Task 55 Towards the Integration of Large
SHC Systems into DHC Networks

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

IEA SHC FACT SHEET A-D1 / D-D3 combined to 1 Fact Sheet

Subject:	Business Models of Solar Thermal and Hybrid Technologies
Description:	A-D1: Assessment of existing and newly integrated large-scale SDH/SDC D-D3: Identification and Preparation of Best Practice Examples
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Download possible at:	http://task55.iea-shc.org/fact-sheets

Intro

This publication of IEA SHC Task 55 shows 18 best practice examples of Solar District Heating (SDH) systems worldwide. Additional systems are described in the brochure “Solar Heat for Cities”.

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Nahwärme Eibiswald

1. Name of the case study: Nahwärme Eibiswald	
General description, pictures, and schemes	
2. GENERAL INFORMATION	
Location:	Eibiswald, Styria, Austria
Link to project/plant home page, if any:	http://www.nahwaerme-eibiswald.at
Size of the town/district/area:	6 000 inhabitants
Share of town/district/area heat demand covered by DH:	N/A
3. INFORMATION ON DHC NETWORK	
Owner:	Nahwärme Eibiswald
Operator:	Nahwärme Eibiswald
Total heat generation per year from all sources [MWh]	8 800
Supply temperature [°C]:	75-95
Return temperature [°C]:	45-50
Network pressure [bar]:	4.2
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	1997: 1 250 m², flat plate collector (single glazed) 2012: 1 200 m², flat plate collectors (single and double glazed) 2 x biomass boilers (700 kW, 2 300 kW)
Storage size and type (if any) [m^3]:	173.5 (insulated steel tank)
Solar fraction in the DH network on yearly base [%]	~11.5
Solar fraction in the DH network in the highest production month [%]	100
Network length (main pipes) [km]:	10.5
Network density [kWh/y/m]:	838
Thermal loss [kWh/y or %]:	16.9 %
Number of users:	> 600 households
Remarks:	
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Nahwärme Eibiswald

Operator:	Nahwärme Eibiswald
In operation since:	1997
Annual Direct Normal Irradiance [kWh/y/m²]:	~1 120
Plant capacity [kW]:	4 000
Yearly Solar heat production [kWh/y/m^2_{gross}]:	~410
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	~1 070 collectors (Ökotech Gluatmugl, flat plate, double glazed and single glazed with foil)
Mounting (ground, on/in roof, ...)	on roof
Overall gross area [m^2]:	2 450
Hydraulic integration:	Bottom / Top of storage
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture (35 %, Tyfocor L)
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	~3 000
Maximum temperature [°C]:	95
Pressure [bar(a)]:	4
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m^3]:	173.5 (insulated steel tank)
Dedicated pumps (number, type, nominal power, head):	2 x WILO (2.2 kW / 4 kW)
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	~35 €/MWh
Solar system capital costs:	N/A
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	N/A
Primary energy demand of entire DH system [MWh/a]:	N/A

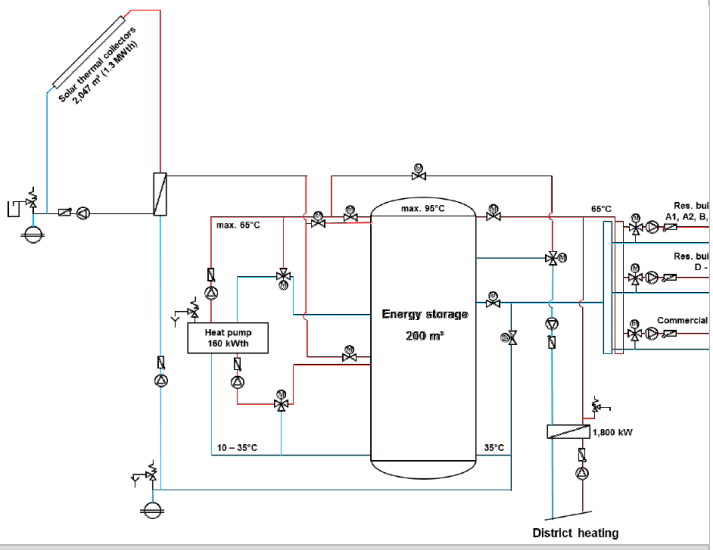
Author:	Werner Doll (S.O.L.I.D. Gesellschaft für Solarinstallation und Design mbH)

Graz – FHW Mitte

1. Name of the case study: Graz – FHW Mitte	
General description, pictures, and schemes	
2. GENERAL INFORMATION	
Location:	Graz, Austria
Link to project/plant home page, if any:	www.solid.at
Size of the town/district/area:	350 000 inhabitants
Share of town/district/area heat demand covered by DH:	35 %
3. INFORMATION ON DHC NETWORK	
Owner:	Energie Steiermark
Operator:	Energie Steiermark
Supply temperature [°C]:	110-130
Return temperature [°C]:	50-70
Network pressure [bar]:	12 bar(a)
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	GuD Mellach (>100 MW, gas + coal) FWZ Puchstraße (430 MW, gas) SAPPI (industrial waste heat, 35 MW) Marienhütte Helios
Storage size (if any) [m^3]:	2 000
Network density [kW/m]:	N/A
Yearly generation [kWh]:	1 200 000 000
Network length [km]:	600
Thermal loss [kWh/a or %]:	N/A
Number of users:	> 100 000
Remarks:	
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Solar.nahwaerme.at
Operator:	SOLID
In operation since:	2007
Plant capacity [kW]:	5 400

Annual Direct Normal Irradiance [kWh/a m²]:	1 127
Solar fraction in the DH network on yearly base (measured):	< 1 %
Solar fraction in the DH network in the highest production month:	~1.85 %
Centralized/Decentralized:	Centralized
Collectors (type, number):	~500 collectors (flat plate, double glazed or foil)
Overall gross area [m^2]:	7 700
Collector efficiency:	55-60 %
Hydraulic integration:	Return to Return Flow
Direct/indirect connection:	Via MX
Type of heat transfer fluid, if indirect connection:	Tyfocor L glycol
Control strategy (supply temperature/preheating)	Preheating of central return flow
Operating hours per year:	N/A
Operating hours in Summer:	~1 200
Maximum temperature [°C]:	95
Pressure [bar(a)]:	4
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Type and size of dedicated storage, if any [m^3]:	N/A
Dedicated pumps (number, type, nominal power, head):	2 x 11 kW, Grundfos CR 64-2
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	35 €/MWh
Overall capital costs:	N/A
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH system [t/a]:	N/A
Primary energy demand of entire DH system [MWh/a]:	N/A
Author:	Werner Doll (S.O.L.I.D. Gesellschaft für Solarinstallation und Design mbH)

