Final report

1. Project details

Project title	Follow up on large scale heat storages in Denmark, Gram
Project identification (program abbrev. and file)	64015-0567
Name of the programme which has funded the project	EUPD2015
Project managing company/institution (name and address)	PlanEnergi Jyllandsgade 1 9520 Skørping
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CVR (central business register)	74038212
Date for submission	December 2018

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2. Short description of project objective and results

Objective 1. Export of monitoring results from Gram to SOLITES and analyse of monitoring results for 2015, 2016 and 2017.
Result: Monitoring data for 2015 were not relevant because of running in of the plant. Monitoring results for 2016 and 2017 have been exported to Solites and analyzed. The results have been discussed at meetings in April 2017 and 2018. Since a leak in the storage has caused water in the insulation, the performance has not been as expected.

Objective 2. Export of real time monitoring results to "Solvarmedata.dk"
Result: A website with a similar design and setup as solvarmedata.dk but dedicated to the continuous monitoring of the storages has been created. Here the real-time charging/discharging can be seen together with present energy content for each storage. Besides this, it is possible to present graphically and/or download historical data of energy and temperature levels for user-defined periods. The website address is http://varmelagre.dk

Objective 3. Check of moisture content in expanded day and of insulation capacity of the lid
Result: Moisture content has been checked but since there has been water in the insulation, the check was only done once.

Objective 4. Yearly check of corrosion and condition of the storage by a professional diving company
Result: The storage was checked in the beginning of 2017. The inspection showed damaged coating at the lowest in- and outlet pipe.

Beside that, the project has given support to the 4th SDH Conference arranged in Billund in September 2016. The conference had 170 participants from 18 countries and had a positive evaluation by the participants.

3. Executive summary

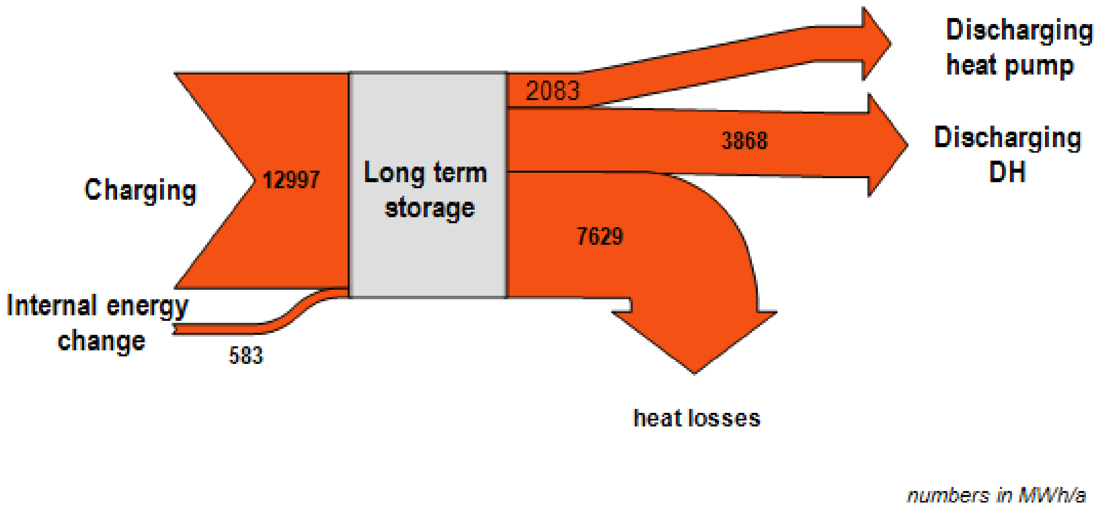
In 2014 to 2015 two new large heat storages have been implemented in Denmark in Vojens and Gram. The two storages have similar design. Before that, three large storages were implemented in Brædstrup, Marstal and Dronninglund from 2011 to 2013. Monitoring results from these three storages are analyzed in the project "Follow up on large scale heat storages in Denmark" (EUDP 14-1, j.nr. 64014-0121).

Since the design of the pit heat storages Vojens and Gram differs from the design of the pit heat storages in Marstal and Dronninglund it has been important to establish similar monitoring and analysis for at least one of those storages. The performance of the pit heat storage in Gram has therefore in this project been monitored in similar way as the performance of the storages in Marstal and Dronninglund. Especially for Gram would be monitoring of the performance of a new and cheaper lid construction.

SDH (Solar District Heating) Conference was arranged in Denmark in 2016. This was an excellent possibility to promote Danish solar and storage solutions. Therefore support to SDH conference was included in the dissemination part of this project. 150 stakeholders from more than 20 countries were expected to participate.

Monitoring results

Performance data for 2016 and 2017 has been transmitted to Solites and analyzed. The energy balance for the storage can be seen below for 2017:



The evaluated storage efficiency is 44% for 2017. The reason for the low efficiency is that water leaks into the lid and makes the expanded clay insulation wet. An arbitration procedure is ongoing to place the responsibility.

Export of real time monitoring results

Data are not exported to "Solvarmedata.dk" but to a special webpage: http://varmelagre.dk.
With a mouseover the present status is shown including charging, discharging, energy content and stage of charge compared to full capacity.
Beside that there is a subpage with among others historical monitoring data, information about the storage and the district heating plant and access to monitoring results.

Other results

Moisture content was monitored in the expanded clay. It was as expected 100% related to the dry weight.
A diver inspection showed damaged coating on the outside of the coldest pipe, but this is not expected to cause corrosion problems.

SDH Conference

The project supported the 4th International Solar District Heating Conference in Billund 20-21 September 2016. 170 people from 18 countries participated and the evaluation showed, that the participants were satisfied with the program and the site visit in Gram.

4. Project results and dissemination of results

4.1 Monitoring results

In this section a summary of evaluation results for the solar district heating (SDH) plant in Gram is given. A detailed evaluation report for the period covered by this project is available in a separate report [Winterscheid et. al., 2018].

For the comparison of the efficiencies of different system concepts a number of characteristic numbers, often called key performance indicators (KPI) can be calculated. The ones used here are:

Solar fraction: $$F_{Sol} = \frac{Q_{Load} - Q_{Aux}}{Q_{Load}} = \left(1 - \frac{Q_{Aux}}{Q_{Load}}\right)$$

Q_{Load}: heat supply to the DH network

Q_{Aux}: auxiliary heat delivered to the system (by boilers, CHP, el. demand heat pump etc.)

