SDHtake-off –

Solar District Heating in Europe

Training Concept: Large Heat Stores in Connection to Solar Thermal and CHP

by

AGFW German Heat and Power Association

www.agfw.de

Solites, Steinbeis Research Institute for Solar and Sustainable Thermal Energy Systems

www.solites.de

Deliverable:

WP 4:	Capacity Building
Task 4.2:	Pilot Training Courses
Deliverable 4.2:	Training Concept – Large Heat Stores in Connection to Solar Thermal and CHP

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Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

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1. OVERVIEW

Seasonal thermal energy storage offers a great potential for substituting fossil fuels using solar energy for domestic hot water preparation and space heating. In 1993 Germany raised the R&D program Solarthermie 2000 and the successor Solarthermie 2000plus that was implemented by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Several technologies for seasonal heat storage have been further developed and tested within these projects and eleven research and demonstration plants for solar assisted district heating with seasonal storage have been built in Germany since 1996. Moreover, there are further applications for this technology. Nowadays, other technologies are developed and spread, which need or could use seasonal storages of big volumes. Thus, the IEA in its Heating and Cooling Roadmap (IEA Technology Roadmap Energy-efficient buildings: heating and cooling equipment) and the District Heating and Cooling Technology Platform in its strategic research agenda (DHC+ Technology Platform, Strategic research agenda) include thermal energy storages as central components in energy efficient systems in the future. The acquired knowledge needs to be spread in order use it in further projects and develop the market for this technology.

This concept presents a concept how the topic of ‘Large Heat Stores in Connection to Solar Thermal and CHP’ can be addressed in training courses. The courses should be addressed to energy suppliers and aims at giving participants a basic technical knowledge of the large storage’s technology and an overview of its numerous applications.

The course deals with different themes:

- Research and development about this technology until today
- Role of heat storage in heat supply
- Politics and strategy
- Technical aspects and state of the art : dimensioning, materials, costs, location, integration in the systems
- Pilot projects, analysis of their functioning
- Materials and products available on the market
- Different application examples of large heat storages

An example of a two-day course program which was pilot implemented in Germany is presented.

2. COURSE CONCEPT

2.1. Introduction

Themes	Learning objectives
• **Background**	o Historical background of the R&D o Actual research programs and their achievements
• **Role of heat storage in heat supply**	o Different applications for large heat storages o Reasons for this technology to develop in the future
• **Politics and strategy**	o State of the market and future development in Germany, Europe and world-wide o Interest of stakeholders

2.1.1. Background

The technology has been investigated in Europe since the middle of the 70's. First demonstration plants were realized in Sweden in 1978/79 based on results of a national research program. Nowadays, within the Solarthermie 2000 & Solarthermie2000plus programs, several technologies for seasonal heat storage are developed, and eleven research and demonstration plants for solar assisted district heating with seasonal storage were already built.

2.1.2. Role of heat storage in heat supply

Seasonal thermal energy storages offer a great potential for substituting fossil fuels using solar energy for domestic hot water preparation and space heating. But nowadays, other technologies are developed and spread, which need or could use storages of big volumes. For example:

- Increased use of biomass for electricity production
- Increased use of geothermal energy and similar
- Increased use of waste heat from the industry
- Increased use of waste energy from electricity production through combined heat and power plants
- Increased use of electricity produced from wind and solar, meaning more and more variation in the electricity production, so that CHP production needs to be adapted.

Heat storages can here regulate load variations and dissociate the electricity production from the heat production through storage.

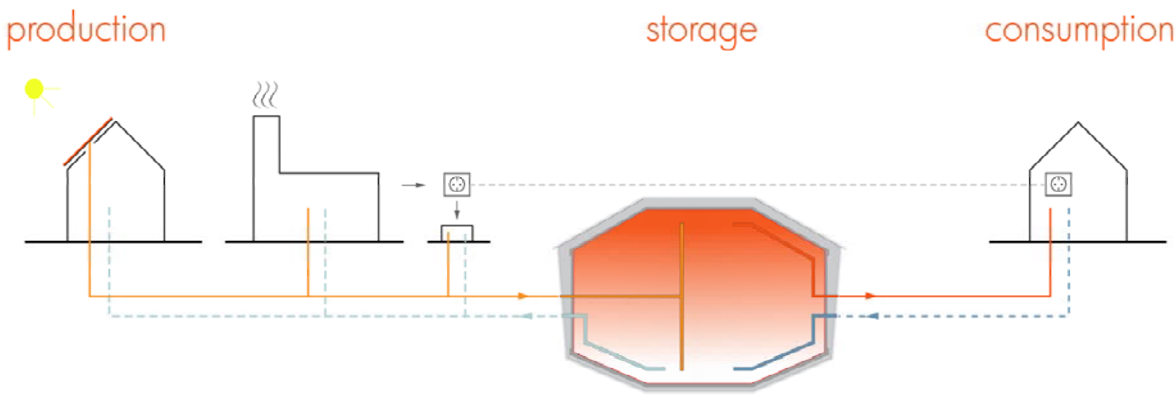

Figure 1: Multifunction storage (source: Solites)

