installed.

PVT systems

Photovoltaic thermal (PVT) systems are developed to produce both electricity and heat. This technology combines the technology of PV panels and the technology of solar collectors in one panel.

PVT systems were installed and monitored at RDS SE1.1 in Växjö (RDP SE-PVT, see Figure 19) and at RDS DK2 in Aarhus (RDP DK-PVT, see Figure 20). The installed PVT area and PV peak power of both PVT systems are found in Table 4.

Table 4: Installed PVT area in Aarhus and Växjö

RDS Code	RDP Code	District	Installed PVT area (m²)	P_{PV} (kW_p)
SE1.1	SE-PVT	Alabastern	96 in part 1	16 in part 1
DK2	DK-PVT	Trigeparken	743	126
Total			**839**	**132**

Figure 19: PVT system (RDP SE-PVT) installed on Alabastern (RDS SE1.1), left: PVT panels, right: PV inverter

Figure 20: PVT system (RDP DK-PVT) installed on Trigeparken (RDS DK2)

In READY, the PVT panels were supplied by RACELL, a company based in Aarhus. In contrast to conventional PVT solutions, RACELL PVT panels count with a number of innovations concerning the material characteristics (e.g. composite materials), structure and dimensions of the components (see Figure 21).[18]

[18] D.8.3

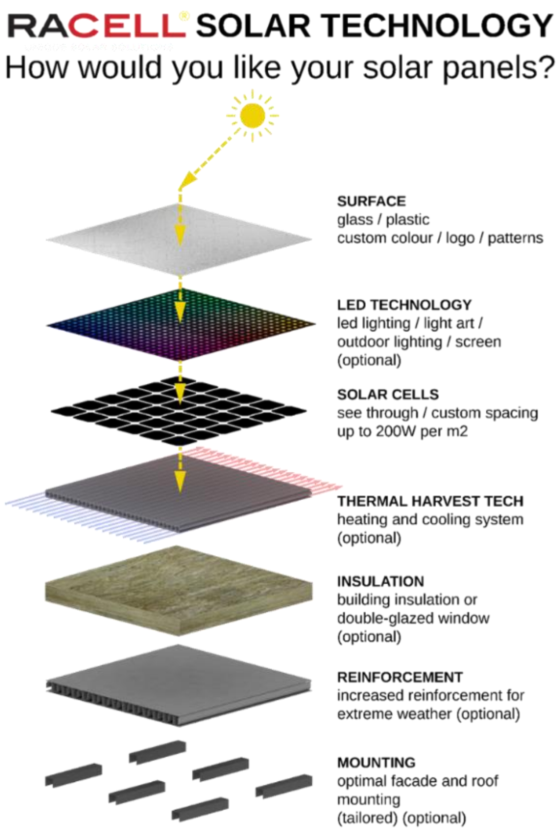


Figure 21: Illustration of PVT technology[19] (insulation is optional)

At RDS DK1, PVT systems were installed on the roofs of three buildings. One heat pump per PVT system uses the generated heat from the collectors as a heat source for DHW preparation. The DHW is then stored in 800 litres storage tanks (one per PVT system, see principle diagram in Figure 22).

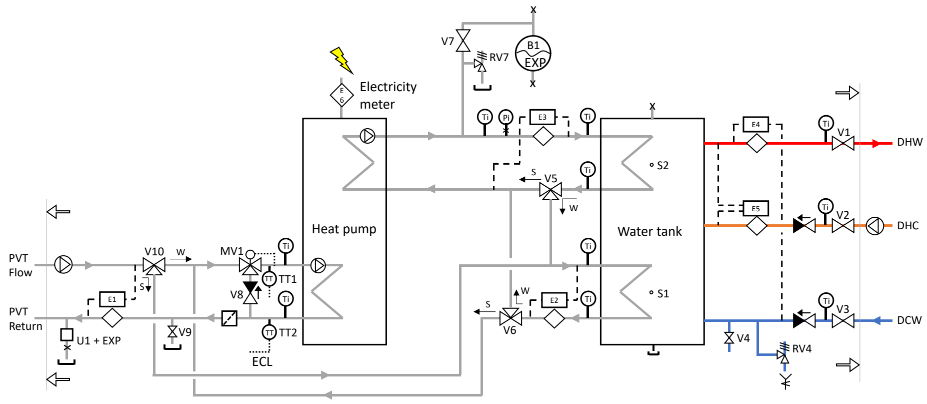


Figure 22: Principle diagram for utilization of PVT for DHW preparation at the RDS DK2[20] (direct solar preheat enabled)

[19] Source: http://racell.dk/products/functionality-technology/, more general information on the technology: D.8.5 Replicability assessments for READY solutions

[20] D.3.1.1

The heat from the PVT system at RDS SE1.1 is first stored in the ground via geothermal probes and then serves as heat source for DHW preparation. The DHW is stored in a 500-litre storage tank (see Figure 23).

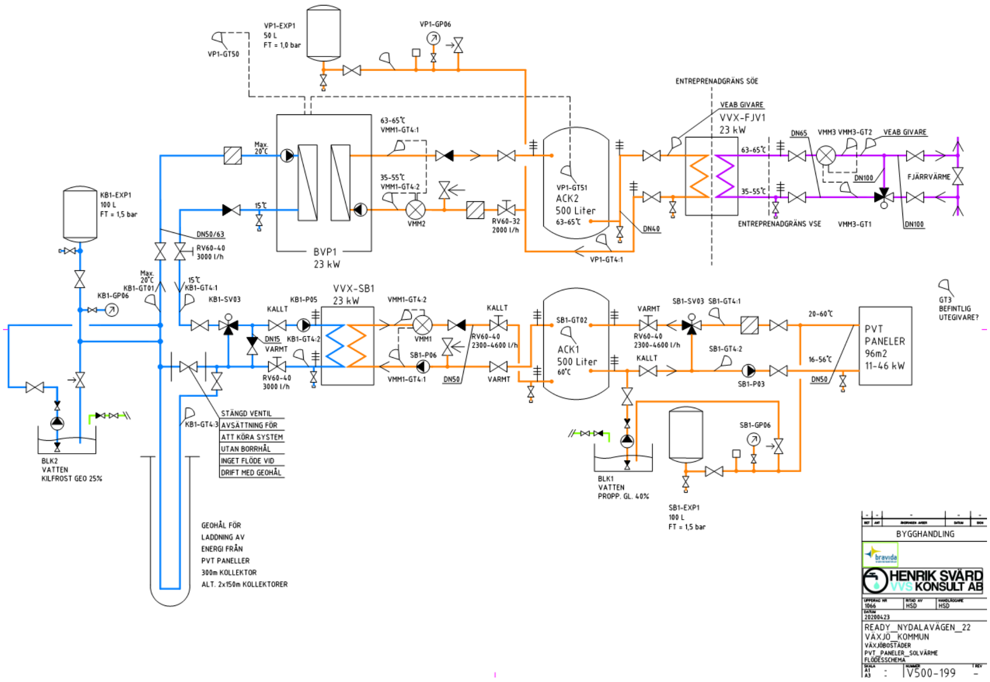


Figure 23: Principle diagram for utilization of PVT for DHW preparation in a ground source hybrid system at the RDS SE1.121

PV systems

Besides innovative PVT systems, conventional Photovoltaic (PV) systems were installed (without EC Support). The PV systems are located on top of the buildings in Rydevænget (RDS DK1, see Figure 24), in Trigeparken (RDS DK2) and Dybedalen 1A (RDS DK3, see Figure 25) and count with a total installed area of approx. 1,877 m² resulting in an installed peak power of approx. 346 kW_p (see Table 5).

Table 5: Installed PV area and peak power in Aarhus

Code	**District**	**Installed PV area (m²)**	**P_{PV} (kW_p)**
DK1	Phase 1&2 (Rydevænget)	844	157
DK1	Phase (Fjældeevænget)[22]	822	153
DK2	Trigeparken	82	14
DK3	Dybedalen 1A	129	22
Total		**1,877**	**346**

[21] Henrik Svärd VVS Konsult AB, 16.03.2020, technical drawing V500-199

[22] Not included in Monitoring Results

Figure 24: View of the installed PV system on the roof of a multi-apartment building in Rydevænget (RDS DK1)

Figure 25: View of the installed PV system on the office building's roof in Dybedalen 1A (RDS DK3)

Battery storage

At the READY Demonstration Site DK2 (Trigeparken) a Battery Energy Storage System (BESS, RDP DK-ST) was installed by Lithium Balance A/S. It consists of one central 40 kW inverter connected to two battery racks, one with four new Nissan cells with a total capacity of 79 kWh and one rack with 2nd life cells (GEN 1) with a total capacity of 35 kWh. (see Figure 26).[23]

[23] See D.5.1.1

Figure 26: The two Battery storage racks, inverter and control system of the RDP DK-ST at RDS DK2[24] (left: new batteries with a capacity of 79 kWh; right: 2nd life batteries from EV with a capacity of 35 kWh)

The purpose of the battery plant at Trigeparken is to optimize the utilization of on-site RE production at the apartment housing. The plant management uses also demand side management in the control scheme.

The 40 kW/114 kWh battery system is installed in parallel with the 135 kW PV system and in parallel with the distribution installation (see Figure 27).

The battery system can in principle also supply energy to the electricity grid through the POC (Point of Connection). However, the delivery to the electricity grid is only expected to occur when the PV production is larger than the energy demand and the battery system's remaining storage capacity.

The monitoring of the Battery Energy Storage System includes the actual power produced by the PV system, the actual (feed-in) power fed into resp. taken from the grid, the building's actual power consumption and the batteries' state of charge. The BESS' technical properties are listed in Table 6.

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[24] Ibid

Table 6: Properties of the BESS (RDP DK-ST) at RDS DK2

Inverter – producer	ABB
Inverter – model	ESI-S type 4
Inverter – nominal power	3 x 60 A ~ 40 kW into the installation
Battery pack – producer	Lithium Balance
Battery pack – model nr.	Xolta – 1 x 79 kWh + 1 x 35 kWh DC-rack (et rack) LiIon
Battery pack – energy storage capacity, with nominal inverter power at POC [kW/h]	110 kWh of usable energy (114 kWh nominal battery capacity)
Battery pack – runtime at rated inverter power at POC [KW/h]	80 minutes at 40 kW

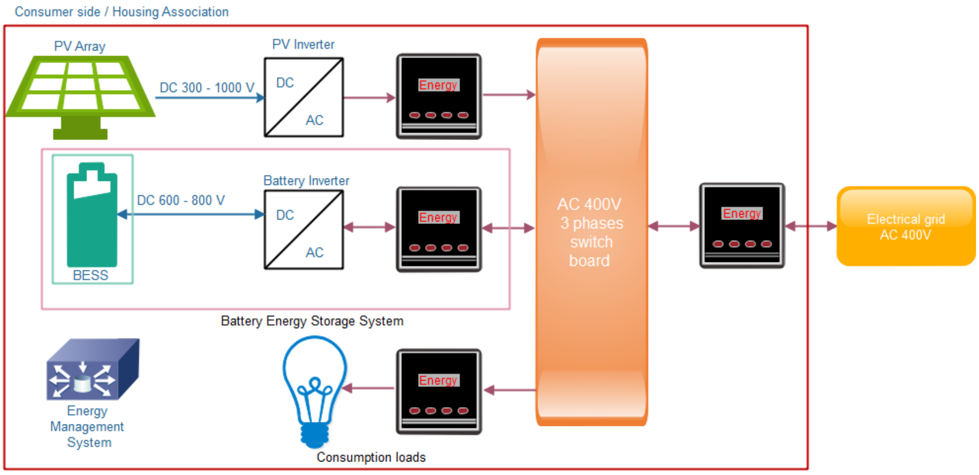

Figure 27: Principle diagram of the Battery Energy Storage System (RDP DK-ST) at RDS DK2

The BESS is monitored, the parameters battery charging state, PV production, electricity consumption and grid contribution (import or export) and the 24 h self-power rate are displayed on a dashboard (see Figure 28).

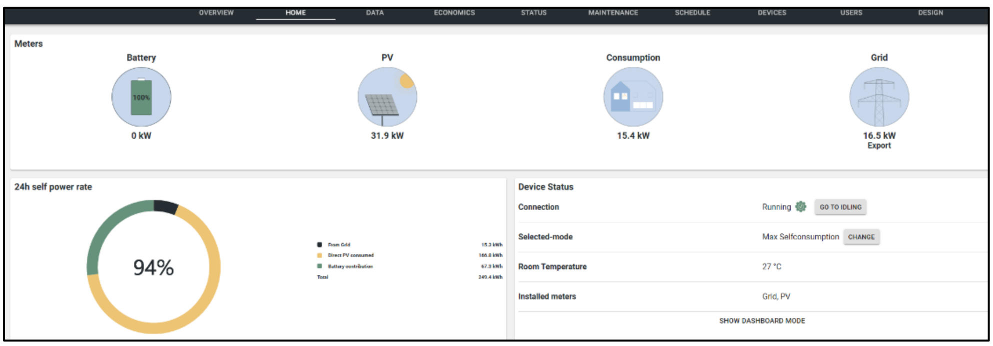

Figure 28: Monitoring dashboard with parameters of the RDP DK-ST at RDS DK2

WW-HR

The WW-HR facilities were developed by ECO Clime and were installed in Aarhus (Trigeparken and Rydevænget) and Växjö (Alabastern District), see Table 7. The technology aims at recovering heat from wastewater from multi-family buildings, where the waste water flow is stable. The system consists of a waste water storage tank, a special heat exchanger and a heat pump that pre-heats DHW for a DHW tank (see Figure 29). A Principle diagram and an image of the prefab plastic manhole of the WW-HR facility in Aarhus are shown in Figure 30 resp. Figure 31.

Table 7: READY Demonstration Sites with WW-HR and installed capacity

Code	**District**	**Capacity (kW_{th})**
SE1.1	Alabastern	15
DK1	Rydevænget	2
DK2	Trigeparken	8
Sum SE		**15**
Sum DK		**10**
Total		**25**

Figure 29: Innovative WW-HR facility (RDP DK-WW2) at RDS SE1.1. Heat exchanger module to the left, pumping unit in the middle and buffer tank with stirring device to the right. All done as prefab and pre-insulated manholes.[25]

[25] VXH-SE

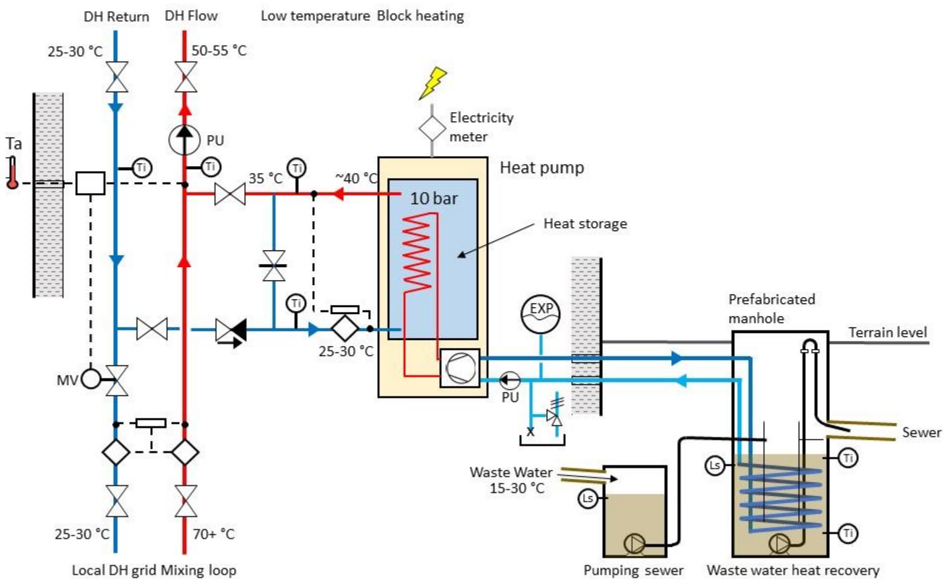

Figure 30: Principle diagram of the WW-HR facility at RDS DK2[26]

Figure 31: Prefab plastic manhole with integrated heat exchanger at RDS DK2[27]

2.2.3 Further energy saving and efficiency measures

Besides the energy efficiency measures related to building refurbishment (RDS SE1-3, DK1-4), and on-site RE production (e.g. RDP DK-PVT) further READY Demonstration Projects (RDP) have been established.

EV charging stations

In Aarhus, mainly in the city centre and industrial areas, EON has implemented 54 Electric Vehicle (EV) charging poles with each two sockets à 11 kW charging

[26] COWI

[27] Ibid

capacity (RDP DK-Ch). The total charging capacity of all EC Charging Stations is 2.3 MW. The installation cost/EC Support was EUR 480,307 resp. EUR 230,876 excl. VAT.

The charging stations are installed in the public street and they are capable of charging car batteries in approx. three hours.[28] In READY, further aspects of mobility were assessed, but WP7 focuses on the supplied electricity to the EVs and the utilization rate of the charging poles only. Figure 32 shows one of the 54 EV charging poles in Aarhus.

Figure 32: Example picture of charging pole of RDP DK-Ch in Aarhus[29]

District heating

In the Alabastern district in Växjö, the supply/return temperatures of the district heating (DH) network (RDP SE-DH) were reduced to approx. 65/35°C. The objective was to decrease the pipe heat losses by approx. 60% (see Table 8).

The monitoring focuses on the heat supply to the district and the total heat consumption of all consumers. This allows to calculate the key indicator values, such as the total pipe heat losses and as a percentage of the total district heating supply. Figure 33 shows the network plan of the optimised district heating network in Alabastern.

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[28] See D.8.5 and D.5.5.2

[29] D.5.5.2

Table 8: Basic planning parameters of the optimised district heating network in Alabastern (RDP SE-DH)

Length of district heating network (m)	582
Max. district heating capacity (kW)	300
Max. specific district heating capacity (kW/km)	500
Panned district heating supply temperature (°C)	65
Planned district heating return temperature winter (°C)	22
Planned district heating return temperature summer (°C)	38
Baseline district heating supply temperature winter (°C)	90-105
Baseline district heating supply temperature summer (°C)	65
Baseline district heating return temperature (°C)	50
Annual district heating supply (GWh)	1,6
Specific annual district heating supply (GWh/km)	2.7
Planned pipe heat losses (%)	5
Baseline - pipe heat losses of conventional DH network	12
Planned pipe heat loss reduction (%)	60

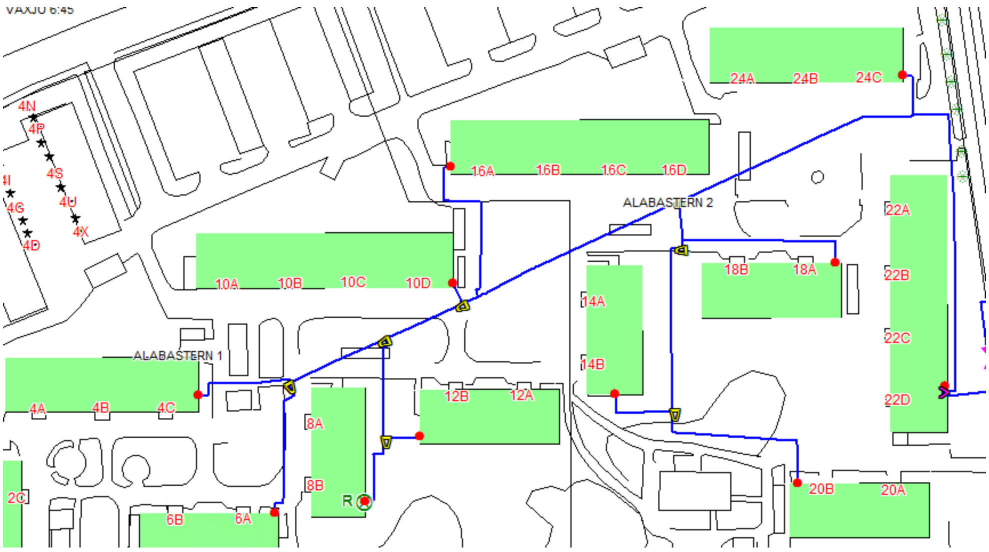


Figure 33: Network plan of district heating network in Alabastern district[30]

30 VXH-SE

District cooling

An innovative district cooling (DC) project in Växjö (RDP SE-WW1) "energy used three times", utilizes the DC flow twice for cooling and once for heating. The process is explained below and illustrated in Figure 34.

1. Air conditioning for shopping mall Grand Samarkand
    - DC supply temperature: 6 to 10°C
    - DC return temperature: 12 to 14°C
2. Server cooling at Wexnet's data centre
    - Innovative server room design, server positioning and air flow design allow higher DC supply temperatures: 12 to 14°C
    - Therefore, the DC return from the shopping mall can be used as cooling supply for the server cooling
    - Return temperatures: 17-20°C
3. "Heating" of football turf of football stadium at Myresjöhus Arena
    - DC return from the data centre serves as "heating" supply releasing heat to the football turf. This extends the outdoor training season significantly
    - Football turf's "heating" return temperature: 10-12°C
    - DC water returns to the cooling plant
4. Cooling plant
    - Reduced heat consumption for the absorption chiller due to "free cooling" via football turf
    - Refrigeration plant partly powered by PV-panels

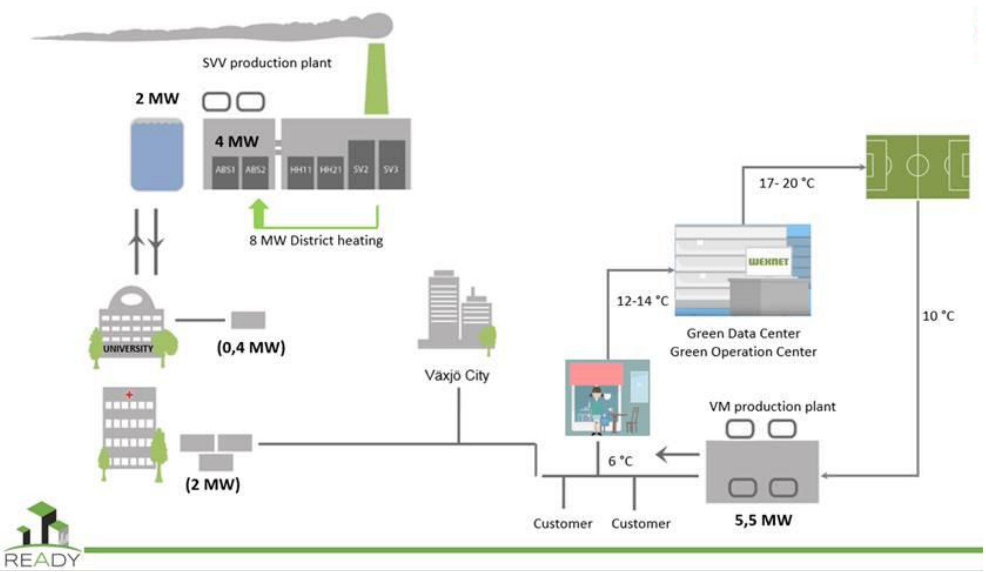


Figure 34: Illustration of the innovative district cooling/"heating" network[31] (RDP SE-WW1)

[31] D.6.4 VEAB-SE

1 MW heat pump

In Aarhus, a 1 MW sea water-fed heat pump contributes to the heat supply of the district heating network (RDP DK-WW1). At the AffaldVarme site, the new heat pump (see Figure 35 and Figure 36) almost fully replaces a traditional heat pump and oil boiler, significantly decreasing the previously required amount of oil.

Figure 35: Water chiller installation of the 1 MW sea water-fed heat pump (RDP DK-WW1)

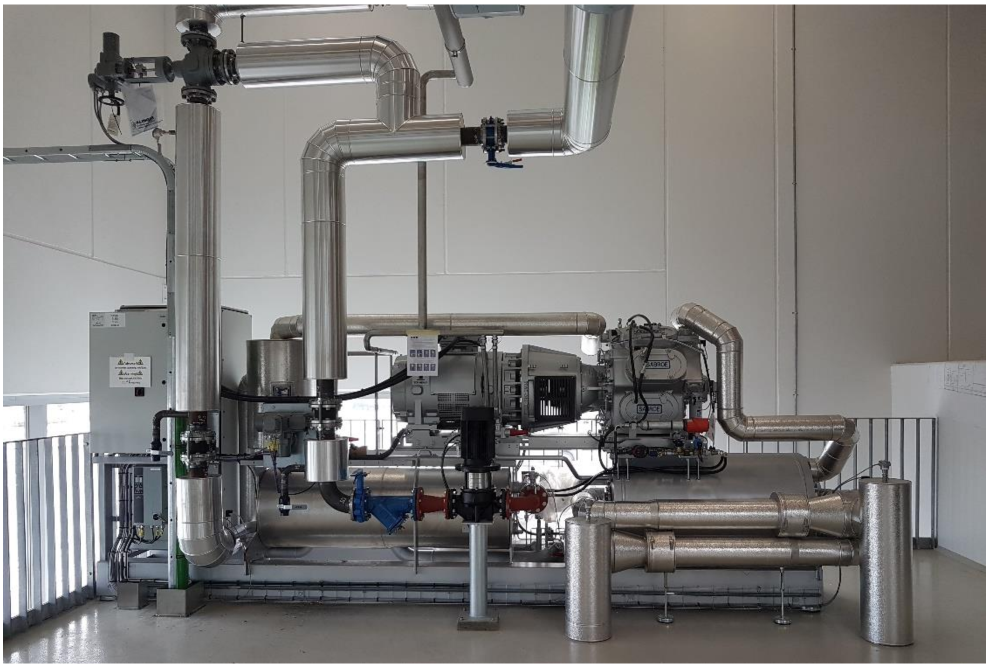


Figure 36: Ammonia chiller installation of the 1 MW sea water-fed heat pump (RDP DK-WW1)

The 1 MW sea water-fed heat pump is used for grid congestion management and power grid control, increasing the energy efficiency of the overall energy system: the heat pump operation is adapted to the volatile electricity production from RES which helps to integrate RES and to reduce congestions in the electricity grid. Furthermore, the heat-bound electricity production at CHP plants is reduced as the heat can be provided by the heat pump instead.

The heat pump can operate approx. 6,000 full-load hours per year resulting on a heat production of 6 GWh. The monitoring focuses on the hourly heating capacity/power input and the monthly resp. annual heat production/electricity consumption. The key performance indicators derived from the monitoring data are the coefficient of performance (COP) at certain operation modes resp. heat source/sink temperatures and the monthly and annual seasonal performance values (for various boundaries).

3 Methodology of energy monitoring

3.1 Monitored energy parameters

The "Smart Cities Information System - Technical Monitoring Guide"[32] prepared by Smart Cities Information System (SCIS)[33], is the basis of the methodology of energy consumption monitoring. In the monitored parameters, all energy meters are included in order to document the total Final Energy consumption[34] of the building or energy production at the RES facilities.

Monitoring data were usually collected as monthly values during a period of several years. In some cases, (reliable) monitoring data were available not for every month, e.g. due to issues during initial operation phases. Then, the values were extrapolated in order to get annual consumption values of a fictitious reference year.

Levels of details

Two levels of details on metering were performed on the demonstration buildings, see Table 9.

Table 9: List of metering points for the buildings in Aarhus and Växjö

Level 1 – Building level		Level 2 – Individual level (in some cases)	
Space heating	kWh	Mean indoor air temperature	°C
Domestic Hot Water (DHW)	kWh and m³	Space heating for selected apartments –	kWh
Electricity (BOPS)	kWh	Electricity for households in groups of app. 20 apartments – kWh	kWh
	kWh	Electricity for ventilation in selected apartments	
Electricity for technical rooms	kWh		
Heat Production from PVT panels	kWh		
Production from PV panels	kWh		
Heat production from heat pumps			
Electricity consumption of heat pumps			
Energy recovered from waste water	kWh		
Cold water	m³		

Figure 37 shows an example of monitoring data output from MinEnergi which provides the energy monitoring system for Dybedalen 1A (RDS DK3).

[32] http://www.smartcities-infosystem.eu/sites/default/files/document/technical-monitoring-guide_2016.pdf

[33] Continued in another scheme since end of 2020

[34] total heat and common electricity consumption

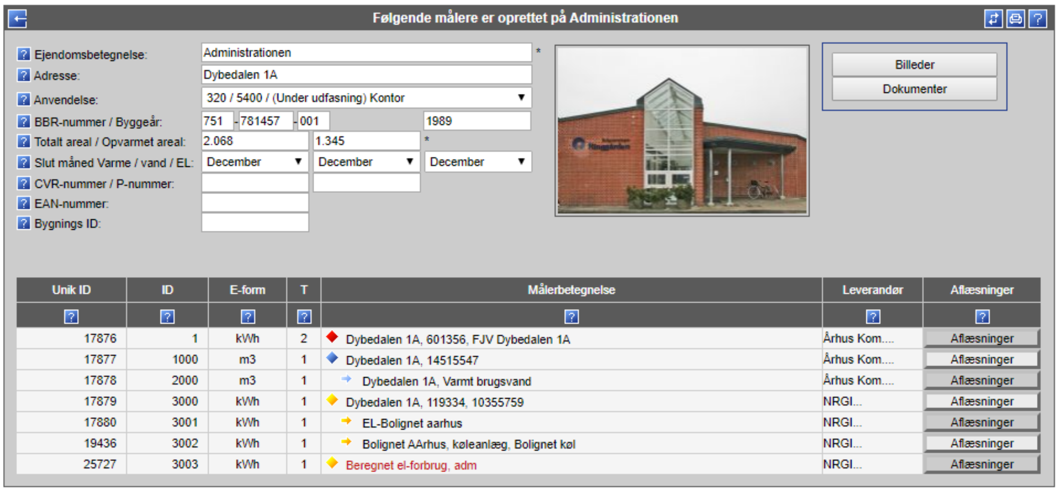


Figure 37: Example of monitoring data output from MinEnergi in Dybedalen 1A (RDS DK3)

3.2 Conventions

3.2.1 Floor area and volume definition

In the Monitoring Data sheets, the SCIS floor area definitions for gross area are used in order to enable comparison of the energy performance indicators between buildings from different EU countries. Aarhus and Växjö use the same definition of floor area as defined by SCIS.

Area/volume definition

Gross Floor Area and Volume are calculated according to the SCIS conventions. According to these conventions, the outside borders of the building and building envelope define the gross floor area and volume. All floor areas in all levels including secondary rooms and external walls are considered and the building volume including all these areas and external walls are considered. The area of balconies, patios and parking spaces is excluded (see Figure 38).

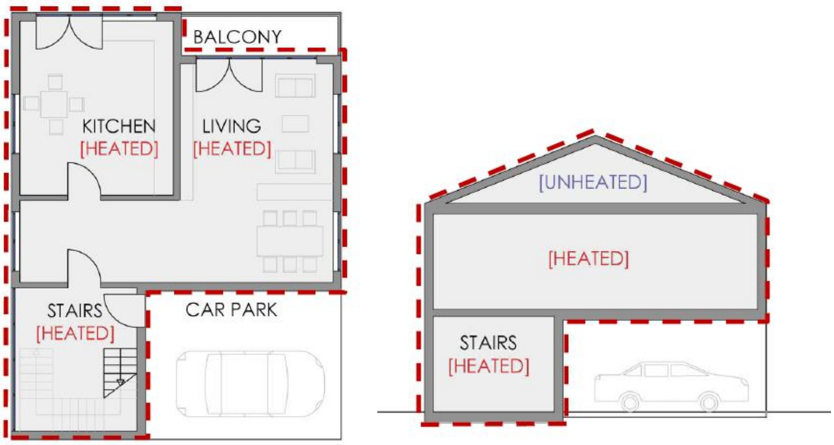


Figure 38: Gross Floor Area and Volume conventions example

3.3 Normalisation of energy consumption

3.3.1 Normalisation to weather conditions

Normalisation of the heating consumption corresponding to that of an average climate year is necessary when one wants to compare the heating consumption of a building in different years. This report compares the energy consumption in a monitored period with the energy consumption stated in the BEST (Building Energy Specification Table) and must therefore be normalised. Normalisation of data follows a standard normalisation technique. The heating data are normalised using the official Danish resp. Swedish degree-days, as they are comparative to the number of annual degree-days in a reference year that the BEST states (see Appendix B – BEST).

The Danish degree-days are measured and managed by the Danish Technological Institute (DTI) at a monitoring station at Landbohøjskolen in Copenhagen.[35]

The Swedish degree-days are measured and managed by the Swedish Meteorological and Hydrological Institute at a monitoring station in Växjö.

Definition of degree-days

According to DTI, who is the Danish contact point on degree-day information:

> *"One degree-day is an expression of the difference of 1°C between the presumed indoor average temperature of 17°C and the outdoor average temperature in one day and night."*[36]

The temperature of 17°C is used as it is assumed that the internal heat load contributes with the last 3°C up to the reference temperature of 20°C, which is the design indoor design temperature in Aarhus. Moreover, the prerequisite of 20°C indoor temperature was used to define the energy consumption targets in the BESTs in the DOW as it is the temperature used in the Danish Energy Labelling System and in the documentation of energy frames according to the Danish Building Regulations, valid for the actual buildings.