Solar collector field efficiency $$\eta_{Coll} = \frac{Q_{Coll}}{G_{sol}}$$

G_{Sol}: global irradiation in solar collector pane

Q_{Coll}: heat delivered by the solar collector field

Storage efficiency $$\eta_{STES} = \frac{Q_{STES,out} + dQ_{STES}}{Q_{STES,in}}$$

$Q_{STES,in}$: heat charged into the seasonal thermal energy storage (STES)

$Q_{STES,out}$: heat discharged from the STES

dQ_{STES}: difference in STES internal energy change in the period

No. of storage cycles $$N_{cyc} = \frac{Q_{STES,out}}{Q_{STES,max}}$$

$Q_{STES,max}$: maximum heat capacity of the STES

The solar district heating plant of Gram Fjernvarme was monitored in the years 2016 and 2017. For the PTES an exemplary energy flow diagram is discussed and data on the utilization and the development of storage temperatures is presented. More evaluations are documented in a separate evaluation report for the period covered by this project [Winterscheid et. al., 2018].

Figure 1 shows the system concept of the plant.

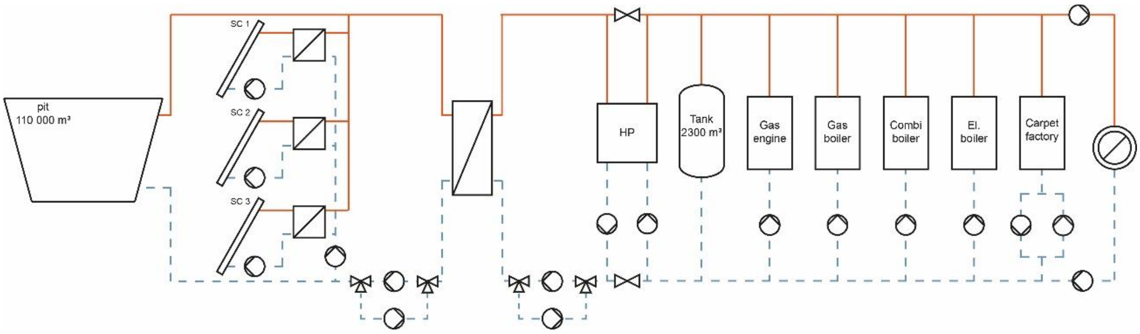


Figure 1. *Gram SDH system concept.*

Table 1. *Overview of evaluation results for the considered evaluation period in Gram*

system heat balance		**2016**	**2017**
solar irradiation on solar collectors	*MWh*	50,943	48,905
heat from solar collectors	*MWh*	18,120	16,041
heat charged into PTES	*MWh*	15,200	12,997
heat discharged from PTES	*MWh*	7,946	5,951
PTES internal energy change	*MWh*	-397	583
PTES thermal losses	*MWh*	6,857	7,629
heat pump heat delivery	*MWh*	2,726	2,614
heat pump electricity demand	*MWh*	564	531
heat from Gas CHP Engine	*MWh*	1,052	125
heat from Gas Boiler	*MWh*	10,112	10,460
heat from combi boiler	*MWh*	61	138
heat from Electrical boiler	*MWh*	4,074	6,132
heat from carpet factory	*MWh*	unknown	932
heat delivery to DH	*MWh*	27,352	27,617
key performance indicators			
solar collector field efficiency	*%*	36	33
PTES storage efficiency	*%*	50	50
PTES no. of storage cycles	-	0.9	0.7
PTES maximum temperature	*°C*	84	79
PTES minimum temperature	*°C*	23	21
PTES used heat capacity	*MWh*	8,628	8,126
heat pump COP	-	4.8	4.9
solar fraction	*%*	42	37
area-related solar heat production	*kWh/(m²*a)*	404	358

The 122,000 m³ water-filled PTES in Gram went into operation in 2015. **Figure 2** shows an energy flow diagram for the energy production from monitoring data for 2017. With the presented numbers a solar fraction of 37% can be calculated for the plant. Additional heat sources are a gas boiler, a combined boiler, an electrical boiler and excess heat from a carpet factory.

In 2017, the second year of data evaluation for the DH system of Gram, 27,617 MWh were delivered to the DH system. A bit less than half of the energy was supplied by the solar collectors in combination with the long-term storage and the heat pump. The gas boiler supplied with 10,460 MWh. With 6,132 MWh the electrical boiler supplied about 15% of the total heat that was supplied to the DH system. The Gas Engine and the combi boiler were only operating for little time and resulted in total in a production of 263 MWh. In contrast to the first year of measurement, there were data for energy supply from the carpet factory, which accounts for 932 MWh of heat from the factory.

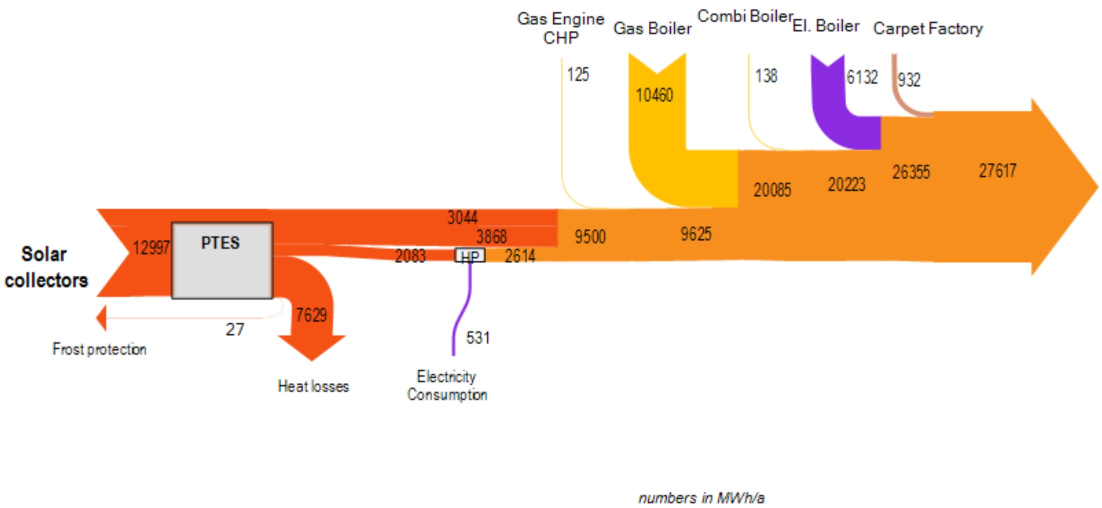


Figure 2. *Heat flow diagram according to monitoring data for 2017, numbers in MWh.*

The sankey diagram in **Figure 3** shows the charging and discharging of the long term storage in 2017. In this year it was charged with 12,997 MWh of heat from the solar collector fields and directly discharged by 3,868 MWh. The heat pump was used when the storage temperature level was not sufficiently high and electricity prices were moderate enough for operation. The heat losses of the storage are based on an annual balance, comparing the amount of charged and discharged heat taking into account the internal energy change. The internal energy change is calculated based on the vertical temperature distribution inside the storage, see also **Figure 5.**