2.1.3. Politics and strategy

The IEA in its Heating and Cooling Roadmap and the District Heating and Cooling Technology Platform in its strategic research agenda include thermal energy storages as central components in energy efficient systems in the future.

Since 2010, different European projects have begun, for example PIME'S (Play it more efficient, Sam, EU 7th Framework Programme, Grant Agreement No 239288), in which the feasibility of three solar seasonal storages is studied in countries where the technology is not yet developed: Hungary, Spain and Norway. More European projects like EINSTEIN (Effective integration of seasonal thermal energy storage systems in existing buildings, EU 7th Framework Programme, grant Agreement No 284932), for retrofitting applications, PYTAGORAS and SUNSTORE 4 include further development of the long term storage technology. Out of Europe, the interest about this technology awakened with the construction in 2006 of the pilot plant "Drake Landing" in Okotoks, Canada.

2.2. State of the art

Themes	Learning objectives
• **Size of storages**	o Notion of surface/volume ratio o Rules to be energy efficient
• **Location**	o Decision criteria on the location
• **Integration in the sys-tem**	o Operation temperatures requirements o Stratification in the storage o Weather data o Load characteristics
• **The four storage types**	o Detail of the functioning principle of each type of storage
• **Geological conditions**	o Hydro geological requirements o Legal authorizations
• **Materials / Thermal losses**	o Quality requirements of the materials o Influence of moisture and high temperatures on the thermal conductivity of porous materials
• **Dimensioning**	o Notion of heat capacity for each storage type
• **Costs**	o Notion of prices according to storage's type and size
• **Cold storage**	o Example and overview of another use for large storages

2.2.1. Minimal size

Storing solar thermal energy seasonally with sensible heat starts to be energy efficient with a storage volume of 1000 m³ of water or more. However, new technologies developments might allow smaller storages to become energy efficient.

2.2.2. Location: underground or on ground-level?

There are many reasons why very large storages are mostly built underground: static,insulation, integration in residential. However, some smaller storages (see Crailsheim) are built on ground level.

2.2.3. Integration in the system

The operation conditions are different for each system: the operation temperatures, the quality of stratification, and the return flow temperature of the heating net influence the thermal losses of a seasonal thermal energy storage.

2.2.4. The different types of underground storages

During the past ten years of research on seasonal storage technologies four different types of storages turned out as main focus for the ongoing engineering research.