Example (indoor temperature 20°C):
+2°C outdoor temperature gives 17-2°C x 1 day=15 degree-days per day
-5°C outdoor temperature gives 17-(-5) °C x 1 day = 22 degree-days per day

If the indoor air temperature is higher than 20°C, for instance 22°C, then a normalisation back to reference temperature is necessary as explained in section 3.3.2.

[35] See https://www.teknologisk.dk/ydelser/graddage/pressemeddelelse/492

[36] See http://www.teknologisk.dk/graddage/hvad-er-graddage/492,3

DRY and new normal year

The official Danish Design Reference Year (DRY) was performed by Danish Technological University and is based upon 20°C indoor temperature. It consists of an average of data collected in the period 1941-1980 and contains many parameters such as outdoor temperature, relative humidity, wind speed and direction, hours of sunshine etc. The DRY has 2,906 degree-days. Because of climate changes, the average of degree-days in the period 2001-2016 has only been 2,529 degree-days, see Figure 39. After a period of voluntariness, in Aarhus since 2015 it is mandated by the Danish Building Regulations to use updated climate data starting in 2001. This means that the old DRY is not used anymore.

In READY, average degree days were calculated of the degree days values of the period 2001-2019 for both Aarhus and Växjö. The monitoring data was normalised according to these values in order to produce as realistic values as possible.

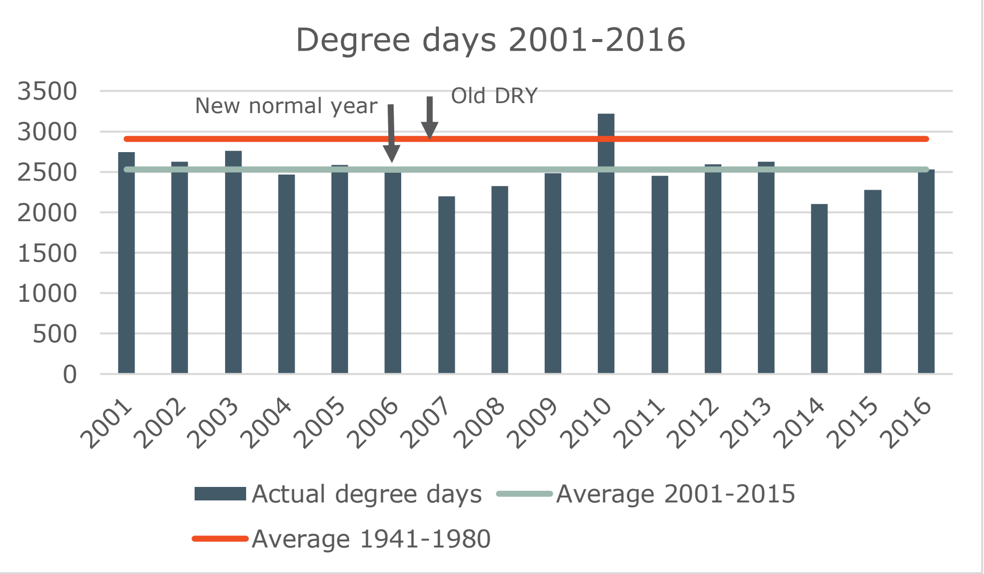


Figure 39: Degree-days measured by Danish Technological Institute in the period 2001-2016. The lines are the Danish Reference Year (1940-1982) in red and the new reference based on average of years between 2001 and 2016 (exemplary) in yellow.

Example - weather conditions

The normalisation of heat energy consumption in relation to the outdoor climate is carried out as shown in the example below. Only one year is presented in the fact sheets and only this year is normalised.

Space heating consumption, 2019: ***100 kWh/m² (metered value)***

Degree-days normal year (20°C): 2,528 (2001-2019)*

Actual degree-days in 2019 (20°C): ***2,237 ****

Normalisation, space heating:

*100 kWh/m²/2237 * 2528 = 113 kWh/m²*

* (from DTI's monitoring station in Copenhagen)

3.3.2 Normalisation to indoor reference temperature: Definition of indoor temperatures

The normalisation of heat consumption in relation to the outdoor climate presumes an indoor air temperature of 20°C (see section 3.3.1). Experience shows that inhabitants often have more than 20°C in actual room temperature, especially when they live in a low energy house. It was assumed that at the monitored READY Demonstration Sites the actual indoor temperature (during the heating period) in multi-family buildings has been 22°C (RDS in Växjö and RDS in Aarhus) and 23°C in office buildings (RDS in Växjö and Aarhus).

Calculating degree-days

The consequence of keeping such a high indoor temperature is a higher energy consumption than calculated. For every degree, a resident keeps the average indoor temperature above 20°C in the heating season, the number of total degree days will rise equally, approximately by 5% per degree. The energy consumption is therefore approx. 15% higher when keeping 23°C instead of 20°C. To compare the actual heating consumption with the BEST Target heating consumption, the additional heating consumption caused by a higher indoor temperature must be normalised. The method for this is to add one degree-day per day for every degree the indoor temperature is higher than 20°C. See example:

Example (indoor temperature of 22°C):
+2°C outdoor temperature gives 17+2-2°C x 1 day= 17 degree-days per day.
-5°C outdoor temperature gives 17+2-(-5)°C x 1 day = 24 degree-days per day.

As the example shows, the number of degree-days increases with increased temperature. Table 10 shows a list of the Danish Reference Year compared with degree-days from 2019 at indoor temperatures from 20-24°C. Specifically, 1 degree-day per day in the month was added when adjusting the year from 20°C to 21°C, 2 degree-days per day in the month at 22°C, etc.

Table 10: The old Danish Reference Year 1941-1980 (DRY), the new normal year 2001-2019 and the annual degree-days from Danish Technological Institute including additional degree-days at higher indoor temperatures.

	Normalisation to weather conditions			Normalisation to reference indoor temperature (extra degree-days/month)			
	DRY 1941-1980	Normal year 2001-2019	2019 (20˚C)	2019 (21˚C)	2019 (22˚C)	2019 (23˚C)	2019 (24˚C)
January	525	477	460	31	62	93	124
February	480	437	338	28	56	84	112
March	460	408	342	31	62	93	124
April	302	229	160	30	60	90	120
May	79	31	109	31	62	93	124
June	1	0	0	0	0	0	0
July	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0
September	36	15	20	30	60	90	120
October	219	189	137	31	62	93	124
November	349	315	303	30	60	90	120
December	455	427	368	31	62	93	124
Total	**2906**	**2528**	**2237**	**273**	**546**	**819**	**1092**

Example – indoor reference temperature

The normalisation of heat energy consumption in relation to the indoor reference temperature is carried out as the following example shows:

Space heating consumption, 2019: ***100 kWh/m² (metered value)***

Degree-days normal year (20°C): ***2,528 (2001-2019)****

Additional actual degree-days in 2019 (23°C): ***819 (see Table 10)****

Normalisation, space heating:

*100 kWh/m²/(2,537+819) * 2528 = 75 kWh/m²*

* (from DTI's monitoring station in Copenhagen)

3.4 Example of normalising heating consumption

To clarify the method for normalising the heating consumption, a complete example will follow from a building block. The monitored data consists of values from direct meter readings and values that derives from meter readings (more information on derived data later). The building is supplied with district heating and has four heat meters and one electricity meter:

- Total delivered heat (kWh)
- DHW (kWh)
- DHW circulation losses (kWh)
- Space heating (kWh)
- Total building electricity for common lightning, centralized ventilation, etc. (kWh)

Presentation of data

The data are presented in the appendix with fact sheets like the example in Figure 40 shows – more data are available in the monitoring spreadsheets. The red boxes and black text highlights directly read monitored data from meters and the other data are either normalisations, summarisations or subtractions.

Address	Nydalavägen 2
Typology of Dwelling	
Occupants number	
Occupants type	
Ownership	
Gross floor area (m²)	20??

Monitoring Period	Energy: Total (kWh)	Energy: Total/m² (kWh/m²)	Tot delivered heat incl. losses (corr.) (kWh/m²)	Tot delivered heat incl. losses (corr.) (kWh)	Diff value Space heating (corr) (kWh)	Measured Values Heat: Total delivered heat (kWh)	DHW (kWh)	DHW (kWh/m²)	DHW circulation losses (kWh)	Space heating (kWh)	Space heating (correct.) (kWh)	Measured Values Electricity: Total building elec (kWh)	Total building elec (kWh/m²)	Measured Values Water: Cold water (m³)	Hot water (m³)
Jan 18	23,768	12	11	22,550	28	22,522	3,468	2	663	16,010	16,03	1,218	1	146.97	59.8
Feb 18	21,816	11	10	20,724	-2,763	23,487	3,459	2	622	17,180	14,41	1,092	1	143.93	59.64
Mrz 18	21,139	10	10	19,979	-3,647	23,626	4,142	2	682	16,050	12,40	1,160	1	171.27	71.42
Apr 18	14,674	7	7	13,632	-194	13,826	3,959	2	647	6,720	6,52	1,042	1	171.88	68.26
Mai 18	9,064	4	4	8,030	543	7,487	3,689	2	630	1,130	1,67	1,034	1	179.14	63.61
Jun 18	7,102	3	3	6,087	637	5,450	3,057	2	588	440	1,07	1,015	0	154.49	52.71
Jul 18	5,960	3	2	4,910	507	4,403	2,401	1	565	40	54	1,050	1	155.29	41.39
Aug 18	6,887	3	3	5,773	261	5,512	2,863	1	581	610	87	1,114	1	121.19	49.37
Sep 18	8,819	4	4	7,568	-336	7,904	3,228	2	588	2,550	2,21	1,251	1	139.13	55.65
Okt 18	13,051	6	6	11,916	-685	12,601	3,263	2	635	6,950	6,26	1,135	1	140.65	56.26
Nov 18	17,868	9	8	16,740	-513	17,253	3,448	2	629	11,120	10,60	1,128	1	148.6	59.44
Dez 18	22,308	11	10	21,076	26	21,050	3,035	1	655	14,190	14,21	1,232	1	130.8	52.32
TOTAL	**172,456**	**85**	**78**	**158,985**	**-6,136**	**165,121**	**40,012**	**20**	**3,779**	**92,990**	**86,85**	**13,471**	**7**	**1,803**	**690**
Jan 19	23,505	12	11	22,356	-1,511	23,867	6,257	3	670	16940	15,42	1,149	1	159.16	54.28
Feb 19	21,028	10	10	20,047	1,454	18,593	5,270	3	583	12740	14,19	981	0	159.16	50.38
Mrz 19	20,303	10	9	19,260	229	19,031	5,865	3	646	12520	12,74	1,043	1	159.16	57.81
Apr 19	13,405	7	6	12,426	-134	12,560	5,381	3	609	6570	6,43	979	0	159.16	54.04
Mai 19	9,914	5	4	8,882	-1,464	10,346	5,430	3	616	4300	2,83	1,032	1	162.85	57.28
Jun 19	6,605	3	3	5,615	365	5,250	4,565	2	565	120	48	990	0	163.39	51.96
Jul 19	5,767	3	2	4,738	-71	4,809	3,879	2	570	360	28	1,029	1	150.19	43.56
Aug 19	5,993	3	2	4,945	97	4,848	4,065	2	573	210	30	1,048	1	150.94	46.79
Sep 19	8,625	4	4	7,594	-663	8,257	4,708	2	559	2990	2,32	1,031	1	157.29	53.84
Okt 19	13,468	7	6	12,374	-928	13,302	5,633	3	599	7070	6,14	1,094	1	169.79	61.76
Nov 19	17,316	9	8	16,229	-421	16,650	5,469	3	601	10,580	10,15	1,087	1	157.95	59.17
Dez 19	21,542	11	10	20,360	969	19,391	5,706	3	635	13,050	14,01	1,182	1	159.84	59.07
TOTAL	**167,472**	**82**	**76**	**154,827**	**-2,077**	**156,904**	**62,228**	**31**	**7,226**	**87,450**	**85,37**	**12,645**	**6**	**1,909**	**650**
READY BEST (kWh/m2)		**160**	**149**				**21**						**11**		
2018	172,456	85	78				20						7		
2019	167,472	82	76				31						6		

Figure 40: *Monitoring spread sheet with monitoring data from a multi-family building. Red boxes highlight the directly read monitoring data. Other data are normalisations, summarisations or subtractions.*

Derivation of data

Figure 41 illustrates the total energy consumption at RDS DK2 in 2019 and how it is obtained from the different energy categories. The total heating consumption, which is read from the district heating meter, includes both space heating, heating of DHW and heat losses from distribution pipes. As only the space-heating share is subject to normalisation to weather and reference temperature, this must be identified, see procedure after the figure.

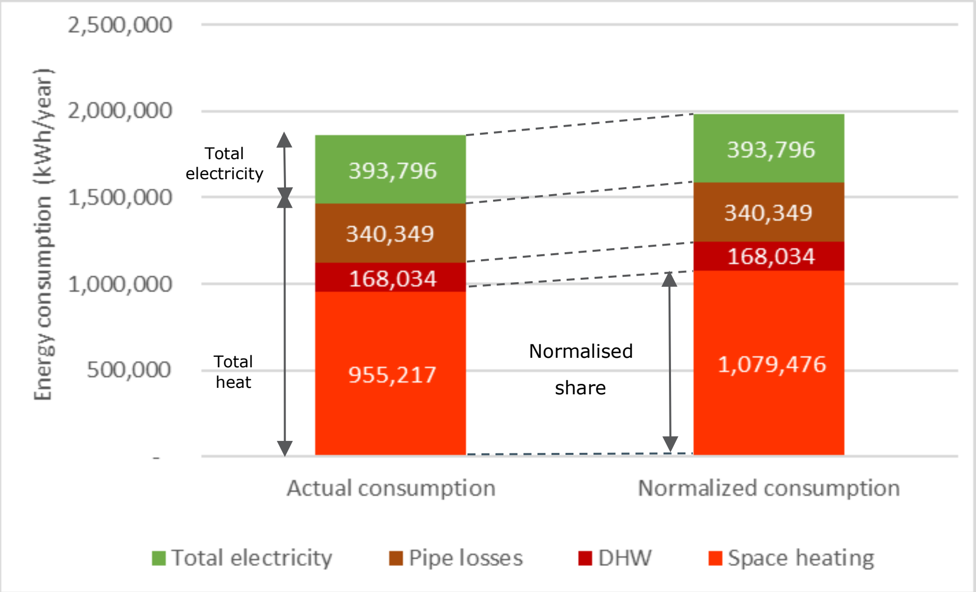


Figure 41: Breakdown of total energy consumption (electricity and heat) into categories: Space heating, DHW and electricity (RDS DK2, year 2019)

The derivation of data follows this principle:

1 Total heating – heating for DHW = Space heating incl. pipe heat losses
2 Space heating incl. pipe heat losses – pipe heat losses = Space heating

Space heating

The monitored data consist of values from direct meter readings and values that derives from meter readings. I.e. if:

A + B = C and

C is a direct meter reading of **total heating**
B is a direct meter of **DHW** (kWh or m³)

then

A is **space heating** and derives from monitored data.

The data derivation and analysis included normalisation of the heating consumption. Only the heating energy consumption needs to be normalised as it can be assumed that the DHW consumption and Pipe heat losses are approximately equal for every month – summer as winter.

DHW

The DHW consumption is metered directly and has not undergone any adjustments.

Pipe heat losses

The pipe heat losses are the remaining heat consumption that can't be ascribed to either space heating or DHW consumption. Therefore, the Pipe heat losses can be identified from the three summer months where there is no space heating demand. The heat losses from pipes are almost constant during the year as hot water circulates constantly. In wintertime, the heat loss from pipes may contribute to heating of the building, depending on the location of pipes and is not a complete loss, but in summertime, the heat cannot be utilised, and losses can be significant.

Detailed derivation of monthly data

When Pipe heat losses are identified, the final conversion and normalisation of data can be conducted. In general, the conversion, derivation and normalisation of data follows this example of method, month by month:

Processing of monitored data per month (For instance DK 2 in January 2019)

<u>Total district heating – heating of hot water:</u>
257,957 kWh – 14,343 kWh = 243,614 kWh

<u>DHW:</u> 14,343 kWh

<u>Pipe heat losses (average of Jun-Aug):</u> 28,362 kWh

<u>Actual space heating:</u>
Actual space heating = Total heating – DHW – Pipe heat losses
(257,95 – 14,343 - 28,362) kWh = 215,252 kWh

<u>Normalised space heating:</u>
Normalised space heating = Actual space heating/(degree-days in January 2020+ additional degree-days for indoor temperature of 23°C) x degree-days in January in normal year
215,252 kWh/(460 + 93) x 477 = 185,669kWh

3.5 Guide to monitoring fact sheets in appendix

The appendix of this report consists of a 1-2 pages monitoring fact sheet for each of the buildings and one sheet per RES facility. The fact sheets present in a visual easy way all the relevant information of the demonstration such as general data, building characteristics and key energy figures. To each building fact sheet belongs an overview table of the monitored data and the procession hereof. Figure 42 shows an example monitoring fact sheet with indicators of the information categories, as listed below.

No.	Content
1	General data (Address, area, year of construction, investment costs etc.)
2	Short description of the performed measures (Insulation thickness, glazing type etc.)
3	U-values defined in BEST, target figures and actual obtained U-values
4	Information on the energy system
5	Reference energy consumption according to BEST
6	Target energy consumption according to BEST and calculated design values.
7	Actual monitored values per m² gross heated area in the specific period and the same values normalised for 2019 resp. 2020

Ringgården afdeling 21 (BEST-DK-1)

Rydevænget 105-131, Aarhus

General Data

Refurbished Building	District 21 - Rydevænget
Year built	1970-1973
Year refurbished	1990
Address	Rydevænget [illegible]
Building function	Social hous[illegible]
Building type	Apartments
Number of Apartments	163
Number of Occupants	Approximately 400
Gross Floor Area (m²)	**14.151**
Gross Volume (m³)	39.623
Net Heated/Cooled Area (m²)	11.321
Net Heated/Cooled Volume (m³)	28.302
Basement Type	Parterre
Attic Type	Roof apart., piched w. PV
Total Investment cost [Euro]	9.86 mio. (VAT excl.)

Building Features

			Before	Normal practice	Project Target (BEST)	Design	Actual (2019/20)
External walls	Concrete sandwich + ext.	W/m²K	0,70	0,30	0,15	0,17	0,12-0,32
Roof	Wooden structure + sheet	W/m²K	0,50	0,20	0,10	0,12	0,09-0,12
Ground floor	-	W/m²K	0,75	[illegible]	0,30	0,30	0,60
Windows (frame & glass)	Aluminum/wood frame	W/m²K	n.a.	[illegible]	[illegible]	0,90	0,90
Average U-value of glazings	-	W/m²K	2,90	[illegible]	[illegible]	-	0,53-0,59
Average g-value of glazings	-	-	n.a.	[illegible]	0,50	-	n.a.
Ventilation Flow Rate	126 m³/h per apartment	h^{-1}	0,70	0,50	0,3-0,6	0,30	0,30
Thermal Bridges	150 mm extra insulation layer in the external columns						
Air tightness & n50 air change rate	-						
Ventilation system type	Decentral un[illegible]ply in livingrooms and exhaust in kitchen and bathroom						
Energy saving measures	Waste wate[illegible] heat recovery, insulation, roof renovation/apartments						
Water saving measures	Taps						
Special building materials	Roof apartments						
Type of Shading	Partial external solar shading (balconies)						

Energy Systems

District Heating connection	yes
Photovoltaic - grid connected	yes
Solar thermal - flat plate	no
Heat pump demo for waste water	yes
Boiler	no

Other information

Key Energy figures

kWh/year/m² gross area	Existing building (reference)	Project Target (BEST)	Design	2019	2020	2021
Total Energy Demand	**194**	**74**	**53,5**	**76,4**	**64,1**	
Total heat	155	55	49,1	76,4	60,8	
Space heating	121	36	32,0	56,1	43,5	
Domestic hot water	[illegible]	19	17,1	20	17,3	
Pipe heat losses (DHW)	[illegible]	[illegible]	Included	Included	[illegible]	
Total electricity (Building operation)	[illegible]	19	4,4	n.a.	[illegible]	
Ventilation	[illegible]	7	[illegible]	n.a.	[illegible]	
Lighting + Heating system	12	4	[illegible]	n.a.	1,4	
Laundry	13	8	[illegible]	3	2	
Household electricity	50	30	20	-	14,4	

Full year data not available

Figure 42: Guide to understanding the monitoring fact sheets for one selected RDS (DK1). See explanation of numbering in list above.

3.6 Other calculation prerequisites

3.6.1 PV systems and photovoltaic part of PVT systems

PV efficiency is calculated on a monthly basis as metered PV output at the AC side of inverter per m² PV(T) array, divided by global solar radiation per m² on horizontal level:

$$PV\ system\ efficiency = \frac{PV\ electricity\ produced, kWh}{Global\ radiation\ x\ F_{area}, kWh}$$

where: F_{area} is a factor of efficient PV area (approximately 0.9)

It is an overall system efficiency for the actual installation so therefore no correction is made for shade, orientation or tilt (tilt is with a few exceptions very low i.e. 10-20 deg.)

Normalisation to a standard year is made on a monthly basis by multiplying the heat produced with a normalization factor

$$Normalisation\ factor\ = \frac{Standard\ global\ radiation \frac{kWh}{m2} month}{Actual\ global\ insolation \frac{kWh}{m2} month}$$

3.6.2 PVT systems – thermal part

The thermal output of PVT systems is monitored as heat to storage per m² collector area vs global solar radiation per m² horizontal:

$$Thermal\ system\ efficiency = \frac{Solar\ heat\ produced, kWh}{Global\ radiation\ x\ F_{area}, kWh}$$

where: F_{area} is a factor of efficient panel area (approximately 0.9)

It is an overall system efficiency for the actual installation so therefore no correction is made for shade, orientation or tilt. Power for circulation pump is minor and therefore not monitored separately.

Normalisation to a standard year is made on a monthly basis by multiplying the heat produced with a normalization factor

$$Normalisation\ factor\ = \frac{Standard\ global\ radiation \frac{kWh}{m2} month}{Actual\ global\ insolation \frac{kWh}{m2} month}$$

4 Energy performance targets from Building Energy Specification Table

In the Building Energy Performance Table (BEST) from the DOW all prerequisites, requirements and performance targets concerning building refurbishment and on-site RE production at the READY Demonstration Sites (RDS) and regarding the renewable energy supply to the RDS were defined. The content and structure of the BEST are exemplarily shown for RDS DK2 in Trigeparken below. The complete BEST of the RDS in Växjö and Aarhus are included in Annex B.

Local climate

In the first BEST section, the prerequisites of the local climate are presented (see Table 11).

Table 11: Local climate conditions in Aarhus as stated in the BEST (RDS DK2)

Local Climate		January average outside temperature	°C	0
		August average outside temperature	°C	16
Climatic Zone	Temperate	Average global horizontal radiation	kWh/m² yr	1000
(national definition)	Denmark DK	Annual heating degree days [3]	°Cd/yr	2700
		Room temperature	°C	20

Building Quality

In the second BEST section, the regulatory requirements, the actual values prior to building refurbishment and the suggested specification concerning the building envelope's properties (e.g. U-values) are presented (see Table 12).

Table 12: Properties of building envelope for RDS DK2 prior to refurbishment, regulatory requirements and suggested specification for the building refurbishment

Maximum requirements of building fabric			Existing building [5]	National regulation for new built [6]	**suggested** specification [7] *)	Energy savings [%] [8]
Façade/wall	U	W / m2K	0,7	0,3	0,17	75,7
Roof	U	W / m2K	0,5	0,2	0,12	76,0
Ground floor	U	W / m2K	0,75	0,2	0,3	60,0
Glazing	U_g	W / m2K	2,9	1,4	0,8	72,4
Average U-value	U_{av}	W / m2K excl windows & doors	n.a.	0,22	0,22	n.a.
Glazing	g	total solar energy transmittance of glazing [%	n.a.	none	0,5	n.a.
Shading	Fs	Shading correction factor	n.a.	none	external	n.a.
Ventilation rate [4]		air changes/hr	0,7	126 m3/dwel	0,3-0,6	n.a.
		*) will depend on optimisation analysis				

Energy consumption

The BEST also includes the target values for the energy consumption of the buildings (see Table 13). The energy consumption is stated for the categories space heating, cooling, ventilation, lighting, hot water and electricity consumption for building operation (BOPS). The table includes the energy performance prior to building refurbishment, the regulatory requirements according to national regulations and the suggested specification.

The total energy performance target excl. appliances of the buildings is **78 kWh/m²** excluding electricity for households.

Table 13: Building energy performance of RDS DK2 before (Existing building) and after (suggested specification = BEST Target) building refurbishment as well as regulatory requirement and relative energy savings; given for each energy consumption category

energy carrier existing building	**suggested energy carrier**		specify energy efficiency measures [13]	Existing building [5]	National regulation / **normal practice** for new built (2006) [6]*	**suggested** specification [7]	% Energy savings [8]
Heating + ventilation							
District Heating	Low temp water	kWh/m²yr	Insulation,windows,tightness, accummulation	121	66	39	67,8
Cooling + ventilation							
Compressor	Water & air	kWh/m²yr	Sunshading	0	0	0	#DIV/0!
Ventilation (if separate from heating/cooling)							
Electricity	Air	kWh/m²yr	Intelligent demand controlled, energy eff fans	14	7	7	50,0
Lighting							
	Electricity PV	kWh/m²yr	Daylight access + LED + controls	12	6	4	66,7
			*) Figure includes common lighting only			*)	
Domestic Hot Water (DHW)							
District Heating	Waste water HP	kWh/m²yr	Taps, Heat recovery, Smart grid control, reduced circ. loss	34	28	20	41,2
Other energy demand							
Electricity	PV & Thermal solar	kWh/m²yr	Freq. contrl, red. idle load, a++ lenergy labels meters	13	9	8	38,5
		kWh/m²yr	Subtotal sum of energy demand	194	116	78	59,8

RE production/supply

The buildings' energy consumption is covered by the supply from district heating and the electricity grid as well as by on-site produced energy from RES such as PV(T) and WW-HR systems. The contribution from the renewable share in district heating and electricity supply is stated as well (see Table 14).

Table 14: Absolute and relative contribution from RE at the RDS DK2 in kWh/m²yr resp. % (suggested specification = BEST Target)

total production kWh/yr	m² installed	kW installed	specify RES measures	Existing building [5]	National regulation / normal practice	**Suggested** specification [7]	RES contribution [%][8]
121500	810	109	PV partly building integrated	0	0	6	8,0
216000	720	288	Solar thermal integrated with DH	0	0	11	14,3
734614		n.a.	85% RES in waste heat from DH	0	0	38	48,5
19468		n.a.	Waste water heat pump on selected blocks	0	0	4	4,5
375000		300	Possible share in common wind turbine	0	0	19	24,7
		kWh/m²yr	Subtotal sum of RES contribution	0	0	78	100

5 Monitoring Results

The monitoring objective was to prove that the BEST Target Values concerning the Final Energy consumption (see Appendix B) were reached. In this chapter, the monitoring results are presented and compared to the BEST Target Values, where applicable. Monitoring results from other READY Demonstration Sites without READY Reference/Target values are presented without comparing to a baseline.

5.1 Monitoring period

For new buildings as well as for refurbished buildings it takes approx. one or two years for the energy consumption to stabilise. There are several reasons for this, and one is that the building (if it is a residential building) typically is not 100% occupied from the beginning and therefore the first periods energy consumption can be misleading. Another reason is that the new installations require a period of running in and optimisation of controls and operation. The energy consumption will also include energy for drying out of the building, which is very energy demanding in a concrete building. In order to have the most accurate monitoring data, representative data should be available for at least one year.

Therefore, data from the last complete calendar year of READY project duration (i.e. 2019) was analysed, whenever possible. The building refurbishment of the buildings at the READY Demonstration Sites in Växjö was finished at the latest in 2018. Therefore, steady state monitoring data were broadly available. The building refurbishment of the buildings at some READY Demonstration Sites in Aarhus were finished in 2019-2020. This applies to some RES facilities in both, Växjö and Aarhus too.

Missing, implausible or non-representative measurement data of affected months were replaced by reliable data from months with similar consumption/production conditions, eventually considering further input values (e.g. DRY heating degree days or global radiation data).

5.2 Final Energy consumption of buildings

Växjö

At the READY Demonstration Sites in Växjö, the monitored normalised Final Energy consumption (heat consumption from heat and electricity consumption (BOPS)) in 2019 resp. 2020 was between 52.4 kWh/m²yr (RDS SE1.1) and 76.7 kWh/m²yr (RDS SE1). All values are floor area-weighted average values.

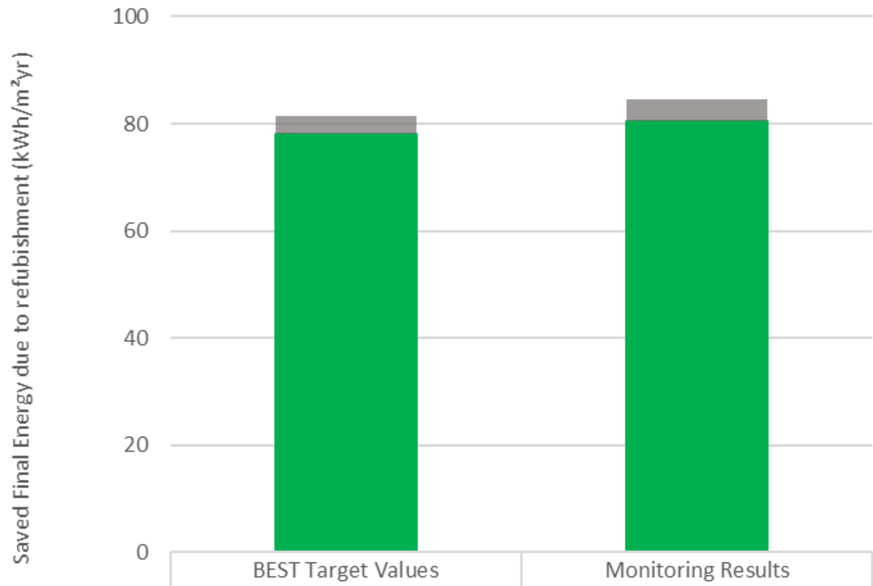
Figure 43 compares the measured normalised Final Energy consumption of all RDS in Växjö with the BEST Reference (see column "existing building" in BEST) and the BEST Target (see column "suggested specification" in BEST). All values are floor area-weighted average values.

	BEST Reference *	BEST Target Values	Monitoring Results
Electricity (BOPS)	13	10	9
DHW	0	19	21
Space heating	143	53	42

*Figure 43: BEST Reference, BEST Target Values and Monitoring Results (2019 resp. 2020) of heat consumption for space heating and DHW (*resp. combined) and electricity consumption (BOPS) at the RDS in Växjö (floor area-weighted average)*

Compared to the baseline, the BEST Reference, these monitoring results correspond to a reduction in Final Energy consumption between 52% (RDS SE1) and 67% (RDS SE1.1). The floor area-weighted average reduction in Final Energy of all buildings at the READY Demonstration Sites in Växjö was 54%.

Figure 44 shows that the average reduction in Final Energy consumption at the RDS in Växjö exceeds the BEST Target. All values are floor area-weighted average values.



	BEST Target Values	Monitoring Results
Electricity (BOPS)	3.30	4.11
District heating	78.02	80.38

Figure 44: BEST Target Values and Monitoring Results (2019 resp. 2020) of the reduction in heat and electricity consumption (BOPS) at the RDS in Växjö (floor area-weighted average)

Aarhus

At the RDS in Aarhus, the monitored normalised Final Energy consumption in 2019 resp. 2020 was between 50.6 kWh/m²yr (RDS DK2) and 76.7 kWh/m²yr (RDS DK4).

Figure 45 compares the measured normalised Final Energy consumption of all RDS in Aarhus with the BEST Reference and the BEST Target. All values are floor area-weighted average values.

Compared to the baseline, the BEST Reference, these monitoring results correspond to a reduction in Final Energy consumption between 60% (RDS DK4) and 72% (RDS DK2). The floor area-weighted average reduction in Final Energy of all buildings at the RDS in Aarhus was 69%.

Figure 45: BEST Reference, BEST Target Values and Monitoring Results (2019 resp. 2020) of heat consumption for space heating and DHW and electricity consumption (BOPS) at the RDS in Aarhus (floor area-weighted average)

Figure 46 shows that the average reduction in Final Energy consumption at the RDS in Aarhus exceeds the BEST Target (see column "suggested specification" in BEST). All values are floor area-weighted average values.