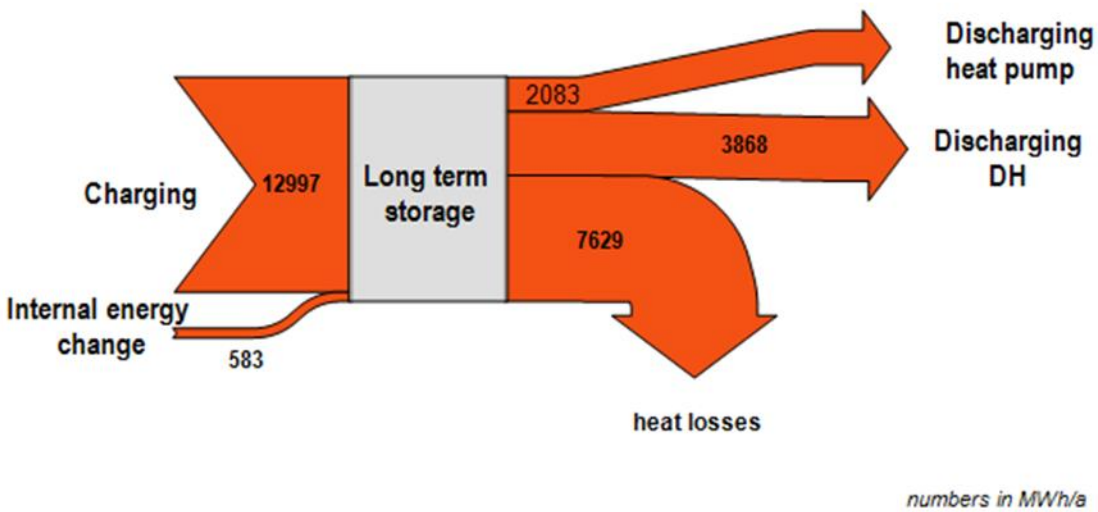


Figure 3. *Heat flow diagram for the Gram PTES in 2017, numbers in MWh.*

The evaluated storage efficiency remained in both years with about 50 % constant. A storage cycle number of 0.7 indicates that the heat capacity of the storage was not used to its full extend in 2017. This shows a purely seasonal operation. This can also be seen in the monthly charged and discharged amounts of heat presented in **Figure 4Fejl! Henvisningskilde ikke fundet.**. The main charging processes are in summer and the main discharging processes in winter. According to the charged and discharged amounts of heat, the energy content of the storage is illustrated as a dashed line.

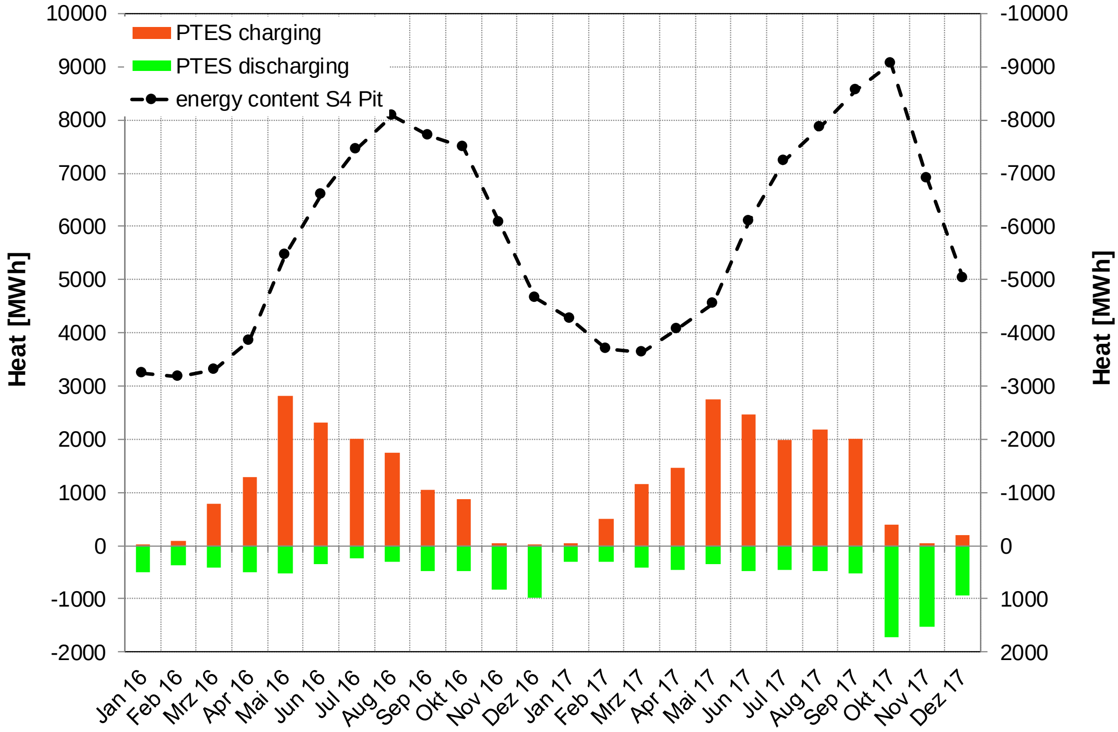


Figure 4. *Monthly heat balance for the Gram PTES for 2016 and 2017.*

In **Figure 4Figure 5** the temperature development in the storage is illustrated from 2016 to 2017. Again the seasonal operation is clearly visible with a charging period from around March to September and a discharging period from around September to March. Minimum temperatures in February are around 40 °C at the top of the storage and 20-25 °C at the bottom. Maximum temperatures in September reached about 85 °C at the top and around 65 °C at the bottom in 2016. In 2017 the temperatures in summer were somewhat lower. The highest thermal stratification, that means the largest temperature differences between the top and the bottom of the storage, of around 40 K can be seen in spring and autumn.