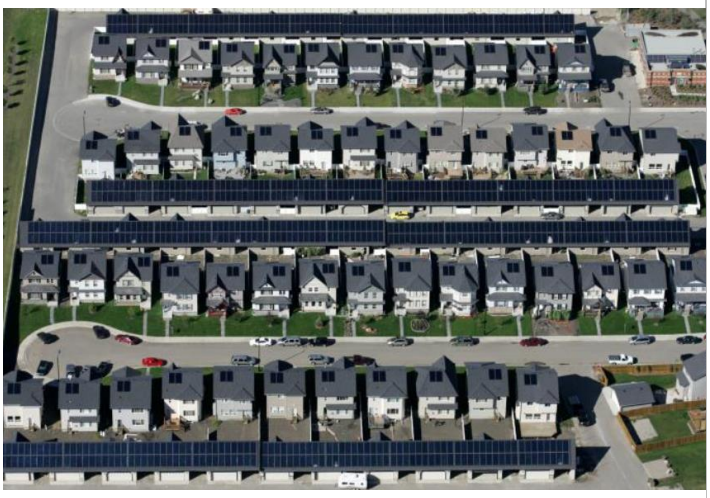
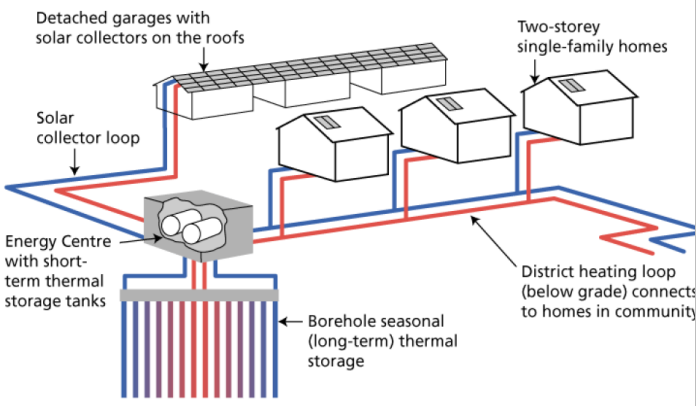
Salzburg-Lehen

1. Name of the case study: Salzburg-Lehen	
General description, pictures, and schemes	The low-temperature network of Lehen receives heat from the main DH network of Salzburg and from a ST system with 2047 m² gross area and including a heat pump and hot-water storage.  
2. GENERAL INFORMATION	
Location:	Salzburg, Austria
Link to project/plant home page, if any:	https://www.salzburg.gv.at/bauenwohnen_/Documents/solarmonitoring_mahler.pdf
Size of the town/district/area:	48 860 m² floor area
Share of town/district/area heat demand covered by DH:	N/A
3. INFORMATION ON DHC NETWORK	
Owner:	N/A
Operator:	Salzburg AG
Total heat generation per year from all sources [MWh]	3 975
Supply temperature [°C]:	60
Return temperature [°C]:	35(-45)
Network pressure [bar]:	N/A
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	Heat transfer station from Salzburg DH network (capacity 1 800 kW), solar thermal (1 300 kW), compression heat pump (thermal capacity 160 kW)

Storage size and type (if any) [m^3]:	200, pressurized steel tank
Solar fraction in the DH network on yearly base [%]	25
Solar fraction in the DH network in the highest-production month [%]	N/A
Trench length (main pipes) [km]:	0.68
Network density [MWh/y/m]:	5.3
Thermal loss [MWh/y or %]:	400 MWh/y
Number of users:	20 buildings
4. INFORMATION ON SOLAR SYSTEM	
Owner:	N/A
Operator:	N/A
In operation since:	2012
Annual Direct Normal Irradiance [kWh/y/m^2]:	N/A
Plant capacity [kW]:	1 300
Yearly Solar heat production [kWh/y/m^2_{gross}]:	483 (533 on aperture)
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	Flat plate
Mounting (ground, on/in roof)	on rooftops
Overall aperture area [m^2]:	1 855
Hydraulic integration:	N/A
Direct/indirect connection to Flow / Return Flow / storage:	Indirect connection (via solar station) from return and storage bottom to storage middle
Control strategy (supply temperature/preheating):	N/A
Operating hours per year:	N/A
Maximum temperature [°C]:	N/A
Pressure [bar(a)]:	N/A
Thermal loss across headers, annual value (or system efficiency: solar power stored/radiation):	N/A
Size and Type of solar thermal dedicated storage, if any [m^3]:	The central storage tank
Dedicated pumps (number, type, nominal power, head):	Pump for solar circuit, pump for storage charge
Hybrid Technologies:	Yes
Specifications on Hybrid Technologies:	Electric heat pump 160 kWth: lower part of storage as source (10-35 °C), upper part of storage as sink (up to 65 °C). Performance factor 4÷5
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …): No technical problems in reducing the temperature or the operation of the network. Flexibility, Need for modernization, profitability through promotion, energetic quarter concept.	
5. ECONOMIC PARAMETERS	

Heat generation costs (Solar system, without subsidies):	N/A
Solar system capital costs:	~1 M€ including planning (650 k€ for collectors collectors) + 150 k€ storage + 330 k€ others + 180 k€ DH network
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	~75 kg/MWh → 298 t/a
Primary energy demand of entire DH system [MWh/a]:	~1 700 (factor ~0.43)
Author:	Paolo Leoni (AIT Austrian Institute of Technology GmbH)

Drake Landing Solar Community

1. Name of the case study: Drake Landing Solar Community	
General description, pictures, and hydraulic scheme	 
2. GENERAL INFORMATION	
Location (longitude and latitude):	Okotoks, Alberta, Canada (113.95 W, 50.73 N)
Link to project/plant home page, if any:	http://www.dlsc.ca
Size of the town/district/area:	Okotoks has about 29 000 inhabitants, DLSC covers a community of 52 houses and approximately 160 inhabitants
Share of town/district/area heat demand covered by DH:	N/A
3. INFORMATION ON DHC NETWORK	
Owner:	Drake Landing Company
Operator:	ATCO
Total heat generation per year from all sources [MWh]	695
Supply temperature [°C]:	37-55
Return temperature [°C]:	28-32 – differential pressure controlled
Network pressure [bar]:	N/A
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	2007: 2 293 m² (gross), flat plate collector (single glazed), 2 x natural gas boilers (352 kW, 469 kW) 2012: Modulating natural gas boiler 112 kW max.

Storage size and type (if any) [m^3]:	Seasonal Borehole Thermal Energy Storage – 144 boreholes, 35 m deep, 35 m diameter field, insulated at the top
Solar fraction in the DH network on yearly base [%]	~90
Solar fraction in the DH network in the highest production month [%]	100
Network length (main pipes) [km]:	1.6
Network density [kWh/y/m]:	434
Thermal loss [kWh/y or %]:	18 %
Number of users:	52 households
Remarks:	5th Generation network operating at low supply and return temperatures (typically 37 °C/28 °C). DHC does not support DHW loads, only space heating loads.
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Drake Landing Company
Operator:	ATCO
In operation since:	2007
Annual Total Irradiance on tilted / horizontal surface [kWh/y/m^2]:	1 284/1 544
Annual Direct Normal Irradiance [kWh/y/m^2]:	~1 700
Plant capacity [kW]:	1 605
Yearly Solar heat production [kWh/y/m^2_{gross}]:	~520
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	~798 collectors (Enerworks, flat plate, single glazed)
Mounting (ground, on/in roof, ...)	on garage roofs
Slope and orientation of collectors	45° South
Overall gross area [m^2]:	2 293
Hydraulic integration:	Bottom / Top of storage
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture (50 %, Tyfocor L)
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	~2 500
Maximum temperature [°C]:	95
Pressure [bar(a)]:	2
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	34 %
Size and Type of solar thermal dedicated storage, if any [m^3]:	2 x 120 (insulated steel tank, piped in series)
Dedicated pumps (number, type, nominal power, head):	Glycol - G&L Goulds 7.5 kW (15.8 l/s at 28.5 m) and Water - Bell & Gossett 2.2 kW (14.2 l/s at 10.2 m)

Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	Occasional collector repair due to glass breakage, usual pump and controls maintenance for mechanical systems
Others (lesson learned, recommendations, remarks, …): Use of unique components such as expansion bellows between collectors make future maintenance difficult as parts are not no longer available. With limited progress in local solar thermal market, finding trained local labour for solar collectors maintenance can be challenging.	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	N/A
Solar system capital costs:	N/A
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	~14 t for NG + ~12 t for electricity (~40 MWh/a total – 20 MWh/a PV onsite production, 0.6 t/MWh intensity)
Primary energy demand of entire DH system [MWh/a]:	N/A
Author:	Lucio Mesquita (Natural Resources Canada)

Langkazi

1. Name of the case study: Langkazi	
General description, pictures, and hydraulic scheme	
2. GENERAL INFORMATION	
Location (longitude and latitude):	Langkazi County, Shannan City, Tibet. 90.404505,28.974307
Link to project/plant home page, if any:	-
Size of the town/district/area:	82 600 m² (heating area)
Share of town/district/area heat demand covered by DH:	N/A
3. INFORMATION ON DHC NETWORK	
Owner:	Langkazi County Government
Operator:	Tibet Sunrise Energy Management Company
Total heat generation per year from all sources [MWh]	14 700
Supply temperature [°C]:	50 - 65
Return temperature [°C]:	35 - 40
Network pressure [bar]:	2.5 ~ 4.5
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	Solar thermal plant, Aperture area: 22 275 m^2 , Average efficiency: 49%
Storage size and type (if any) [m^3]:	15 000 m^3 (Pit storage)
Solar fraction in the DH network on yearly base [%]	>90
Solar fraction in the DH network in the highest production month [%]	100
Network length (main pipes) [km]:	10
Network density [kWh/y/m]:	-
Thermal loss [kWh/y or %]:	-
Number of users:	>1 000 households
Remarks:	DH network supplies only space heating
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Longjia County Government
Operator:	Tibet Sunrise Energy Management Company

In operation since:	2018
Annual Total Irradiance on tilted / horizontal surface [kWh/y/m²]:	2 135 (40° tilted surface)
Annual Direct Normal Irradiance [kWh/y/m²]:	~1930
Plant capacity [kW]:	17 500
Yearly Solar heat production [kWh/y/m^2_{gross}]:	14 920
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	1 620 collectors (Arcon-sunmark)
Mounting (ground, on/in roof, ..)	Ground
Slope and orientation of collectors	40° south
Overall gross area [m^2]:	24 300
Hydraulic integration:	Bottom / Top of storage
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture (40%)
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	~ 5 880
Maximum temperature [°C]:	83
Pressure [bar(a)]:	-
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	NA
Size and Type of solar thermal dedicated storage, if any [m^3]:	15 000 m^3 (Pit storage)
Dedicated pumps (number, type, nominal power, head):	2 x Grundfos (160 kW)
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	~35 €/MWh
Solar system capital costs:	N/A
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	0
Primary energy demand of entire DH system [MWh/a]:	N/A

Author:	Chenhui Jia (Jiangsu Sunrain solar Energy Co.; Ltd.)

Brønderslev

1. Name of the case study: 16.6 MW_{th} combined heat and power CSP generation in Brønderslev, DK	
General description, pictures, and schemes	
2. GENERAL INFORMATION	
Location:	Brønderslev, Denmark
Link to project/plant home page, if any:	https://www.aalborgcsp.com/projects/166mwth-csp-for-combined-heat-and-power-generation-denmark/
Size of the town/district/area:	12 598 inhabitants
Share of town/district/area heat demand covered by DH:	More than 95 %
3. INFORMATION ON DHC NETWORK	
Owner:	Brønderslev Forsyning A/S
Operator:	Brønderslev Forsyning A/S
Total heat generation per year from all sources [MWh]	N/A
Supply temperature [°C]:	80
Return temperature [°C]:	40
Network pressure [bar]:	7
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	2 x 10 MW_{th} Biomass Boilers (Wood Chips) 15 MW_{th} Organic Rankine Cycle (ORC) Turbine Condenser 2 MW_{th} Waste Heat Recovery Heat Pump 16.6th Concentrated Solar Power Solar Field Natural Gas Engines/Boilers (pre-existing)
Storage size and type (if any) [m^3]:	4 000 m^3 Steel accumulation tank (unpressurized)
Solar fraction in the DH network on yearly base [%]	N/A
Solar fraction in the DH network in the highest production month [%]	100
Network length (main pipes) [km]:	N/A
Network density [kWh/y/m]:	N/A
Thermal loss [kWh/y or %]:	N/A
Number of users:	4 500 households
Remarks:	

4. INFORMATION ON SOLAR SYSTEM	
Owner:	Brønderslev Forsyning A/S
Operator:	Brønderslev Forsyning A/S
In operation since:	December 2016
Annual Direct Normal Irradiance [kWh/y/m²]:	1 190
Plant capacity [kW]:	16 600
Yearly Solar heat production [kWh/y/m^2_{gross}]:	474
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	400 AAL-Trough™ 3 Trough Modules
Mounting (ground, on/in roof, ..)	On ground
Overall aperture area [m²]:	26 920
Hydraulic integration:	Bottom / Top of storage
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Heat Transfer Oil (Therminol 66)
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	2 450
Maximum temperature [°C]:	330
Pressure [bar(a)]:	17
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m^3]:	N/A
Dedicated pumps (number, type, nominal power, head):	2 x KSB (132 kW) (169 m) 1 x DESMI (55 kW) (45 m)
Hybrid Technologies:	Concentrated Solar Power, Biomass, Organic Rankine Cycle, Heat Pumps
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	260 DKK/MWh_{th}
Solar system capital costs:	N/A
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	

Annual CO2 emissions of entire DH System [t/a]:	N/A
Primary energy demand of entire DH system [MWh/a]:	N/A
Author:	Andreas Zourellis (Aalborg CSP A/S)

Dronninglund Fjernvarme

1. Name of the case study: Dronninglund Fjernvarme	
General description, pictures, and hydraulic scheme	
2. GENERAL INFORMATION	
Location (longitude and latitude):	Dronninglund, Denmark, 57°10’ N, 10°15’ E
Link to project/plant home page, if any:	https://www.dronninglundfjernvarme.dk/
Size of the town:	3 427 inhabitants (2019)
Share of town/district/area heat demand covered by DH:	~100 %
3. INFORMATION ON DHC NETWORK	
Owner:	Dronninglund Fjernvarme
Operator:	Dronninglund Fjernvarme
Total heat generation per year from all sources [MWh]	~40 000
Supply temperature [°C]:	73
Return temperature [°C]:	34
Network pressure [bar]:	2.5-4.0
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	1973: 2 oil burners (6 and 10 MW) + heat pump 1990: 4 gas engines (3.5 MW electricity, 6.0 MW heat), water tank storage 865 m^3 2008: gas boiler (8 MW) 2014: 2 982 solar collectors (26 MW), water pit storage 60 000 m^3 https://www.dronninglundfjernvarme.dk/profil/om-os/
Storage size and type (if any) [m^3]:	60 000 (water pit storage)
Solar fraction in the DH network on yearly base [%]	~46 (18 550 MWh / 40 000 MWh) (www.solvarmedata.dk, 2018)
Solar fraction in the DH network in the highest production month [%]	100