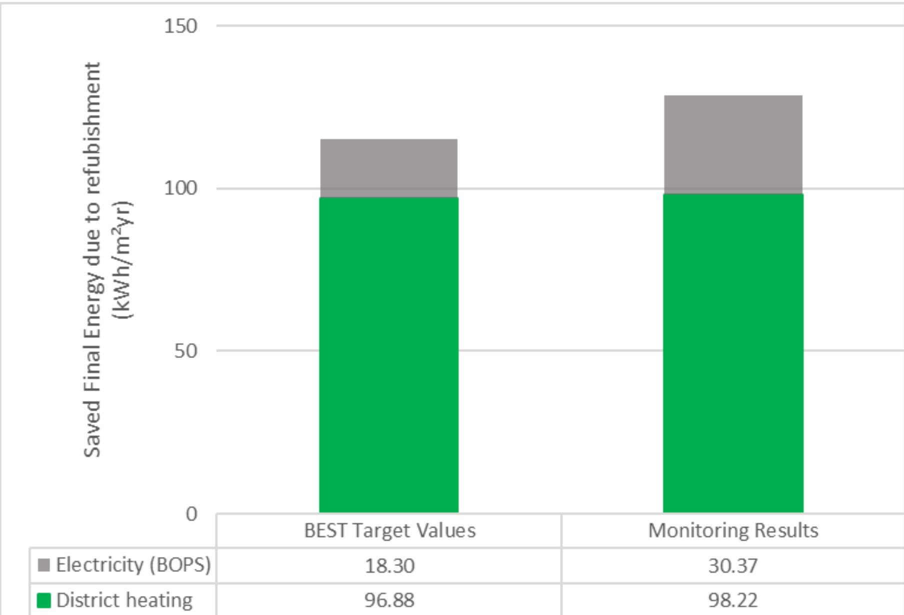


Figure 46: BEST Target Values and Monitoring Results (2019 resp. 2020) of the reduction in heat and electricity consumption (BOPS) at the RDS in Aarhus (floor area-weighted average)

READY total

In 2019 resp. 2020, the monitored normalised Final Energy consumption of the buildings at all RDS was 64.1 kWh/m²yr (floor area-weighted average).

Figure 47 compares the measured normalised Final Energy consumption of all RDS with the BEST Reference and the BEST Target. All values are floor area-weighted average values.

	BEST Reference	BEST Target Values	Monitoring Results
Electricity (BOPS)	25	13	6
DHW	20	19	17
Space heating	129	44	41

Figure 47: BEST Reference, BEST Target Values and Monitoring Results (2019 resp. 2020) of heat consumption for space heating and DHW as well as for BOPS at all RDS (floor area-weighted average)

Compared to the baseline, the BEST Reference, these monitoring results correspond to a reduction in Final Energy consumption of 63%.

Figure 46 shows that the average reduction in Final Energy consumption at the RDS exceeds the BEST Target (see column "suggested specification" in BEST). All values are floor area-weighted average values.

Figure 48: BEST Target Values and Monitoring Results (2019 resp. 2020) of the reduction in heat and electricity consumption (BOPS) in READY (floor area-weighted average)

Table 15 shows the heat consumption from district heating, the electricity consumption (BOPS) and the resulting Final Energy consumption as well as the reduction in heat, electricity (BOPS) and the resulting total Final Energy consumption of all buildings in READY. The electricity consumption (BOPS) at RDS SE1.1 is higher than at the other RDS as the electricity consumption of heat pumps in PVT and WW-HR systems has been included in this category.

Table 15: Normalised (reduction in) Final Energy, heat and electricity consumption (BOPS) in READY

Code	Final Energy consumption	Heat consumption	Electricity consumption (BOPS)	Reduction in Final Energy consumption	Reduction in heat consumption	Reduction in electricity consumption (BOPS)	Rel. reduction in Final Energy consumption
	kWh/m²yr	kWh/m²yr	kWh/m²yr	kWh/m²yr	kWh/m²yr	kWh/m²yr	%
SE1	76.7	68.2	8.5	83.3	80.8	2.5	52
SE1.1	52.4	37.1	15.3	107.6	111.9	-4.3	67
SE3	52.9	47.8	5.2	71.1	45.2	25.8	57
DK1	64.2	60.9	3.3	129.8	94.1	35.7	67
DK2	50.6	47.4	3.2	130.4	107.6	22.8	72
DK3	57.8	43.1	14.7	81.2	52.9	28.3	58
DK4	76.7	51.9	3.2	117.3	103.1	35.8	60
Sum SE	**71.9**	**63.0**	**8.9**	**84.5**	**80.4**	**4.1**	**54**
Sum DK	**58.7**	**55.0**	**3.6**	**128.6**	**98.2**	**30.5**	**69**
Total	**64.1**	**58.3**	**5.7**	**110.7**	**91.0**	**19.8**	**63**

5.3 RE production at READY Demonstration Sites

Växjö

At the READY Demonstration Sites in Växjö, the monitored normalised on-site RE production[37] in 2019 resp. 2020 was 2.8 kWh/m²yr regarding heat and 0.4 kWh/m²yr regarding electricity. The total on-site RE production in Växjö was 3.2 kWh/m²yr. All values are floor area-weighted average values.

Figure 49 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the floor area-weighted average heat (ST yield) and electricity (PV yield) production from roof-top Photovoltaic (PV) and Photovoltaic Thermal (PVT) systems as well as from WW-HR facilities (WW-HR yield) at the RDS in Växjö.

The actual on-site RE production does not meet the target according to the BEST. This is due to changes in the planning of facilities for on-site RE production during the project duration.

	BEST Target Values	Monitoring Results
PV yield	1.20	0.43
ST yield	2.20	1.09
WW-HR yield	0.00	1.67

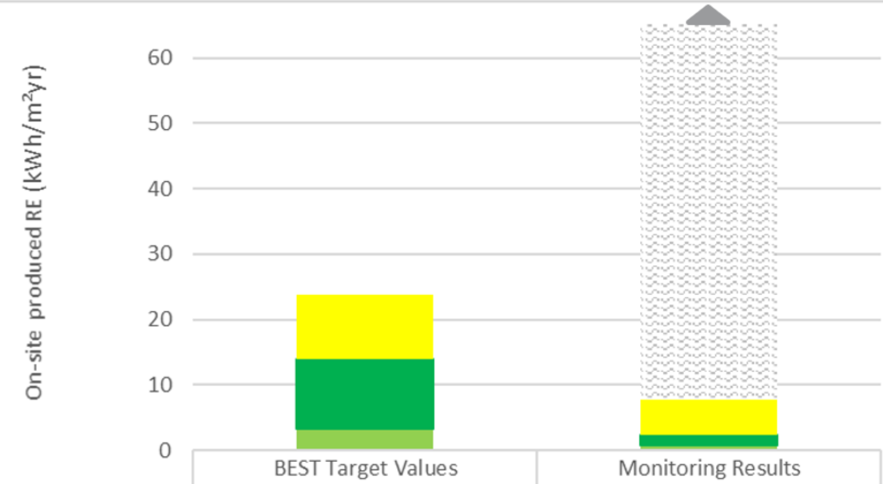
Figure 49: BEST Target Values and Monitoring Results (2019 resp. 2020) of on-site RE production (heat and electricity) at the RDS in Växjö (floor area-weighted average)

[37] Due to delays in construction and commissioning as well as difficulties in the first months of operation at some RES facilities, missing, implausible or non-representative measurement values were replaced by values calculated from reliable measurement values from other months and further input values (e.g. global radiation).

Aarhus

At the READY Demonstration Sites in Aarhus, the monitored normalised on-site RE production in 2019 resp. 2020 was 2.3 kWh/m²yr regarding heat and 5.5 kWh/m²yr regarding electricity. The total on-site RE production in Aarhus was 7.8 kWh/m²yr. All values are floor area-weighted average values.

Figure 50 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the floor area-weighted average heat (ST yield) and electricity (PV yield) production from roof-top Photovoltaic (PV) and Photovoltaic Thermal (PVT) systems as well as from WW-HR facilities (WW-HR yield) at the RDS in Aarhus. Due to deviations from the original plans for the installation of RES facilities, the on-site RE production of heat and electricity does not meet the target. But this is more than overcompensated by a 1 MW heat pump (see 5.4) in Aarhus harbour which had not been planned originally. The heat pump's contribution is indicated as it does not belong to this category and as its corresponding bar height does not fit into the graph's y axis scale (indicated with the grey arrow). This applies to all graphs where the contribution of the 1 MW heat pump is indicated. The HP electricity consumption is not included in the graph.



	BEST Target Values	Monitoring Results
1 MW heat pump		122.29
PV yield	9.79	5.45
ST yield	10.64	1.53
WW-HR yield	3.29	0.76

Figure 50: BEST Target Values and Monitoring Results (2019 resp. 2020) of on-site RE production (heat and electricity) at the RDS in Aarhus (floor area-weighted average). The contribution from the 1 MW heat pump is indicated.

READY total

In 2019 resp. 2020, the normalised on-site RE production (heat and electricity), as monitored in READY, was 2.5 kWh/m²yr resp. 3.4 kWh/m²yr. The total on-site RE production in READY was 5.9 kWh/m²yr.

Figure 51 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the floor area-weighted average heat (ST yield) and electricity (PV yield) production from all roof-top Photovoltaic (PV) and Photovoltaic Thermal

(PVT) systems as well as from all WW-HR facilities (WW-HR yield) in READY. The above mentioned 1 MW heat pump, whose contribution is also indicated in this graph, can compensate not only the shortcomings regarding the RE production at the RDS in Aarhus, but also in a project wide view. In Figure 51, the heat pump's bar height does not fit into the graph's y axis scale neither. The on-site heat, electricity and resulting total RE production at each READY Demonstration Site is listed in Table 16.

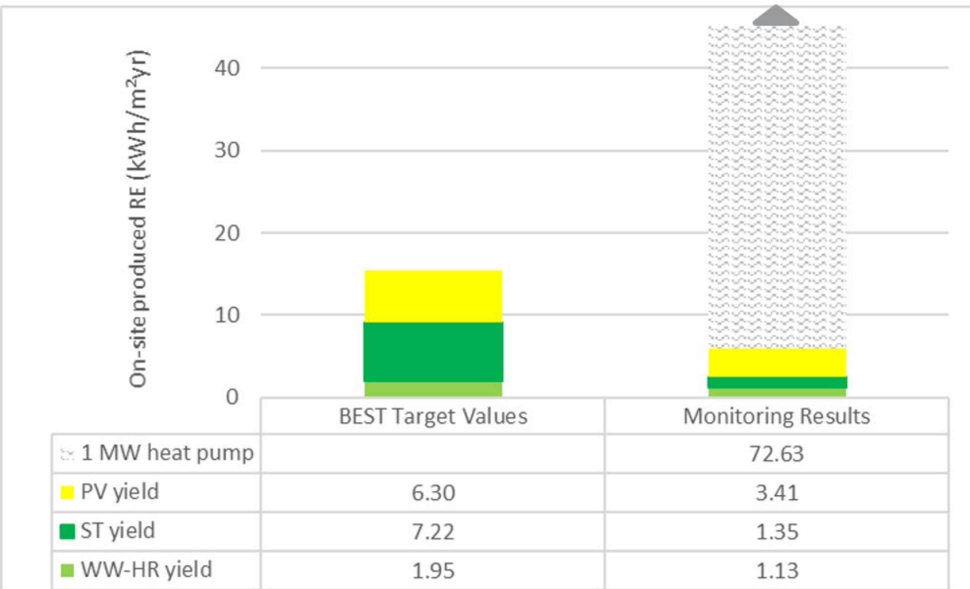


Figure 51: BEST Target Values and Monitoring Results (2019 resp. 2020) of on-site RE production (heat and electricity) in READY (floor area-weighted average). The contribution from the 1 MW heat pump is indicated.

Table 16: Monitored on-site RE production (heat and electricity) at the RDS in absolute numbers. Cells with calculated numbers due to missing monitoring data are highlighted in grey

Code	PV(T)		WW-HR	Total RE production	
	Electricity yield	Heat yield	Heat yield	Heat	Electricity
	kWh/yr	kWh/yr	kWh/yr	kWh/yr	kWh/yr
SE1					
SE1.1	14,329	36,644	55,964	92,608	14,329
SE3					
DK1	144,449		7,462	7,462	144,449
DK2	95,693	75,221	29,847	105,068	95,693
DK3	27,366				27,366
DK4					
Sum SE	**14,329**	**36,644**	**55,964**	**92,608**	**14,329**
Sum DK	**267,509**	**75,221**	**37,309**	**112,530**	**267,509**
Total	**281,838**	**111,865**	**93,273**	**205,138**	**281,838**

5.4 Heat production and electricity consumption by 1 MW sea water-fed heat pump

The 1 MW sea water-fed heat pump at Aarhus harbour (RDP DK-WW1) has been monitored since January 2020. The heat pump's performance of the first 11 month of operation is shown in Figure 52. The graph shows a normal operation only in May. During the first months of operation, technical issues that are normal in initial operation phases of large heat pump systems lead to limited operating conditions.

As the heat pump is still in experimental operation mode, standard operation conditions could not be investigated for longer periods of time. Nevertheless, under standard operating conditions, the heat pump is expected to provide an annual heat generation of approx. 6 GWh (assuming 6.000 full load hours per year). As no better data are available, this reference value serves as representative "monitoring result" for the analyses in WP7.

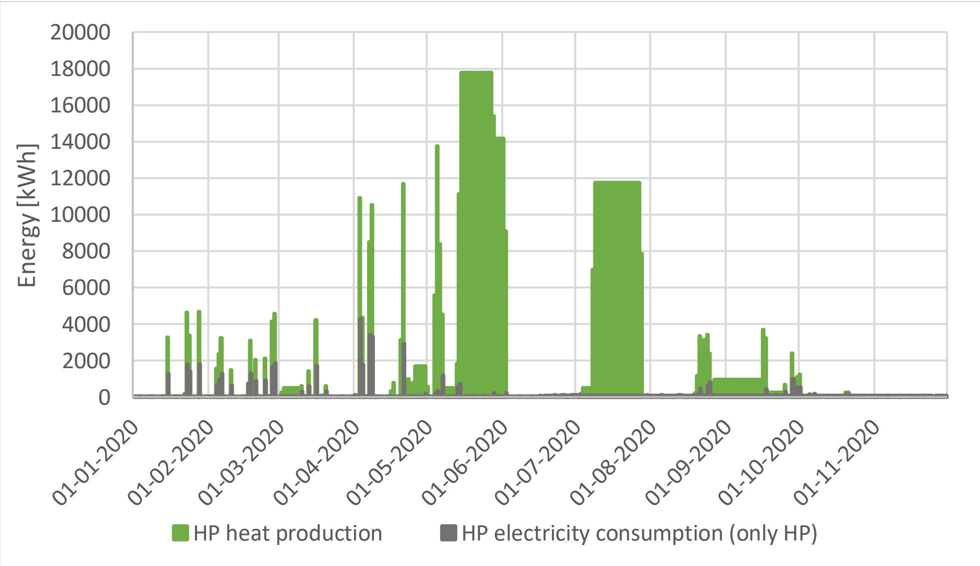


Figure 52: Heat production and electricity consumption of the 1 MW sea water-fed heat pump in Aarhus harbour (RDP DK-WW1) from January to November 2020.

Figure 53 shows the inlet and outlet temperatures of the 1 MW sea water-fed heat pump. This graph shows consistency with the energy production values in Figure 52 as the outlet temperature falls below the inlet temperature only during the few, mainly short operation periods.

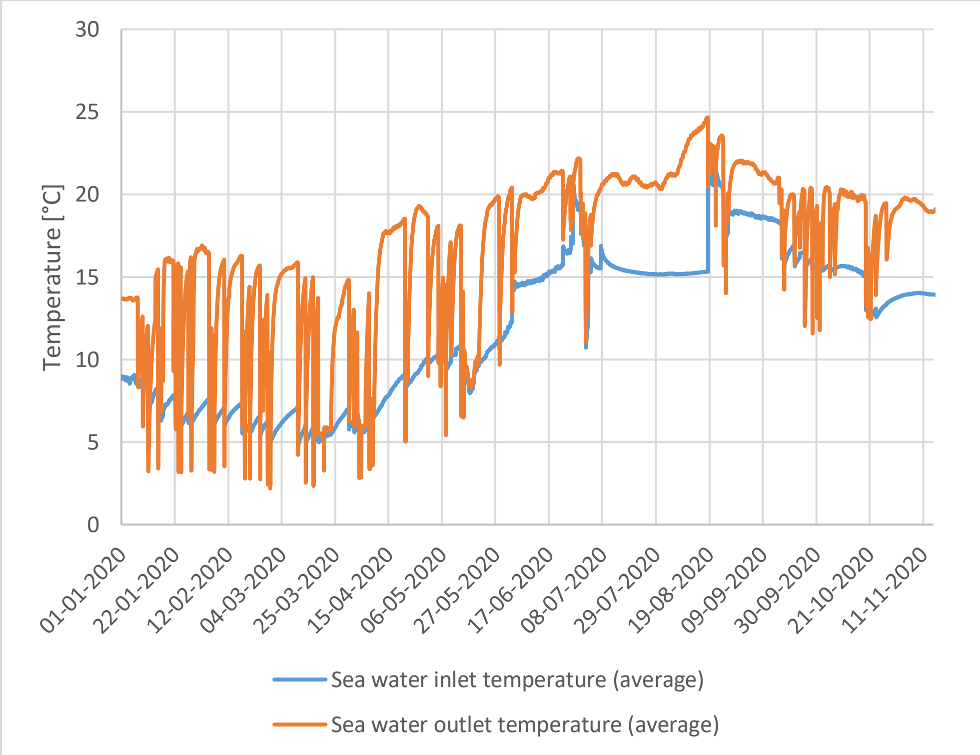


Figure 53: Seawater inlet and outlet temperatures of the 1 MW sea water-fed heat pump in Aarhus harbour (RDP DK-WW1), from January to November 2020

Table 17 shows the heat pump's heat and electricity production as well as the resulting COPs. The table only contains the values of the months January to April as later measurements were not reliable. The COP varies from 2.1 in January to 3.6 in April. As expected, the COP is affected by the water temperature, where a higher temperature ensures a better performance of the heat pump. As it is shown in Figure 52 and Figure 53, the heat pump had many starts and stops during this initial period of operation, which negatively affect the COP. The COP is expected to be higher when the system operates continuously. The monitoring is being continued until standard operating conditions are achieved and the heat pump's expected efficiency can be confirmed.

Table 17: Monitored performance of the seawater heat pump and calculated COP (January to April 2020)

Month	Heat Production (kWh)	Electricity consumption (only HP) (kWh)	COP
January 2020	16,140	7,695	2.1
February 2020	24,610	11,334	2.2
March 2020	10,450	4,328	2.4
April 2020	61,900	16,996	3.6

Table 18 presents a further evaluation of the heat pump's performance considering the primary energy (PE) factors for electricity and district heating, which were respectively **2.1 and 1.0**, following the inputs from the Directive (EU) 2019/2002. It is therefore possible to evaluate the primary energy input and output for the seawater heat pump and the related COP factor for the monitored months. In relation to the primary energy balance, the use of a heat pump can lead to a reduction in primary energy consumption, when the COP is higher than 2.1.

Table 18: Performance of the seawater heat pump considering the primary energy factors (January to April 2020)

Month	Heat Production (kWh)	PE consumption of HP (kWh)	COP_{PE}'
January 2020	16,140	16,160	1.0
February 2020	24,610	23,801	1.0
March 2020	10,450	9,089	1.1
April 2020	61,900	35,692	1.7

5.5 Renewable heat and electricity supply to the READY Demonstration Sites

The READY Demonstration Sites are supplied by renewable heat and electricity from on-site RES facilities as well as from the local district heating and electricity networks. The share of renewable heat and electricity supply via the local district heating networks and the electricity grids was determined regarding the networks' corresponding energy mix. In Aarhus resp. Växjö the renewable share in district heating is 80% resp. 95%. The renewable share in electricity production is 66%[38] resp. 90%[39].

Växjö

Figure 54 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the energy supply to the RDS in Växjö as floor area-weighted average values. To show the complete picture, the non-renewable energy supply is also included in the graphs. Consequently, the total heights of the bars correspond to the buildings' Final Energy consumption of heat and electricity (see Figure 43). The supply's highly renewable energy mix leads to a very small non-renewable share of 3 kWh/m²yr. This value is even slightly better than the BEST Target Value, although the actual energy production at RES facilities does not meet the target. The buildings' heat and electricity consumption (BOPS) is significantly below the BEST Target Values, which compensates the reduced RE production.

[38] See https://en.wikipedia.org/wiki/Electricity_sector_in_Denmark (as of 2017)

[39] See https://www.energimyndigheten.se/nyhetsarkiv/2020/2019-rekordar-for-svensk-elproduktion/ (as of 2019)

	BEST Target Value	Monitoring Results
non-ren electr. supply	0.8	0.8
non-ren heat supply	3.2	3.0
ren electr. supply	7.6	7.6
local ren electr. prod	1.2	0.4
ren heat supply	60.0	57.3
local ren heat prod	2.2	2.8

Figure 54: BEST Target Values and Monitoring Results (2019 resp. 2020) of the total renewable and non-renewable energy supply to the buildings and the on-site RE production in Växjö (floor area-weighted average).

Aarhus

Figure 55 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the energy supply to the buildings and the on-site RE production in Aarhus as floor area-weighted average values.

Due to the contribution of the 1 MW heat pump in Aarhus harbour, there is no non-renewable share in the heat supply at all, but just the opposite: the heat pump could supply the heat for the RDS in Aarhus several times.

As its corresponding bar height does not fit into the graph's y axis scale, the heat pump's contribution is indicated. The HP electricity consumption is not included in the graph.

Over the course of one year, the electricity consumption (BOPS) at the RDS in Aarhus is completely covered by the on-site PV yield, so that there is neither renewable, nor non-renewable electricity supply in the Monitoring Results bar.

	BEST Target Value	Monitoring Results
1 MW heat pump (surplus)		162.0
1 MW heat pump		9.9
non-ren electr. supply	1.9	0.0
non-ren heat supply	8.6	0.0
ren electr. supply	3.7	0.0
local ren electr. prod	8.9	5.6
ren heat supply	34.4	39.6
local ren heat prod	13.9	3.1

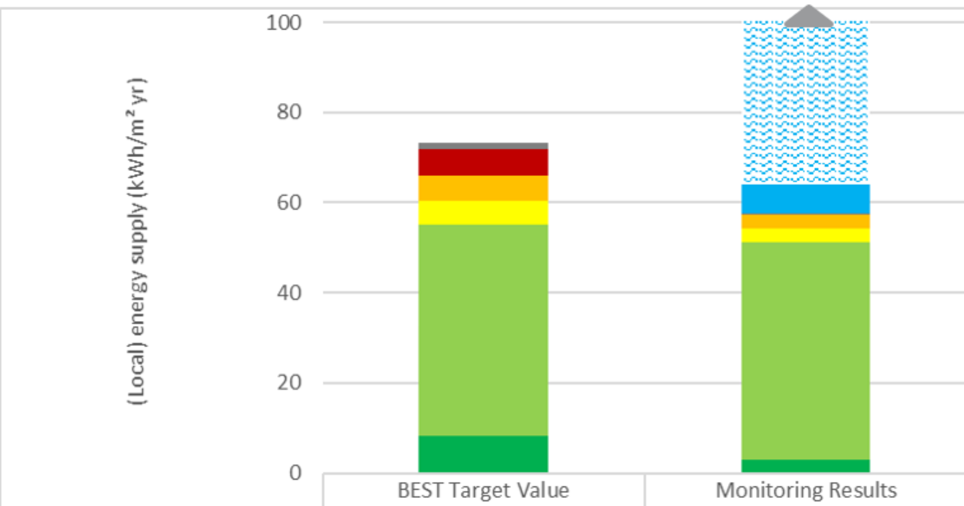
Figure 55: BEST Target Values and Monitoring Results (2019 resp. 2020) of the total renewable and non-renewable energy supply to the buildings and the on-site RE production in Aarhus (floor area-weighted average). The surplus heat production of the 1 MW sea water-fed heat pump is indicated.

READY total

Figure 56 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the energy supply to all READY Demonstration Sites as floor area-weighted average values.

Due to the contribution of the 1 MW heat pump in Aarhus harbour, there is no non-renewable share in the heat supply at all, but just the opposite: the heat pump could supply the heat for all READY Demonstration Sites twice.

As its corresponding bar height does not fit into the graph’s y axis scale, the heat pump’s contribution is indicated. The HP electricity consumption is not included in the graph.



	BEST Target Value	Monitoring Results
1 MW heat pump (surplus)		81.1
1 MW heat pump		6.5
non-ren electr. supply	1.4	0.1
non-ren heat supply	5.9	0.0
ren electr. supply	5.6	3.1
local ren electr. prod	5.1	3.1
ren heat supply	47.0	48.3
local ren heat prod	8.2	3.0

Figure 56: *BEST Target Values and Monitoring Results (2019 resp. 2020) of the total renewable and non-renewable energy supply to the buildings and on-site RE production in READY (floor area-weighted average). The surplus heat production of the 1 MW sea water-fed heat pump is indicated.*

5.6 Primary Energy savings at READY Demonstration Sites

The evaluation of the Primary Energy (PE) savings due to refurbishment and on-site RE production was performed considering PE factors for electricity (2.1) and district heating (1.0), following the inputs from the Directive (EU) 2019/2002.

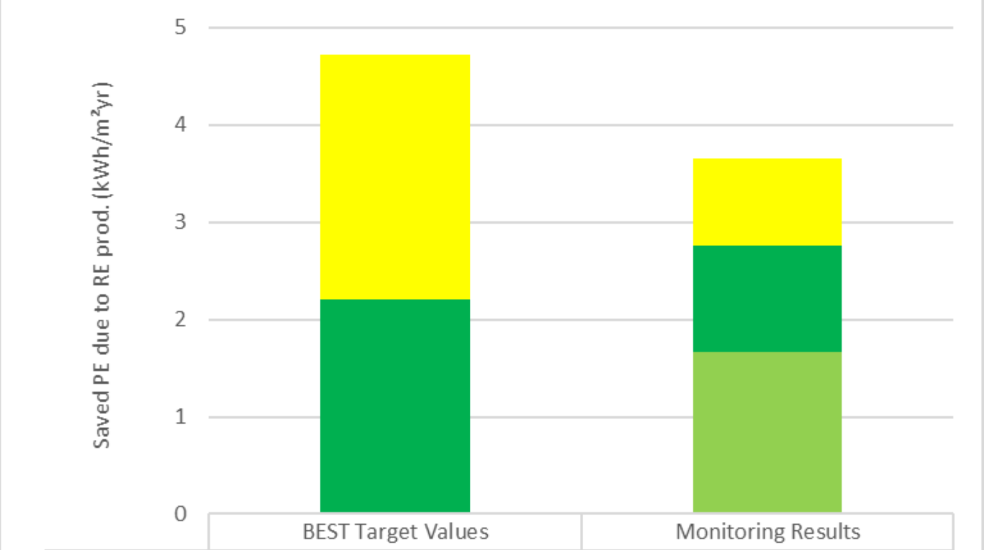
Växjö

The Final Energy savings due to refurbishment at the RDS in Växjö lead to PE savings of 80.4 kWh/m²yr regarding heat and 8.6 kWh/m²yr regarding electricity. Figure 57 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the floor area-weighted average PE savings regarding heat and electricity consumption (BOPS) at the RDS in Växjö.

	BEST Target Values	Monitoring Results
Electricity (BOPS)	6.93	8.64
District heating	78.02	80.38

Figure 57: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding PE savings due to refurbishment in Växjö (floor area-weighted average)

The Final Energy savings due to on-site RE production lead to PE savings of 2.8 kWh/m²yr regarding heat and 0.9 kWh/m²yr regarding electricity. Figure 58 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the floor area-weighted average PE savings due to on-site RE production (heat and electricity) in Växjö.



	BEST Target Values	Monitoring Results
PV yield	2.52	0.90
ST yield	2.20	1.09
WW-HR yield	0.00	1.67

Figure 58: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding PE savings due to on-site RE production in Växjö (floor area-weighted average)

Aarhus

The Final Energy savings due to refurbishment at the READY Demonstration Sites in Aarhus lead to PE savings of 98.2 kWh/m²yr regarding heat and 63.8 kWh/m²yr regarding electricity. Figure 57 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the floor area-weighted average PE savings regarding heat and electricity consumption (BOPS) at the RDS in Aarhus.

Figure 59: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding PE savings due to refurbishment in Arhus (floor area-weighted average)

The Final Energy savings due to on-site RE production lead to PE savings of 2.3 kWh/m²yr regarding heat and 11.5 kWh/m²yr regarding electricity.

Figure 58 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the floor area-weighted average PE savings due to on-site RE production at the RDS in Aarhus.

As a consequence of the deviations between planned and actually installed RES capacities (see 5.3), the BEST Target regarding saved PE due to on-site RE production is not met either but this shortcoming is also compensated by the contribution of the 1 MW heat pump (indicated in the graph, HP electricity consumption not shown).

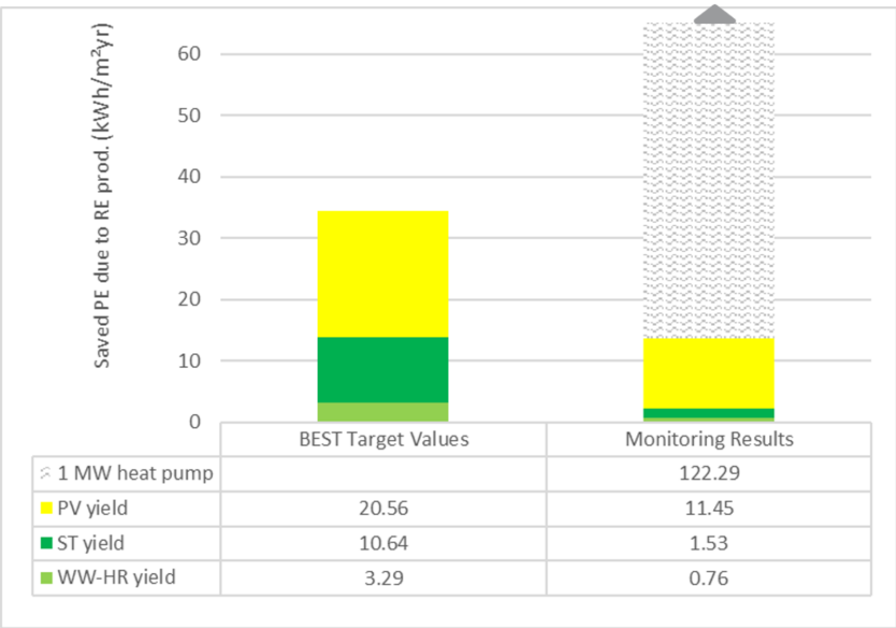


Figure 60: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding PE savings due to on-site RE production in Aarhus (floor area-weighted average). The contribution from the 1 MW sea water-fed heat pump is indicated.

READY total

In READY, the Final Energy savings due to building refurbishment lead to PE savings of 91.0 kWh/m²yr regarding heat and 41.4 kWh/m²yr regarding electricity. Figure 57 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the floor area-weighted average PE savings regarding heat and electricity (BOPS) in READY.

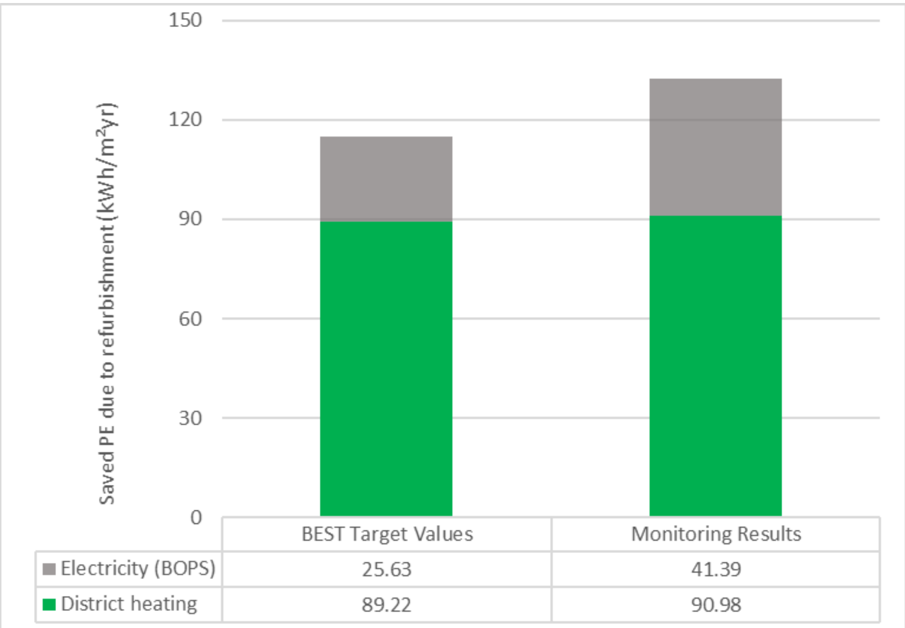
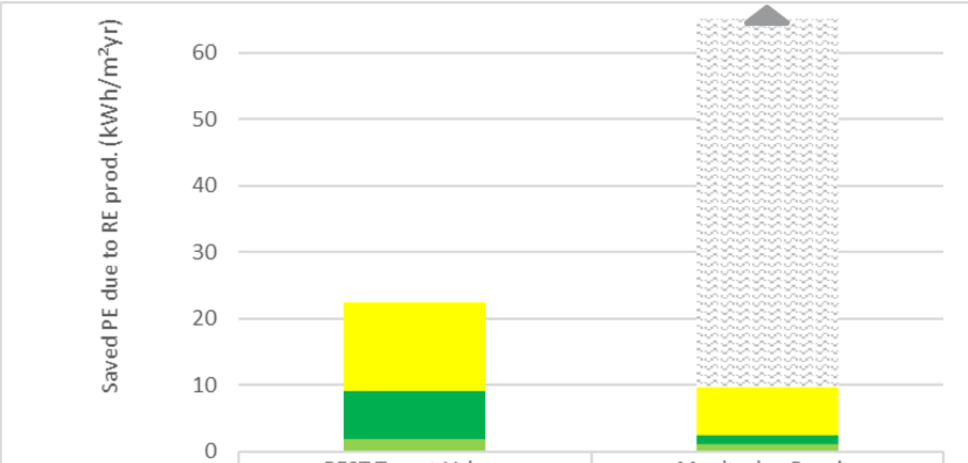


Figure 61: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding PE savings due to refurbishment in READY (floor area-weighted average)

The Final Energy savings due to on-site RE production lead to PE savings of 2.5 kWh/m²yr regarding heat and 7.2 kWh/m²yr regarding electricity.