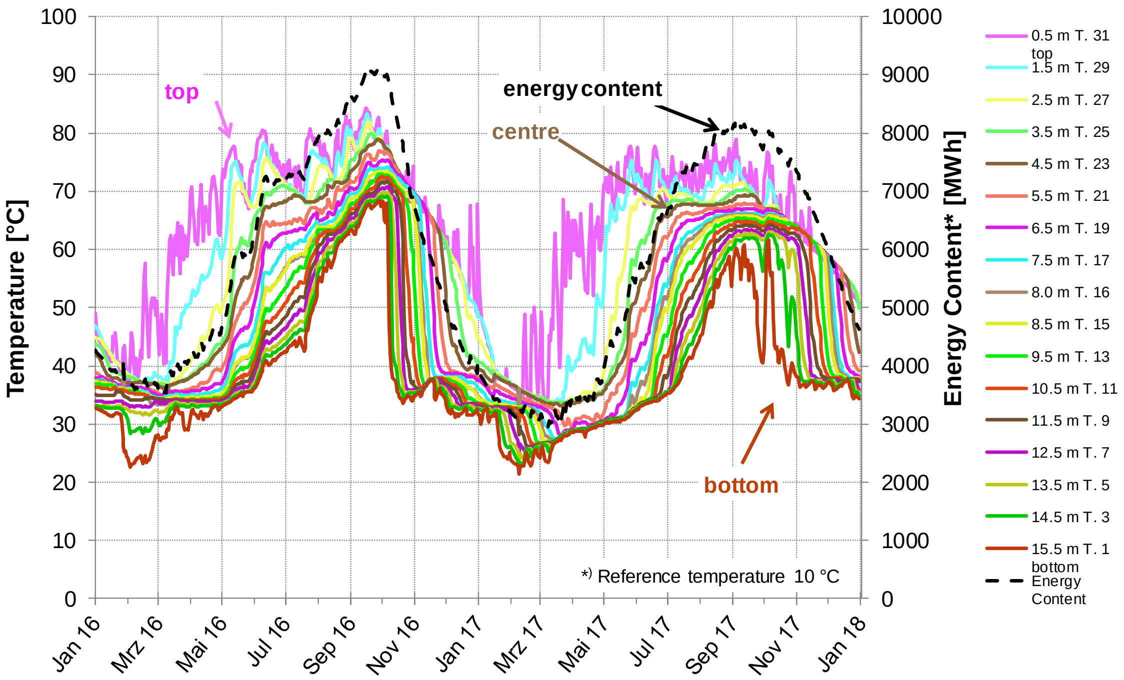


Figure 5. *Temperature development in the Gram PTES in 2016 and 2017.*

4.2 Export of data to Varmelagre.dk

Though the storage monitoring was originally planned to be part of the solvarmedata.dk website, a dedicated website has been developed for the long-term heat storages: http://varmelagre.dk. This has been done to promote the storages separately and avoid that a mix with solar heating plant data confuses users. The website has been created with a similar design and setup as solvarmedata.dk to make the connection intuitive for users familiar with that website. Direct links between the websites enforces the connection.

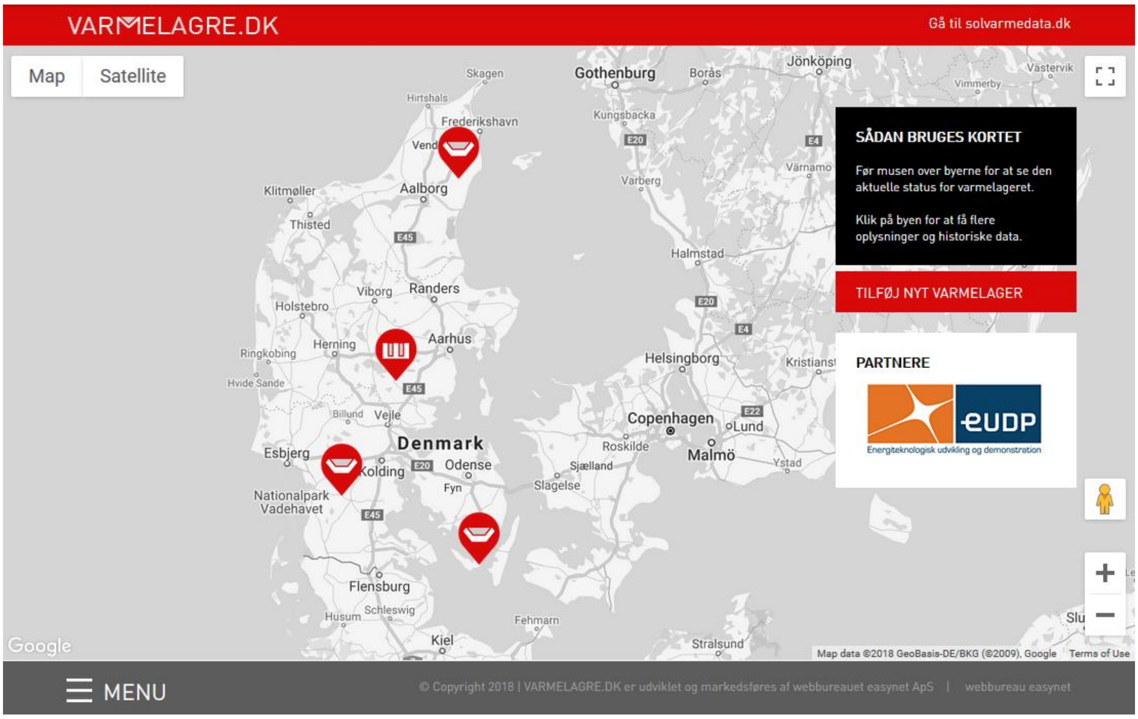


Figure 6. *Screen shot of varmelagre.dk.*

4.2.1 The key features of varmelagre.dk

The front page gives an overview map of the storages with icons showing the type of storage (see **Figure 6**). With a mouseover the present status of the storage is shown including

- Charging
- Discharging
- Energy content in MWh
- State of charge in percent (of "full")

These values are based on a continuous monitoring of the storages and shown in real time (updates every 5 minutes).

Figure 7. *Icons used at varmelagre.dk. From left to right are seen icons for pit heat storage, borehole storage and indication of several overlaying icons (i.e. two or more storages located close to each other for the chosen zoom level).*

By clicking on one of the storage icons the user is presented with the "subpage" for the chosen storage which includes a top menu including three sections

a) present and historical monitoring data
b) information about the storage and district heating plant
c) access to monitoring results from previous periods

Besides the real-time monitoring data in menu section a) above, each subpage includes graphical presentation and historical data download of

- charged energy
- discharged energy
- energy content
- charging temperature
- discharging temperature
- temperature levels in the storage

The graphics are divided in two charts: One for energy and one for temperatures. In **Figure 8** is seen an example of the energy chart.