Network length (main pipes) [km]:	46
Network density [kWh/y/m]:	870 (40 000 000 kWh / 46 000 m)
Thermal loss [kWh/y or %]:	~23 %
Number of users:	~1 350
Remarks:	
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Dronninglund Fjernvarme
Operator:	Dronninglund Fjernvarme
In operation since:	Solar field: 2014
Annual Total Irradiance on tilted / horizontal surface [kWh/y/m²]:	~1 245 (www.solvarmedata.dk, 2018)
Annual Direct Normal Irradiance [kWh/y/m²]:	N/A
Plant capacity [MW]:	Solar collector field: 26 MW (~37 573 m² x 0.7) https://www.dronninglundfjernvarme.dk/profil/om-os/
Yearly Solar heat production [kWh/y/m^2_{gross}]:	384 (www.solvarmedata.dk, 2018)
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	Flat-plate collectors, Arcon-Sunmark, 2 982 collectors
Mounting (ground, on/in roof, …)	ground
Slope and orientation of collectors	Tilt 35°, south
Overall collector aperture area [m^2]:	37 573
Overall collector gross area [m^2]:	40 466
Hydraulic integration:	Bottom / Top of storage
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	~3 000
Maximum temperature [°C]:	95
Pressure [bar(a)]:	N/A
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m^3]:	60 000 (water pit storage)
Dedicated pumps (number, type, nominal power, head):	N/A
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	

5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	~1 €/MWh (~7.5 kr/MWh) incl. O&M
Solar system capital costs:	87 mio Dkr (www.solvarmedata.dk)
Solar system O&M costs per year:	Included in heat generation costs above
6. ENVIRONMENTAL PARAMETERS	
Annual savings of CO2 emissions due to solar system [t/a]:	4 100 (www.solvarmedata.dk)
Author:	Jan Erik Nielsen (PlanEnergi)

Halskov

1. Name of the case study: 8 MW_{th} solar district heating in Korsør, Denmark	
General description, pictures, and schemes	
2. GENERAL INFORMATION	
Location:	Halskov (near Korsør), Denmark
Link to project/plant home page, if any:	N/A, will be available on www.aalborgcsp.com in mid April 2019
Size of the town/district/area:	7 498 inhabitants (Halskov); 14 583 inhabitants (Korsør)
Share of town/district/area heat demand covered by DH:	N/A
3. INFORMATION ON DHC NETWORK	
Owner:	SK Varme A/S (part of SK Forsyning)
Operator:	SK Varme A/S (part of SK Forsyning)
Total heat generation per year from all sources [MWh]	N/A MWh (Total Consumption), 6 000 MWh (Solar share)
Supply temperature [°C]:	68-73
Return temperature [°C]:	41-47
Network pressure [bar]:	7.6
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	2018: Biomass boiler 11.5 MW_{th} 2019: 11 733 m^2, flat plate collector (double glazed)
Storage size and type (if any) [m^3]:	7 000 m^3
Solar fraction in the DH network on yearly base [%]	N/A
Solar fraction in the DH network in the highest production month [%]	100
Network length (main pipes) [km]:	N/A
Network density [kWh/y/m]:	N/A
Thermal loss [kWh/y or %]:	N/A
Number of users:	5 500 households
Remarks:	
4. INFORMATION ON SOLAR SYSTEM	
Owner:	SK Varme A/S (part of SK Forsyning)
Operator:	SK Varme A/S (part of SK Forsyning)

In operation since:	Under construction (expected operation June 2019)
Annual Direct Normal Irradiance [kWh/y/m²]:	1 125
Plant capacity [kW]:	8 000 (kW)
Yearly Solar heat production [kWh/y/m^2_{gross}]:	511
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	GREENoneTEC GK3003 series, double glazed. 63 rows with up to 38 collectors per row. In total, 1 018 collectors.
Mounting (ground, on/in roof, ..)	On ground
Overall gross area [m²]:	13 407 m^2
Hydraulic integration:	Bottom / Top of storage
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture (30 %, Tyfocor L)
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	2 260
Maximum temperature [°C]:	95
Pressure [bar(a)]:	7.6
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m^3]:	N/A
Dedicated pumps (number, type, nominal power, head):	2 x DESMI (75 kW/18.5 kW)
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	N/A
Solar system capital costs:	N/A
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	1 300 t/a, CO_2 savings
Primary energy demand of entire DH system [MWh/a]:	N/A

Author:	Andreas Zourellis (Aalborg CSP A/S)

Løgumkloster Fjernvarme

1. Name of the case study: Løgumkloster Fjernvarme	
General description, pictures, and hydraulic scheme	
2. GENERAL INFORMATION	
Location (longitude and latitude):	Løgumkloster Denmark
Link to project/plant home page, if any:	http://www.lgkfjernvarme.dk
Size of the town/district/area:	1 543 consumers
Share of town/district/area heat demand covered by DH:	N/A
3. INFORMATION ON DHC NETWORK	
Owner:	Løgumkloster Fjernvarme
Operator:	Løgumkloster Fjernvarme
Total heat generation per year from all sources [MWh]	35 000
Supply temperature [°C]:	70
Return temperature [°C]:	35 in wintertime and 40 in summertime
Network pressure [bar]:	2-3
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	2014: 2 250 m², flat plate collector (single glazed and cupper) 2014: 7 500 m², flat plate collectors (single glazed and alu) 2015: 5 000 m², flat plate collectors (single glazed and alu version 2) 1 x biomass boiler (3 MW), 1 x gasboiler (12 MW), 2 gasengines (each 3 MWel and 3.7 MW heat), 1 x heatpump (1.4 MW), 1 x absorptionheatpump (3 MW)
Storage size and type (if any) [m³]:	1 x 2 100 and 1 x 5 400 (insulated steel tank)
Solar fraction in the DH network on yearly base [%]	~22
Solar fraction in the DH network in the highest production month [%]	100
Network length (main pipes) [km]:	32.5
Network density [kWh/y/m]:	N/A
Thermal loss [kWh/y or %]:	19 %

Number of users:	> 1 543 households
Remarks:	
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Løgumkloster Fjernvarme
Operator:	Løgumkloster Fjernvarme/savosolar
In operation since:	2014
Annual Total Irradiance on tilted / horizontal surface [kWh/y/m²]:	N/A
Annual Direct Normal Irradiance [kWh/y/m²]:	N/A
Plant capacity [kW]:	8 300
Yearly Solar heat production [kWh/y/m^2_{gross}]:	~410
Centralized/Decentralized:	decentralized
Collectors (type, manufacturer, number):	~1 070 collectors (Savosolar, flat plate, single glazed without foil)
Mounting (ground, on/in roof, ...)	ground
Slope and orientation of collectors	South
Overall gross area [m²]:	15 500
Hydraulic integration:	Bottom / Top of storage
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture (30 %, Coracon sol 5f-12)
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	N/A
Maximum temperature [°C]:	95
Pressure [bar(a)]:	2
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m³]:	2 100 + 5 400 (insulated steel tank)
Dedicated pumps (number, type, nominal power, head):	N/A
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	N/A
Solar system capital costs:	N/A
Solar system O&M costs per year:	N/A