Figure 58 shows the BEST Target Values and Monitoring Results (2019 resp. 2020) of the floor area-weighted average PE savings due to on-site RE production in READY.

The graph shows that the 1 MW heat pump, whose contribution is also indicated in this graph (electricity consumption not included), can compensate not only the shortcomings regarding the on-site RE production in Aarhus, but also in a project wide view. In Figure 58, the heat pump's bar height does not fit into the graph's y axis scale neither.



	BEST Target Values	Monitoring Results
1 MW heat pump		72.63
PV yield	13.24	7.16
ST yield	7.22	1.35
WW-HR yield	1.95	1.13

Figure 62: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding PE savings due to on-site RE production in READY (floor area-weighted average). The contribution from the 1 MW sea water-fed heat pump is indicated.

5.7 Performance of Battery Energy Storage System

The performance of the Battery Energy Storage System (BESS, RDP DK-ST) in Trigeparken (RDP DK2) was examined for the two representative operating conditions

1. High PV yield (PVH)
2. Low PV yield (PVL)

The performance of the BESS at PVH operating conditions is shown in Figure 63. The graph shows the PV production (yellow line), the battery state of charge (green line) between 0% (corresponds to the y axis label "-90 kW") and 100% ("90 kW"), the buildings' electricity consumption (blue line) and the power at the billing point of the building (black line) from the evening of June 23rd to the evening of June 25th.

The PV production starts on June 24th after sun rise. When the PV production exceeds the building's consumed power at (1), the BESS starts to capture the surplus electricity production from the PV system. Then, grid supply is zero or negative. The latter happens, when PV production exceeds the total of the building's power consumption and the BESS' max. charging power. On a sunny day like this, the battery gets fully charged after a few hours of PV production at (2). In the evening, the PV production falls below the building's power consumption, hence, the BESS starts to supply power to the building in order to substitute the gap between production and consumption (3). Over the night, the BESS is discharged completely (state of charge = 0%) (4) but is being charged again with the excess PV production of the next day (June 25th).

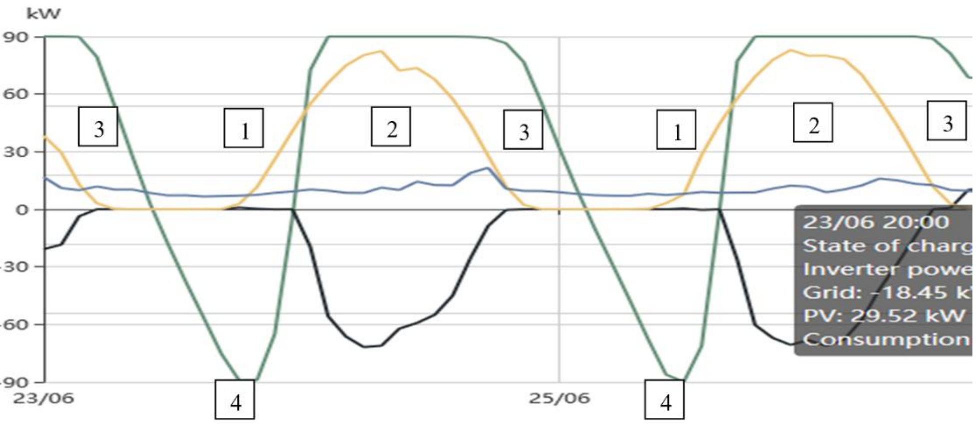


Figure 63: BESS performance at PVH operation condition (RDP DK-ST)[40]

The performance of the BESS during the night and morning after a day with low PV generation (PVL) is shown in Figure 64. Analogously to Figure 63, the graph shows the PV production, the battery state of charge, the buildings' electricity consumption and the power at the billing point of the building.

As the BESS must start to supply power to the building early in the day due to low PV production, the BESS is discharged completely already before midnight (1). Then, the buildings' electricity consumption must be fully covered by the grid, until the PV production starts again at the morning of the next day. Although the PV production (of the next day) is low, it exceeds the building's consumed power at some point and the surplus electricity production is captured as described above (PVH).

[40] See D.5.5.1

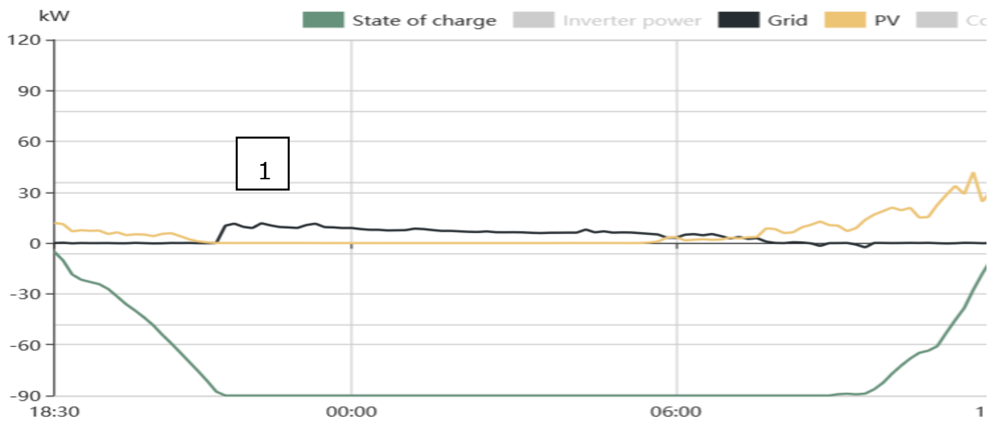


Figure 64: BESS performance at PVL operating condition (RDP DK-ST)

Figure 65 shows the electricity supply to the buildings at RDS DK2 from January to December 2020[41]. In winter, December and January in particular, the supply is almost completely provided by the grid, but in summer, almost the whole consumption can be covered with the PV yield. From May to September, approx. 20% more PV yield can be used due to the BESS, which is charged when PV production exceeds the consumption and discharged, when the PV production provides less power, than the buildings' electricity demand.

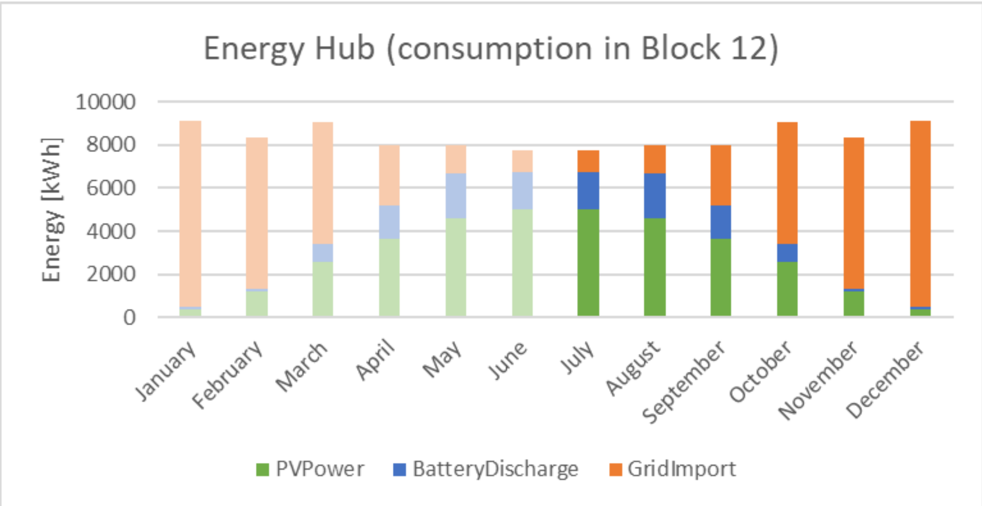


Figure 65: Electricity supply to RDS DK2 directly from PV yield ("PVPower", green), from the Battery ("BatteryDischarge", blue) and from the grid ("GridImport", orange) from January to December 2020

[41] Reliable monitoring data was available for the period July to December. The data from January to June were obtained by mirroring the available data.

5.8 Reduction in pipe heat losses in optimised district heating network

The pipe heat losses of the Low-temperature district heating network in Alabastern (RDP SE-DH) were determined by centrally measuring the total heat supplied to the district and by comparing this value to the sum of all heat metering values from the meters in the buildings. Compared to empirical pipe heat loss values in similar districts, the reduction in pipe heat losses is approx. 106 MWh per year, i.e. a reduction of 60% compared to pipe heat losses in conventional district heating networks (baseline: 12 % of DH supply). This reduction corresponds exactly to the planning value. The saved PE is equal to the saved heat. The Monitoring Results in 2020 and calculated heat reduction values are shown in Table 19.

Table 19: District heating supply and end users' heat consumption in Alabastern (Växjö), derived pipe heat losses and saved heat in 2020 (baseline)*

Month	Supply	Consumption	Heat loss			Saved heat
	kWh	kWh	kWh	%	%*	kWh
Jan	191,730	184,105	7,625	4.0	12	15,383
Feb	186,430	179,429	7,001	3.8	12	15,371
Mar	191,380	184,025	7,355	3.8	12	15,611
Apr	127,680	121,524	6,156	4.8	12	9,166
May	102,970	97,474	5,496	5.3	12	6,860
Jun	54,470	52,161	2,309	4.2	12	4,227
Jul	54,380	49,525	4,855	8.9	12	1,671
Aug	55,620	50,765	4,855	8.7	12	1,819
Sep	63,310	58,503	4,807	7.6	12	2,790
Oct	107,410	102,014	5,396	5.0	12	7,493
Nov	139,560	133,794	5,766	4.1	12	10,981
Dec[42]	190,864	182,978	7,886	4.1	12	15,018
Year	**1,465,804**	**1,396,297**	**69,507**	**4.7**	**12**	**106,390**

5.9 Energy savings in the innovative district cooling project "energy used three times"

The innovative district cooling project "energy used three times" in Växjö (RDP SE-WW1) achieved a reduction in cooling energy consumption by increasing the energy efficiency of a data centre's cooling system by 1 GWh per year. Additionally, by heating a football turf with waste heat from the district cooling network, 600 MWh of cooling energy and the same amount of heat from district heating can be saved per year (2019, see Figure 66).

[42] No monitoring values available, supply value from 2019, relative losses from November 2020. Other values derived from those.

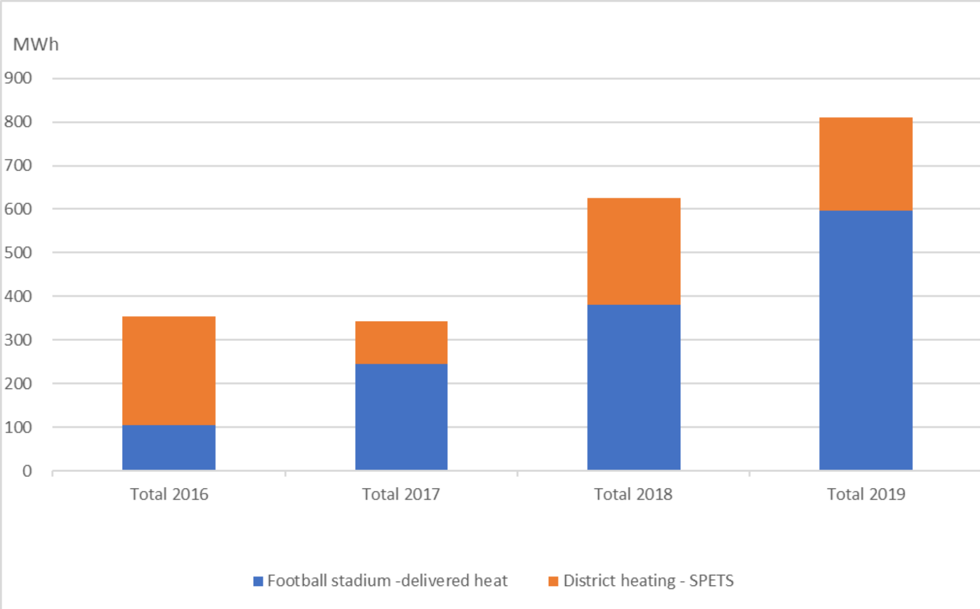


Figure 66: Heat for the heating of the football turf, supplied by conventional district heating (orange) and the district cooling network (blue) in 2019

Saved cooling energy

As the cooling energy is provided by an absorption chiller (COP of 0.65), powered by heat from the district heating network, the total saved heat due to the reduction in cooling energy consumption was 2.5 GWh. Including the free cooling waste heat used for the football turf the total heat savings in 2019 were approx. 3.1 GWh. As the two cooling energy consumers (shopping centre and data centre) could be supplied by the same flow, energy consumption for pumping could be reduced as well (not part of monitoring). The monitored cooling energy and heat consumption values as well as the derived energy savings (both for 2019) are listed in Table 20.

Table 20: Monitored district cooling resp. heating supply to the data centre and the football turf as well as derived energy savings in 2019

Cooling energy consumption - data centre (MWh/yr)	1,292
Saved cooling energy at data centre (MWh/yr)	1,034
Heat consumption – football turf (MWh/yr)	811
Waste heat consumption – football turf (MWh/yr)	597
Total saved cooling energy (MWh/yr)	1,631
COP of absorption chiller (-)	0.65
Saved heat for absorption chiller (MWh/yr)	2,509
Total saved DH heat (MWh/yr)	**3,106**

5.10 Monitoring of EV charging stations

At the charging stations for electrical vehicles (EV) in Aarhus (DK-Ch), the annually supplied electricity and the usage of each charging sock were monitored. The annual electricity volume of all charging stations increased by approx. 100% every year, as shown in Table 21. The utilization rate of the charging stations, which has been on average 3%, is presented in Figure 67. The utilization rate is the total time of usage per day divided by 24 hours.

Table 21: Total annually supplied electricity of EV charging stations between 2015 and 2019

Year	Consumption (kWh)
2015	17,289
2016	39,183
2017	78,440
2018	107,824
2019	186,858

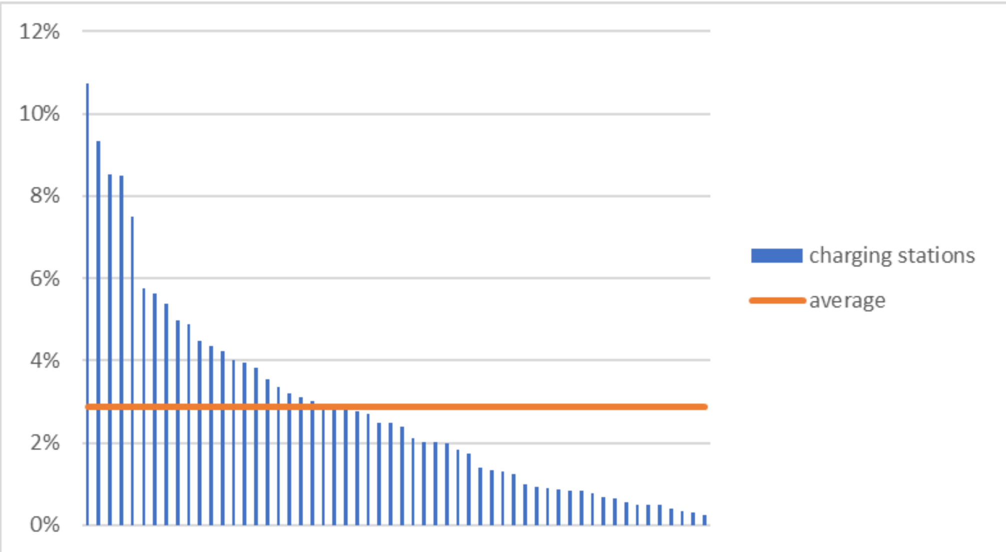


Figure 67: Utilization rate of all charging stations of DK-Ch (average utilization rate of all charging stations, and per charging station, sorted from the maximum to the minimum value)

6 Environmental impact

6.1 CO_2 emission factors

In order to determine the CO_2 emission[43] savings due to READY energy saving/production measures, CO_2 emission factors for heat and electricity are required. These values depend on the energy mix of the respective energy form. Different approaches to determine CO_2 emission factors exist, but in READY only the following 2 approaches were applied:

Approach 1 "Planning values"

The CO_2 emission factors are derived from the energy mix of marginal heat/electricity production in the city/region where the measure is applied. Marginal heat/electricity production refers to energy production supply peaks. The used CO_2 emission factors were official planning values from 2012 used as basis for the READY project (DOW) and hence, used to calculate the expected CO_2 emission savings.

Approach 2 "Average values"

The CO_2 emission factors are derived from the average energy mix of heat/electricity production in the specific country of the respective READY Demonstration Site.

The CO_2 emission factors for heat from the district heating network and electricity from the grid of both approaches are presented in Table 22.

Table 22: CO_2 emission factors for heat from the district heating network and electricity from the grid used in READY

	Aarhus	Växjö
Approach 1 "Planning values" (main approach in WP7)		
CO_2 emission factor of marginal heat production according to DOW	108 g CO_2/kWh	74 g CO_2/kWh
CO_2 emission factor of marginal electricity production according to DOW	770 g CO_2/kWh	400 g CO_2/kWh
Approach 2 "Average values (2019)"		
CO_2 emission factor of heat production according to actual energy mix in Sweden resp. Denmark	33 g CO_2/kWh	0 g CO_2/kWh
CO_2 emission factor of electricity production according to actual energy mix in Sweden resp. Denmark	130 g CO_2/kWh	125 g CO_2/kWh

[43] The term "CO_2 emissions" includes all climate relevant emissions which are considered as CO_2 equivalent emissions. In WP7, no further emissions than CO_2 emissions were analysed.

For the assessment of the expected ecological impact of the energy saving and RE production measures in READY, approach 1 was used for first assessments in the project's initial phase. In order to assess the target fulfilment, the same approach was applied to calculate the respective CO_2 emission savings according to the Monitoring Results.
Alternatively, approach 2 was applied too, but as the heat and electricity production in Aarhus and Växjö is becoming more and more carbon-free, these values are close to zero and hence, for the analysis of READY's environmental impact not very meaningful. Therefore, the results of these calculations are not presented in this report.

6.2 CO_2 emission savings

The extensive energy savings due to building refurbishment and on-site RE production achieved at the READY Demonstration Sites lead to significant CO_2 emission savings, which were derived from the Monitoring Results regarding Final Energy savings due to building refurbishment (see 5.2), regarding on-site RE production, the potential heat production of the 1 MW sea-water fed heat pump, the saved heat losses due to the optimisation of the district heating network and the heat savings achieved in the RDP "energy used three times". The monitoring data is from 2019 resp. 2020.

Building refurbishment

The CO_2 emission savings due to the building refurbishment in 2019 resp. 2020 were approx. 255 tons (RDS in Växjö) resp. 1,668 tons (RDS in Aarhus) or 1,923 tons (total) per year. Figure 68 shows the environmental impact of the building refurbishment at all READY Demonstrations Sites as floor area-weighted average values.

	BEST Target Values	Monitoring Results
Electricity (BOPS)	8.90	14.56
District heating	8.56	8.72

Figure 68: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding the CO_2 emission savings regarding building refurbishment in READY (floor area-weighted average).

RE production

The annual CO_2 emission savings due to on-site RE production at READY Demonstration Sites in **Växjö** were approx. 6.9 tons regarding heat and 5.7 tons regarding electricity.

The annual CO_2 emission savings due to on-site RE production at RDS in **Aarhus** were approx. 12 tons regarding heat and 206 tons regarding electricity.

For the whole READY project, this sums up to total annual CO_2 emission savings of approx. 19 tons regarding heat and 212 tons regarding renewable electricity production resp. 231 tons in total.

Additionally, the 1 MW sea water-fed heat pump in Aarhus harbour (Denmark) saves CO_2 emissions of approx. 648 tons per year.

Figure 69 shows the environmental impact of on-site RE production in READY. The 1 MW heat pump's impact is indicated. The CO_2 emission savings in the improved district heating network in Växjö and the other measures, not mentioned in this paragraph, are not included.

	BEST Target Values	Monitoring Results
1 MW heat pump		7.84
PV yield	4.67	2.56
ST yield	0.75	0.13
WW-HR yield	0.21	0.10

Figure 69: BEST Target Values and Monitoring Results (2019 resp. 2020) regarding the CO_2 emission savings due to on-site RE production in READY (floor area-weighted average). The contribution from the 1 MW sea water-fed heat pump is indicated.

Further measures

The improvement of the district heating network in Alabastern district (RDP SE-DH) saves approx. 106 MWh heat which results in CO_2 emission savings of 7.9 tons every year.

The saved heat of approx. 3.1 GWh by of the innovative district cooling project “energy used three times” in Växjö (RDP SE-WW1) lead to CO_2 emission savings of approx. 230 tons per year (see 5.9).

READY total

Summarising all calculation results regarding CO_2 emission savings, READY counts with an environmental impact of **2,320 tons** of avoided CO_2 emissions every year. Assuming an average lifespan of buildings and RE production facilities of 30 years, READY’s total environmental impact would account to almost **70 thousand tons** of avoided CO_2 emissions.

These results are close to the results of the rough calculations performed during the project’s initial phase. From the energy saving/RE production measures in READY, **3,689 tons** of yearly saved CO_2 emissions were expected. Within the assumed 30 years lifespan, this would account to **110 thousand tons** of avoided CO_2 emissions. These numbers are higher than the actual values, but it should be considered, that these values were calculated in a very early stage of the project.

The 30 years GHG emission saving target derived from the BEST Target Values regarding Final Energy savings/production (not all READY measures included) is 57 thousand tons, the corresponding actual savings are 62 thousand tons. Compared to the BEST Target, the READY project was successful in this regard as well.

7 Economic analysis

Energy savings and hence CO_2 emission savings not only help to tackle the climate change but also lead to significant cost savings which are the basis for economic analyses regarding the cost effectiveness of energy saving measures. One common financial indicator used to evaluate the cost effectiveness of energy saving measures is the simple payback time (see 7.3), another important indicator is the cost of reducing greenhouse gas emissions.

7.1 Investment costs and O&M costs regarding building refurbishment

To determine the share of the investment costs for building refurbishment that was necessary to achieve the energy savings presented above, certain empirical factors had to be used. These allocation factors for the determination of the energy-related investment costs are presented in Table 23.

Table 23: Allocation factors for the calculation of the energy-related investment costs, lifespan of the building components and RES facilities and relative O&M costs in READY

Component	**Allocation factor**	**Lifespan**	**rel. O&M costs**
	%	years	%
Windows	25	30	-
Building envelope	20	40	-
Ventilation	90	30	1

The basis for the determination of the energy-related investment costs are the actual investment costs for windows, the building envelope and the ventilation system.

Considering the component's lifespan, fictitious annual reinvestment costs were calculated. The total and the planned resp. actual energy-related investment costs as well as reinvestment costs and Operating and Maintenance (O&M) costs are listed for the READY Demonstration Sites in Table 24.

Baseline

In READY, the expected energy-related share of investment costs for building refurbishment was 100 EUR/m². Based on that value, the EC Support for building refurbishment was defined to 50% of the corresponding energy-related share of investment costs with an upper limit of 50 EUR/m².

Actual situation

In Växjö, the actual energy-related share of investment costs for building refurbishment turned out to be 244 EUR/m² while in Aarhus, the actual value was equal to the expected value of around 100 EUR/m².

Consequently, the floor area-weighted average of all READY Demonstration Sites is 166 EUR/m² which is in absolute numbers 13 MEUR. As READY could count on

4 MEUR EC support for building refurbishment, 9 MEUR had to be covered by the READY project partners.

The total cost of refurbishment is significantly higher, e.g. approx. 1500 EUR/m² for Demonstration Sites in Aarhus, as this figure includes cost for new bathrooms, new kitchens, balconies, surfaces, gardening etc. These non-energy relevant cost shares are not part of READY and hence, not investigated in WP7.

Table 24: Energy-related investment costs, annual reinvestment as well as annual O&M costs for building refurbishment in READY (floor area-weighted average values excl. VAT)

Code	**Planned energy-related investment costs**	**Max EC Support**	**Actual energy-related investment costs**	**Actual energy-related investment costs incl. EC**	**Reinvestment costs buildings (annual)**	**O&M costs buildings (ventilation)**	**Total annual energy-related O&M costs buildings**
	€/m²	€/m²	€/m²	€/m²	€/m²yr	€/m²yr	€/m²yr
SE1	100	50	244	194	6.9	0.8	7.7
SE1.1	100	50	246	196	7.0	0.8	7.8
SE3	100	50	243	193	7.6	1.8	9.4
DK1	100	50	97	48	3.0	0.4	3.5
DK2	100	50	97	48	3.0	0.4	3.5
DK3	100	50	148	98	4.8	0.9	5.7
DK4	100	50	135	85	4.3	0.9	5.2
Sum SE	**100**	**50**	**244**	**194**	**7.0**	**0.9**	**7.9**
Sum DK	**100**	**50**	**100**	**50**	**3.1**	**0.5**	**3.6**
Total	**100**	**50**	**166**	**116**	**4.9**	**0.7**	**5.3**

7.2 Investment costs and O&M costs regarding on-site RE production

The actual investment costs of facilities for the on-site RE production were 170 kEUR (RDS in Växjö) resp. 871 kEUR (RDS in Aarhus) or 1.04 MEUR (READY total). The EC Support for PVT systems and WW-HR is 50% of the investment costs, the PV systems were not supported (see Table 25).

Table 25: Investment costs of RES facilities in READY (Excl. VAT)

Code	Investment costs of on-site RE production - PV(T)	Investment costs of on-site RE production - heat pump, etc.	Total investment costs of on-site RE production	EC Support on-site RE production
	€	€	€	€
SE1.1	170,316	158,000	328,316	164,158
DK1	299,353	15,000	314,353	7,500
DK2	524,747	103,000	627,747	313,874
DK3	46,570		46,570	-
Sum SE	170,316	158,000	328,316	164,158
Sum DK	870,670	118,000	988,670	321,374
Total	**1,040,986**	**276,000**	**1,316,986**	**485,532**

To determine the fictitious annual reinvestment and O&M costs for RES facilities, empirical lifespans and relative O&M costs for movable parts (per centage of investment costs) from Table 26 were used.

Table 26: Lifespan and relative O&M costs of the RES facilities in READY

Component	Lifespan	rel. O&M costs
	years	%
PV(T) systems (non-movable parts)	30	-
Movable parts, e.g. heat pumps for PVT	20	1

The fictitious annual reinvestment costs and estimated annual O&M costs are presented in Table 27.

Table 27: Annual reinvest and O&M costs of on-site RE production in READY (Excl. VAT)

Code	Reinvestment costs RE production - PV(T) (annual)	Reinvestment costs RE production - heat pumps, etc. (annually)	O&M costs (heat pumps)
	€/yr	€/yr	€/yr
SE1.1	5,677	7,900	3,283
DK1	9,978	750	3,144
DK2	17,492	5,150	6,277
DK3	1,552	-	466
Sum SE	5,677	7,900	3,283
Sum DK	29,022	5,900	9,887
Total	**34,700**	**13,800**	**13,170**

The energy prices for electricity and district heating in Aarhus and Växjö are listed in Table 28 resp. Table 29.

Table 28: Energy prices for electricity in Aarhus and Växjö

City (currency)	Energy price incl. VAT	VAT	Energy price excl. VAT	Energy price excl. VAT
	DKK/kWh resp. SEK/kWh	-	DKK/kWh resp. SEK/kWh	EUR/kWh
Aarhus (DKK)	1.8854	25%	1.50832	0.202
Växjö (SEK)	1.7760	25%	1.4208	0.134

Table 29: Energy prices for district heating (variable part) in Aarhus and Växjö

City (currency)	Energy price incl. VAT	VAT	Energy price excl. VAT	Energy price excl. VAT
	DKK/kWh resp. SEK/kWh	-	DKK/kWh resp. SEK/kWh	EUR/kWh
Aarhus (DKK)	0.52	25%	0.42	0.056
Växjö (SEK)	0.63[44]	25%	0.50	0.048

[44] As in Växjö, the pure heat price is very low, the heat cost impact of capacity reduction was included as well.

7.3 Simple payback time

As the name indicates, the simple payback time is a simple calculation of the number of years prior to investment has been paid back only due to the annual energy savings. This calculation method does not include the inflation, interests, technical lifetime of the installed measures or changes in the energy prices. On the other hand, it is a term that is easy to understand. However, there is a risk that a simple payback time of more than 10-15 years easily can sound unattractive even though the technical lifetime of the measure is 20 years or more.

The simple payback time is calculated as:

$$Payback\ period = \frac{Investment\ costs}{Annual\ savings\ in\ energy\ costs - O\&M\ costs}$$

Simple payback time

Table 30 shows the simple payback times for the energy-related investment costs of the building refurbishment and the investment costs of the installation of RES facilities in READY. The values are given for a calculation variant considering EC Support and for a calculation variant without considering the EC Support for the energy saving/RE production measure.

Annual operating and maintenance (O&M) costs related to energy savings are in general assumed to be 1% of the energy-related investment costs of the corresponding facility, when there are movable parts involved (e.g. ventilation, heat pumps). For systems without or with very few movable parts, O&M costs were neglected.

Table 30: Simple payback time incl./excl. EC Support concerning building refurbishment and RE production in READY (excl. O&M costs)

Code	**Building refurbishment**			**RE production**	
	excl. EC Support	**incl. EC Support**		**excl. EC Support**	**incl. EC Support**
	years	years		years	years
SE1	72	57		N/A	N/A
SE1.1	62	50		78	39
SE3	63	50		N/A	N/A
DK1	8	4		12	12
DK2	10	5		33	17
DK3	19	13		9	9
DK4	11	7		N/A	N/A
Sum SE	**70**	**56**		**78**	**39**
Sum DK	**9**	**5**		**20**	**13**
READY	**34**	**25**		**24**	**15**

In order to perform these calculations, several assumptions had to be made and not all desired input values were available. For the sake of simplicity, the electricity consumption of heat pumps (basically from solar PV with a low marginally value) in PVT and WW-HR systems were not included in the payback times regarding RE production (but included in the buildings' electricity consumption (BOPS)). Hence, the calculated simple payback times should be viewed regarding their order of magnitude only.

7.4 Simple cost of reducing greenhouse gas emissions

As the name indicates, the simple cost of reducing greenhouse gas emissions[45] (CO_2 emission saving cost) is a simple calculation of the cost of saving one kg resp. ton CO_2. This characteristic value considers investment costs, periodically incurred reinvestment costs, O&M costs, energy cost savings due to reduced energy consumption and on-site RE production as well as the achieved saving of CO_2 emission.
This simplified calculation method does not include the inflation, interests or changes in the energy prices, but the technical lifetime is considered in the fictitious annual (re)investment costs (see below).
For the calculation of (simple) GHG saving costs, it is irrelevant, whether the costs and savings refer to a period of one year, ten years or 50 years. In this report, costs and savings from one year were used. Investment costs and reinvestment costs are therefore allocated on an annual basis using the term "reinvestment costs". In this report, the GHG reduction cost was calculated as:

$$CO2\ emission\ saving\ cost = \frac{an.(re)invest.\&O\&M\ costs - an.e.cost\ savings}{an.CO2\ emission\ savings}$$

Positive calculation results (> 0, no sign) mean that the total cost of reducing greenhouse gas emissions are higher than the achieved energy cost savings, while negative calculation results (< 0, "-" sign) mean that the total costs to achieve CO_2 emission savings are lower than the cost savings due to energy savings. Hence, negative GHG saving cost values are preferable.

Analogously to the calculation of the simple payback time, several assumptions were necessary and the electricity consumption of heat pumps in PVT and WW-HR systems were also not included in this approach. Therefore, the calculated values of the simple cost for reducing GHG emissions should also be viewed regarding their order of magnitude only.