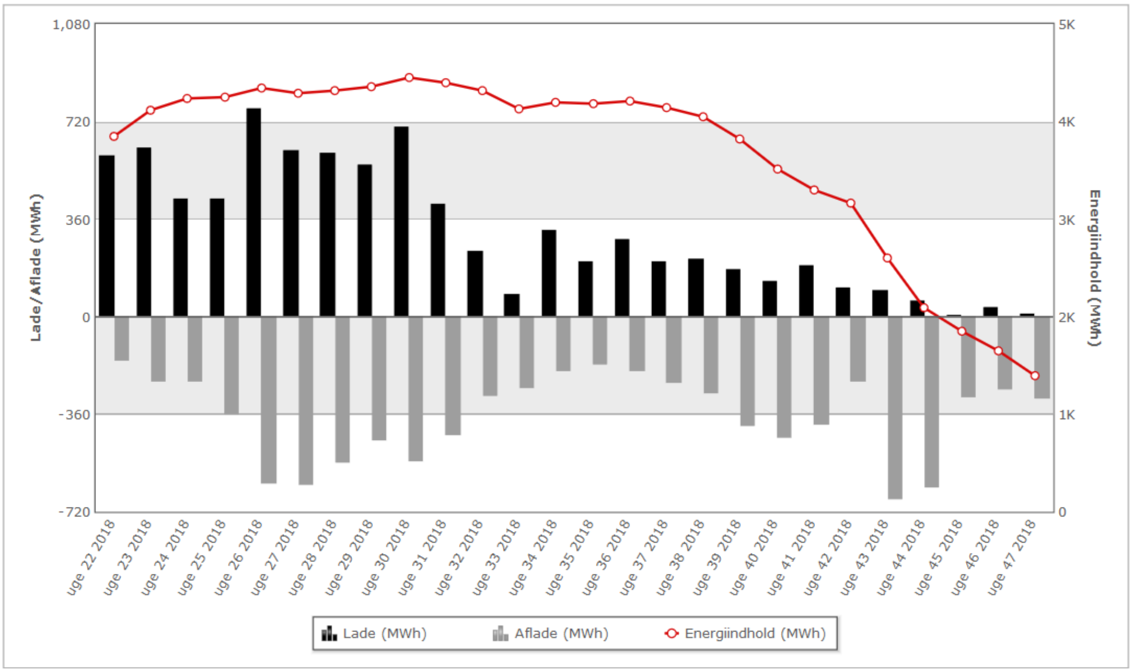


Figure 8. *Example of the energy chart for half a year with a chosen timestep of one week. Black and grey bars represent charging and discharging energy respectively (left axis, both in MWh). These are paired so that each timestep includes one charging and one discharging bar. The red line shows the energy content (right axis) which in this example stays between 1,000 and 5,000 MWh.*

In the top menu (point b above) general information about the plant is found (e.g. storage type, volume etc.) besides a download option to access a short introduction to the district heating plant and storage in question. The last top menu (point c above) enables users to download presentations of annual monitoring data overview from previous years developed by Solites.

4.2.2 Data details

Regarding temperature levels it has been decided that mean temperature is not included for pit heat storages since it could lead to confusion if it represents the temperature in the mean height of the storage or the average water temperature. A mean temperature is only included for borehole storages.
Correspondingly the storage top and bottom temperature – which for pit storages represent high and low temperatures respectively due to the stratification in the storage – are not included for borehole storages since a similar stratification is not present.

Energy content is provided as the value at the end of the given time step. If hourly values are chosen, a value provided for the period 13:00-14:00 represents the energy content at 14:00.

4.2.3 General information available in bottom menu

In a bottom menu which can be hidden or not the user can access further, general information:

- About the website (who is behind it, how to use the website)
- Sources of further information on heat storages in general
- How to get a heat storage connected to the website and contact information in case of technical issues.

4.2.4 The future for the website

Other storages can be connected to the website. With the button "tilføj nyt varmelager" the user is presented with what is required to connect a new storage.

It is expected that the financing of the website after funding from the EUDP project no. 64014-0121 ends can be handled by sponsors which in turn are presented at the website. To secure such financing a folder has been created to present the sponsor option. This is available from the project website at http://varmelagre.dk/files/files/Varmelagre-folder_web.pdf .

4.3 Check of moisture content in expanded clay and of insulation capacity of the lid

On the 29.th of September 2016 a sample of the insulation (Expanded clay – Leca) was weighed and dried to determine the moisture content.
Due to one or more leakages, it was visible wet.
The result was 100% moisture, related to the dried weight.

An arbitration procedure is ongoing, to place the responsibility for the leakages etc. As long as this arbitration procedure is ongoing, no action can be taken to improve the situation, due to legal issues.

Because of this, no more samples were tested.

In the autumn 2018, the lid was opened in three places.
It showed no water, but did show that the insulation still was wet, although less wet, than in September 2016. (Visible).

At the pit in Toftlund, the Leca also got wet. This time due to penetration of rainwater.
The drying did take place from spring 2018 and is almost finished in December 2018.
It was simply done by extracting air from the Leca.
A fan of a capacity of 500 – 1000 m3/h, was installed at the centre of the lid, to extract air from the layer of insulation.
Along the edges of the lid is placed vacuum valves. These vacuum valves act as inlet for the dry ambient air to the Leca.

From the first months, the exhausted air was quite warm (40-45 ^{0}C), and 100% RH.
In December 2018, the RH has dropped to 80%, as well as the temperature now is significant lower. (22 ^{0}C)
The temperature in the top of the storage was 75-80 ^{0}C over the summer and is now reduced to 65 ^{0}C.
This development indicates that it is an efficient way to remove moisture from the construction.

4.4 Yearly check of corrosion and conditions of the storage by a professional diving company

Only one inspection has been possible.
It took place 17.th of January 2017.
The reason for only one inspection is that the storage is extraordinary charged all the way through 2018.
2018 was an extraordinary hot and sunny summer, giving more than expected for an average year to the storage.

In addition to this fact, there have been favourable conditions for the electric boiler in periods and for the CHP. Both resulting in a postponed discharging of the storage.
To use the storage for all the production units (electric boiler, CHP and solar) is the major purpose for a plant like Gram District Heating, because it improves the economy for the customers.

The inspection in 2017 showed the same pattern as in other similar storages, that the coating on the cold pipes was damaged by condensate emerging between the steel and the coating. This damage is not considered to be a problem now, because the risk of corrosion is small. In the first year of operation it served the purpose to protect the steel structure from corrosion.

4.5 Dissemination of project results

4.5.1 General dissemination

PlanEnergi dissemination

1. Brochure. Long term storage and solar district heating. Distributed at SDH Conference 2016 and at conferences and workshops during 2016, 2017 and 2018. www.planenergi.dk/arbejdsområder/fjernvarme/saesonvarmelagre/
2. Trier, D.: Presentation of the project results at Solvarme-ERFA meeting 20th September 2016
3. Nielsen, J.E.: Presentation of the project results at Solvarme-ERFA meeting September 2017.
4. Ingeniøren: https://ing.dk/artikel/efter-utaette-fjernvarmelagre-raadgiver-svarer-paa-laesernes-spoergsmaal-213124
5. Sørensen, P.A.: Siver varmen ud af damvarmelagrene? House of Energy, Aalborg Energidag 12.09.2018
6. Sørensen, P.A.: Driftserfaringer fra storskala varmelagre i Danmark. Dansk Fjernvarmes temadag om geotermi og varmelagring. 20.11.2018
7. Sørensen, P.A.: "Best practice" for implementation and operation of the Large Scale Borehole and Pit Heat Thermal Storages (BTES and PTES) in Brædstrup, Marstal, Dronninglund and Gram, Denmark, PlanEnergi 2018.