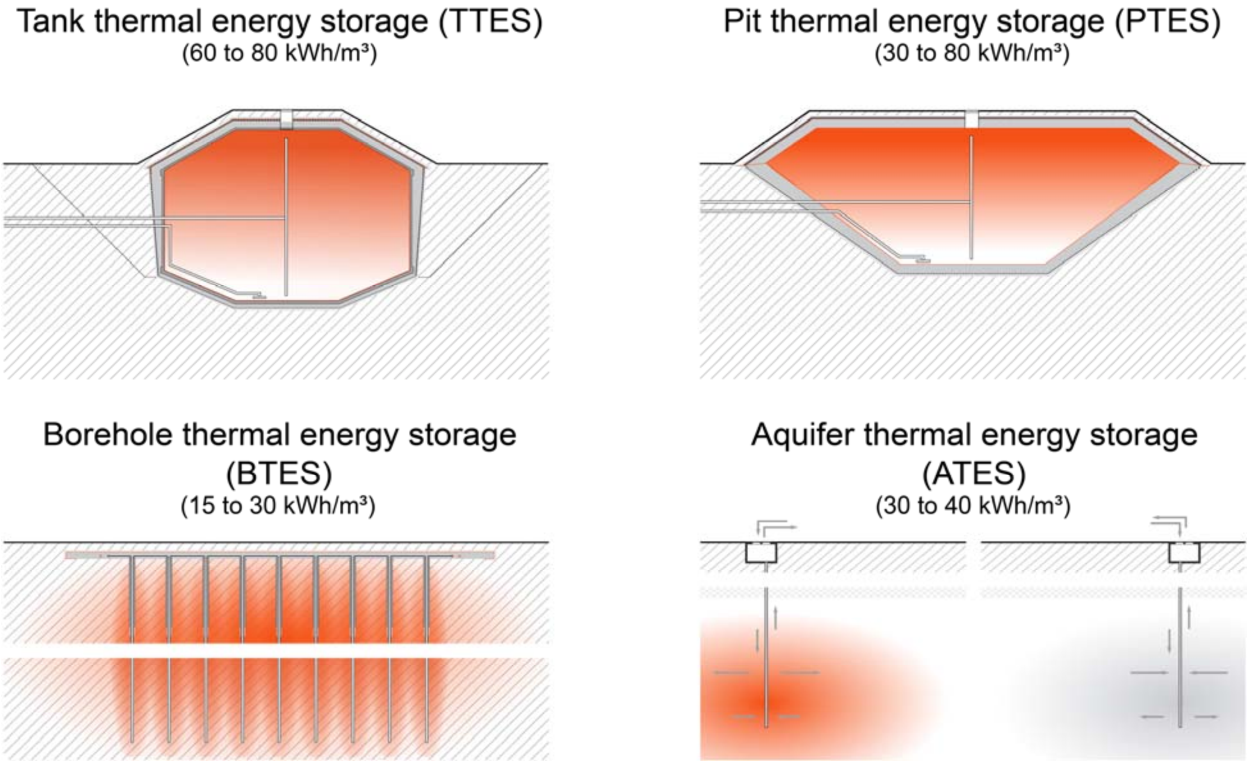

Figure 2: The four sensible seasonal thermal energy storage technologies (source: Solites)

2.2.5. Geological conditions

For each storage, a hydro-geological study is needed: stratigraphy, location and drift of the groundwater layers, hydraulic conductivity of the ground, flow rate and direction of the ground waters. A legal authorization procedure must be started early in the project about water in the area. The conditions enabling the construction of a storage are different for each type of storage.

2.2.6. Materials and thermal losses

For every storage, the materials and structures used must ensure that the functioning is guaranteed over a period of 40 to 50 years. Problems are encountered in the practice of higher thermal losses than predicted. Study on the influence of increasing moisture content and increasing temperatures on the thermal conductivity of porous materials showed that the thermal conductivity of the insulation material was assumed too low.

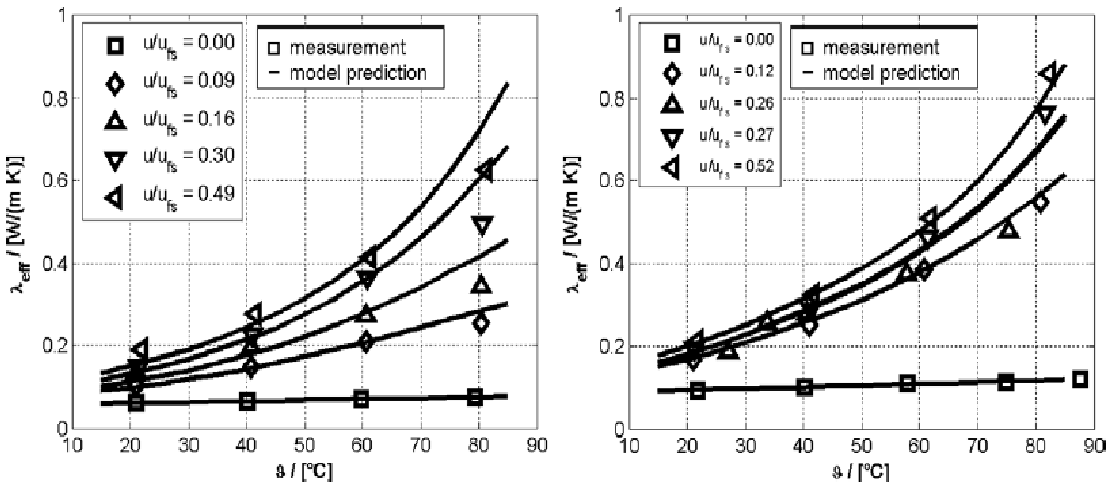

Figure 3: Model predictions and measured data for the thermal conductivity (λ_{eff}) of expanded glass granules 4-8 mm type II (left) and expanded clay 4-8 type I (right) as function of the temperature (source: Ochs et.al 2006-2, Ochs et.al. 2006-3)

For example, the thermal conductivity of the insulation was taken from DIN 4108 (DIN4108 Teil 4 2004), which gives thermal conductivities for average temperatures of 10°C. However, as can be observed on the graphic (Figure 20, source: Ochs et.al 2006-2, Ochs et.al. 2006-3), the thermal conductivity of porous materials increases with increasing moisture content and with increasing temperature. The assumption of constant materials properties such as effective thermal conductivity of the insulation material and of the surrounding ground, but also the water vapour resistance index of the liner leads to wrong results. Hence, a major part of the increased thermal losses of pilot and research storages may result from moistened insulation. The quality of the envelope with respect to protection against moisture penetration is therefore often deficient. This phenomenon is now taken into account in newest projects for better simulation and design.