Baseline

At the READY project start, the expected cost of reducing greenhouse gas emissions due to building refurbishment and RE production was roughly

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[45] In this report, the terms "CO_2 emission saving costs", GHG saving costs and "costs of reducing greenhouse gas emissions" is used interchangeable.

calculated. According to this calculation, in Växjö, the CO_2 emission saving costs were expected to be -283 EUR/ton compared to -55 EUR/ton in Aarhus.

Actual situation

According to the monitoring data, in **Växjö**, the costs for saved CO_2 emissions due to building refurbishment is 490 EUR/ton and 484 EUR/ton due to RE production at the READY Demonstration Sites. Considering EC support in this calculation, the CO_2 emission saving costs fall to 329 EUR/ton (building refurbishment) resp. 49 EUR/ton (on-site RE production). CO_2 emission savings due to further energy saving measures (e.g. RDS SE-DH) are excluded.

These positive values mean that the total costs to achieve CO_2 emission savings are higher than the cost savings due to energy savings. Reasons for this are the relatively high energy-related investment costs for building refurbishment (244 EUR/m² compared to 100 EUR/m² in Aarhus), the low variable prices for heat from district heating and high investment costs of some RES facilities, e.g. WW-HR facilities. In future, the economic feasibility may be improved due to better operation settings gained with experience.

In **Aarhus**, the CO_2 emission saving costs are negative values (-163 EUR/ton regarding building refurbishment and -117 EUR/ton regarding on-site RE production), considering EC support they are even lower.

These negative values mean that the energy cost savings and earnings from RE production are higher than the sum of all relevant expenses and confirms economic feasibility. The 1 MW sea water-fed heat pump and further energy saving measures are not taken into consideration but would not lead to worse results.

These results from Aarhus are even so good that they can compensate the higher CO2 emission saving costs in Växjö, hence the area-weighted average costs of GHG emission saving in READY confirm the cost efficiency of the whole project. In READY, the overall CO2 emission saving costs regarding building refurbishment is -77 EUR/ton and -84 EUR/ton regarding the on-site RE production. The simple cost of reducing GHG emissions are listed in Table 31.

Table 31: Costs for CO_2 emission savings in READY

Code	Building refurbishment			RE production	
	excl. EC Support	incl. EC Support		excl. EC Support	incl. EC Support
	€/ton	€/ton		€/ton	€/ton
SE1	488	308		N/A	N/A
SE1.1	517	327		484	49
SE3	485	394		N/A	N/A
DK1	-163	-195		-169	-171
DK2	-168	-210		-30	-153
DK3	-100	-145		-189	-189
DK4	-100	-132		N/A	N/A
Sum SE	**490**	**325**		**484**	**49**
Sum DK	**-163**	**-199**		**-117**	**-166**
READY	**-77**	**-129**		**-84**	**-154**

Conclusion

The economic analysis could prove the cost effectiveness of READY, nevertheless the data shows that in future projects some optimisations could be done, learning from experiences made in READY.

Further investigations on the relatively high energy-related investment costs for building refurbishment in Växjö and further Research & Development (R&D) concerning the technologies Photovoltaic Thermal (PVT) systems and Waste Water Heat Recovery (WW-HR) systems in future are highly recommended.

Nevertheless, it should be mentioned that the investment in energy saving measures as performed in READY is not only beneficial to energy savings, but also have an impact on several further aspects, e.g. the tenants' health and comfort, the lifespan of building components, etc. Therefore, and because of the gathered knowledge about the applied technologies, the demonstration activities in READY are a success.

List of Figures

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References

D.3.1.1 Report describing the feasibility of heat recovery from waste water, PVT and heat storage in multi-family buildings and recommendations for demonstration including final design notes (UNI-DK)

D.5.1.1 Documentation of performed refurbishment - hand-out certificate (HOUSE-DK)

D.5.5.1 Documentation of use of 2nd life batteries and the integration with an energy system with a high amount of renewables(LB-DK)

D.5.5.2 Documentation of EV battery charging demonstration (EON-DK)

D.6.2 Report on energy performance of the project in close collaboration with WP7 (CA-SE)

D.6.4 Report on energy performance of the project in close collaboration with WP7 (VEAB-SE)

D.8.3 Market assessment for READY set of solutions (LGI)

D.8.5 Replicability assessment for READY solutions (LGI)

Appendix A – Monitoring data sheets

READY - Aarhus

56°09'N 10°13'E

General Data

Country	Denmark
Region	Central Denmark Region (Midtjylland)
City	Aarhus
Start of READY activities	1st December 2014
End of READY activities	December 2020

Demonstration	GFA (m^2)	RES			Comments	Occup. estimated
		PV [kWp]	Solar thermal [m^2]	HP [kW]		
BEST	**49.062**					
DK-1	28.302	157		2		800
DK-2	19.140	143	743	3*12 + 8		400
DK-3	1.446	24,8				28
DK-4	174					2
Seawater Heat Pump				1.000	First module of 1 MW out of 2 MW	-
Subtotal Residential	**47.616**					
Subtotal non-residential	**1.446**					
Total	**49.062**					

Ringgården afdeling 21 (BEST-DK-1)

General Data

Rydevænget 105-131, Aarhus

Refurbished Building	District 21 - Rydevænget
Year built	1970-1973
Year refurbished	1990
Address	Rydevænget 105-131
Building function	Social housing
Building type	Apartments
Number of Apartments	163
Number of Occupants	Approximately 400
Gross Floor Area (m²)	**14.151**
Gross Volume (m³)	39.623
Net Heated/Cooled Area (m²)	11.321
Net Heated/Cooled Volume (m³)	28.302
Basement Type	Parterre
Attic Type	Roof apart., piched w. PV
Total Investment cost [Euro]	9.86 mio. (VAT excl.)

Building Features

			Before	Normal practice	Project Target (BEST)	Design	Actual (2019/20)
External walls	Concrete sandwich + ext.	W/m²K	0,70	0,30	0,15	0,17	0,12-0,32
Roof	Wooden structure + sheet	W/m²K	0,50	0,20	0,10	0,12	0,09-0,12
Ground floor	-	W/m²K	0,75	0,20	0,30	0,30	0,60
Windows (frame & glass)	Aluminum/wood frame	W/m²K	n.a.	n.a.	n.a.	0,90	0,90
Average U-value of glazings	-	W/m²K	2,90	1,40	0,80	-	0,53-0,59
Average g-value of glazings	-	-	n.a.	none	0,50	-	n.a.
Ventilation Flow Rate	126 m³/h per apartment	h^{-1}	0,70	0,50	0,3-0,6	0,30	0,30
Thermal Bridges	150 mm extra insulation layer in the external columns						
Air tightness & n50 air change rate	-						
Ventilation system type	Decentral units with supply in livingrooms and exhaust in kitchen and bathroom						
Energy saving measures	Waste water heat pump, heat recovery, insulation, roof renovation/apartments						
Water saving measures	Taps						
Special building materials	Roof apartments						
Type of Shading	Partial external solar shading (balconies)						

Energy Systems

District Heating connection	yes
Photovoltaic - grid connected	yes
Solar thermal - flat plate	no
Heat pump demo for waste water	yes
Boiler	no

Other information

Key Energy figures

kWh/year/m² gross area	Existing building (reference)	Project Target (BEST)	Design	2019	2020	2021
Total Energy Demand	**194**	**74**	**53,5**	**76,4**	**64,2**	
Total heat	155	55	49,1	76,4	60,9	
Space heating	121	36	32,0	56,1	43,5	
Domestic hot water	34	19	17,1	20	17,3	
Pipe heat losses (DHW)	Included	Included	Included	Included	Included	
Total electricity (Building operation)	39	19	4,4	n.a.	3,3	
Ventilation	14	7	3	n.a.	1,9	
Lighting + Heating system	12	4	2	n.a.	1,4	
Laundry	13	8	-	3	2	
Household electricity	50	30	20	-	14,4	

(highlighted) Full year data not available

Ringgården afdeling 21 (BEST-DK-1)

Address	Rydevænget 105-131
Typology of Dwelling	Social housing / Multi-family buildings
Occupants number	Approx. 600
Occupants type	Residential
Ownership	Boliforening Ringaarden
Gross floor area (m²)	14151

Monitoring Period	Energy: Total	Total/m²	Total heating	Domestic hot water	Heat losses DHW	Heat losses DH	Space heating	Space heating (Normalized)	Space heating (Normalized)	Electricity: Building operation total	Vent.	Lighting+ Heating system	House-holds	PV-production	Laundry	Total	Water: Cold water	Cold water for laundry	Hot water
	kWh	kWh/m²	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh		m³	m³	m³
jan-19	**150.299**	11	187.000	23.000	6.361	17.886	146.114	**127.299**	**127.299**						2.000	24.476	771	23	318
feb-19	**141.624**	10	160.000	25.000	7.785	16.155	118.845	**116.624**	**116.624**						1.920	23.521	974	26	329
mar-19	**133.885**	9	148.000	25.000	7.105	17.886	105.114	**108.885**	**108.885**						2.081	23.810	628	27	342
apr-19	**88.514**	6	119.200	27.400	10.515	17.309	74.491	**61.114**	**61.114**						8.644	21.905	776,4	27,4	322,7
maj-19	**34.873**	2	97.800	26.600	5.340	17.886	53.314	**8.273**	**8.273**						10.885	27.585	977,6	34,6	406,3
jun-19	**20.000**	1	35.000	20.000	5.401	17.309	0	**0**	**0**						8.983	19.308	718	23	279
jul-19	**20.000**	1	37.000	20.000	6.239	17.886	0	**0**	**0**						2.505	23.842	736	29	263
aug-19	**13.000**	1	24.000	13.000	3.843	17.886	0	**0**	**0**						1.788	20.975	515	19	175
sep-19	**21.003**	1	57.000	17.000	5.227	17.309	22.691	**4.003**	**4.003**						2.076	25.114	648	22	225
okt-19	**66.439**	5	75.000	16.000	5.849	17.886	41.114	**50.439**	**50.439**						2.064	51.519	733	19	194
nov-19	**98.066**	7	92.000	14.000	5.733	17.309	60.691	**84.066**	**84.066**						1.649	61.431	828	16	158
dec-19	**130.956**	9	157.000	17.000	7.215	17.886	122.114	**113.956**	**113.956**						1.684	58.551	882	18	187
TOTAL	**918.660**	65	1.189.000	244.000	76.612	210.590	744.490	**674.660**	**674.660**	**0**	0	0	0		46.279	382.037	9.187	284	3.199
jan-20	**154.093**	11	151.000	17.000	7.268	17.886	116.114	**133.141**	**81.400**	3.953	2.227	1.726	17.224	230	1.638	63.353	566	15	186
feb-20	**155.008**	11	158.500	21.000	8.573	16.732	120.768	**130.310**	**74.574**	3.698	2.084	1.614	16.112	290	1.894	52.707	660	17	238
mar-20	**136.204**	10	154.500	21.000	5.590	17.886	115.614	**111.251**	**69.625**	3.953	2.227	1.726	17.224	1.670	2.348	65.356	819	21	295
apr-20	**58.154**	4	79.459	16.216	4.634	17.309	45.934	**38.112**	**39.079**	3.825	2.155	1.670	16.668	2.550	1.433	20.503	539	11	221
maj-20	**30.610**	2	89.398	21.498	4.699	17.886	50.014	**5.159**	**5.290**	3.953	2.227	1.726	17.224	170	2.053	24.843	786	19	321
jun-20	**24.706**	2	44.602	20.880	4.042	17.309	6.413	**0**	**0**	3.825	2.155	1.670	16.668	10	2.147	22.640	817	22	322
jul-20	**21.530**	2	20.483	17.577	958	17.886	0	**0**	**0**	3.953	2.227	1.726	17.224	18.740	2.333	12.355	756	24	318
aug-20	**25.537**	2	33.057	21.585	6.205	17.886	0	**0**	**0**	3.953	2.227	1.726	17.224	19.750	2.327	12.834	826	25	294
sep-20	**35.546**	3	71.900	27.844	11.956	17.309	26.747	**3.877**	**2.560**	3.825	2.155	1.670	16.668	12.860	2.739	17.558	870	28	304
okt-20	**53.408**	4	82.502	18.000	1.639	17.886	46.617	**31.455**	**32.253**	3.953	2.227	1.726	17.224	6.110	2.969	19.898	894	29	313
nov-20	**77.231**	5	105.243	20.981	3.522	17.309	66.953	**52.425**	**53.755**	3.825	2.155	1.670	16.668	2.970	3.594	25.094	970	34	334
dec-20	**135.820**	10	142.274	21.500	5.942	17.886	102.888	**110.367**	**72.868**	3.953	2.227	1.726	17.224	760	3.459	28.149	867	29	297
TOTAL	**907.847**	64	1.132.919	245.081	65.027	211.167	698.063	**616.098**	**431.403**	**46.667**	26.295	20.372	203.350	66.110	28.933	365.291	9.371	273	3.441
(Before)																			
2019	918.660	65	*84*	*17*	*5,4*	*15*	*53*	*48*	*48*	0	0	0	0	0	3	27			
2020	907.847	64	*80*	*17*	*4,6*	*15*	*49*	*44*	*30*	3	2	1	14	5	2	26			
mean 20	**907.847**	**64**	*80*	*17*	*4,6*	*15*	*49*	*44*	*30*	**3**	**2**	**1**	**14**	**5**	**2**	**26**			

XXXXXXX	Measured data
XXXXXXX	Calculated data
XXXXXXX	Measured data
XXXXXXX	Calculated data
	Construction works ongoing

Ringgården afdeling 21 (BEST-DK-1)

General Data

Rydevænget 105-131, Aarhus

New RES	Photovoltaic system
Year installed	2020
Installation type	PV
Address	Rydevænget
Installed capacity [kWp]	157,38 kWp
Quantity [pieces]	516 panels
Area [m²]	827
Slope [°]	25°
Orientation	South, east and west
Est. annual prod. [kWh]	136.306 kWh
Total Investment cost [€]	165,000 €

Period	Electricity	Climate			Performance	Electricity		
	Electricity produced	**Normal year global radiation**	**Actual tilted irradiation on PV (calc)**	**Actual tilted irradiation on PV (calc)**	***Efficiency***	**Sold**	**Bought**	**Used from PV**
	kWh	kWh/m²	kWh/m²	kWh	%	kWh	kWh	kWh
jan-20	**230**	*19*	**13**	**10,996**	***2***	0		230
feb-20	**290**	*36*	**29**	**23,919**	***1***	0		290
mar-20	**1,670**	*83*	**89**	**73,764**	***2***	0		1,670
apr-20	**2,550**	*122*	**142**	**117,835**	***2***	0	20,503	2,550
maj-20	**170**	*148*	**180**	**148,614**	***0***	0	24,843	170
jun-20	**10**	*170*	**182**	**150,695**	***0***	0	22,640	10
jul-20	**18,740**	*161*	**145**	**120,201**	***16***	6,095	12,355	12,645
aug-20	**19,750**	*122*	**143**	**118,100**	***17***	7,584	12,834	12,166
sep-20	**12,860**	*83*	**92**	**76,263**	***17***	5,418	17,558	7,442
okt-20	**6,110**	*44*	**39**	**32,461**	***19***	1,008	19,898	5,102
nov-20	**2,970**	*19*	**18**	**15,221**	***20***	0	25,094	2,970
dec-20	**760**	*14*	**6**	**4,755**	***16***	0	28,149	760
TOTAL	**66,110**	***1,020***	**1,080**	**892,825**	***7***	**20,106**	**183,875**	**46,004**

The PV system was not fully operational.

Ringgården afdeling 21 (BEST-DK-1)

General Data

Fjældevænget 110-136, Aarhus

Refurbished Building	District 21 - Fjældevænget
Year built	1970-1973
Year refurbished	1990
Address	Fjældevænget 110-136
Building function	Social housing
Building type	Apartments
Number of Apartments	164
Number of Occupants	Approximately 400
Gross Floor Area (m²)	**14,151**
Gross Volume (m³)	39,623
Net Heated/Cooled Area (m²)	11,321
Net Heated/Cooled Volume (m³)	28,302
Basement Type	Parterre
Attic Type	Roof apart., piched w. PV
Total Investment cost [Euro]	9.86 mio (VAT excl.)

Building Features

			Before	Normal practice	Project Target (BEST)	Design	Actual (2019/20)
External walls	Concrete structure	W/m²K	0.70	0.30	0.15	0.17	0,12-0,32
Roof	Wooden structure + sheet	W/m²K	0.50	0.20	0.10	0.10	0,09-0,12
Ground floor	-	W/m²K	0.75	0.20	0.30	0.30	0.60
Windows (frame & glass)	Aluminum/wood frame	W/m²K	n.a.	n.a.	n.a.	0.90	0.90
Average U-value of glazings	-	W/m²K	2.90	1.40	0.80	-	0,53-0,59
Average g-value of glazings	-	-	n.a.	none	0.50	-	n.a.
Ventilation Flow Rate	126 m³/h per apartment	h^{-1}	0.70	0.50	0,3-0,6	0.30	0,30
Thermal Bridges	150 mm extra insulation layer in the external columns						
Air tightness & n50 air change rate	-						
Ventilation system type	Decentral units with supply in livingrooms and exhaust in kitchen and bathroom						
Energy saving measures	Waste water heat pump, heat recovery, insulation, roof renovation/apartments						
Water saving measures	Taps						
Special building materials	Roof apartments						
Type of Shading	Partial external solar shading (balconies)						

Energy Systems

District Heating connection	yes
Photovoltaic - grid connected	yes
Solar thermal - flat plate	no
Heat pump demo for waste water	yes
Boiler	no

Other information

Key Energy figures

kWh/year/m² gross area	Existing building (referenc	Project Target (BEST)	Design	2019	2020	2021
Total Energy Demand	**194.0**	**74.0**	**53.5**	**47.8**	**65.2**	
Total heat	155.0	55.0	49.1	47.8	61.8	
Space heating	121.0	36.0	32.0	22.0	44.8	
Domestic hot water	34.0	19.0	17.1	25.9	17.0	
Pipe heat losses	Included	Included	Included	Included	Included	
Total electricity (Building operation)	39.0	19.0	4.4	'n.a.	3.4	
Ventilation	14.0	7.0	2.7	'n.a.	1.9	
Lighting + Heating system	12.0	4.0	1.7	n.a.	1.5	
Laundry	13.0	8.0	-	0.0	1.5	
Household electricity	50.0	30.0	20.3	-	14.4	

Full year data not available

Ringgården afdeling 21 (BEST-DK-1)

Address	Fjældevænget 110-136
Typology of Dwelling	Social housing / Multi-family buildings
Occupants number	Approx. 600
Occupants type	Residential
Ownership	Boliforening Ringaarden
Gross floor area (m²)	14151

Monito-ring Period	Energy Total	Energy Total/m²	Total heating	Domestic hot water	Heat losses DHW	Heat losses DH	Space heating	Space heating (Normalized)	Space heating (Normalized)	Electricity Building operation total	Vent.	Lighting+ Heating system	House-holds	PV-production	Laundry	Total	Construc-tion site	Water Cold water	Cold water for laundry	Hot water
	kWh	kWh/m²	kWh	kWh	kWh		kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	m³	m³	m³
jan-19	159,385	11	184,000	27,000	10,047	12,126	144,874	132,385	-							24,861		851	39	324
feb-19	159,040	11	157,000	27,000	20,669	10,953	119,047	132,040	-							23,677		826	40	121
mar-19	136,942	10	148,000	28,000	-412	12,126	107,874	108,942	-							23,902		859	39	543
apr-19	110,481	8	119,100	31,200	14,430	11,735	76,165	79,281	-							23,008		872.4	43.8	320.5
maj-19	38,766	3	95,900	28,800	7,687	12,126	54,974	9,966	-							28,974		1098.6	55.2	403.5
jun-19	23,000	2	44,000	23,000	7,826	11,735	9,265	0	-							22,024		833	44	290
jul-19	25,000	2	46,000	25,000	7,994	12,126	8,874	0	-							26,277		956	50	325
aug-19	18,000	1	33,000	18,000	6,227	12,126	2,874	0	-							18,050		677	35	225
sep-19	31,362	2	75,000	24,000	8,093	11,735	39,265	7,362	-							24,787		884	45	304
okt-19	115,207	8	132,000	27,000	9,680	12,126	92,874	88,207	-							25,695		910	46	331
nov-19	125,023	9	152,000	25,000	8,936	11,735	115,265	100,023	-							23,680		819	39	307
dec-19	163,912	12	177,000	27,000	10,256	12,126	137,874	136,912	-							23,920		864	42	320
TOTAL	**1,106,118**	78	**1,363,000**	**311,000**	**111,432**	**142,774**	**909,226**	**795,118**	**0**	**0**	**0**	**0**	**0**		**0**	**288,855**		10,450	518	3,814
jan-20	**167,875**	12	164,960	23,760	8,390	19,311	121,889	**139,762**	**94,613**	4,353	2,227	2,126	17,224	-	2,495	25,851	1,779	793	43	294
feb-20	**174,016**	12	177,886	29,457	14,563	18,066	130,363	**140,663**	**86,679**	3,896	2,084	1,812	16,112	-	2,470	35,598	11,526	826	44	285
mar-20	**134,525**	10	154,000	26,400	10,237	19,311	108,289	**104,202**	**80,927**	3,923	2,227	1,695	17,224	-	2,688	40,224	16,152	905	48	309
apr-20	**50,442**	4	70,541	20,270	5,421	18,689	31,582	**26,204**	**45,422**	3,968	2,155	1,812	16,668	-	1,528	22,449	0	703	28	284
maj-20	**36,111**	3	77,721	25,396	8,839	19,311	33,013	**6,733**	**6,149**	3,981	2,227	1,754	17,224	-	1,827	35,800	11,728	879	20	316
jun-20	**24,274**	2	40,387	20,306	9,509	18,689	1,392	**0**	**0**	3,968	2,155	1,812	16,668	-	1,413	26,817	2,746	774	37	206
jul-20	**22,065**	2	19,408	18,084	11,226	19,311	0	**0**	**0**	3,981	2,227	1,754	17,224	-	1,293	19,822	0	548	24	131
aug-20	**19,211**	1	19,333	15,553	11,253	19,311	0	**0**	**0**	3,658	2,227	1,431	17,224	-	1,162	22,044	0	576	19	82
sep-20	**18,550**	1	56,710	10,290	6,413	18,689	27,731	**4,292**	**2,975**	3,968	2,155	1,812	16,668	-	1,277	36,050	11,979	553	18	74
okt-20	**44,581**	3	62,634	14,866	10,660	19,311	28,457	**25,734**	**37,488**	3,981	2,227	1,754	17,224	-	1,468	45,894	21,822	596	20	80
nov-20	**85,244**	6	100,782	16,879	10,001	18,689	65,214	**64,397**	**62,480**	3,968	2,155	1,812	16,668	-	1,850	42,561	18,489	596	23	131
dec-20	**145,797**	10	135,700	19,625	7,530	19,311	96,764	**122,190**	**84,695**	3,981	2,227	1,754	17,224	-	2,138	42,600	18,528	675	28	231
TOTAL	**922,690**	65	**1,080,062**	**240,887**	**114,042**	**228,000**	**644,693**	**634,177**	**501,429**	**47,626**	**26,296**	**21,330**	**203,350**		**21,609**	**395,707**	**114,751**	8,424	353	2,424
(Before)																				
2019	1,106,118	78	*96.3*	*22.0*	*7.9*	*10.1*	*64.3*	*56.2*	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	20.4	0.0			
2020	922,690	65	*76.3*	*17.0*	*8.1*	*16.1*	*45.6*	*44.8*	*35.4*	3.4	1.9	1.5	14.4	0.0	1.5	28.0	8.1			
mean 20	**922,690**	**65**	*76.3*	*17.0*	*8.1*	*16.1*	*45.6*	*44.8*	*35.4*	**3.4**	**1.9**	**1.5**	**14.4**	**0.0**	**1.5**	**28.0**	**8.1**			

XXXXXXX	Measured data
XXXXXXX	Calculated data
XXXXXXX	Measured data
XXXXXXX	Calculated data
	Construction works ongoing

Ringgården Afdeling 20 (BEST-DK-2)

General Data

Trige Parkvej 1-39, Aarhus

Refurbished Building	District 20 - Trigeparken
Year built	1980 (1994)
Year refurbished	2019
Address	Trige Parkvej 1-39
Building function	Social housing
Building type	Apartments/Multi-family
Number of Apartments	153
Number of Occupants	Approx 400
Gross Floor Area (m²)	**19.140**
Gross Volume (m³)	53.592
Net Heated/Cooled Area (m²)	15.312
Net Heated/Cooled Volume (m³)	38.280
Basement Type	Partly parterre
Attic Type	Flat roof
Total Investment cost [Euro]	16.4 mio. (VAT excl.)

Building Features

			Before	Normal practice	Project Target (BEST)	Design	Actual (2019/20)
External walls	Wooden cassette	W/m²K	0,70	0,30	0,17	0,15	0,15
Roof	Concrete deck + wood	W/m²K	0,50	0,20	0,12	0,12	0,12
Ground floor	Concrete structure	W/m²K	0,75	0,20	0,30	0,30	0,30
Windows (frame & glass)	Aluminum/wood frame	W/m²K	n.a.	n.a.	n.a.	0,80	0,80
Average U-value of glazings	-	W/m²K	2,90	1,40	0,80	0,80	<0,80
Average g-value of glazings	-	-	n.a.	none	0,50	0,45	0,45
Ventilation Flow Rate	126 m³/h per apartment	h^{-1}	0,70	0,30	0,3-0,6	0,30	0,30
Thermal Bridges	Reduced						
Air tightness & n50 air change rate	-						
Ventilation system type	Decentral balanced systems with supply in livingrooms and exhaust in kitchen and bathroom						
Energy saving measures	Waste water heat pump, heat recovery, insulation, PVT hybrid heat pumps, battery, controls						
Water saving measures	Taps, reduced circulation loss						
Special building materials	Wooden cassette, PVT panels, BIPV						
Type of Shading	External solar shading, overhangs of balconies						

Energy Systems

District Heating connection	yes
Photovoltaic - grid connected	yes
Solar thermal - flat plate	yes, PVT
Heat pump(s)	yes
Boiler	no

Other information

Key Energy figures

kWh/year/m² gross area	Existing building (reference)	Project Target (BEST)	Design	2019	2020	2021
Total Energy Demand	**181**	**70**	**54,6**	**n.a.**	**50,6**	
Total heat	155	59	50,3	60,2	47,4	
Space heating	121	39	37,2	51,5	27,8	
Domestic hot water	34	20	13,1	8,8	9,3	
Pipe heat losses	Included	Included	Excluded	Excluded	10,3	
Total electricity (building operation)	26	11	4,3	n.a.	3,2	
Ventilation	14	7	2,7	n.a.	1,9	
Lighting+common ventilation	12	4	1,6	n.a.	0,9	
Other energy demand (heating system)	13	8	-	n.a.	0,4	
Laundry	13	8	-	n.a.	1,4	
Household electricity	50	30	30,7	n.a.	14	

Full year data not available

Ringgården Afdeling 20 (BEST-DK-2)

Address	Trige Parkvej 1-39
Typology of Dwelling	Social housing / Multi-family buildings
Occupants number	383
Occupants type	Residential
Ownership	Boliforening Ringaarden
Gross floor area (m²)	19140

Monito-ring Period	Energy: Total	Energy: Total/m²	Total heating	Domestic hot water	Heat losses	Space heating	Space heating (normalized)	Electricity: Building operation total	Heating system	Lighting + common ventilation	Ventilation apartments	PV production	Laundry (meter number)	House-holds	Total	Water: Cold water total	Cold water for laundry	Hot water
	kWh	kWh/m²	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh			kWh	kWh	kWh	m³	m³	m³
jan-19	202.402	11	257.957	14.343	28.362	215.252	188.059						8.120		40.879	1181	23,7	274,1
feb-19	181.447	9	189.543	9.159	28.362	152.022	172.289						#VALUE!		34.450	0	16,2	175,0
mar-19	174.912	9	119.500	14.056	28.362	77.081	160.855						#VALUE!		41.327	506	21,6	268,6
apr-19	103.151	5	90.200	12.867	28.362	48.971	90.284						#VALUE!		39.937	600	18	245,9
maj-19	30.323	2	101.400	18.101	28.362	54.936	12.222						#VALUE!		33.902	563	18	345,9
jun-19	13.156	1	52.700	13.156	39.544	0	0						#VALUE!		26.710	491	21,8	251,4
jul-19	16.222	1	40.900	16.222	24.678	0	0						#VALUE!		19.845	551	21,9	310,0
aug-19	15.035	1	35.900	15.035	20.865	0	0						#VALUE!		20.203	480	19,9	287,3
sep-19	24.300	1	83.400	16.044	28.362	38.994	8.256						#VALUE!		22.975	615	24,8	306,6
okt-19	119.928	6	148.200	17.092	28.362	102.745	102.836						#VALUE!		26.470	635	18,9	326,7
nov-19	130.032	7	174.500	9.990	28.362	136.147	120.041						#VALUE!		28.587	674	22,7	190,9
dec-19	142.240	7	169.400	11.969	28.362	129.069	130.272						1.857		33.035	787	26,1	228,7
TOTAL	1.153.148	60	1.463.600	168.034	340.349	955.217	985.114	0	0	0	0		#VALUE!	0	368.320	7.083	254	3.211
jan-20	120.131	6	103.511	15.539	16.646	86.647	99.352	5.240	688	1.508	3.044	0	2.413	21.208	28.861	831	26,1	126
feb-20	107.163	6	97.366	14.237	15.572	81.513	87.954	4.973	535	1.661	2.777	0	2.308	22.085	29.365	776	30	106
mar-20	113.726	6	113.362	15.924	16.646	96.427	92.788	5.014	484	1.489	3.041	0	2.505	25.729	33.248	998	32	127
apr-20	66.552	3	72.075	15.059	16.109	55.258	45.848	5.644	826	1.830	2.988	0	1.858	23.629	31.132	985	23	138,3
maj-20	28.832	2	56.268	15.395	16.646	38.782	7.909	5.527	756	1.672	3.099	4.760	2.311	22.615	30.453	902	27	49,5
jun-20	19.215	1	27.425	13.977	16.109	11.452	0	5.238	670	1.528	3.040	16.530	1.938	18.650	30.491	1136	31,4	46
jul-20	20.919	1	30.025	15.684	16.646	13.084	0	5.234	642	1.583	3.009	13.420	2.125	17.157	30.491	1029	31,8	80,2
aug-20	20.472	1	22.187	15.298	16.646	6.265	0	5.174	647	1.334	3.193	11.780	1.932	17.650	30.491	1034	26,5	61
sep-20	22.628	1	38.577	14.864	16.109	21.966	3.124	4.640	705	1.236	2.699	7.410	2.011	20.514	30.491	962	23,3	33,3
okt-20	61.689	3	64.768	13.781	16.646	47.647	43.087	4.821	770	1.218	2.832	3.480	2.223	24.461	30.491	949	29	15,1
nov-20	84.061	4	83.312	13.123	16.109	66.991	66.151	4.788	714	1.240	2.834	1.400	2.285	27.241	30.491	993	30	15
dec-20	105.867	6	106.114	14.325	16.646	89.145	86.511	5.031	747	1.274	3.010	390	2.539	31.660	30.491	972	34	28
TOTAL	771.256	40	814.990	177.206	196.525	615.176	532.725	61.324	8.186	17.572	35.566	59.170	26.449	272.598	366.498	11.567	344	825
(Before)																		
2019	1.153.148	60	76	9	18	50	51	3	0	1	2	3	1	14	19			
2020	771.256	40	43	9	10	32	28	3	0	1	2	3	1	14	19			
mean 20	1.153.148	40	42,6	9,3	10,3	32,1	27,8	3,2	0,4	0,9	1,9	3,1	1,4	14,2	19,1			

XXXXXXX	Measured data
XXXXXXX	Calculated data
XXXXXXX	Measured data
XXXXXXX	Calculated data

Ringgården Afdeling 20 (BEST-DK-2)

Trige Parkvej 1-39, Aarhus

General Data

New RES	Photovoltaic system
Year installed	2020
Installation type	Combined PV and solar collectors
Address	Trigeparken
Installed capacity [kWp]	143 kWp
Quantity [pieces]	128 panels (PVT)
Area [m²]	720
Slope [˚]	0°
Orientation	West
Est. annual prod. [kWh]	105.834 kWh
Total Investment cost [€]	524,747.00 €

Period	Electricity	Climate			Performance	Electricity		
	Electricity produced	**Normal year global radiation**	**Actual tilted irradiation on PV (calc)**	**Actual tilted irradiation on PV (calc)**	***Efficiency***	**Sold**	**Bought**	**Used from PV**
	kWh	kWh/m²	kWh/m²	kWh	%	kWh	kWh	kWh
jan-20	**0**	*19*	**13**	**9,573**	***0***	0	0	0
feb-20	**0**	*36*	**29**	**20,825**	***0***	0	0	0
mar-20	**0**	*83*	**89**	**64,220**	***0***	0	0	0
apr-20	**0**	*122*	**142**	**102,589**	***0***	0	0	0
maj-20	**4,760**	*148*	**180**	**129,385**	***4***	1,598	5,099	3,162
jun-20	**16,530**	*170*	**182**	**131,197**	***13***	10,178	1,855	6,352
jul-20	**13,420**	*161*	**145**	**104,649**	***13***	6,651	1,001	6,769
aug-20	**11,780**	*122*	**143**	**102,820**	***11***	5,070	1,284	6,710
sep-20	**7,410**	*83*	**92**	**66,396**	***11***	2,189	2,760	5,221
okt-20	**3,480**	*44*	**39**	**28,261**	***12***	78	5,647	3,402
nov-20	**1,400**	*19*	**18**	**13,252**	***11***	57	7,003	1,343
dec-20	**390**	*14*	**6**	**4,140**	***9***	0	8,621	390
TOTAL	**59,170**	***1,020***	**1,080**	**777,308**	***8***	**25,821**	**33,269**	**33,349**

Dybedalen 1A (BEST DK-3)

Dybedalen 1A, Aarhus

General Data

Refurbished Building	Dybedalen 1A
Year built	1989
Year refurbished	2019
Address	Dybedalen 1A
Building function	Administration
Building type	Office
Number of Apartments	0
Number of Occupants	28
Gross Floor Area (m²)	**1.446**
Gross Volume (m³)	4.049
Net Heated/Cooled Area (m²)	1.157
Net Heated/Cooled Volume (m³)	3.008
Basement Type	Heated full height
Attic Type	Piched roof
Total Investment cost [Euro]	1.6 million € (VAT excl.)