Gram Fjernvarme dissemination

1. Damkjær, L.M.: Presentation at SDH Conference in Billund, 21-22 September 2016
2. Visit from 150 out of 170 participants in SDH Conference in Billund, 21-22 September 2016
3. Site visit with SDHp2m stakeholders from Hamburg and Schleswig-Holstein, 13.06.2017
4. Site visit with SDHp2m stakeholders from Poland 4. okt 2017
5. Site visit with Ramboll 11. Okt. 2017

Rambøll

1. Ingeniøren**:** https://ing.dk/artikel/efter-utaette-fjernvarmelagre-raadgiver-svarer-paa-laesernes-spoergsmaal-213124

Kristensen Consult

1. SDH Conference 2016. PlanEnergi and Kristensen Consult arranged the conference. There were 170 participants. Program is annexed.

4.5.2 SDH Conference

The project supported 4th International Solar District Heating Conference. The conference took place in Billund 21 and 22 September 2016 at Hotel Legoland and had 170 participants from 18 countries.

Figure 9. *Opening session at SDH Conference. Source: Kristensen Consult*

The objectives for the 4th edition of the SDH Conference was to focus on sharing the international experiences from system concepts and technologies for large-scale solar heating plants and their integration into district heating networks.
Market actors and policy makers from countries with new and developed markets shared their know-how and lessons learned regarding market preparation and support instruments.
Experienced Danish operators were available as SDH ambassadors and advisors during the whole event and leaded technical visits to one of the most modern Danish SDH plants in Gram.
During the conference, professionals from the Solar District Heating sector presented their products and services in an exhibition area.
The full programme is annexed. The main activities were:

The welcome
The welcome and introduction of the conference was taken of:
Kim Behnke, DDHA, Paul Voss, Euroheat & Power, Henrik Lund, Aalborg University and Thomas Pauschinger, Solites.

After the opening plenary session, the participants were divided into parallel sessions:

- RES and solar district heating in your country – market aspects
- SDH components/Plant Performance

Technical tour
After lunch, there was an introduction to the technical tour to the SDH-plant in the town Gram in the southern part of Jutland. This introduction was followed by transport and visits to Gram.
Here the solar plant exist of 44.800 m2 solar panels and a pit store system of 122.000 m3 water.
As an alternative to the visit in Gram the company Savosolar offered a visit to the company's delivery of a solar plant to the district heating company in the town Jelling.

Figure 10. *Site visit in Gram. Source: Kristensen Consult*

Day 2
Day 2 was divided in five parallel sessions and a technical workshop. The sessions was:
- Industry session
- Poster session
- Advanced SDH systems I
- Advanced SDH systems II
- RES and district heating in your country – new projects

Figure 11. *SDH session "Starting SDH project". Source: Kristensen Consult*

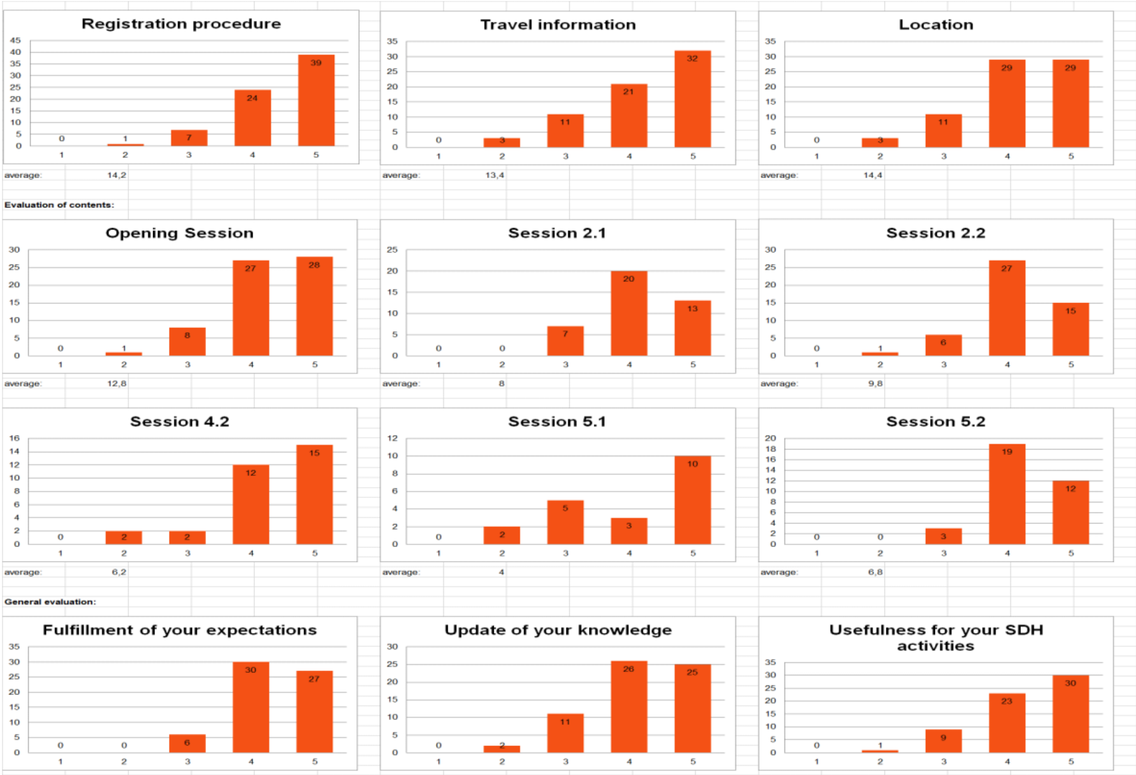
Closing Session
The theme of the session was "Solar District Heating – a reliable and feasible option for HD operators?
Kim Behnke, DDHA was chair and as guests to the session, the following were invited:
Torben Sørensen, VKR Group
Johan Frey, Dronninglund District Heating
Helle Richelieu, DDHA consumer
Robert Werner, Hamburg Institute
Alexis Pellat, Regional Council of Auvergne-Rhöne Alpes
Heiko Huther, AGFW