6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	N/A
Primary energy demand of entire DH system [MWh/a]:	N/A
Author:	Morten Hofmeister (Savosolar Oyj)

Silkeborg Fjernvarme

1. Name of the case study: Silkeborg Fjernvarme	
General description, pictures, and hydraulic scheme	 Video (In Danish): https://vimeo.com/293123383 https://vimeo.com/290217025
2. GENERAL INFORMATION	
Location (longitude and latitude):	Silkeborg, Denmark, 56°12'30'' N, 9°32'50'' E
Link to project/plant home page, if any:	https://www.silkeborgforsyning.dk
Size of the town:	46 179 inhabitants (2019)
Share of town/district/area heat demand covered by DH:	~100 %
3. INFORMATION ON DHC NETWORK	
Owner:	Silkeborg Forsyning
Operator:	Silkeborg Forsyning
Total heat generation per year from all sources [MWh]	All sources: ~400 000 Solar system: ~80 000
Supply temperature [°C]:	63-80
Return temperature [°C]:	35-45
Network pressure [bar]:	max. 6.5
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	1995: Combined heat and power, gas (108 MW electricity, 175 MW heat) 2015: Electrical boiler (30 MW) 2016: Solar field (110 MW, 12 436 solar collectors) Back-up: 1953 - 1983: 4 gas boilers + 4 oil burners 63 MW 1964 - 2013: 2 gas boilers + 5 oil burners 93 MW 1986: 2 gas boilers 7 MW
Storage size and type (if any) [m^3]:	4 x 16 000 (water tanks)
Solar fraction in the DH network on yearly base [%]	~20 % (80 000 MWh / 400 000 MWh) (www.solvarmedata.dk)
Solar fraction in the DH network in the highest production month [%]	100 %
Network length (main pipes) [km]:	600 km
Network density [kWh/y/m]:	670 (400 000 000 kWh / 600 000 m)
Thermal loss [kWh/y or %]:	~ 18 %
Number of users:	~ 13 000 users
Remarks:	

4. INFORMATION ON SOLAR SYSTEM	
Owner:	Silkeborg Forsyning
Operator:	Silkeborg Forsyning
In operation since:	Solar field: 2016
Annual Total Irradiance on tilted / horizontal surface [kWh/y/m²]:	~1 314 (www.solvarmedata.dk, 2018)
Annual Direct Normal Irradiance [kWh/y/m²]:	N/A
Plant capacity [MW]:	110 MW (~ 156 694 m² x 0.7)
Yearly Solar heat production [kWh/y/m²]:	kWh/y/m²$_{aperture}$: 512 (www.solvarmedata.dk, 2018) kWh/y/m²$_{gross}$: 476
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	Flat-plate collectors, Arcon-Sunmark
Mounting (ground, on/in roof, ...)	ground
Slope and orientation of collectors	Tilt 35°, south
Overall collector aperture area [m²]:	156 694
Overall collector gross area [m²]:	168 760
Hydraulic integration:	Via heat exchanger
Direct/indirect connection to Flow / Return Flow / storage:	-
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	~3 000
Maximum temperature [°C]:	95
Pressure [bar(a)]:	N/A
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m³]:	4 x 16 000 (water tanks)
Dedicated pumps (number, type, nominal power, head):	N/A
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	~2-3 €/MWh (~ 15-20 kr/MWh) incl. O&M
Solar system capital costs:	250 mio Dkr (www.solvarmedata.dk)
Solar system O&M costs per year:	Included in heat generation costs above

6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	N/A
Primary energy demand of entire DH system [MWh/a]:	N/A
Annual savings of CO2 emissions due to solar system [t/a]:	15 000 (www.solvarmedata.dk)
Author:	Jan Erik Nielsen (PlanEnergi)

Smørum

1. Name of the case study: 8MW$_{th}$ solar district heating plant in Smørum, Denmark	
General description, pictures, and schemes	
2. GENERAL INFORMATION	
Location:	Smørum, Denmark
Link to project/plant home page, if any:	https://www.aalborgcsp.com/projects/8mwth-solar-district-heating-plant-in-smoerum-denmark/
Size of the town/district/area:	19 816 inhabitants
Share of town/district/area heat demand covered by DH:	N/A PAS
3. INFORMATION ON DHC NETWORK	
Owner:	Smørum Kraftvarme A.m.b.A
Operator:	Smørum Kraftvarme A.m.b.A
Total heat generation per year from all sources [MWh]	47 000 MWh (Total Consumption), 5 568 MWh (Solar)
Supply temperature [°C]:	70 - 80
Return temperature [°C]:	45 - 50
Network pressure [bar]:	7
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	N-Gas Engines & N-Gas Boilers 11 312 m², flat plate collector (single and double glazed)
Storage size and type (if any) [m^3]:	2 x 1 100 m^3 Steel Accumulation Tanks (unpressurized)
Solar fraction in the DH network on yearly base [%]	12
Solar fraction in the DH network in the highest production month [%]	100
Network length (main pipes) [km]:	N/A
Network density [kWh/y/m]:	N/A
Thermal loss [kWh/y or %]:	N/A
Number of users:	2 583 households
Remarks:	
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Smørum Kraftvarme A.m.b.A
Operator:	Smørum Kraftvarme A.m.b.A

In operation since:	March 2018
Annual Direct Normal Irradiance [kWh/y/m²]:	1 095
Plant capacity [kW]:	8 000
Yearly Solar heat production [kWh/y/m^2_{gross}]:	493
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	GREENoneTEC GK3003 series, single and double glazed. 59 rows with up to 20 collectors in one row.
Mounting (ground, on/in roof, ..)	On ground
Overall gross area [m^2]:	11 312 m^2
Hydraulic integration:	Bottom / Top of storage
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture (30 %, Tyfocor L)
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	2 100
Maximum temperature [°C]:	95
Pressure [bar(a)]:	6
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m^3]:	N/A
Dedicated pumps (number, type, nominal power, head):	2 x DESMI (30 kW/ 18,5) (4.3 bar/ 2.76)
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	N/A
Solar system capital costs:	N/A
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	1 100 t/a, CO_2 savings
Primary energy demand of entire DH system [MWh/a]:	N/A
Author:	Andreas Zourellis (Aalborg CSP A/S)

Havdrup, Solrød Fjernvarme

1. Name of the case study: 1.9MW$_{th}$ solar district heating plant in Havdrup, Denmark	
General description, pictures, and schemes	
2. GENERAL INFORMATION	
Location:	Havdrup, Solrød, Denmark
Link to project/plant home page, if any:	https://www.aalborgcsp.com/projects/19mwth-solar-district-heating-plant-denmark/
Size of the town/district/area:	4 236 inhabitants
Share of town/district/area heat demand covered by DH:	Less than 50 %. The old part of the town is not connected to the DH grid.
3. INFORMATION ON DHC NETWORK	
Owner:	Solrød Fjernvarme A.m.b.A
Operator:	Solrød Fjernvarme A.m.b.A
Total heat generation per year from all sources [MWh]	4 300
Supply temperature [°C]:	70 – 75
Return temperature [°C]:	45 – 52
Network pressure [bar]:	2.5
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	Natural Gas Boilers
Storage size and type (if any) [m^3]:	200 m^3 pressurized accumulation tank
Solar fraction in the DH network on yearly base [%]	28.5
Solar fraction in the DH network in the highest production month [%]	100 (Up to 4 months uninterrupted operation from May to September)
Network length (main pipes) [km]:	N/A
Network density [kWh/y/m]:	N/A
Thermal loss [kWh/y or %]:	N/A
Number of users:	350 households
Remarks:	
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Solrød Fjernvarme A.m.b.A
Operator:	Solrød Fjernvarme A.m.b.A