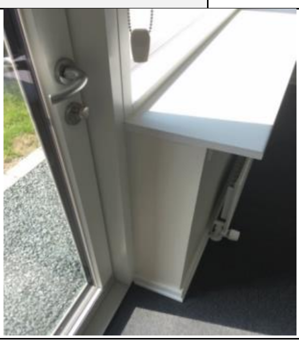
Building Features

			Before	Normal practice	Project Target (BEST)	Design	Actual (2019/20)
External walls	Bricks with insulated cavity	W/m²K	0,70	0,30	0,15	0,15	0,15
Roof	Wooden structure	W/m²K	0,50	0,20	0,10	0,10	0,10
Ground floor	Concrete structure	W/m²K	0,75	0,20	0,30	0,24	0,24
Windows (frame & glass)	Aluminum/wood frame	W/m²K	n.a.	n.a.	n.a.	n.a.	n.a.
Average U-value of glazings	-	W/m²K	2,90	1,40	0,80	0,80	0,80
Average g-value of glazings	-	-	n.a.	none	0,50	0,39	-
Ventilation Flow Rate	VAV with heat recovery	h^{-1}	0,70	0,30	0,3-0,6	0,30	0,3-0,6
Thermal Bridges	-						
Air tightness & n50 air change rate	-						
Ventilation system type	VAV with heat recovery						
Energy saving measures	Insulation, new windows						
Water saving measures	-						
Special building materials	-						
Type of Shading	Internal screens and fixed overhang						

Energy Systems

District Heating connection	yes
Photovoltaic - grid connected	yes
Solar thermal - flat plate	no
Heat pump	no
Boiler	no

Other information



Key Energy figures

kWh/year/m² gross area	Existing building (reference)	Project Target (BEST)	Design	2019	2020	2021
Total Energy Demand	**139**	**61**	**59**	**53**	**57,8**	
Total heat	96	46	45	43	43,1	
Space heating	81	36	35	43	38,6	
Domestic hot water	15	10	10,3	0,5	0,6	
Pipe heat losses	Included	Included	Included	Included	4,0	
Total electricity (ekskl. office equip.)	43	15	14	10	14,7	
Ventilation	14	7	6,1	5	6,2	
Lighting	16	8	7,6	-	2,8	
Cooling	13	9	n.a.	4	5,6	
Office equipment	45	30	-	-	31,5	

Full year data not available

Dybedalen 1A (BEST DK-3)

Address	Dybedalen 1A
Typology of Dwelling	Office
Occupants number	28
Occupants type	Administration
Ownership	Ringaarden Boligforening
Gross floor area (m²)	1446

Monito-ring Period	Energy Total	Energy Total/m²	Total heating	Domestic hot water	Heat losses	Space heating	Normalized space heating	Electricity Building operation total	Vent.	Lighting	Cooling	Total electricity	PV	Water Cold water	Hot water
	kWh	kWh/m²	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh			kWh	m³	m³
jan-19	10.867	8	16.891	0	0	16.891	10.867	0	-	-	-		-	7,7	0,0
feb-19	9.956	7	10.749	0	0	10.749	9.956	0	-	-	-		-	4,9	0,0
mar-19	9.337	6	5.773	42	0	5.731	9.295	0	-	-	-		-	7,5	0,8
apr-19	5.259	4	5.586	42	0	5.545	5.217	0	-	-	-		-	7,2	0,8
maj-19	748	1	5.773	42	0	5.731	706	0	-	-	-		-	7,5	0,8
jun-19	42	0	5.586	42	0	5.545	0	0	-	-	-		-	7,2	0,8
jul-19	42	0	5.773	42	0	5.731	0	0	-	-	-		-	7,5	0,8
aug-19	42	0	5.586	42	0	5.545	0	0	-	-	-		-	7,2	0,8
sep-19	1.486	1	4.820	105	472	4.244	579	331	0	331	0		820	13,2	2,0
okt-19	7.095	5	8.090	105	488	7.498	6.161	342	0	342	0		1.270	13,4	2,0
nov-19	8.578	6	8.893	105	472	8.317	6.666	1.336	488	331	517		353	12,8	2,0
dec-19	14.522	10	13.776	105	488	13.184	12.211	1.718	826	342	551		290	11,7	2,0
TOTAL	67.973	47	97.296	670	1.919	94.707	61.658	3.726	1.314	1.344	1.068		2.732	108	13
jan-20	11.920	8	10.005	105	488	9.413	10.045	1.284	510	342	432	5.354	367	14,1	2,0
feb-20	11.407	8	10.150	105	440	9.605	9.671	1.191	449	309	434	5.009	685	12,7	2,0
mar-20	9.481	7	9.058	52	488	8.518	7.638	1.303	511	342	450	6.338	2.590	6,4	1,0
apr-20	6.216	4	6.203	52	472	5.679	4.250	1.442	601	331	510	2.874	3.910	10,2	1,0
maj-20	2.635	2	4.140	105	488	3.548	601	1.442	628	342	472	3.890	4.540	11,2	2,0
jun-20	2.426	2	1.541	52	472	1.017	0	1.902	698	331	873	4.171	4.290	19,1	1,0
jul-20	2.796	2	3.645	52	488	3.105	0	2.257	1.013	342	902	5.122	3.660	6,4	1,0
aug-20	3.219	2	2.177	105	488	1.585	0	2.627	1.043	342	1.242	5.300	3.710	8,8	2,0
sep-20	2.827	2	3.351	52	472	2.827	446	1.857	847	331	679	5.524	2.430	10	1,0
okt-20	7.968	6	7.514	52	488	6.974	5.492	1.936	885	342	709	7.105	1.190	5,7	1,0
nov-20	10.125	7	9.201	52	472	8.677	7.832	1.770	803	331	636	6.959	556	6	1,0
dec-20	12.532	9	13.903	52	488	13.363	9.810	2.182	1.043	342	797	9.138	130	3,2	1,0
TOTAL	83.552	58	80.888	837	5.741	74.310	55.785	21.190	9.032	4.022	8.135	66.784	28.057	114	16
(Before)			kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²								
2019	67.973	47,0	67,3	0,5	1,3	65,5	42,6	2,6							
2020	83.552	57,8	55,9	0,6	4,0	51,4	38,6	14,7							
mean 20	83.552	57,8	55,9	0,6	4,0	51,4	38,6	14,7							

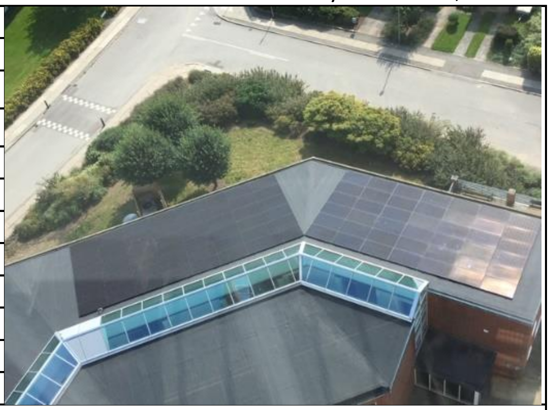
XXXXXXX	Measured data
XXXXXXX	Calculated data
XXXXXXX	Measured data
XXXXXXX	Calculated data

Dybedalen 1A (BEST DK-3)

General Data

Dybedalen 1A, Aarhus

New RES	Photovoltaic system
Year installed	2019
Installation type	PV
Address	Dybedalen A1
Installed panel capacity [kWp]	24.8
Quantity [pieces]	75 panels
Area [m²]	128.5
Slope [˚]	6°
Orientation	48 panels SE and 42 panels S
Est. annual prod. [kWh]	23,760 kWh
Total Investment cost [€]	46,570 €



Period	Electricity	Climate			*Performance*	Electricity		
	Electricity produced	**Normal year global radiation**	**Actual tilted irradiation on PV**	**Actual tilted irradiation on PV (calc)**	***Efficiency***	**Sold**	**Bought**	**Used from PV**
	kWh	kWh/m²	kWh/m²	kWh	*%*	kWh	kWh	kWh
jan-19								
feb-19								
mar-19								
apr-19								
maj-19								
jun-19								
jul-19								
aug-19								
sep-19	**820**	*83*	**83**	**10,729**	***8***			
okt-19	**1,270**	*44*	**46**	**5,943**	***21***			
nov-19	**353**	*19*	**10**	**1,343**	***26***	0		353
dec-19	**290**	*14*	**8**	**994**	***29***	0		290
TOTAL	**2,732**	***160***	**148**	**19,010**	***14***	**0**	**0**	**643**
jan-20	**367**	*19*	**13**	**1,709**	***21***	0		367
feb-20	**685**	*36*	**29**	**3,717**	***18***	0		685
mar-20	**2,590**	*83*	**89**	**11,462**	***23***	0	4,678	2,590
apr-20	**3,910**	*122*	**142**	**18,309**	***21***	721	4,311	3,189
maj-20	**4,540**	*148*	**180**	**23,092**	***20***	930	3,890	3,610
jun-20	**4,290**	*170*	**182**	**23,415**	***18***	961	4,171	3,329
jul-20	**3,660**	*161*	**145**	**18,677**	***20***	1,282	5,122	2,378
aug-20	**3,710**	*122*	**143**	**18,351**	***20***	1,510	5,300	2,200
sep-20	**2,430**	*83*	**92**	**11,850**	***21***	454	5,524	1,976
okt-20	**1,190**	*44*	**39**	**5,044**	***24***	795	7,105	395
nov-20	**556**	*19*	**18**	**2,365**	***23***	0	6,959	556
dec-20	**130**	*14*	**6**	**739**	***18***	**0**	**9,138**	**130**
TOTAL	**28,057**	***1,020***	**1,080**	**138,728**	***20***	**6,653**	**56,198**	**21,037**

DK4

Hasle/Skelby, Aarhus

General Data

Refurbished Building	
Year built	1968, extension in 2013
Year refurbished	Jun-Nov 2016
Address	Hasle/Skelby
Building function	Residence
Building type	Single family house
Number of Apartments	-
Number of Occupants	2 adults
Gross Floor Area (m²)	**174**
Gross Volume (m³)	-
Net Heated/Cooled Area (m²)	**149**
Net Heated/Cooled Volume (m³)	-
Basement Type	Dirt basement crawling space /in Danish: krybekælder)
Attic Type	Low - only suited for limited storage
Total Investment cost [Euro]	Approx. 18.000 €

Building Features

			Normal practice/Before	**"Project" Target**	**Design (calc)**	**Actual ("year")**
External walls	Light structure + insulation	W/m²K	0.70	0.30	0.10	0.10
Roof	Additional attic insulation	W/m²K	0.40	0.12	0.10	0.10
Ground floor	Wooden structure	W/m²K	0.75	-	-	-
Windows (frame & glass)	Aluminum/wood frame	W/m²K	2.90	0.80	0.70	0.90
Average U-value of glazings	-	W/m²K	-		0.80	0.70
Average g-value of glazings	-	-	-		0.50	-
Ventilation Flow Rate average	-	h^{-1}	0.3-0.6		0.30	0.30
Thermal Bridges	-					
Air tightness & n50 air change rate	-					
Ventilation system type	Natural ventilation					
Energy saving measures	Energy refurbishment and replacement of white goods					
Water saving measures	Taps					
Special building materials	-					
Type of Shading	Curtains					

Energy Systems

District Heating connection	yes
Photovoltaic - grid connected	no
Solar thermal - flat plate	no
Heat pump	no
Boiler	no

Other information

Key Energy figures

kWh/year/m² gross area	Existing building	BEST-table	Design	2017	2018	2019*
Total Energy Demand	**194.0**	**94.0**	**59.8**	**58.5**	**52.8**	**55.1**
Total heat	155.0	79.0	56.5	55.8	50.0	51.9
Space heating	121.0	60.0	38.0	40.7	35.2	35.7
Domestic hot water	34.0	19.0	18.5	15.1	14.8	16.2
Pipe heat losses	Included	Included	Included	Included	Included	Included
Total electricity	39.0	15.0	3.3	2.8	2.8	3.2
Ventilation**	10.0	7.0	0.3	0.2	0.2	0.2
Lighting**	12.0	3.0	3.0	2.6	2.6	3.0
Other electricity**	17.0	5.0	0.0	0.0	0.0	0.0
Household electricity**	50.0	30.0	14.5	18.6	18.7	21.6

** = Not a full year.*

**The total electricity is shared as:
1% Ventilation
12% Lighting
87% Appliances
Source:
https://sparenergi.dk/forbruger/el/dit-elforbrug

Dwelling no. 1

Address	Hasle/Skelby
Typology of Dwelling	DK4
Occupants number	2
Occupants type	Family
Ownership	Private
Gross floor area (m²)	174

Monito-ring Period	Energy						Electricity				Water	
	Total	Total/m²	Total heating	Hot water	Space heating	Space heating corrected (DTI)	**Total**	Vent.	Lighting	Tenants	Cold water	Hot water
	kWh	kWh/m²	kWh	kWh	kWh	kWh	**kWh**	kWh	kWh	kWh	m³	m³
jan-17	**1,988**	11	1,950	225	1,725	**1,434**	330	3	40	287	-	-
feb-17	**1,797**	10	*1,698*	225	1,473	**1,311**	261	3	31	227	-	-
mar-17	**1,672**	10	*1,495*	225	1,270	**1,162**	285	3	34	248	-	-
apr-17	**1,032**	6	*1,002*	225	777	**480**	327	3	39	284	-	-
maj-17	**598**	3	*472*	225	247	**45**	328	3	39	285	-	-
jun-17	**448**	3	*208*	208	0	**0**	240	2	29	209	-	-
jul-17	**492**	3	*207*	207	0	**0**	285	3	34	248	-	-
aug-17	**478**	3	*187*	187	0	**0**	291	3	35	253	-	-
sep-17	**538**	3	*411*	225	186	**0**	313	3	38	272	-	-
okt-17	**1,009**	6	*759*	225	534	**439**	345	3	41	300	-	-
nov-17	**1,407**	8	*1,336*	225	1,111	**841**	341	3	41	297	-	-
dec-17	**1,957**	11	*1,780*	225	1,555	**1,363**	369	4	44	321	-	-
TOTAL	**13,416**	77	11,505	2,627	8,878	**7,074**	**3,715**	37	446	3,232	0	0
jan-18	**1,950**	11	1,859	225	1,634	**1,358**	367	4	44	319	-	-
feb-18	**2,081**	12	*1,958*	225	1,733	**1,542**	314	3	38	273	-	-
mar-18	**1,735**	10	*1,960*	225	1,735	**1,184**	326	3	39	284	-	-
apr-18	**1,116**	6	*847*	225	622	**596**	295	3	35	257	-	-
maj-18	**490**	3	*249*	225	24	**0**	265	3	32	231	-	-
jun-18	**530**	3	*247*	247	0	**0**	283	3	34	246	-	-
jul-18	**445**	3	*194*	194	0	**0**	251	3	30	218	-	-
aug-18	**411**	2	*142*	142	0	**0**	269	3	32	234	-	-
sep-18	**473**	3	*184*	184	0	**0**	289	3	35	251	-	-
okt-18	**743**	4	*622*	225	397	**292**	226	2	27	197	-	-
nov-18	**1,375**	8	*1,242*	225	1,017	**797**	353	4	42	307	-	-
dec-18	**1,087**	6	*1,462*	225	1,237	**357**	505	5	61	439	-	-
TOTAL	**12,436**	71	10,966	2,567	8,399	**6,126**	**3,743**	37	449	3,256	0	0
jan-19	**1,960**	11	1,778	225	1,553	**1,340**	395	4	47	344	-	-
feb-19	**1,606**	9	*1,221*	225	996	**1,031**	350	4	42	305	-	-
mar-19	**1,546**	9	*1,190*	225	965	**905**	416	4	50	362	-	-
apr-19	**1,091**	6	*812*	225	587	**538**	328	3	39	285	-	-
maj-19	**572**	3	*467*	225	242	**37**	310	3	37	270	-	-
jun-19	**665**	4	*305*	305	0	**0**	360	4	43	313	-	-
jul-19	**617**	4	*257*	257	0	**0**	360	4	43	313	-	-
aug-19	**585**	3	*282*	225	57	**0**	360	4	43	313	-	-
sep-19	**605**	3	*372*	225	147	**20**	360	4	43	313	-	-
okt-19	**1,099**	6	*851*	225	626	**514**	360	4	43	313	-	-
nov-19	**1,363**	8		225	**971**	**778**	360	4	43	313	-	-
dec-19	**1,640**	9		225	**1,139**	**1,055**	360	4	43	313	-	-
jan-20	**13,348**	77	7,535	2,812	7,283	**6,219**	**4,318**	43	518	3,756	0	0
(Before)			kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²					
2017	13,416	77	66.1	15.1	51.0	40.7	21.4					
2018	12,436	71	63.0	14.8	48.3	35.2	21.5					
2019	13,348	77	43.3	16.2	41.9	35.7	24.8					
mean 19	**13,348**	**77**	**43**	**16**	**42**	**36**	**25**		77			

Sea water heat Pump 1 MW

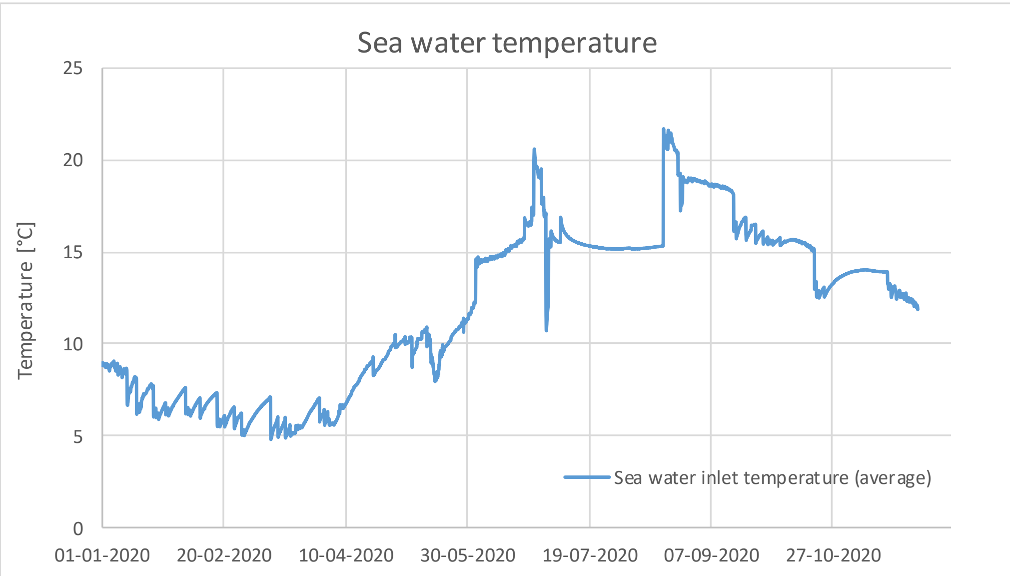
General Data

Hjortholmsvej 2A, Aarhus

New RES	Heat pump
Year installed	2019
Installation type	Seawater heat pump
Address	Hjortholmsvej 2A
Installed capacity [kW_t]	1000
Quantity [pieces]	1
Total Investment cost [€]	Confidential

Monitoring Period	Heat produced kWh	Cooling produced kWh	Electricity consumed kWh	COP, heating [-]	COP, cooling [-]	COP, combi. [-]
jan-20	16.140	8445	7.695	*2,10*	*1,10*	*3,19*
feb-20	24.610	13276	11.334	*2,17*	*1,17*	*3,34*
mar-20	10.450	6122	4.328	*2,41*	*1,41*	*3,83*
apr-20	61.900	44904	16.996	*3,64*	*2,64*	*6,28*
maj-20	32.770	-	2.069	*15,84*	*0,00*	*15,84*
jun-20	23.330	-	4.694	*4,97*	*0,00*	*4,97*
jul-20	240.370	-	5.671	*42,39*	*0,00*	*42,39*
aug-20	22240	13015	9225	*2,41*	*1,41*	*3,82*
sep-20	27180	17905	9275	*2,93*	*1,93*	*4,86*
okt-20	2.040	-	6.916	*0,29*	*0,00*	*0,29*
nov-20	Out of operation	-	5.246	*n.a.*	*0,00*	*n.a.*
dec-20	Repair					
TOTAL	**461.030**		**83.450**	*5,52*	*0,00*	*5,52*

The heat pump was not fully operational.
Tests and reparations were ongoing for all the period.
Measurment error



Alabastern, Växjö (BEST-category SE1)

General Data

Nydalavägen and Hjalmar Petris väg

Refurbished Building	
Year built	1964-1966
Year refurbished	2016-2018
Address	Nydalavägen and Hjalmar Petris väg
Building function	Apartments
Building type	Renting buildings
Number of Apartments	301
Gross Floor Area (m²)	31,576
Total Investment cost [Euro]	37,891,200

Building Features

			Normal practice/Before	**Project target**	**Design (calc)**	**Actual ("year")**
External walls	Additional insulation	W/m²K	0.36	0.36	0.36	0.33
Roof	Additional attic insulation	W/m²K	0.24	0.07	0.07	0.11
Ground floor	Partly renovated	W/m²K	0.41	0.41	0.41	0.38
Windows (frame & glass)	-	W/m²K	2.50	0.90	0.90	0.90
Average U-value of glazings	Aluminum/wood frame	W/m²K	0.71	0.48	0.48	-
Average g-value of glazings	-	-	0.76	0.46	0.46	-
Ventilation Flow Rate average	Mechanical ventilation	h^{-1}	0.61	0.61	0.61	0.77

Thermal Bridges	-
Air tightness & n50 air change rate	q50 = 0.31-0.51 l/s
Ventilation system type	Central aggregate for each block located in technical room on the roof
Energy saving measures	Insulation, roof renovation/apartments, new ventilation system, new windows, LTDH, automation
Water saving measures	Pipe insulations, new meters, new taps
Special building materials	-
Type of Shading	Curtains, building's overhangs

Energy Systems

District Heating connection	yes
Photovoltaic - grid connected	no

Other information

Key Energy figures	Existing building kWh/m² yr	Suggested specification	Result Total energy delivered (kWh/m²) Average 2018-2019
District Heating kWh/m² yr (space heating incl losses)	149	46	45
Domestic hot water kWh/m² yr	0	21	26
Building electricity kWh/m² yr	11	8	8
TOTAL	**160**	**75**	**79**

*DHW incl

(BEST-category SE1)

Address	Nydalavägen 2
Typology of Dwelling	Multifamily buildings
Occupants number	
Occupants type	
Ownership	
Gross floor area (m²)	2031

Monito-ring Period	Energy Total	Energy Total/m²		Tot delivered heat. incl.losses(corr.)	Tot delivered heat. incl.losses(corr.)	Diff value Space heating (corr)	Measured Values Heat: Total delivered heat	DHW	DHW	DHW circulation losses	Space heating	Space heating (correct.)	Measured Values Electricity: Total building elec	Total building elec	Measured Values Water: Cold water	Hot water
	kWh	kWh/m²		kWh/m²	kWh	kWh	kWh	kWh	kWh/m²	kWh	kWh	kWh	kWh	kWh/m²	m³	m³
jan-18	23,768	12	14%	11	22,550	28	22,522	3,468	2	663	16,010	16,038	1,218	1	146.97	59.8
feb-18	21,816	11	13%	10	20,724	-2,763	23,487	3,459	2	622	17,180	14,417	1,092	1	143.93	59.64
mar-18	21,139	10	13%	10	19,979	-3,647	23,626	4,142	2	682	16,050	12,403	1,160	1	171.27	71.42
apr-18	14,674	7	9%	7	13,632	-194	13,826	3,959	2	647	6,720	6,526	1,042	1	171.88	68.26
maj-18	9,064	4	5%	4	8,030	543	7,487	3,689	2	630	1,130	1,673	1,034	1	179.14	63.61
jun-18	7,102	3	4%	3	6,087	637	5,450	3,057	2	588	440	1,077	1,015	0	154.49	52.71
jul-18	5,960	3	3%	2	4,910	507	4,403	2,401	1	565	40	547	1,050	1	155.29	41.39
aug-18	6,887	3	4%	3	5,773	261	5,512	2,863	1	581	610	871	1,114	1	121.19	49.37
sep-18	8,819	4	5%	4	7,568	-336	7,904	3,228	2	588	2,550	2,214	1,251	1	139.13	55.65
okt-18	13,051	6	7%	6	11,916	-685	12,601	3,263	2	635	6,950	6,265	1,135	1	140.65	56.26
nov-18	17,868	9	11%	8	16,740	-513	17,253	3,448	2	629	11,120	10,607	1,128	1	148.6	59.44
dec-18	22,308	11	13%	10	21,076	26	21,050	3,035	1	655	14,190	14,216	1,232	1	130.8	52.32
TOTAL	**172,456**	**85**	**36%**	**78**	**158,985**	**-6,136**	**165,121**	**40,012**	**20**	**3,779**	**92,990**	**86,854**	**13,471**	**7**	**1,803**	**690**
jan-19	23,505	12	14%	11	22,356	-1,511	23,867	6,257	3	670	16940	15,429	1,149	1	159.16	54.28
feb-19	21,028	10	13%	10	20,047	1,454	18,593	5,270	3	583	12740	14,194	981	0	159.16	50.38
mar-19	20,303	10	12%	9	19,260	229	19,031	5,865	3	646	12520	12,749	1,043	1	159.16	57.81
apr-19	13,405	7	8%	6	12,426	-134	12,560	5,381	3	609	6570	6,436	979	0	159.16	54.04
maj-19	9,914	5	6%	4	8,882	-1,464	10,346	5,430	3	616	4300	2,836	1,032	1	162.85	57.28
jun-19	6,605	3	4%	3	5,615	365	5,250	4,565	2	565	120	485	990	0	163.39	51.96
jul-19	5,767	3	3%	2	4,738	-71	4,809	3,879	2	570	360	289	1,029	1	150.19	43.56
aug-19	5,993	3	3%	2	4,945	97	4,848	4,065	2	573	210	307	1,048	1	150.94	46.79
sep-19	8,625	4	5%	4	7,594	-663	8,257	4,708	2	559	2990	2,327	1,031	1	157.29	53.84
okt-19	13,468	7	8%	6	12,374	-928	13,302	5,633	3	599	7070	6,142	1,094	1	169.79	61.76
nov-19	17,316	9	10%	8	16,229	-421	16,650	5,469	3	601	10,580	10,159	1,087	1	157.95	59.17
dec-19	21,542	11	13%	10	20,360	969	19,391	5,706	3	635	13,050	14,019	1,182	1	159.84	59.07
TOTAL	**167,472**	**82**	**37%**	**76**	**154,827**	**-2,077**	**156,904**	**62,228**	**31**	**7,226**	**87,450**	**85,373**	**12,645**	**6**	**1,909**	**650**
READY BEST (kWh/m2)		**160**		**149**			**21**	**21**			**21**			**11**		
2018	172,456	85		78			81	20			46			7		
2019	167,472	82		76			77	31			43			6		
Average 2019		***82***		***76***			***77***	***31***			***43***			***6***		

xxxx Measured values

xxxx Calculated values

Alabastern area — NYD22, Växjö — (BEST-category SE1.1)

General Data

Refurbished Building	
Year built	1964-1966
Year refurbished	2018
Address	Nydalavägen 22
Building function	apartments
Building type	renting buildings
Number of Apartments	36
Gross Floor Area (m²)	3,361
Total Investment cost [Euro]	4,361,516
Heat recovery system [Euro]	158,000
PVT hybrid-system [Euro]	170,316

Building Features

Building Features			Normal practice/Before	Project target	Design (calc)	Actual ("year")
External walls	Additional insulation	W/m²K	0.36	0.36	0.36	0.33
Roof	Additional attic insulation	W/m²K	0.24	0.073	0.07	0.11
Ground floor	Partly renovated	W/m²K	0.41	0.413	0.41	0.38
Windows (frame & glass)	-	W/m²K	2.50	0.9	0.90	0.90
Average U-value of glazings	Aluminum/wood frame	W/m²K	0.71	0.475	0.48	-
Average g-value of glazings	-	-	0.76	0.46	0.46	-
Ventilation Flow Rate average	Mechanical ventilation	h^{-1}	0.61	0.609	0.61	0.77
Thermal Bridges	-					
Air tightness & n50 air change rate	q50 = 0.4 l/s					
Ventilation system type	Central aggregate located in technical room on the roof					
Energy saving measures	Insulation, roof renovation/apartments, new ventilation system, new windows, LTDH, automation					
Water saving measures	Pipe insulations, new meters, new taps					
Special building materials	Waste water heat recovery with heat pump, PVT with heat pump and BTES					
Type of Shading						

Energy Systems

Energy Systems	
District Heating connection	yes
Photovoltaic - grid connected	yes

Other information

Key Energy figures

Key Energy figures (BEST-Table SE1.1)	Existing building kWh/m² yr	Suggested specification	Result 2020 (kWh/m²)	
District Heating kWh/m² yr	149*	45	37	*DHW incl
Domestic hot water kWh/m² yr	see above	21	19.1	
Electricity kWh/m² yr	11	8	15	incl. elect. to heat pumps
Heat from PVT kWh/m²		-22	-7	only seven months
Electricity from PVT kWh/m²		-9	-2	only seven months
Heat recovery from waste water kWh/m²		-8	-21	
TOTAL- supplied district heating and building electricity	**160**	**35**	**22**	

(BEST-category SE1.1)

Address	Nydalavägen 22
Typology of Dwelling	Multifamily building
Occupants number	
Occupants type	
Ownership	
Gross floor area (m²)	3361