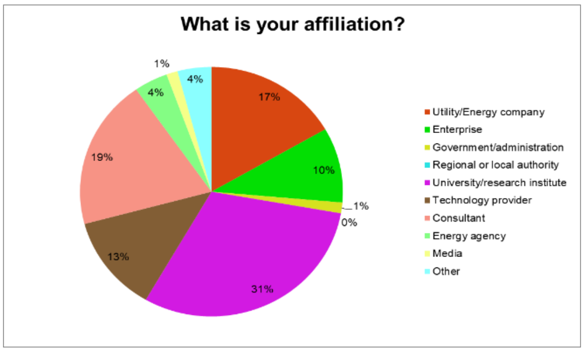
The day 2 – and the conference - ended with the Wrap-up of the conference with Thomas Pauschinger, Solites and Per Alex Sorensen, PlanEnergi

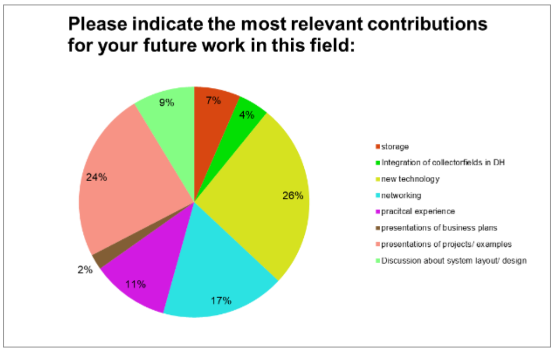
Exhibitions
During the whole conference 13 professionals from the Solar District Heating sector presented their products and services in an exhibition-area.

All presentations and the book of papers are available to download at http://solar-district-heating.eu/Documents.aspx

The participants had possibility to fill in an evaluation questionnaire with scores from 1 to 5. Some of the results were







5. Utilization of project results

Utilization PlanEnergi

Experiences from the PTES in Dronninglund and Marstal have been used within the IEA DHC Annex XII Project 03 "Integrated Cost-effective Large-scale Thermal Energy Storage for Smart District Heating and Cooling" (https://www.iea-dhc.org/index.php?id=528) for the deliverable "Design Aspects for Large-Scale Aquifer and Pit Thermal Energy Storage for District Heating and Cooling".

PlanEnergi has utilized the project results in design projects in Austria, Germany, Bulgaria and Denmark (Høje Taastrup and Aalborg).

Utilization Gram Fjernvarme

In particular, Gram Fjernvarme has used the measurement data from Solites to get the energy flow in the heat storage. In addition, experience from the other participants has helped to optimize the plant.

Utilization Solites

Monitoring data from the PTES in Dronninglund and Marstal have been used within the IEA DHC Annex XII Project 03 "Integrated Cost-effective Large-scale Thermal Energy Storage for Smart District Heating and Cooling" (https://www.iea-dhc.org/index.php?id=528) for validation of TRNSYS simulation models for PTES.

Project results and monitoring data are furthermore used within the ongoing Austrian research project "giga-TES - Giga-scale thermal energy storage for renewable districts", supported by the Austrian Climate and Energy Fund.

Utilization Rambøll

Rambøll has used the results to optimize their storage concept before the implementation of a new storage in Toftlund

Utilization Kristensen Consult

Per Kristensen arranged the practical part of SDH Conference in cooperation with FIF Marketing. The concept functioned very well as can be seen from the evaluation and can be replicated for other conferences.

Utilization DTU Byg

The project results have been presented for students following the solar energy courses at the Technical University of Denmark. Measurements from the project on the heat storage have been used in connection with Master Thesis projects on water pit storages carried out at the Technical University of Denmark.

6. Project conclusion and perspective

The Results from the evaluations of the monitoring data of Gram in 2016 and 2017 show good agreements with the design figures in terms of usable temperature ranges. The contributions of solar heat to the heat supply of the connected district heating network turned out to be lower than expected. Instead of 51 % solar fraction the plant arrived on 42 % and 37 % for 2016 and 2017 respectively. This result may also be influenced by higher storage losses than design values were showing. In 2016 the PTES losses were about 2 % higher than design values and in 2017 the losses were 14 % higher than design values.

The increased storage losses can be explained by increasingly wet insulation in the lid. Resolving this issue is likely to reduce the losses mentionable. A comparison with other PTES systems will be easier when the insulation is in expected conditions.

The purpose of the monitoring program was to compare the solution in Marstal and Dronninglund, but this has not been possible due water leaking into the lid.
Monitoring in Gram will continue in another project called "Heatstore" (EUDP 18 ERA NET Geothermica) and hopefully the storage lid will be repaired so that this project can give a true picture of the performance of the storage design used in Gram.

7. References

Sørensen, P.A.: "Best practice" for implementation and operation of the Large Scale Borehole and Pit Heat Thermal Storages (BTES and PTES) in Brædstrup, Marstal, Dronninglund and Gram, Denmark, PlanEnergi 2018.

Winterscheid et. al., 2018 Winterscheid, C, Schmidt, T.: Gram district heating monitoring data evaluation the years 2016-2017, report within EUDP project 'Follow up on large scale heat storages in Denmark, Gram' (project no. 64015-0567), Solites, Germany, 2018.

Annex A: Brochure and program for SDH Conference, Billund 2016

10:30h - 11:00h **Coffee break**

11:00h - 12:30h **Parallel session 5.1: RES and solar district heating in your country - new projects**

Chair: Mathieu Eberhardt, Rhônalpénergie-Environnement

Chateaubriant: The first French large scale solar plant connected to exisiting district heating
Amandine Le Denn, TECSOL

Solar district heating of Varese
Results and experiences from the first year of operation
Zeno Benciolini, SDH Energy

Construction of the renewable energy hybrid demonstration site using seasonal storage in Jincheon, Korea
Dong-Won Lee, Korea Institute of Energy Research

Planning and operation of two small SDH plant as test site: comparison between flat plate and vacuum collectors
Luca Degiorgis, Politecnico of Torino

11:00h - 12:30h **Parallel session 5.2: Advanced SDH systems II**

Chair: Morten Vang Bobach & Per Alex Sørensen, PlanEnergi

Germany's largest Solar District Heating System with Seasonal Thermal Energy Storage in Crailsheim - Monitoring Results and Future Potentials
Roman Marx, ITW University of Stuttgart

Operational analysis and detailed monitoring results of measurements taken from large-scale solar thermal plants integrated into district heating
Samuel Knabl, AEE INTEC

First year of operating the world's largest solar heating plant and the world's largest seasonal storage
Flemming Ulbjerg, Ramboll Energy

Monitoring results from large-scale solar thermal plants with long term storage in Marstal, Braedstrup and Dronninglund, Denmark
Thomas Schmidt, Steinbeis Research Institute Solites