In operation since:	March 2017
Annual Direct Normal Irradiance [kWh/y/m²]:	1 095
Plant capacity [kW]:	1 852 kW_{th}
Yearly Solar heat production [kWh/y/$m^2_{aperture}$]:	478
Centralized/Decentralized:	Decentralized
Collectors (type, manufacturer, number):	GREENoneTEC GK3003 series, single and double glazed. 13 rows with up to 20 collectors in a row.
Mounting (ground, on/in roof, ..)	On ground
Overall gross area [m^2]:	2 569
Hydraulic integration:	Bottom / Middle / Top of storage
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture (30 %, Tyfocor L)
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	1 950
Maximum temperature [°C]:	95
Pressure [bar(a)]:	6
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m^3]:	1 250 m^3 accumulation tank
Dedicated pumps (number, type, nominal power, head):	2 x DESMI (11 kW/ 3 kW) (4 bar/ 2,5 bar)
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	None
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	N/A
Solar system capital costs:	N/A
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	130 t/a, CO_2 savings
Primary energy demand of entire DH system [MWh/a]:	N/A
Author:	Andreas Zourellis (Aalborg CSP A/S)

Stenløse, Egedal Fjernvarme

1. Name of the case study: 2.6MW$_{th}$ solar district heating plant in Egedal, Denmark	
General description, pictures, and schemes	
2. GENERAL INFORMATION	
Location:	Stenløse, Egedal, Denmark
Link to project/plant home page, if any:	https://www.aalborgcsp.com/projects/26mwth-solar-district-heating-plant-denmark/
Size of the town/district/area:	5 770 inhabitants (Stenløse)
Share of town/district/area heat demand covered by DH:	Approx. 50%
3. INFORMATION ON DHC NETWORK	
Owner:	Egedal Fjernvarme A/S
Operator:	Egedal Fjernvarme A/S
Total heat generation per year from all sources [MWh]	7 125 MWh (Total Consumption) – 1 640 MWh (Solar share)
Supply temperature [°C]:	50-80
Return temperature [°C]:	38-40
Network pressure [bar]:	3.5
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	11 733 m², flat plate collector (double glazed)
Storage size and type (if any) [m^3]:	2 400
Solar fraction in the DH network on yearly base [%]	23.1
Solar fraction in the DH network in the highest production month [%]	100
Network length (main pipes) [km]:	N/A
Network density [kWh/y/m]:	N/A
Thermal loss [kWh/y or %]:	N/A
Number of users:	875 households
Remarks:	
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Egedal Fjernvarme A/S
Operator:	Egedal Fjernvarme A/S

In operation since:	Under construction (expected operation June 2019)
Annual Direct Normal Irradiance [kWh/y/m²]:	1 095
Plant capacity [kW]:	2 600 kW
Yearly Solar heat production [kWh/y/$m^2_{aperture}$]:	476 kWh/ m^2
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	GREENoneTEC GK3003 series, double glazed. 34 rows with up to 10 collectors per row. In total, 280 collectors.
Mounting (ground, on/in roof, ..)	On ground
Overall gross area [m^2]:	3 458 m^2
Hydraulic integration:	Bottom / Middle / Top of storage
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture (30%, Tyfocor L)
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	2 100
Maximum temperature [°C]:	95
Pressure [bar(a)]:	3.5
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m^3]:	Accumulation tank with a capacity of 2 400 m^3 (existing)
Dedicated pumps (number, type, nominal power, head):	2 x DESMI (15 kW/ 5.5 kW)
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	N/A
Solar system capital costs:	N/A
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	N/A
Primary energy demand of entire DH system [MWh/a]:	N/A

Author:	Andreas Zourellis (Aalborg CSP A/S)

Hybrid solar district heating in the city of Taars

1. Name of the case study: Hybrid solar district heating in the city of Taars, DK	
General description, pictures, and schemes	
2. GENERAL INFORMATION	
Location:	Taars, Denmark
Link to project/plant home page, if any:	https://www.aalborgcsp.com/projects/68mwth-solar-district-heating-system-in-taars-denmark/
Size of the town/district/area:	1 895 inhabitants
Share of town/district/area heat demand covered by DH:	More than 95 %
3. INFORMATION ON DHC NETWORK	
Owner:	Taars Varmeværk A.m.b.A
Operator:	Taars Varmeværk A.m.b.A
Total heat generation per year from all sources [MWh]	20 273 MWh
Supply temperature [°C]:	68 - 78
Return temperature [°C]:	38
Network pressure [bar]:	6
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	Solar Thermal 6.8 MW_{th} (5 960 m^2, flat plate collector 4 040 m^2, Parabolic trough) N-Gas CHP (5.2 MW_{th}, 5.0 MW_{el}), 2 N-Gas Boilers (6.0 MW_{th} and 2.9 MW_{th})
Storage size and type (if any) [m^3]:	Two existing (unpressurized) storage tanks with a total of 2 430 m^3
Solar fraction in the DH network on yearly base [%]	31 (based on heat generated resp. final DH output)
Solar fraction in the DH network in the highest production month [%]	100
Network length (main pipes) [km]:	13
Network density [kWh/y/m]:	N/A
Thermal loss [kWh/y or %]:	23.6 %
Number of users:	850 households
Remarks:	

4. INFORMATION ON SOLAR SYSTEM	
Owner:	Taars Varmeværk A.m.b.A
Operator:	Taars Varmeværk A.m.b.A
In operation since:	August 2015
Annual Direct Normal Irradiance [kWh/y/m²]:	1 190
Plant capacity [kW]:	4 500 kW (FPC) 2 300 kW (PTC) 6 800 kW
Yearly Solar heat production [kWh/y/m²$_{aperture}$]:	6 082 MWh (FPC: 3 970 MWh, PTC: 2 112 MWh) (FPC: 660 kWh/ (m² $_{aperture}$)) - (PTC: 523 kWh/ (m² $_{aperture}$))
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	The flat plate collector field consists of two types of collectors (in total 473 panels), both from Arcon-Sunmark. First half of the field is equipped with collectors optimized for lower temperatures, while the second half is equipped with advanced flat plate collectors with reduced thermal (convection) losses for higher temperatures. For even higher output temperatures of up to 95 °C the parabolic through collector field is serial connected to the flat plate collector field. This field consists of 60 modules of parabolic troughs delivered by Aalborg CSP A/S.
Mounting (ground, on/in roof, ..)	on ground
Overall gross area [m²]:	10 011
Hydraulic integration:	Bottom / Top of storage
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture (35 %, Tyfocor L)
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	2 300
Maximum temperature [°C]:	98
Pressure [bar(a)]:	6
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m³]:	Two existing (unpressurized) storage tanks with a total of 2 430 m³
Dedicated pumps (number, type, nominal power, head):	3 x Grundfos (7.5 kW/1.5 kW/11 kW) (15 m /5 m /22 m)
Hybrid Technologies:	Flat Plate Collectors and Parabolic Trough Collectors (CSP)
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	Renewal of lubrication oil in parabolic trough drive unit (annually)
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	248 DKK/MWh – 25 years lifetime
Solar system capital costs:	N/A

Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	1 300 t/a CO_2 savings
Primary energy demand of entire DH system [MWh/a]:	N/A
Author:	Andreas Zourellis (Aalborg CSP A/S)

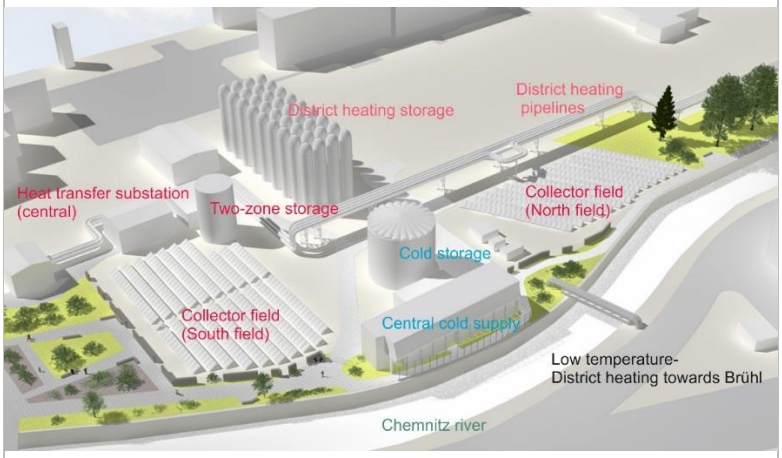
Chateaubriant

1. Name of the case study: Chateaubriant (FR)	
General description, pictures, and hydraulic scheme	
2. GENERAL INFORMATION	
Location (longitude and latitude):	Châteaubriant, FRANCE (47.718764, -1.388666)
Link to project/plant home page, if any:	http://www.mairie-chateaubriant.fr/la-centrale-solaire-thermique/
Size of the town/district/area:	12 000 inhabitants
Share of town/district/area heat demand covered by DH	N/A
3. INFORMATION ON DHC NETWORK	
Owner:	City of Chateaubriant
Operator:	ENGIE
Total heat generation per year from all sources [MWh]	19 122 (2017)
Supply temperature [°C]:	95
Return temperature [°C]:	75
Network pressure [bar]:	4.2
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	2018 : 2 400 m² solar plant (1.4 MW) 2017 : 2 MW gas cogeneration 2011 : 2 x 3 MW gas boiler, 3 MW biomass boiler
Storage size and type (if any) [m³]:	150 (insulated steel tank)
Solar fraction in the DH network on yearly base [%]	~3 %
Solar fraction in the DH network in the highest production month [%]	N/A
Network length (main pipes) [km]:	10
Network density [kWh/y/m]:	N/A
Thermal loss [kWh/y or %]:	18 %
Number of users:	42 substations (schools, hospital, social collectiv dwellings, swimming pool, …)
Remarks:	

4. INFORMATION ON SOLAR SYSTEM	
Owner:	City of Chateaubriant
Operator:	ENGIE
In operation since:	2018
Annual Total Irradiance on tilted / horizontal surface [kWh/y/m²]:	1 367
Annual Direct Normal Irradiance [kWh/y/m²]:	N/A
Plant capacity [kW]:	1 400
Yearly Solar heat production [kWh/y/m^2_{gross}]:	362
Centralized/Decentralized:	Decentralized
Collectors (type, manufacturer, number):	200 collectors (EKLOR/KBB K5Giga + single glazed with foil)
Mounting (ground, on/in roof, ..)	ground
Slope and orientation of collectors	South, 30°/hz
Overall gross area [m^2]:	2 484
Hydraulic integration:	Direct or via a storage
Direct/indirect connection to Flow / Return Flow / storage:	Return/return
Type and concentration of heat transfer fluid, if indirect connection:	Biosource MPG 30 %
Control strategy (supply temperature/preheating)	Fixed flow, preheating of the DH return northern branch
Operating hours per year:	N/A
Maximum temperature [°C]:	105
Pressure [bar(a)]:	1.5 (max. 6)
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m^3]:	150 (insulated steel tank)
Dedicated pumps (number, type, nominal power, head):	1 primary pump, 1 secondary pump for direct charging or discharging the storage
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …): The integration of the plant into the DH would have been better if a third pump had been installed to store/destore or make the direct injection at the same time	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	N/A
Solar system capital costs:	1.4 M€ i.e. approx.
Solar system O&M costs per year:	10 k€/year

Additional economic parameters:	70 % subsidies No land cost The collectors (without installation) represent 30% of the total investment cost
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	N/A
Primary energy demand of entire DH system [MWh/a]:	N/A
Author:	Nicolas Lamaison (CEA Ines)

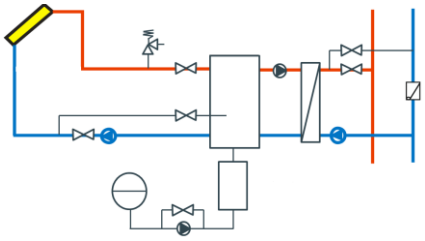
Brühl solar district heating in Chemnitz

1. Name of the case study: Brühl solar district heating in Chemnitz	
General description, pictures, and schemes	A low-temperature DH network fully decoupled from the network of Chemnitz supplies the quarter of Brühl. Heat sources are two solar fields with approx. 2093 m² collector aperture area and the DH network of Chemnitz. 
2. GENERAL INFORMATION	
Location:	Georgstrasse, Chemnitz, Germany
Link to project/plant home page, if any:	www.solfw.de
Size of the town/district/area:	6 000 inhabitants
Share of town/district/area heat demand covered by DH:	N/A
3. INFORMATION ON DHC NETWORK	
Owner:	eins energie in Sachsen GmbH & Co. KG
Operator:	Inetz GmbH
Total heat generation per year from all sources [MWh]	27 GWh/a (for 2020)
Supply temperature [°C]:	70-90
Return temperature [°C]:	45-60
Network pressure [bar]:	3-6
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	Primary DH network (receiving heat from brown coal and natural gas/oil fired CHPs) supplies Brühl through a heat transfer station with thermal capacity 18 MW
Storage size and type (if any) [m³]:	1 000
Solar fraction in the DH network on yearly base [%]	5 (simulated value for 2017)
Solar fraction in the DH network in the highest production month [%]	36.5 (June 2017)
Trench length (main pipes) [km]:	6
Network density [kWh/y/m]:	3
Thermal loss [kWh/y or %]:	(calculated) 8

Number of users:	240 houses
Remarks:	
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Inetz
Operator:	Inetz
In operation since:	2016
Annual Direct Normal Irradiance [kWh/y/m²]:	971
Plant capacity [kW]:	1 400
Yearly Solar heat production [kWh/y/m^2_{gross}]:	N/A
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	Large flat plate collectors; No. of WGK133AR = 165; No. of WGK80AR = 7; glazed
Mounting (ground, on/in roof)	ground
Overall aperture area [m^2]:	2 093
Hydraulic integration:	From solar fields to the low temperature DH network or storage
Direct/indirect connection to Flow / Return Flow / storage:	Direct connection
Control strategy (supply temperature/preheating):	According to matched flow operation → desired supply temperature
Operating hours per year:	2 300 (simulated value for 2017)
Maximum temperature [°C]:	90
Pressure [bar(a)]:	3 (max.)
Thermal loss across headers, annual value (or system efficiency: solar power stored/radiation):	Efficiency 46 % (simulated for 2017)
Size and Type of solar thermal dedicated storage, if any [m^3]:	Two-zone-storage, unpressurized steel tank (up to 108 °C), 1 000 m^3, charging/discharging capacity: 8 MW_{th}
Dedicated pumps (number, type, nominal power, head):	4, Grundfos / TP 50-190/4, 2.2 kW, 18.3 mWC
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …): No technical problems in reducing the temperature or the operation of the network. Flexibility, Need for modernization, profitability through promotion, energetic quarter concept.	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	N/A
Solar system capital costs:	971 000 € (10.5 M€ for the overall DH system)
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	
Annual CO2 emissions of entire DH System [t/a]:	9 234