Monito-ring Period	Energy Total	Energy Total/m²	Measured Values Heat: Tot delivered heat. incl.losses(corr.)	Tot delivered heat. incl.losses(corr.)	Diff value Space heating (corr)	Total delivered DH-heat	DHW-consumption		DHW circulation losses	Space heating	Space heating (correct.)	Measured Values Electricity: Total building elec	Total building elec	Measured Values Water: Cold water	Hot water
	kWh	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh	kWh/m²	kWh	kWh	kWh	kWh	kWh/m²	m³	m³
jan-19	29,044	8.6	8.6	29,044	-2,374	31,418	4,347	1.3	577	26,610	24,236	0	0	164.23	74.94
feb-19	25,210	7.5	7.5	25,210	2,055	23,155	4,692	1.4	542	18,000	20,055	0	0	175.64	80.9
mar-19	24,353	7.2	7.2	24,353	319	24,034	6,375	1.9	605	17,390	17,709	0	0	221.87	109.91
apr-19	14,839	4.4	4.4	14,839	-180	15,019	6,042	1.8	585	8,810	8,630	0	0	215.47	104.18
maj-19	9,499	2.8	2.8	9,499	-1,780	11,279	6,038	1.8	614	5,230	3,450	0	0	230.24	104.11
jun-19	5,626	1.7	1.7	5,626	426	5,200	5,087	1.5	566	140	566	0	0	208.95	87.71
jul-19	5,074	1.5	1.5	5,074	-69	5,143	4,851	1.4	583	350	281	0	0	198.58	83.63
aug-19	30,968	9.2	1.6	5,348	153	5,195	5,003	1.5	588	330	483	25,620	7.6	200.44	86.26
sep-19	10,279	3.1	2.2	7,291	-674	7,965	5,072	1.5	593	3,040	2,366	2,988	0.9	193.74	87.45
okt-19	16,960	5.0	4.3	14,312	-1,386	15,698	5,104	1.5	611	10,560	9,174	2,648	0.8	190.08	88
nov-19	23,301	6.9	6.1	20,472	-644	21,116	4,781	1.4	601	16,180	15,536	2,829	0.8	176.62	82.43
dec-19	29,051	8.6	7.8	26,077	1,438	24,639	5,047	1.5	633	19,380	20,818	2,974	0.9	184.9	87.01
TOTAL	224,204	66.7	55.7	187,145	-2,716	189,861	62,439	19	7,098	126,020	123,304	37,059	11	2,361	1,077
jan-20	30,347	9.0	8.2	27,427	3,774	23,653	5,261	1.6	635	18190	21,964	2,920	0.9	189.92	90.71
feb-20	23,833	7.1	6.1	20,367	1,514	18,853	4,869	1.4	526	17480	18,994	3,466	1.0	180.52	83.95
mar-20	22,202	6.6	5.3	17,863	-371	18,234	6,486	1.9	574	18920	18,549	4,339	1.3	231.15	111.83
apr-20	11,485	3.4	2.1	6,947	-761	7,708	6,168	1.8	493	9580	8,819	4,538	1.4	221.38	106.35
maj-20	6,605	2.0	0.5	1,612	-2,483	4,095	5,693	1.7	480	6650	4,167	4,993	1.5	222.34	98.15
jun-20	3,453	1.0	0.2	762	528	234	5,013	1.5	362	454	982	2,691	0.8	214.35	86.4
jul-20	6,701	2.0	0.1	228	-388	616	5,336	1.6	389	767	379	6,473	1.9	217.5	92
aug-20	7,583	2.3	1.4	4,868	106	4,762	5,394	1.6	533	267	373	2,715	0.8	218.7	93
sep-20	6,259	1.9	0.4	1,263	-339	1,602	4,988	1.5	408	2671	2,332	4,996	1.5	214.5	86
okt-20	11,914	3.5	2	7,355	-413	7,768	5,110	1.5	470	10283	9,870	4,559	1.4	226	88
nov-20	18,888	5.6	4	14,186	1,738	12,448	4,980	1.5	494	15,023	16,761	4,702	1.4	220.8	86
dec-20	26,775	8.0	6	21,829	1,974	19,855	5,047	1.5	521	21,628	23,602	4,946	1.5	185	87
TOTAL	176,044	52	37	124,706	4,878	119,828	64,345	19		121,913	126,791	51,338	15		
READY BEST (kWh/m2)		160	149				21						11		
2019	224,204	67	56				19						11		
2020	176,044	52	37				19						15		

xxxx	Measured values
xxxx	Calculated values
xxxx	Waste water heat recovery in operation since 12 february

Alabastern area, Växjö - NYD22 (specialhouse)

General Data

Nydalavägen 22, Växjö

New RES	Heat Recovery from wastewater + Heat pump
Year installed	2020
Installation type	EcoClime
Address	Nydalavägen 22
Installed capacity [kWp]	15 kW(heatpump)
Quantity [pieces]	n.a.
Area [m²]	n.a.
Slope [˚]	n.a.
Orientation	n.a.
Est. annual prod. [kWh]	65 MWh
Annual CO_2-savings [tons]	
Total Investment cost [€]	

Monitoring Period	Measured: Electricity to heat pump (kWh)	Measured: Heat produced by heat pump (kWh)	Measured: Electricity to pumps (kWh)	Measured: Delivered heat to heating system (kWh)	Measured: Delivered heat to DHW (kWh)	Measured: COP, overall calc.	Measured: Inlet average/ Outlet lowest waste water (°C)	Calculated values: Net heat recovery from waste water (*kWh*)	Calculated values: Net heat recovery of what is possible (*%*)	Calculated values: Net heat recovery to DHW (*% of DHW*)
jan-20										
feb-20	799	3884	69	1,700	2,700	4.5	22,2/7,9	3085	*90*	*54*
mar-20	1539	7342	102	3,833	3,100	4.5	23,1/6,3	5803	*92*	*46*
apr-20	1908	8327	103	4,400	4,000	4.1	24,5/6,2	6419	*89*	*62*
maj-20	2248	8594	101	3,900	4,300	3.7	24,9/6,2	6346	*88*	*80*
jun-20	1866	5611	64	500	4,933	2.9	25,0/6,2	3745	*99*	100
jul-20	1707	5471	64	600	4,900	3.1	24,9/6,1	3764	*103*	95
2020-08-01**	155	341	22	0	600	1.9	24,4/9,4	186	*80*	12
sep-20	1900	6605	75	2,000	4,500	3.3	25,4/6,7	4705	*95*	87
okt-20	1849	8386	97	5,033	3,900	4.3	25,3/6,2	6537	93	64
nov-20	1706	8435	105	5,728	2,675	4.7	25,2/6,1	6729	87.5	44.4
dec-20	1423	6983	99	4,644	2,273	4.6	23,9/6,1	*5560*	*86*	*45*
TOTAL	**17100**	**69979**	**901**							

*=first day of operation was 12th February

**=heatpump not in operation 7 Aug-3 Sept

PVT system - SE1.1

Nydalavägen 22, Växjö

General Data

New RES	PVT
Year installed	2020
Installation type	PVT + Heat pump
Address	Nydalavägen 22, Växjö
Installed capacity [kWp]	16
Quantity [pieces]	
Area [m²]	96
Slope [˚]	
Orientation	
Est. annual prod. [kWh]	
Annual CO_2-savings [tons]	
Total Investment cost [€]	


	Produced solar electricity	Produced solar heat, via ground heat storage, to heat pump (cold side)	Produced heat by heat pump (warm side) to low district heating	Electricity to heat pump	
jan-20	-	-	-	-	
feb-20	-	-	-	-	
mar-20	-	-	-	-	
apr-20	-	-	-	-	
maj-20	-	-	-	-	
jun-20	-	60	4	-	
jul-20	-	9,229	13,369	-	
aug-20	-	4,931	4,673	-	
sep-20	7469	3,946	4,478	-	
okt-20	428	216	6	55	
nov-20	129	0	7	54	
dec-20	39	**0**	345	123	
TOTAL	***8065***	***18,382***	***22,882***	***232***	

xxxx Production of electricity started 1st June 2020, accumulated production June-September=7469 kWh

Tvinnaren 4, Växjö (BEST-category SE3)

Arabygatan

General Data

Refurbished Building	
Year built	1945
Year refurbished	2017-2019
Address	Arabygatan
Building function	Office
Building type	Renting offices
Number of Apartments	-
Gross Floor Area (m²) in project	3,340
Gross Floor Area (m²) in total	9,600
Total Investment cost [Euro]	2,620,000

Building Features

			Normal practice/Before	Project target	Design (calc)	Actual ("year")
External walls	Parapet insulation	W/m²K	0.35	0.35	0.35	0.35
Roof	Ceiling insulation	W/m²K	0.50	0.25	0.25	0.25
Ground floor	-	W/m²K	-	-	-	-
Windows (frame & glass)	Triple glazing 2+1	W/m²K	3.00	1	0.50	0.50
Average U-value of glazings	-	W/m²K	-	-	-	-
Average g-value of glazings	-	-	-	-	-	-
Ventilation Flow Rate average	Additional occupants	h -	4.00	5.8	5.80	5.80
Thermal Bridges	-					
Air tightness & n50 air change rate	-					
Ventilation system type	Balance mechanical ventilation with heat recovery (VAV)					
Energy saving measures	New windows, insulation, ventilation with heat recovery, low-energy ligthing, automation, DC					
Water saving measures	Taps					
Special building materials	-					
Type of Shading	External shading					

Energy Systems

District Heating connection	yes
Photovoltaic - grid connected	no

Other information

Key Energy figures — BEST-Table SE3	Existing building kWh/m² yr	Suggested specification	Result Total energy delivered (kWh/m²) 2020
District Heating kWh/m² yr	93	52	48
District Cooling, electric, kWh/m² yr	10	21	1
Lighting*	21	4	4
TOTAL	**124**	**77**	**53**
Decrease		-38%	-57%

*Lightning is a calculated value as there are no submetres distinguishing lightning from other electricity use. The description is detailed in D6.2

(BEST-category SE3)

Address	Tvinnaren 4, Växjö
Typology of Dwelling	Office
Occupants number	
Occupants type	
Ownership	Private
Gross floor area (m²)	3340

Monitoring Period	Energy kWh	Energy kWh/m²	Measured Values District Heat and Cooling: *DH* kWh	*DH* kWh/m²	*DC* kWh	*DC* kWh/m²	Measured Values Electricity: *Electr.* kWh	*Electr.* kWh/m²	
jan-14	151,916	16	125220	13		0	26696	3	
feb-14	112,712	12	89460	9		0	23252	2	
mar-14	99,389	10	76090	8		0	23299	2	
apr-14	74,768	8	50870	5		0	23898	2	
maj-14	57,178	6	29750	3		0	27428	3	
jun-14	47,660	5	15610	2		0	32050	3	
jul-14	49,838	5	8200	1		0	41638	4	
aug-14	49,734	5	16780	2		0	32954	3	
sep-14	54,957	6	24730	3		0	30227	3	
okt-14	74,925	8	44620	5		0	30305	3	
nov-14	98,748	10	70590	7		0	28158	3	
dec-14	143,598	15	116600	12		0	26998	3	
TOTAL	**1,015,423**	**106**	**668,520**	**70**	**0**	**0**	**346,903**	**36**	
jan-15	138,581	14	112380	12		0	26201	3	
feb-15	126,101	13	102470	11		0	23631	2	
mar-15	112,234	12	86430	9		0	25804	3	
apr-15	86,986	9	61760	6		0	25226	3	
maj-15	70,093	7	45400	5		0	24693	3	
jun-15	47,909	5	21580	2		0	26329	3	
jul-15	49,544	5	14750	2		0	34794	4	
aug-15	50,432	5	12580	1		0	37852	4	
sep-15	63,419	7	30970	3		0	32449	3	
okt-15	96,950	10	66230	7		0	30720	3	
nov-15	118,535	12	88240	9		0	30295	3	
dec-15	136,260	14	103760	11		0	32500	3	
TOTAL	**1,097,044**	**115**	**746,550**	**78**	**0**	**0**	**350,494**	**37**	
jan-16	170,708	18	141720	15		0	28988	3	
feb-16	137,429	14	107630	11		0	29799	3	
mar-16	123,428	13	92400	10		0	31028	3	
apr-16	91,635	10	63290	7		0	28345	3	
maj-16	58,410	6	24600	3		0	33810	4	
jun-16	48,743	5	12800	1		0	35943	4	*
jul-16	46,529	5	11890	1		0	34639	4	*
aug-16	51,619	5	16930	2		0	34689	4	
sep-16	55,222	6	20100	2		0	35122	4	
okt-16	96,803	10	66780	7		0	30023	3	
nov-16	136,286	14	102230	11		0	34056	4	
dec-16	143,352	15	106800	11		0	36552	4	
TOTAL	**1,160,164**	**121**	**767,170**	**80**	**0**	**0**	**392,994**	**41**	

jan-17	164,649	17	129240	13		0	35409	4
feb-17	135,911	14	103940	11		0	31971	3
mar-17	127,284	13	89920	9		0	37364	4
apr-17	107,224	11	74620	8		0	32604	3
maj-17	52,802	6	31490	3		0	21312	2
jun-17	36,469	4	16500	2		0	19969	2
jul-17	32,004	3	13530	1		0	18474	2
aug-17	40,185	4	18590	2		0	21595	2
sep-17	53,200	6	32360	3		0	20840	2
okt-17	85,895	9	65110	7		0	20785	2
nov-17	120,813	13	97430	10		0	23383	2
dec-17	135,774	14	114560	12		0	21214	2
TOTAL	1,092,210	114	787,290	82	0	0	304,920	32
jan-18	155,211	16	132780	14	0	0	22431	2
feb-18	149,740	16	132550	14	0	0	17190	2
mar-18	148,490	16	131750	14	0	0	16740	2
apr-18	87,580	9	70790	7	0	0	16790	2
maj-18	45,841	5	24360	3	2	0	21479	2
jun-18	28,097	3	9360	1	3	0	18734	2
jul-18	25,898	3	4480	0	0	0	21418	2
aug-18	31,423	3	9900	1	0	0	21523	2
sep-18	42,697	4	25080	3	0	0	17617	2
okt-18	81,600	9	62040	6	0	0	19560	2
nov-18	114,912	12	95450	10	0	0	19462	2
dec-18	137,016	14	119640	12	0	0	17376	2
TOTAL	1,048,505	110	818,180	85	5	0	230,320	24
jan-19	163,106	17	143330	15	0	0	19776	2
feb-19	122,674	13	105010	11	0	0	17664	2
mar-19	122,895	13	104090	11	0	0	18805	2
apr-19	84,950	9	65570	7	729	0	18651	2
maj-19	68,910	7	48590	5	1026	0	19294	2
jun-19	37,385	4	11870	1	5918	1	19597	2
jul-19	35,235	4	14430	2	3282	0	17523	2
aug-19	39,500	4	16200	2	4280	0	19020	2
sep-19	50,363	5	31870	3	569	0	17924	2
okt-19	89,614	9	69970	7	36	0	19608	2
nov-19	107,866	11	90010	9	0	0	17856	2
dec-19	119,263	12	100490	10	0	0	18773	2
TOTAL	1,041,761	109	801,430	84	15,840	2	224,491	23

jan-20	**117,324**	**12**	94010	10	0	0	23314	2
feb-20	**117,528**	**12**	95240	10	0	0	22288	2
mar-20	**116,069**	**12**	92240	10	0	0	23829	2
apr-20	**78,977**	**8**	57070	6	232	0	21675	2
maj-20	**67,385**	**7**	43700	5	634	0	23051	2
jun-20	**47,279**	**5**	13820	1	4534	0	28925	3
jul-20	**44,760**	**5**	20940	2	1080	0	22740	2
aug-20	**47,717**	**5**	14400	2	4061	0	29256	3
sep-20	**55,190**	**6**	28390	3	556	0	26244	3
okt-20	**77,640**	**8**	52350	5	119	0	25171	3
nov-20	**91,442**	**10**	67810	7	15	0	23617	2
TOTAL	**861,311**	**90**	**579,970**	**61**	**11,231**	**1**	**270,110**	**28**

	Monito-ring Period	Energy kWh	kWh/m²	Measured Values District Heat and Cooling *DH*** kWh	*DH*** kWh/m²	*DC** kWh	*DC** kWh/m²	Measured Values Electricity *Electr.* kWh	*Electr.* kWh/m²	
	2014	878,820	92	531,917	56	0	0	346,903	36	
	2015	1,026,927	107	676,433	71	0	0	350,494	37	
	2016	1,123,134	117	730,140	76	0	0	392,994	41	
	2017	1,044,181	109	739,261	77	0	0	304,920	32	
	2018	974,597	102	744,272	78	5	0	230,320	24	*
	2019	987,403	103	747,072	78	15,840	2	224,491	23	*
	2020***	762,155	80	457,326	48	11,231	1	293,598	31	*
BEFORE	***Average 2014-2016***		***105***		***67***		***0***		***38***	
MIDDLE	***Middle 2017***		***109***		***77***		***0***		***32***	
AFTER	***Average 2018-2020***		***95***		***68***		***1***		***26***	

* Not adjusted for degree days
** DH adjusted for degree days and hot water use
*** Not full year, EXTRAPOLATED (DH jan-nov/full year =0,85 in average 2014-2019,
DC jan-nov/full year=1 in 2019, EL jan-nov/full year=0,92 in average 2014-2019)

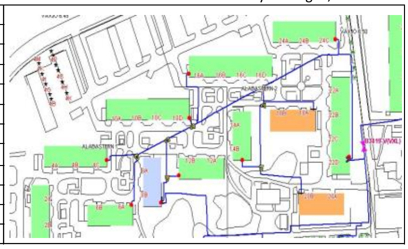
xxxx Measured values
xxxx Calculated values

Demonstration low temperature district heating

General Data

Nydalavägen, Alabastern

New RES	District Heating
Year installed	Jan 19
Installation type	
Address	
Installed capacity [kWp]	
Quantity [pieces]	
Area [m²]	
Slope [°]	
Orientation	
Est. annual prod. [kWh]	
Annual CO_2-savings [tons]	
Total Investment cost [€]	



Monitoring Period	Heat consumed the Alabastern Area (2 connections) kWh	Delivered Heat to Alabastern area through the substation lowering the kWh	Heat consumed by customers kWh	Heat loss kWh	Electricity consumed kWh	COP, heating [-]	COP, cooling [-]	COP, combi. [-]	Supply temperature [-]
Jan 16	421084		421084	0		#BEZUG!	#DIV/0!	#BEZUG!	105
Feb 16	364409		364409	0		#BEZUG!	#DIV/0!	#BEZUG!	105
Mrz 16	356869		356869	0		#BEZUG!	#DIV/0!	#BEZUG!	
Apr 16	282350		282350	0		#BEZUG!	#DIV/0!	#BEZUG!	
Mai 16	169633		169633	0		#BEZUG!	#DIV/0!	#BEZUG!	
Jun 16	117315		117315	0		#BEZUG!	#DIV/0!	#BEZUG!	
Jul 16	102552		102552	0		#BEZUG!	#DIV/0!	#BEZUG!	
Aug 16	94211		94211	0		#BEZUG!	#DIV/0!	#BEZUG!	
Sep 16	103527		103527	0		#BEZUG!	#DIV/0!	#BEZUG!	
Okt 16	232085		232085	0		#BEZUG!	#DIV/0!	#BEZUG!	
Nov 16	295139		295139	0		#BEZUG!	#DIV/0!	#BEZUG!	
Dez 16	312915		312915	0		#BEZUG!	#DIV/0!	#BEZUG!	
TOTAL	**2815309**	**0**	**2852089.003**	**0**	**0**	#DIV/0!	#DIV/0!	#DIV/0!	
Jan 17	309810		345574.001	-345574.001		#BEZUG!	#DIV/0!	#BEZUG!	
Feb 17	264713		294748	-294748		#BEZUG!	#DIV/0!	#BEZUG!	
Mrz 17	247793		275650	-275650		#BEZUG!	#DIV/0!	#BEZUG!	
Apr 17	198914		221816	-221816		#BEZUG!	#DIV/0!	#BEZUG!	
Mai 17	112350		133524.006	-133524.006		#BEZUG!	#DIV/0!	#BEZUG!	
Jun 17	70443		88388	-88388		#BEZUG!	#DIV/0!	#BEZUG!	
Jul 17	52658		68294	-68294		#BEZUG!	#DIV/0!	#BEZUG!	
Aug 17	55350		71832	-71832		#BEZUG!	#DIV/0!	#BEZUG!	
Sep 17	80916		103711	-103711		#BEZUG!	#DIV/0!	#BEZUG!	
Okt 17	133070		168487	-168487		#BEZUG!	#DIV/0!	#BEZUG!	
Nov 17	157933		219589.38	-219589.38		#BEZUG!	#DIV/0!	#BEZUG!	
Dez 17	176639		264530.615	-264530.615		#BEZUG!	#DIV/0!	#BEZUG!	
TOTAL	**3721178**	**0**	**2256144.002**	**-2256144.002**	**0**	#DIV/0!	#DIV/0!	#DIV/0!	
Jan 18			271454	-271454		#BEZUG!	#DIV/0!	#BEZUG!	
Feb 18			286548	-286548		#BEZUG!	#DIV/0!	#BEZUG!	
Mrz 18			286780	-286780		#BEZUG!	#DIV/0!	#BEZUG!	
Apr 18			148899	-148899		#BEZUG!	#DIV/0!	#BEZUG!	
Mai 18			65662	-65662		#BEZUG!	#DIV/0!	#BEZUG!	
Jun 18	LT DH in process		48084	-48084		#BEZUG!	#DIV/0!	#BEZUG!	
Jul 18			40246.997	-40246.997		#BEZUG!	#DIV/0!	#BEZUG!	
Aug 18			46958	-46958		#BEZUG!	#DIV/0!	#BEZUG!	
Sep 18			79042	-79042		#BEZUG!	#DIV/0!	#BEZUG!	
Okt 18			130008.001	-130008.001		#BEZUG!	#DIV/0!	#BEZUG!	
Nov 18			149486	-149486		#BEZUG!	#DIV/0!	#BEZUG!	
Dez 18			187378	-187378		#BEZUG!	#DIV/0!	#BEZUG!	
TOTAL	**0**	**0**	**1740545.998**	**-1740545.998**	**0**	#DIV/0!	#DIV/0!	#DIV/0!	
Jan 19			231015	-231015		#BEZUG!	#DIV/0!	#BEZUG!	
Feb 19			178658.001	-178658.001		#BEZUG!	#DIV/0!	#BEZUG!	
Mrz 19			184311	-184311		#BEZUG!	#DIV/0!	#BEZUG!	
Apr 19			126728.999	-126728.999		#BEZUG!	#DIV/0!	#BEZUG!	
Mai 19			99841	-99841		#BEZUG!	#DIV/0!	#BEZUG!	
Jun 19	LT DH in process		47804.006	-47804.006		#BEZUG!	#DIV/0!	#BEZUG!	
Jul 19			46666	-46666		#BEZUG!	#DIV/0!	#BEZUG!	
Aug 19			47278.001	-47278.001		#BEZUG!	#DIV/0!	#BEZUG!	
Sep 19			74140	-74140		#BEZUG!	#DIV/0!	#BEZUG!	
Okt 19			123714	-123714		#BEZUG!	#DIV/0!	#BEZUG!	
Nov 19			163587.997	-163587.997		#BEZUG!	#DIV/0!	#BEZUG!	
Dez 19		100,550	190864	-90,314		#BEZUG!	#DIV/0!	#BEZUG!	
TOTAL	**0**	**100,550**	**1514608.004**	**-1414058.004**	**0**	#DIV/0!	#DIV/0!	#DIV/0!	
Jan 20		191730	184105	7625	4%	#BEZUG!	4629304.55	#BEZUG!	
Feb 20		186430	179429.004	7,001	4%	#BEZUG!	4778027.19	#BEZUG!	
Mrz 20		191380	184025.00	7,355	4%	4788403.06	0.00	4788403.06	
Apr 20		127,680	121524	6,156	5%	2520497.78	0.00	2520497.78	
Mai 20		102,970	97474	5,496	5%	1826218.66	0.00	1826218.66	
Jun 20	LT DH in process	54,470	52161	2,309	4%	1230493.58	0.00	1230493.58	
Jul 20		54,380	49525	4,855	9%	554720.803	0.00	554720.80	
Aug 20		55,620	50765	4,855	9%	581575.551	0.00	581575.55	
Sep 20		63,310	58503	4,807	8%	770506.538	0.00	770506.54	
Okt 20		107,410	102014	5,396	5%	2030638.2	0.00	2030638.20	
Nov 20		139,560	133794	5,766	4%	3238343.85	0.00	3238343.85	
Dez 20				0		#DIV/0!	#DIV/0!	#DIV/0!	
TOTAL	**0**	**1,274,940**	**1213319.004**	**61620.997**	**1**	2009531.56	0.00	2009531.56	

	SHUNT Substation for the area ENERGY (kWh)	TOTAL CONSUMPTION OF DH IN ALABASTERN NET (all 11 buildings)- (kWh)	Heat loss (kWh)	
Dez 19	100550	191521	-90971	Measuring via substation was started December 16th , 2019
Jan 20	191730	184779	6951	
Feb 20	186430	179429	7001	

Calculation with different temperatures in the new system with the new pipes and larger dimension and isolation. (calculation is provided by our s

HIGH (STANDARD) TEMPERATURES - as the standard network in Växjö with normal supply temperatures

without LTDH

Month	Supply temperature	Return temperature	Average temperature	Days
Dec	78.87	39.42	3.14	31
Jan	84.75	42.78	-3	31
Feb	83.33	42.07	-2.51	28
March	86.86	42.92	-4.99	31
April	79.13	38.6	2.61	30
May	76.84	39.56	10.53	31
June	76.07	42.75	13.4	30
July	75.11	45.26	15.77	31
August	76.18	42.69	14.42	31
Sep	75.9	39	9.38	30
Oct	76.9	37.07	8.16	31
Nov	77.66	38.6	3.89	30
Dec	78.87	39.42	3.14	31

Yearly average temperature (°C)	8.5
General lambda constant	0.03

Heat loss calculation

Jan	5	MWh
Feb	4	MWh
March	5	MWh
April	4	MWh
May	4	MWh
June	4	MWh
July	4	MWh
August	4	MWh
Sep	3	MWh
Oct	4	MWh
Nov	4	MWh
Dec	4	MWh
Q1	14	MWh
Q2	12	MWh
Q3	11	MWh
Q4	12	MWh
Yearly	48	MWh

Comment and conclusion

By lowering the temperature the heat losses is minimized by 10 MWh during one year.

Supprised in how less energy savigings the system generates with low temparature on district heating, compared to high temperature DH.

Don't feel like it is profitable with LTDH systems in Växjö ... .. just had the task SEK 800,000 in my head and with the saving SEK 2491 / year it is payback time of over 300 years ...

LOW TEMPERATURE - with supply temperatur of 65 degrees yearly

LTDH

Month	Supply temperature	Return temperature	Average temperature	Days
Dec	65	31	3.14	31
Jan	65	31	-3	31
Feb	65	31	-2.51	28
March	65	31	-4.99	31
April	65	31	2.61	30
May	65	31	10.53	31
June	65	31	13.4	30
July	65	31	15.77	31
August	65	31	14.42	31
Sep	65	31	9.38	30
Oct	65	31	8.16	31
Nov	65	31	3.89	30
Dec	65	31	3.14	31

Yearly average temperature (°C)	8.5
General lambda constant	0.03

Heat loss calculation

Jan	4	MWh
Feb	3	MWh
March	4	MWh
April	4	MWh
May	3	MWh
June	3	MWh
July	3	MWh
August	3	MWh
Sep	3	MWh
Oct	3	MWh
Nov	3	MWh
Dec	3	MWh
Q1	11	MWh
Q2	9	MWh
Q3	8	MWh
Q4	9	MWh
Yearly	38	MWh

	SPORT CENTRE			DATA CENTRE					
	Football stadium -delivered heat	District heating - SPETS	TOTAL Delivered heat to SPORT CENTRE	Distrcit cooling wexnet GDC	District cooling wexnet GDC	District cooling wexnet GOP - Working to find the meter	District cooling to CNV - not installed yet	Wexnet - total demand of DC return	% of Wexnet DC return to football stadium
	(193303)Value (MWh)	(193301) Value MWh		(194138) Value (MWh)	(194139) Value (MWh)	MISSING DATA	(231458) Value (MWh)		
Jan 16	0.000	94.254	94.254	36.43	36.64			73.07	0.00%
Feb 16	0.000	7.456	7.456	35.58	35.68			71.26	0.00%
Mrz 16	26.520	37.474	63.994	38.81	38.95			77.76	34.10%
Apr 16	58.520	10.984	69.504	39.32	39.45			78.77	74.29%
Mai 16	12.240	0.274	12.514	41.14	41.19			82.33	14.87%
Jun 16	0.040	0	0.040	40.31	40.24			80.55	0.05%
Jul 16	0.010	0	0.010	41.7	41.38			83.08	0.01%
Aug 16	0.110	0	0.110	42.16	42.04			84.2	0.13%
Sep 16	0.490	0	0.490	41.1	41.09			82.19	0.60%
Okt 16	3.060	60.543	63.603	41.6	42.07			83.67	3.66%
Nov 16	4.130	38.162	42.292	39.52	39.62			79.14	5.22%
Dez 16	0.000	0	0.000	42.02	42.07			84.09	0.00%
									Yearly Average
Total 2016	**105.120**	**249.147**	**354.267**					**960.11**	**10.95%**
Jan 17	0	0	0.000	42.47	42.55			85.02	0.00%
Feb 17	39.96	36.978	76.938	41.2	41.32			82.52	48.42%
Mrz 17	79.12	33.629	112.749	45.51	45.61			91.12	86.83%
Apr 17	80.61	0.918	81.528	46.27	46.42			92.69	86.97%
Mai 17	26.27	0	26.270	49.85	49.95			99.8	26.32%
Jun 17	0.12	0	0.120	47.42	47.3			94.72	0.13%
Jul 17	0.07	0	0.070	49.02	48.83			97.85	0.07%
Aug 17	0.1	0	0.100	49.33	48.87			98.2	0.10%
Sep 17	0.44	0	0.440	45.61	45.04			90.65	0.49%
Okt 17	3.88	0	3.880	47.78	47.14			94.92	4.09%
Nov 17	7.18	8.179	15.359	47	46.22			93.22	7.70%
Dez 17	7.59	18.868	26.458	47.57	47.78			95.35	7.96%
Total 2017	**245.34**	**98.572**	**343.912**					**1116.06**	**21.98%**
Jan 18	7.09	43.485	50.575	49.08	49.29			98.37	7.21%
Feb 18	41.16	51.833	92.993	43.94	43.99			87.93	46.81%
Mrz 18	90.78	63.094	153.874	47.63	47.62			95.25	95.31%
Apr 18	58.72	3.11	61.830	48.08	48.09			96.17	61.06%
Mai 18	9.22	0	9.220	51.65	51.47			103.12	8.94%
Jun 18	0.05	0	0.050	48.91	48.69			97.6	0.05%
Jul 18	0	0	0.000	51.85	51.47			103.32	0.00%
Aug 18	0.02	0	0.020	52.41	51.86			104.27	0.02%
Sep 18	0.92	0	0.920	50.63	50.25			100.88	0.91%
Okt 18	3.19	26.142	29.332	50.53	50.24			100.77	3.17%
Nov 18	73.8	25.013	98.813	48.64	48.4			97.04	76.05%
Dez 18	95.12	33.505	128.625	48.41	48.55			96.96	98.10%
Total 2018	**380.07**	**246.182**	**626.252**					**1181.68**	**32.16%**
Jan 19	94.04	56.21	150.250	48.48	48.45			96.93	97.02%
Feb 19	80.19	37.663	117.853	43.9	43.75			87.65	91.49%
Mrz 19	29.96	75.456	105.416	51.86	49.98			101.84	29.42%
Apr 19	53.2	11.317	64.517	51.24	51.16			102.4	51.95%
Mai 19	39.88	0	39.880	53.75	54.42			108.17	36.87%
Jun 19	0.72	0	0.720	54.36	54.98			109.34	0.66%
Jul 19	1.47	0	1.470	56.92	57.54			114.46	1.28%
Aug 19	0.89	0	0.890	58.52	58.97			117.49	0.76%
Sep 19	14.54	0	14.540	55.52	55.85			111.37	13.06%
Okt 19	63.33	1.368	64.698	57.17	57.9			115.07	55.04%
Nov 19	107	9.337	116.337	55.31	56.07			111.38	96.07%
Dez 19	112.11	22.275	134.385	57.65	58.25			115.9	96.73%
Total 2019	**597.33**	**213.626**	**810.956**					**1292**	**46.23%**
Jan 20	114.92	1.469	116.389	58.9	59.47			118.37	97.09%
Feb 20	111.08	6.242	117.322	56.97	57.52			114.49	97.02%
		383.704						**1033.6**	