12:30h - 14:00h **Lunch break and Exhibition**

14:00h - 15:00h **Closing session**

Chair: Kim Behnke, DDHA

Panel debate: Solar District Heating - a reliable and feasible option for DH operators?
Torben Sörensen, VKR group
Johan Frey, Dronninglund District Heating
Helle Richelieu, DDHA customer
Robert Werner, Hamburg Institute
Alexis Pellat, Regional Council of Auvergne-Rhône Alpes
Heiko Huther, AGFW – German Heat and Power Association

Wrap-up of the conference, SDH Highlights to come?
Thomas Pauschinger, Steinbeis Research Institute Solites
Per-Alex Sørensen, PlanEnergi

15:00h - 17:00h **Exhibition still open**

Exhibition:

During the conference, professionals from the Solar District Heating sector will present their products and services in the exhibition area. As participant, you will have the opportunity to get in direct contact with manufacturers from all Europe and discover the products on the market.

Sponsors:

AALBORG CSP, TiSUN, SOLDEX, SAVOSOLAR, PlanEnergi, ALFA LAVAL, ARCON SUNMARK, HELIAC, SOLID, RAMBØLL, NIRAS, solites

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Organized by: DANSK FJERNVARME, PlanEnergi, solites

SDH solar district heating

4th International Solar District Heating Conference

21 and 22 September 2016, Billund, Denmark

Supported by: EUDP, DANSK FJERNVARME

Program

Wednesday, 21 September 2016

08:00h - 09:00h **Registration**

09:00h - 10:30h **Opening plenary session**

Welcome and introduction to the conference

Welcome address by Kim Behnke, DDHA

Heating and Cooling in the European Energy Transition
Paul Voss, Euroheat & Power

Solar District Heating in Future Smart Energy Systems,
Henrik Lund, Aalborg University

Aims and activities of the SDHp2m project team
Thomas Pauschinger, Steinbeis Research Institute Solites

10:30h - 11:00h **Coffee break**

11:00h - 13:00h **Parallel session 2.1: RES and solar district heating in your country - market aspects**

Chair: Riccardo Battisti, Ambiente Italia

Solar and biomass for Italian communities: analysis of two case studies,
Alice Dénarié, AIRU

Enhancing energy efficiency of biomass district heating by integration of thermal solar energy
Wolfgang Jilek, Government of Styria

Solar district heating in Baden-Württemberg – Overcoming barriers and market introduction within the project SolnetBW
Oliver Miedaner, Steinbeis Research Institute Solites

Feasibility for SDH in region Västra Götaland
Jan-Olof Dalenbäck, CIT Energy management AB

Monitoring results for the two firsts solar plants on district heating network in France: Balma Gramont and Juvignac
Fabrice Renaude, Cofely Services GDF Suez

Small, modular and renewable district heating & cooling grids for communities in South-Eastern Europe
Dominik Rutz, WIP Renewable Energies

11:00h - 13:00h **Parallel session 2.2: SDH components / plant performance**

Chair: Cédric Paulus, CEA INES

Thermal performance of a novel combined solar heating plant with parabolic trough collectors and flat plate collectors
Zhiyong Tian, Technical University of Denmark

Development and test results for liners for tightening of large scale water storages
Per Alex Sørensen, PlanEnergi

The right choice of pre-insulated pipe system for big scale solar district heating networks
Peter Jorsal, Logstor

Variations of yearly thermal performance of Danish solar heating plants - measured and calculated
Simon Furbo, Technical University of Denmark

Online Monitoring of SDH system performance
Daniel Trier, PlanEnergi

13:00h - 14:30h **Lunch break and Exhibition**

14:30h - 15:00h **Introduction to technical tour**

15:00h - 18:00h **Technical tour: SDH plant of Gram**
The solar thermal systems consists of 3556 collectors representing a total area of 44.800 m². The annual heat production is 20.800 MWh, which covers 60% of the annual heat demand.

19:00h **Dinner at Knights' restaurant at Legoland**

Thursday, 22 September 2016

08:00h - 09:00h **Parallel session 3.1: Industry session**

Chair: Jan-Olof Dalenbäck, Chalmers University

Aalborg CSP, Alfa-Laval, Heliac Aps, SavoSolar, Climalife Thermaflex and KBB Kollektorbau, Shandong Linuo Paradigma Co. Ltd.

08:00h - 09:00h **Parallel session 3.2: Poster session**

Chair: Laure Deschaintre, Steinbeis Research Institute Solites

New CPC based flat plate collector for solar heating plants
Bengt Perers, Technical University of Denmark

Decentralised integration of solar thermal plants into an existing district heating system
Daniel Beckenbauer, Technische Hochschule Ingolstadt

Local approach to renewable district heating: case study Croatia
Borna Doracic, University of Zagreb

Shine doctoral school – results from six PHD studies on large scale solar thermal
Frederico Bava, Technical University of Denmark

Precise measurement of collector arrays for the development of new test methods to increase planning reliability
Moritz Schubert, S.O.L.I.D.

Integration of solar thermal systems in existing district heating systems
Carlo Winterscheid, Chalmers University of Technology

Feed-in from distributed solar thermal plants in district heating systems
Gunnar Lennermo, Energieanalys AB

09:00h - 10:30h **Technical workshop 4.1: Starting an SDH project**
Moderator: Rasmus Bundegaard Eriksen, DDHA: ERFA group for solar thermal

Business plan for SDH and consumer ownership,
Per Kristensen, kristensen consult ApS, former manager of Brædstrup District Heating

Permission procedures, landscape integration and environmental impact analysis
Simona Weisleder, Hamburg Institute

Feedback and lessons learned on the implementation of SDH in Denmark
Rasmus Bundegaard Eriksen, DDHA: ERFA group for solar thermal

Risk Assessment of Large Solar Thermal Installations
Robert Werner, Hamburg Institute

Open discussion with all speakers

09:00h - 10:30h **Parallel session 4.2: Advanced SDH systems I**

Chair: Dirk Mangold, Steinbeis Research Institute Solites

Technical challenges for solar thermal plants with decentralized feed-in into district heating networks and deduced plant concept for the experimental feed-in station in the SWD.SOL project
Kai Schäfer, Steinbeis Research Institute Solites

Solar District Heating and Heat Pump at Rye Kraftvarmevaerk (Rye CHP)
Morten Vang Bobach, PlanEnergi

BIG Solar Graz: Solar District Heating in Graz - 500,000 m² for 20% solar fraction
Robert Söll, S.O.L.I.D.

Concept, construction and first measurement results of two decentralized feed-in substations
Karin Rühling, Technical University of Dresden