Primary energy demand of entire DH system [MWh/a]:	18 900
Author:	Paolo Leoni (AIT Austrian Institute of Technology GmbH)

Senftenberg

1. Name of the case study: Senftenberg	
General description, pictures, and hydraulic scheme	 
2. GENERAL INFORMATION	
Location (longitude and latitude):	Senftenberg, Germany
Link to project/plant home page, if any:	
Size of the town/district/area:	24 000 inhabitants
Share of town/district/area heat demand covered by DH:	N/A
3. INFORMATION ON DHC NETWORK	
Owner:	Stadtwerke Senftenberg
Operator:	Stadtwerke Senftenberg
Total heat generation per year from all sources [MWh]	100 000
Supply temperature [°C]:	85-110
Return temperature [°C]:	60-70
Network pressure [bar]:	8
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	N/A
Storage size and type (if any) [m^3]:	None
Solar fraction in the DH network on yearly base [%]	~4
Solar fraction in the DH network in the highest production month [%]	30
Network length (main pipes) [km]:	35
Network density [kWh/y/m]:	285
Thermal loss [kWh/y or %]:	N/A
Number of users:	N/A
Remarks:	
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Stadtwerke Senftenberg
Operator:	Stadtwerke Senftenberg

In operation since:	2016
Annual Total Irradiance on tilted / horizontal surface [kWh/y/m²]:	1 107
Annual Direct Normal Irradiance [kWh/y/m²]:	960
Plant capacity [kW]:	5 000
Yearly Solar heat production [kWh/y/m^2_{gross}]:	522 into the DHN (result after 3 years of operation)
Centralized/Decentralized:	Decentralized
Collectors (type, manufacturer, number):	CPC-VRK XL 19/49 P, Ritter, 820
Mounting (ground, on/in roof, ...)	Ground
Slope and orientation of collectors	20° slope, 20° to East
Overall gross area [m²]:	8 300
Hydraulic integration:	direct into the DHN
Direct/indirect connection to Flow / Return Flow / storage:	heat exchanger, > 90 % supply Flow, < 10 % return flow
Type and concentration of heat transfer fluid, if indirect connection:	Water
Control strategy (supply temperature/preheating)	Matched Flow
Operating hours per year:	~1 800
Maximum temperature [°C]:	115 °C
Pressure [bar(a)]:	4
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m³]:	no storage tank
Dedicated pumps (number, type, nominal power, head):	KSB max. 2 x 16 kW primary, max. 2 x 7 kW secondary circle max. 35 kW DHN supply flow, max. 5 kW DHN return flow
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	~45 €/MWh
Solar system capital costs:	N/A
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	

Annual CO2 emissions of entire DH System [t/a]:	N/A
Primary energy demand of entire DH system [MWh/a]:	45 MWh solar + 45 MWh feed in DHN (= saved in the plant)
Author:	Rolf Meissner (Ritter XL Solar)

Sonnen- und Bioenergiedorf Mengsberg

1. Name of the case study: Sonnen- und Bioenergiedorf Mengsberg	
General description, pictures, and hydraulic scheme	
2. GENERAL INFORMATION	
Location (longitude and latitude):	D-35279 Neustadt-Mengsberg, Germany
Link to project/plant home page, if any:	https://www.begmengsberg.de/
Size of the town/district/area:	900 inhabitants, 280 households
Share of town/district/area heat demand covered by DH:	151 households
3. INFORMATION ON DHC NETWORK	
Owner:	Bioenergiegenossenschaft Mengsberg BEGM eG
Operator:	Bioenergiegenossenschaft Mengsberg BEGM eG
Total heat generation per year from all sources [MWh]	5 800
Supply temperature [°C]:	85-70
Return temperature [°C]:	55-50
Network pressure [bar]:	3.6
Heat generation plants (list, capacity, efficiency, fuels or waste heat…):	2 950 m², flat plate collector (single glazed) 1 x biomass boilers (1 100 kW) 1 x biogas boiler (1 600 kW)
Storage size and type (if any) [m^3]:	2 x 150 (insulated steel tank)
Solar fraction in the DH network on yearly base [%]	~17
Solar fraction in the DH network in the highest production month [%]	100
Network length (main pipes) [km]:	9.2
Network density [kWh/y/m]:	550
Thermal loss [kWh/y or %]:	16.9 %
Number of users:	150 households
Remarks:	
4. INFORMATION ON SOLAR SYSTEM	
Owner:	Bioenergiegenossenschaft Mengsberg BEGM eG

Operator:	Bioenergiegenossenschaft Mengsberg BEGM eG
In operation since:	2018
Annual Total Irradiance on tilted / horizontal surface [kWh/y/m²]:	N/A
Annual Direct Normal Irradiance [kWh/y/m²]:	N/A
Plant capacity [kW]:	2 100
Yearly Solar heat production [kWh/y/m^2_{gross}]:	~330
Centralized/Decentralized:	Centralized
Collectors (type, manufacturer, number):	224 collectors (Viessmann Vitosol 100-F XL13, flat plate, single glazed)
Mounting (ground, on/in roof, ...)	ground
Slope and orientation of collectors	17° East
Overall gross area [m^2]:	2 950
Hydraulic integration:	Top / Mid of each storage controlled via storage temperature
Direct/indirect connection to Flow / Return Flow / storage:	Via heat exchanger to storage
Type and concentration of heat transfer fluid, if indirect connection:	Glycol Water Mixture (38 %, Tyfocor L)
Control strategy (supply temperature/preheating)	Variable Flow
Operating hours per year:	N/A
Maximum temperature [°C]:	95
Pressure [bar(a)]:	3.6
Thermal loss across headers, annual value: (or system efficiency: solar power stored/radiation)	N/A
Size and Type of solar thermal dedicated storage, if any [m^3]:	2 x 150 (insulated steel tank)
Dedicated pumps (number, type, nominal power, head):	2 x Grundfos Magna3 100-120 F (max. 2 x 1.6 kW)
Hybrid Technologies:	N/A
Specifications on Hybrid Technologies:	N/A
Type of needed maintenance:	N/A
Others (lesson learned, recommendations, remarks, …):	
5. ECONOMIC PARAMETERS	
Heat generation costs (Solar system, without subsidies):	~30 €/MWh
Solar system capital costs:	N/A
Solar system O&M costs per year:	N/A
6. ENVIRONMENTAL PARAMETERS	

Annual CO2 emissions of entire DH System [t/a]:	N/A
Primary energy demand of entire DH system [MWh/a]:	N/A
Author:	Georg Stegemann (Viessmann Deutschland GmbH)