	SHOPPING MALL								DATA CENTRE						SPORTCENTRE	
Datum	Flowtemp. (Celsius)			Average	Returntemp. (Celsius)			Average	Flowtemp. (Celsius)		Average	Returntemp. (Celsius)		Average	Flowtemp. (Celsius)	Returntemp. (Celsius)
01.01.2016 00:00	7	7	7	7	8	9	8	8	9	9	9	14	14	14	10	13
01.02.2016 00:00	8	8	8	8	9	10	9	9	11	11	11	18	17	18	12	16
01.03.2016 00:00	9	9	9	9	9	10	9	9	8	8	8	14	14	14	9	14
01.04.2016 00:00	7	7	7	7	8	8	7	8	14	14	14	19	19	19	18	15
01.05.2016 00:00				0				0			0			0		
01.06.2016 00:00				0				0			0			0		
01.07.2016 00:00				0				0			0			0		
01.08.2016 00:00				0				0			0			0		
01.09.2016 00:00				0				0			0			0		
01.10.2016 00:00				0				0			0			0		
01.11.2016 00:00				0				0			0			0		
01.12.2016 00:00				0				0			0			0		
01.01.2017 00:00				0				0			0			0		
01.02.2017 00:00				0				0			0			0		
01.03.2017 00:00				0				0			0			0		
01.04.2017 00:00				0				0			0			0		
01.05.2017 00:00				0				0			0			0		
01.06.2017 00:00				0				0			0			0		
01.07.2017 00:00				0				0			0			0		
01.08.2017 00:00	7	7	7	7	7	8	7	7	12	12	12	20	20	20	21	21
01.09.2017 00:00	7	7	7	7	7	7	7	7	12	12	12	19	18	19	21	21
01.10.2017 00:00	7	7	7	7	7	8	7	7	10	10	10	16	16	16	19	14
01.11.2017 00:00	7	7	7	7	7	7	7	7	11	11	11	17	17	17	17	7
01.12.2017 00:00	8	8	8	8	8	8	8	8	13	13	13	19	19	19	18	5
01.01.2018 00:00	7	8	7	7	7	8	7	7	15	15	15	19	19	19	18	5
01.02.2018 00:00	7	7	7	7	7	7	7	7	14	13	14	20	20	20	18	5
01.03.2018 00:00	7	8	7	7	7	8	7	7	8	8	8	16	16	16	14	9
01.04.2018 00:00	8	8	7	8	7	8	7	7	13	13	13	18	18	18	18	13
01.05.2018 00:00	7	7	7	7	7	7	7	7	14	14	14	19	19	19	20	16
01.06.2018 00:00	7	7	7	7	7	7	7	7	14	14	14	20	20	20	21	20
01.07.2018 00:00	8	8	8	8	8	8	8	8	14	14	14	19	19	19	20	20
01.08.2018 00:00	7	7	7	7	8	8	8	8	14	14	14	19	19	19	20	20
01.09.2018 00:00	7	7	7	7	7	8	7	7	12	12	12	20	20	20	21	21
01.10.2018 00:00	7	7	7	7	7	8	7	7	13	13	13	20	20	20	20	13
01.11.2018 00:00	7	7	7	7	7	7	7	7	13	14	14	19	19	19	18	12
01.12.2018 00:00	7	7	6	7	7	7	7	7	11	11	11	17	17	17	17	12
01.01.2019 00:00	8	8	7	8	7	8	7	7	12	12	12	18	19	19	17	13
01.02.2019 00:00	7	7	7	7	7	7	7	7	10	10	10	17	17	17	17	11
01.03.2019 00:00	7	7	6	7	7	7	7	7	14	14	14	20	20	20	20	11
01.04.2019 00:00	8	8	8	8	8	8	8	8	13	13	13	20	20	20	19	14
01.05.2019 00:00	7	7	7	7	7	7	7	7	14	14	14	20	20	20	20	16
01.06.2019 00:00	8	8	8	8	8	8	8	8	14	14	14	19	19	19	21	18
01.07.2019 00:00	8	8	8	8	8	8	8	8	14	14	14	19	19	19	21	21
01.08.2019 00:00	7	7	7	7	7	7	7	7	14	14	14	21	21	21	21	21
01.09.2019 00:00	7	7	7	7	7	8	8	8	15	15	15	20	19	20	20	21
01.10.2019 00:00	8	8	8	8	8	8	8	8	13	13	13	19	19	19	20	17
01.11.2019 00:00	7	7	7	7	7	8	7	7	12	13	13	19	19	19	20	14
01.12.2019 00:00	6	6	6	6	6	7	6	6	11	11	11	18	18	18	18	12
01.01.2020 00:00	7	7	7	7	7	8	7	7	10	10	10	18	18	18	18	11
01.02.2020 00:00	7	7	7	7	8	8	7	8	12	12	12	19	19	19	19	13

Appendix B – BEST

Building Energy Specification Table (BEST)

Community / site	Aarhus	Ringgården afd 21	BEST no. DK-1

1,1	**Building Category**		residential retrofitted	total area / category / BEST sheet [2]	23960	m^2		
		[1]	Social multiappartment housing					
1,2	**Local Climate**			January average outside temperature	°C		0	
				August average outside temperature	°C		16	
	Climatic Zone		Temperate	Average global horizontal radiation	kWh/m^2 yr		1000	
	(national definition)		Denmark DK	Annual heating degree days [3]	°Cd/yr		2700	
				Room temperature	°C		20	

1,3	**Maximum requirements of building fabric**			Existing building [5]	National regulation for new built [6]	**suggested** specification [7] *)	Energy savings [%] [8]
	Façade/wall	U	W / m2K	0,7	0,3	0,15	78,6
	Roof	U	W / m2K	0,5	0,2	0,1	80,0
	Ground floor	U	W / m2K	0,75	0,2	0,3	60,0
	Glazing	U_g	W / m2K	2,9	1,4	0,8	72,4
	Average U-value	U_{av}	W / m2K	n.a.	0,22	0,21	n.a.
	Glazing	g	total solar energy transmittance of glazing [%	n.a.	none	0,5	n.a.
	Shading	Fs	Shading correction factor	n.a.	none	external	n.a.
	Ventilation rate [4]		air changes/hr	0,7	126 m3/dwel	0,3-0,6	n.a.
			*) will depend on optimisation analysis				

2 Building Energy Performance

2,1 Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses

energy carrier existing building	**suggested energy carrier**		specify energy efficiency measures [13]	Existing building [5]	National regulation / **normal practice** for new built (2006) [6]*	**suggested** specification [7]	% Energy savings [8]
Heating + ventilation							
District Heating	Low temp water	kWh/m^2yr	Insulation,windows,tightness, accummulation	121	66	36	70,2
Cooling + ventilation							
Compressor	Water & air	kWh/m^2yr	Sunshading	0	0	0	#DIV/0!
Ventilation (if separate from heating/cooling)							
Electricity	Air	kWh/m^2yr	Intelligent demand controlled, energy eff fans	14	7	7	50,0
Lighting							
	Electricity PV	kWh/m^2yr	Daylight access + LED + controls	12	6	4	66,7
			*) Figure includes common lighting only			*)	
Domestic Hot Water (DHW)							
District Heating	Waste water HP	kWh/m^2yr	Taps, Heat recovery, Smart grid control, reduced circ. loss	34	28	19	44,1
Other energy demand							
Electricity	PV & Thermal solar	kWh/m^2yr	Freq. contrl, red. idle load, a++ lenergy labels meters	13	9	8	38,5
		kWh/m^2yr	Subtotal sum of energy demand	194	116	74	61,9
	Appliances (please indicate, but costs are not eligible)						
	Electricity	kWh/m^2yr	a++apliances, user campaign, PV etc	50	45	30	40,0

2.2 RES contribution per m2 of total used conditioned area (kWh / m2 yr)

total production kWh/yr	m^2 installed	kW installed	specify RES measures	Existing building [5]	National regulation / normal practice	**Suggested** specification [7]	RES contribution [%][8]
150000	1000	135	PV partly building integrated	0	0	6	8,5
270000	900	360	Solar thermal integrated with DH	0	0	11	15,2
822913		n.a.	85% RES in waste heat from DH	0	0	34	46,4
23963		n.a.	Waste water heat pump on selected blocks	0	0	3	4,5
450000		360	Possible share in common wind turbine	0	0	19	25,4
		kWh/m^2yr	Subtotal sum of RES contribution	0	0	74	100

Building Energy Specification Table (BEST)

Community / site	Aarhus	Dybedalen 1a	BEST no. DK-3

1,1	**Building Category**	tertiary retrofitted		total area / category / BEST sheet [2]	2.068	m^2
		[1] Administration				
1,2	**Local Climate**			January average outside temperature	°C	0
				August average outside temperature	°C	16
	Climatic Zone		Temperate	Average global horizontal radiation	kWh/m^2 yr	1000
	(national definition)		Denmark DK	Annual heating degree days [3]	°Cd/yr	2700
				Room temperature	°C	20

1,3	**Maximum requirements of building fabric**			Existing building [5]	National regulation for new built [6]	**suggested** specification [7] *)	Energy savings [%] [8]
	Façade/wall	U	W / m2K	0,7	0,3	0,15	78,6
	Roof	U	W / m2K	0,5	0,2	0,1	80,0
	Ground floor	U	W / m2K	0,75	0,2	0,3	60,0
	Glazing	U_g	W / m2K	2,9	1,4	0,8	72,4
	Average U-value	U_{av}	W / m2K	n.a.	0,22	0,22	n.a.
	Glazing	g	total solar energy transmittance of glazing [%	n.a.	none	0,5	n.a.
	Shading	Fs	Shading correction factor	n.a.	none	external	n.a.
	Ventilation rate [4]		air changes/hr	0,7	126 m3/dwel	0,3-0,6	n.a.
			*) will depend on optimisation analysis				

2 Building Energy Performance

2,1 Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses

energy carrier existing building	**suggested energy carrier**		specify energy efficiency measures [13]	Existing building [5]	National regulation / **normal practice** for new built (2006) [6]*	**suggested** specification [7]	% Energy savings [8]
Heating + ventilation							
District Heating	Low temp water	kWh/m^2yr	Insulation,windows,tightness, accummulation	81	66	36	55,6
Cooling + ventilation							
Compressor	Water & air	kWh/m^2yr	Sunshading	5	5	0	100,0
Ventilation (if separate from heating/cooling)							
Electricity	Air	kWh/m^2yr	Intelligent demand controlled, energy eff fans	14	10	7	50,0
Lighting							
	Electricity PV	kWh/m^2yr	Daylight access + LED + controls	16	11	8	50,0
Domestic Hot Water (DHW)							
District Heating	Waste water HP	kWh/m^2yr	Taps, Heat recovery, Smart grid control, reduced circ. loss	15	13	10	33,3
Other energy demand							
Electricity	PV & Thermal solar	kWh/m^2yr	Freq. contrl, red. idle load, a++ lenergy labels meters	13	15	9	30,8
		kWh/m^2yr	Subtotal sum of energy demand	144	120	70	51,4
	Appliances (please indicate, but costs are not eligible)						
	Electricity	kWh/m^2yr	a++apliances, user campaign, PV etc	50	45	30	40,0

2,2 RES contribution per m2 of total used conditioned area (kWh / m2 yr)

total production kWh/yr	m^2 installed	kW installed	specify RES measures	Existing building [5]	National regulation / normal practice	**Suggested** specification [7]	RES contribution [%][8]
36000	240	32	PV partly building integrated	0	0	17	24,8
0	0	0	Solar thermal	0	0	0	0,0
90372		n.a.	95% RES in District Heating	0	0	44	62,3
0		n.a.	n.n.	0	0	0	0,0
18750		15	Possible share in common wind turbine	0	0	9	12,9
		kWh/m^2yr	Subtotal sum of RES contribution	0	0	70	100

Building Energy Specification Table (BEST)

				Community / site	Aarhus	houses	BEST no.	DK-4
1,1	**Building Category**		[1] houses	total area / category / BEST sheet [2]		10.000	m²	
1,2	**Local Climate**			January average outside temperature		°C		0
				August average outside temperature		°C		16
	Climatic Zone		Temperate	Average global horizontal radiation		kWh/m² yr		1000
	(national definition)		Denmark DK	Annual heating degree days [3]		°Cd/yr		2700
				Room temperature		°C		20

				Existing building [5]	National regulation for new built [6]	**suggested** specification [7] *)		Energy savings [%] [8]
1,3	**Maximum requirements of building fabric**							
	Façade/wall	U	W / m2K	0,7	0,3	0,3	*)	57,1
	Roof	U	W / m2K	0,4	0,2	0,12		70,0
	Ground floor	U	W / m2K	0,75	0,2	-		n.a.
	Glazing	U_g	W / m2K	2,9	1,4	0,8		72,4
	Average U-value	U_{av}	W / m2K excl windows & doors	n.a.	0,22	0,22		n.a.
	Glazing	g	total solar energy transmittance of glazing [5	n.a.	none	0,5		n.a.
	Shading	Fs	Shading correction factor	n.a.	none	external		n.a.
	Ventilation rate [4]		air changes/hr	0,7	126 m3/dwel	0,3-0,6		n.a.
			*) will depend on optimisation analysis					

2 Building Energy Performance

2,1 RES contribution per m2 of total used conditioned area (kWh / m2 yr) - on top of scale of unit costs

energy carrier existing building	**suggested energy carrier**		specify energy efficiency measures [13]	Existing building [5]	National regulation / **normal practice** for new built (2006) [6]*	**suggested** specification [7]		% Energy savings [8]
Heating + ventilation								
District Heating	Low temp water	kWh/m²yr	Insulation,windows,tightness, accummulation	121	66	60		50,4
Cooling + ventilation								
Compressor	Water & air	kWh/m²yr	Sunshading	0	0	0		#DIV/0!
Ventilation (if separate from heating/cooling)								
Electricity	Air	kWh/m²yr	Intelligent demand controlled, energy eff fans	10	7	7		30,0
Lighting								
	Electricity PV	kWh/m²yr	Daylight access + LED + controls	12	6	3		75,0
			*) Figure includes common lighting only			*)		
Domestic Hot Water (DHW)								
District Heating	Waste water HP	kWh/m²yr	Taps, Heat recovery, Smart grid control, reduced circ. loss	34	28	19		44,1
Other energy demand								
Electricity	PV & Thermal solar	kWh/m²yr	Freq. contrl, red. idle load, a++ lenergy labels meters	17	9	5		70,6
		kWh/m²yr	Subtotal sum of energy demand	194	116	94		51,5
	Appliances (please indicate, but costs are not eligible)							
	Electricity	kWh/m²yr	a++apliances, user campaign, PV etc	50	45	30		40,0

2,2 RES contribution per m2 of total used conditioned area (kWh / m2 yr)

total production kWh/yr	m² installed	kW installed	specify RES measures	Existing building [5]	National regulation / normal practice	**Suggested** specification [7]	RES contribution [%][8]
75000	500	68	PV partly building integrated	0	0	8	10,0
18000	60	30	Solar thermal integrated with DH	0	0	2	2,4
639200		n.a.	85% RES in waste heat from DH	0	0	64	85,0
20000			Supplementary heat pumps	0	0	2	2,7
0				0	0		0,0
		kWh/m²yr	Subtotal sum of RES contribution	0	0	75	80

Building Energy Specification Table (BEST)

Community / site	Växjö	Sweden	BEST no.	SE1	
1,1 Building Category	[1] Kv.Alabastern-Växjö	total area / category / BEST sheet [2]	17494	m²	

1,2 Local Climate				
		January average outside temperature	°C	-0,9
		August average outside temperature	°C	17,3
Climatic Zone		Average global horizontal radiation	kWh/m² yr	942
(national definition)	zone 3 - southern Sweden	Annual heating degree days [3]	°Cd/yr	3715
		Room temperature	°C	20

1,3 Maximum requirements of building fabric			Existing building [5]	National regulation BBR19 (2012)* [6]	suggested specification [7]	Energy savings [%] [8]
Façade/wall	U	W / m2K	0,36		0,36	
Roof	U	W / m2K	0,236		0,073	69
Ground floor	U	W / m2K	0,413		0,413	
Glazing	U_g	W / m2K	2,50		0,90	64
Average U-value	U_{av}	W / m2K	0,710	0,500	0,475	33
Glazing	g	total solar energy transmittance of glazing [%]	76		46	
Shading	Fs	Shading correction factor	61		36	
Ventilation rate [4]		air changes/hr	0,609		0,609	

2 Building Energy Performance

2,1 Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses

energy carrier existing building	suggested energy carrier		specify energy efficiency measures [13]	Existing building [5]	National regulation BBR19 (2012)* [6]	suggested specification [7]	% Energy savings [8]
Heating							
district heating	district heating	kWh/m²yr	Additional insulation of attic joists, Replacement of windows	149 (total distr.heating)		25	
Ventilation							
district heating	district heating	kWh/m²yr	Air handling units with supply and exhaust air, and energy recovery			21	
Domestic Hot Water (DHW)							
district heating	district heating	kWh/m²yr	Individual measurement of cold and hot water.			21	55 (total distr.heating)
Other energy demand							
electricity	electricity	kWh/m²yr	Electricity to the building, (fans, pumps, etc.)	11		8	27
		kWh/m²yr		160	90	75	53
Appliances (please indicate, but costs are not eligible)							
	electricity	kWh/m²yr	Class A++ or A+ Appliances, LED ligth, Meaqsuring and Behaviour changing solutions	46		33	28
Food							
		Co2/m²yr	Solutions for lowering food waste and promoting change of diet	67		57	15
Avoided emissions in society							
		Co2/m²yr	Decreased emisions from waste and water treatment				0
		kWh/m²yr		46	0	33	28
		CO2/m²yr		67	0	57	15

2,2 RES (building integrated) contribution per m2 of total used conditioned area (kWh / m2 yr)

district heating in Växjö is 95% biomass (=RES) and 5% fossil fuel

total production kWh/yr	m² installed	kW installed	specify RES measures	Existing building [5]	National regulation BBR19 (2012)* [6]	suggested specification [7]	RES contribution [%][8]
		kWh/m²yr	Subtotal sum of RES contribution	0	0	0	0

Building Energy Specification Table (BEST)				Community / site	Växjö	Sweden	**BEST** no. SE1.1
1,1	**Building Category**			total area / category / BEST sheet [2]		4133 m²	
		[1]	Kv.Alabastern-Växjö, plus prototypes				
1,2	**Local Climate**			January average outside temperature		°C	-0,9
				August average outside temperature		°C	17,3
	Climatic Zone			Average global horizontal radiation		kWh/m² yr	942
	(national definition)		zone 3 - southern Sweden	Annual heating degree days [3]		°Cd/yr	3715
				Room temperature		°C	20
1,3	**Maximum requirements of building fabric**			Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	Energy savings [%] [8]
	Façade/wall	U	W / m2K	0,36		0,36	
	Roof	U	W / m2K	0,236		0,073	76
	Ground floor	U	W / m2K	0,413		0,413	
	Glazing	U_g	W / m2K	2,50		0,90	64
	Average U-value	U_{av}	W / m2K	0,710	0,500	0,475	33
	Glazing	g	total solar energy transmittance of glazing [%]	76		46	
	Shading	Fs	Shading correction factor	61		36	
	Ventilation rate [4]		air changes/hr	0,609		0,609	
2	**Building Energy Performance**						
2,1	**Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses**						
energy carrier existing	**suggested energy carrier**		specify energy efficiency measures [13]	Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	% Energy savings
Heating							
district heating	district heating	kWh/m²yr	Additional insulation of attic joists, Replacement of windows	149		24	
				total distr.heating			
Ventilation							
district heating	district heating	kWh/m²yr	Air handling units with supply and exhaust air, and energy recovery			21	
Domestic Hot Water (DHW)							
district heating	district heating	kWh/m²yr	Individual measurement of cold and hot water,			21	55
							total distr.heating
Other energy demand							
electricity	electricity	kWh/m²yr	Electricity to the building, (fans, pumps, etc.)	11		8	27
		kWh/m²yr		160	90	75	53
	Appliances (please indicate, but costs are not eligible)						
		kWh/m²yr	Class A++ or A+ Appliances, LED ligth, Meaqsuring and Behaviour changing solutions	46		33	29
	Food						
		Co2/m²yr	Solutions for lowering food waste and promoting change of diet	67		57	15
	Avoided emissions in society						
		Co2/m²yr	treatment				0
		kWh/m²yr		46	0	33	29
		CO2/m²yr		67	0	57	15
2,2	**RES (building integrated) contribution per m2 of total used conditioned area (kWh / m2 yr) - on top of scale-of-unit costs**						
	district heating in Växjö is 95% biomass (=RES) and 5% fossil fuel						
total production kWh/yr	m² installed	kW installed	specify RES measures	Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	RES contribution
90000	300	207	Solar collectors to make hot water -PVT	0		22	
39000	-	-	Solar collectors to make electricity - PVT	0		9	
31028	n.a.	n.a.	Waste water heat pump	0		8	
		kWh/m²yr	Subtotal sum of RES contribution	0	0	39	0

Building Energy Specification Table (BEST)				Community / site	Växjö	Sweden	**BEST no.** SE2
1,1	**Building Category**			total area / category / BEST sheet [2]		13567 m²	
		[1]	Kv.Bämstenen-Växjö				
1,2	**Local Climate**			January average outside temperature		°C	-0,9
				August average outside temperature		°C	17,3
	Climatic Zone			Average global horizontal radiation		kWh/m² yr	942
	(national definition)		zone 3 - southern Sweden	Annual heating degree days [3]		°Cd/yr	3715
				Room temperature		°C	20
1,3	**Maximum requirements of building fabric**			Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	Energy savings [%] [8]
	Façade/wall	U	W / m2K	0,36		0,36	
	Roof	U	W / m2K	0,236		0,073	69
	Ground floor	U	W / m2K	0,413		0,413	
	Glazing	U_g	W / m2K	2,50		2,50	
	Average U-value	U_{av}	W / m2K	0,710	0,500		
	Glazing	g	total solar energy transmittance of glazing [%]	76			
	Shading	Fs	Shading correction factor	61			
	Ventilation rate [4]		air changes/hr	0,609		0,609	
2	**Building Energy Performance**						
2,1	**Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses**						
energy carrier existing	**suggested energy carrier**		specify energy efficiency measures [13]	Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	% Energy savings [8]
Heating							
district heating	district heating	kWh/m²yr	Thermal photography, air tightness test and tightning measures , additional insulation of attic joists etc., optimization of heating system, ref. temp in each apartment	157 total distr.heating		33	
Ventilation							
district heating	district heating	kWh/m²yr	Air handling units with supply and exhaust air, and energy recovery			21	
Domestic Hot Water (DHW)							
district heating	district heating	kWh/m²yr	Water and energy saving taps and showers			21	75 total distr.heating
Other energy demand							
electricity	electricity	kWh/m²yr	Electricity to the building, (fans, pumps, etc.)	16		11	
		kWh/m²yr		173	90	86	
	Appliances (please indicate, but costs are not eligible)						
	electricity	kWh/m²yr	Class A++ or A+ Appliances, LED ligth, Meaqsuring and Behaviour changing solutions	46		33	28
	Food						
		Co2/m²yr	Solutions for lowering food waste and promoting change of diet	67		57	15
	Avoided emissions in society						
		Co2/m²yr	Decreased emisions from waste and water treatment				0
		kWh/m²yr		46	0	33	28
		CO2/m²yr		67	0	57	15
2,2	**RES (building integrated) contribution per m2 of total used conditioned area (kWh / m2 yr)**						
	district heating in Växjö is 95% biomass (=RES) and 5% fossil fuel						
total production kWh/yr	m² installed	kW installed	specify RES measures	Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	RES contribution [%][8]
		kWh/m²yr	Subtotal sum of RES contribution	0	0	0	0

Building Energy Specification Table (BEST)

Community / site	Växjö	Sweden	BEST no.	SE2.1

1,1	Building Category	[1] Kv.Bärnstenen-Växjö, plus prototypes	total area / category / BEST sheet [2]	2045	m^2
1,2	Local Climate		January average outside temperature	°C	-0,9
			August average outside temperature	°C	17,3
	Climatic Zone		Average global horizontal radiation	kWh/m^2 yr	942
	(national definition)	zone 3 - southern Sweden	Annual heating degree days [3]	°Cd/yr	3715
			Room temperature	°C	20

1,3	Maximum requirements of building fabric			Existing building [5]	National regulation-BBR19 (2012)* [6]	suggested specification [7]	Energy savings [%] [8]
	Façade/wall	U	W / m2K	0,36		0,36	
	Roof	U	W / m2K	0,236		0,073	69
	Ground floor	U	W / m2K	0,413		0,413	
	Glazing	U_g	W / m2K	2,50		2,50	
	Average U-value	U_{av}	W / m2K	0,710	0,500		
	Glazing	g	total solar energy transmittance of glazing [%]	76			
	Shading	Fs	Shading correction factor	61			
	Ventilation rate [4]		air changes/hr	0,609		0,609	

2 Building Energy Performance

2,1 Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses

energy carrier existing building	suggested energy carrier		specify energy efficiency measures [13]	Existing building [5]	National regulation-BBR19 (2012)* [6]	suggested specification [7]	% Energy savings [8]
Heating							
district heating	district heating	kWh/m^2yr	Thermal photography, air tightness test and tightning measures , additional insulation of attic joists etc, optimization of heating system, ref. temp in each apartment	157 (total distr.heating)		33	
Ventilation							
district heating	district heating	kWh/m^2yr	Air handling units with supply and exhaust air, and energy recovery			21	
Domestic Hot Water (DHW)							
district heating	district heating	kWh/m^2yr	Water and energy saving taps and showers			21	75 (total distr.heating)
Other energy demand							
electricity	electricity	kWh/m^2yr	Electricity to the building, (fans, pumps, etc.)	16		11	
		kWh/m^2yr		173	90	86	
	Appliances (please indicate, but costs are not eligible)						
	electricity	kWh/m^2yr	Class A++ or A+ Appliances, LED ligth, Meaqsuring and Behaviour changing solutions	46		33	28
	Food						
		$Co2/m^2yr$	Solutions for lowering food waste and promoting change of diet	67		57	15
	Avoided emissions in society						
		$Co2/m^2yr$	Decreased emisions from waste and water treatment				0
		kWh/m^2yr		46	0	33	28
		$CO2/m^2yr$		67	0	57	15

2,2 RES (building integrated) contribution per m2 of total used conditioned area (kWh / m2 yr)

district heating in Växjö is 95% biomass (=RES) and 5% fossil fuel

total production kWh/yr	m^2 installed	kW installed	specify RES measures	Existing building [5]	National regulation-BBR19 (2012)* [6]	suggested specification [7]	RES contribution [%][8]
45000	150	104	Solar collectors to make hot water -PVT	0		22	
19500	-	-	Solar collectors to make electricity - PVT	0		10	
15353	n.a.	n.a.	Waste water heat pump	0		8	
		kWh/m^2yr	Subtotal sum of RES contribution	0	0	39	0

Building Energy Specification Table (BEST)

Building Energy Specification Table (BEST)				Community / site	Växjö	Sweden	BEST no. SE3
1,1	Building Category			total area / category / BEST sheet [2]		3340 m²	
		[1]	Kv. Tvinnaren 4-Växjö				
1,2	Local Climate			January average outside temperature		°C	-0,9
				August average outside temperature		°C	17,3
	Climatic Zone			Average global horizontal radiation		kWh/m² yr	942
	(national definition)		zone 3 - southern Sweden	Annual heating degree days [3]		°Cd/yr	3787
				Room temperature		°C	20
1,3	Maximum requirements of building fabric			Existing building [5]	National regulation-BBR19 (2012)* [6]	suggested specification [7]	Energy savings [%] [8]
	Façade/wall	U	W / m2K	0,35		0,35	
	Roof	U	W / m2K	0,5		0,25	50
	Ground floor	U	W / m2K				
	Glazing	U_g	W / m2K	3,00		1,00	67
	Average U-value	U_{av}	W / m2K				
	Glazing	g	total solar energy transmittance of glazing [%]				
	Shading	Fs	Shading correction factor				
	Ventilation rate [4]		m3/s (max air flow)	4		5,8	55
2	Building Energy Performance						
2,1	Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses						
energy carrier existing	suggested energy carrier		specify energy efficiency measures [13]	Existing building [5]	National regulation-BBR19 (2012)* [6]	suggested specification [7]	% Energy savings [8]
Heating + ventilation + DHW + building electricity							
district heating	district heating	kWh/m²yr	New ventilation unit with heat recovery, mounting of triple glass windows, insulation in roof, installation of combined district heating and cooling central, reduction of water circuits and tuning, waste heat from personnel	93		52	44
Cooling							
electric	district cooling	kWh/m²yr	Conversion to district cooling	10		21	n.a
Lighting							
electric	electric	kWh/m²yr	Exchange of lighting to LED-lighting	21		4	82
Other energy demand							
		kWh/m²yr					
		kWh/m²yr		124	90	77	38
	Appliances (please indicate, but costs are not eligible)						
		kWh/m²yr					
2,2	RES (building integrated) contribution per m2 of total used conditioned area (kWh / m2 yr)						
	district heating in Växjö is 95% biomass (=RES) and 5% fossil fuel						
total production kWh/yr	m² installed	kW installed	specify RES measures	Existing building [5]	National regulation-BBR19 (2012)* [6]	suggested specification [7]	RES contribution [%][8]
91100	561	107,4	PV-system	0		26	100
87100	573	109,7	PV-system (option)	0		27	100
		kWh/m²yr	Subtotal sum of RES contribution	0	0	53	200

Building Energy Specification Table (BEST)						**BEST** no.	SE1 ext
			Community / site	Växjö	Sweden		
1,1	**Building Category**		residential retrofitted	total area / category / BEST sheet [2]		m^2 Gross area	8059
		[1]	Kv.Alabastern-Växjö				
1,2	**Local Climate**			January average outside temperature		°C	-0,9
				August average outside temperature		°C	17,3
	Climatic Zone			Average global horizontal radiation		kWh/m^2 yr	942
	(national definition)		zone 3 - southern Sweden	Annual heating degree days [3]		°Cd/yr	3715
				Room temperature		°C	20
				NEW EXTENTION			
				Kv.Alabastern		**8059**	**SE1 ext**
1,3	**Maximum requirements of building fabric**					**87**	**apt**
				Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	Energy savings [%] [8]
	Façade/wall	U	W / m2K	0,36		0,36	
	Roof	U	W / m2K	0,236		0,073	69
	Ground floor	U	W / m2K	0,413		0,413	
	Glazing	U_g	W / m2K	2,50		0,90	64
	Average U-value	U_{av}	W / m2K	0,710	0,500	0,475	33
	Glazing	g	total solar energy transmittance of glazing [%]	76		46	
	Shading	Fs	Shading correction factor	61		36	
	Ventilation rate [4]		air changes/hr	0,609		0,609	
2	**Building Energy Performance**			Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	% Energy savings [8]
2,1	Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses						
energy carrier existing building	**suggested energy carrier**		specify energy efficiency measures [13]				
Heating				total distr.heating			
district heating	district heating	kWh/m^2yr	Additional insulation of attic joists, Replacement of windows	149		25	
Ventilation							
district heating	district heating	kWh/m^2yr	Air handling units with supply and exhaust air, and energy recovery			21	
Domestic Hot Water (DHW)							total distr.heating
district heating	district heating	kWh/m^2yr	Individual measurement of cold and hot water,			21	55
Other energy demand							
electricity	electricity	kWh/m^2yr	Electricity to the building, (fans, pumps, etc.)	11		8	27
		kWh/m^2yr		160	90	75	53
	Appliances (please indicate, but costs are not eligible)						
	electricity	kWh/m^2yr	Class A++ or A+ Appliances, LED ligth, Meaqsuring and Behaviour changing solutions	46		33	28
		kWh/m^2yr		46	0	33	28
2,2	RES (building integrated) contribution per m2 of total used conditioned area (kWh / m2 yr)						
	district heating in Växjö is 95% biomass (=RES) and 5% fossil fuel						
total production kWh/yr	m^2 installed	kW installed	specify RES measures	Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	RES contribution
		kWh/m^2yr	Subtotal sum of RES contribution	0	0	0	0

Building Energy Specification Table (BEST)						**BEST** no.	SE1.1 ext
			Community / site	Växjö	Sweden		
1,1	**Building Category**		residential retrofitted	total area / category / BEST sheet [2]		m^2 Gross area	1891
		[1]	Kv.Alabastern-Växjö				
1,2	**Local Climate**			January average outside temperature		°C	-0,9
				August average outside temperature		°C	17,3
	Climatic Zone			Average global horizontal radiation		kWh/m^2 yr	942
	(national definition)		zone 3 - southern Sweden	Annual heating degree days [3]		°Cd/yr	3715
				Room temperature		°C	20
							SE1.1ext
				NEW EXTENTION			
				Kv.Alabastern		**1891**	**m2 BTA**
1,3	**Maximum requirements of building fabric**					**18**	**apt**
				Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	Energy savings [%] [8]
	Façade/wall	U	W / m2K	0,36		0,36	
	Roof	U	W / m2K	0,236		0,073	69
	Ground floor	U	W / m2K	0,413		0,413	
	Glazing	U_g	W / m2K	2,50		0,90	64
	Average U-value	U_{av}	W / m2K	0,710	0,500	0,475	33
	Glazing	g	total solar energy transmittance of glazing [%]	76		46	
	Shading	Fs	Shading correction factor	61		36	
	Ventilation rate [4]		air changes/hr	0,609		0,609	
2	**Building Energy Performance**			Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	% Energy savings [8]
2,1	Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses						
energy carrier existing building	**suggested energy carrier**		specify energy efficiency measures [13]				
Heating				total distr.heating			
district heating	district heating	kWh/m^2yr	Additional insulation of attic joists, Replacement of windows	149		25	
Ventilation							
district heating	district heating	kWh/m^2yr	Air handling units with supply and exhaust air, and energy recovery			21	
Domestic Hot Water (DHW)							total distr.heating
district heating	district heating	kWh/m^2yr	Individual measurement of cold and hot water,			21	55
Other energy demand							
electricity	electricity	kWh/m^2yr	Electricity to the building, (fans, pumps, etc.)	11		8	27
		kWh/m^2yr		160	90	75	53
	Appliances (please indicate, but costs are not eligible)						
	electricity	kWh/m^2yr	Class A++ or A+ Appliances, LED ligth, Meaqsuring and Behaviour changing solutions	46		33	28
		kWh/m^2yr		46	0	33	28
2,2	RES (building integrated) contribution per m2 of total used conditioned area (kWh / m2 yr)						
	district heating in Växjö is 95% biomass (=RES) and 5% fossil fuel						
total production kWh/yr	m^2 installed	kW installed	specify RES measures	Existing building [5]	National regulation-BBR19 (2012)* [6]	**suggested** specification [7]	RES contribution [%][8]
45000	150	104	Solar collectors to make hot water -PVT	0		24	
19500	-	-	Solar collectors to make electricity - PVT	0		10	
		kWh/m^2yr	Subtotal sum of RES contribution	0	0	34,1	0