2.2.7. Dimensioning

The following table summarizes some of the main parameters for each type of storage.

Table 1: Comparison of storage concepts regarding storage medium, heat capacity and volume (source: High-Combi, D2.6 State of the Art of Similar Applications, 2007)

	TTES	PTES	BTES	ATES
storage medium	water	gravel-water	soil/rock	sand water
heat capacity [kWh/m³]	60-80	30-50	15-30	30-40
storage volume for 1 m³ equivalent	1	1.3 -2	3 - 5	2 – 3

Table 2: Energy capacities, power, efficiency and storage time of thermal energy storage technologies (source: IEA technology roadmap energy-efficient buildings: heating and cooling equipment, 2011) (TES: thermal energy storage)

TES technology	Capacity [kWh/t]	Power [kW]	Efficiency [%]	Storage time	Cost [€/kWh]
Hot water tank	20-80	1-10 000	50-90	day-year	0.08-0.1
Chilled water tank	10-20	1-2 000	70-90	hour-week	0.08-0.2
ATES low temp.	5-10	500-10 000	50-90	day-year	varies
BTES low temp.	5-30	100-5 000	50-90	day-year	varies
PCM-general	50-150	1-1 000	75-90	hour-week	10-53
Ice storage tank	100	100-1 000	80-90	hour-week	4.7-15.6
Thermal-chemical	120-150	10-1 000	75-100	hour-day	7.8-40.6

Note: ATES stands for aquifer thermal energy storage and BTES stands for borehole thermal energy storage

2.2.8. Costs

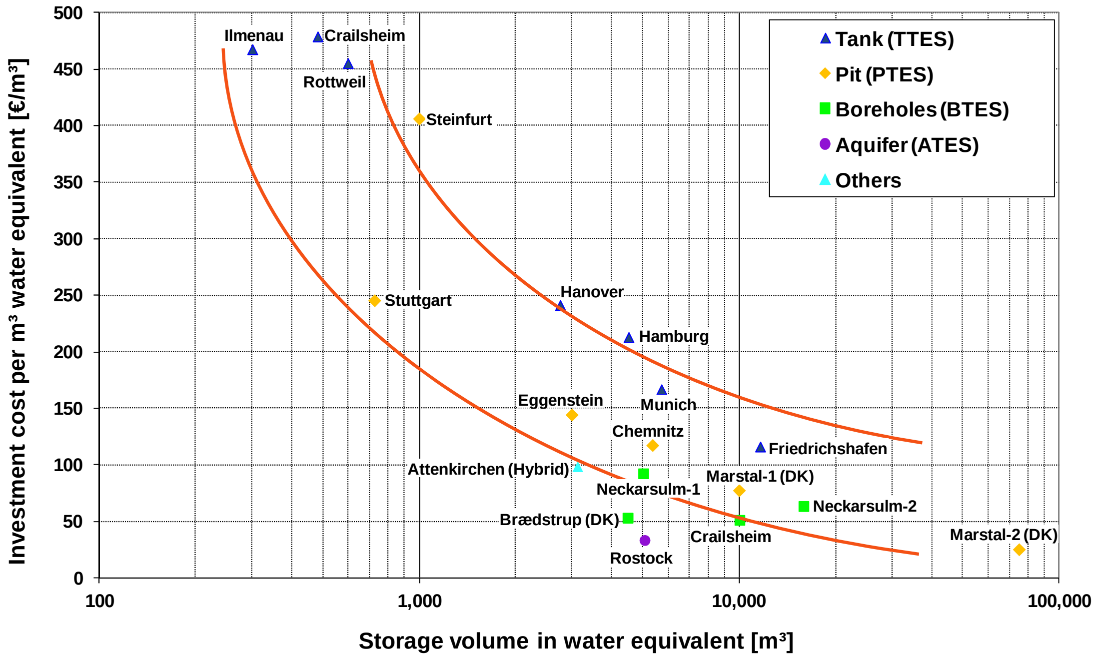

Figure 4: Specific storage costs of demonstration plants (cost figures without VAT) (source: Solites)

2.2.9. Cold storage

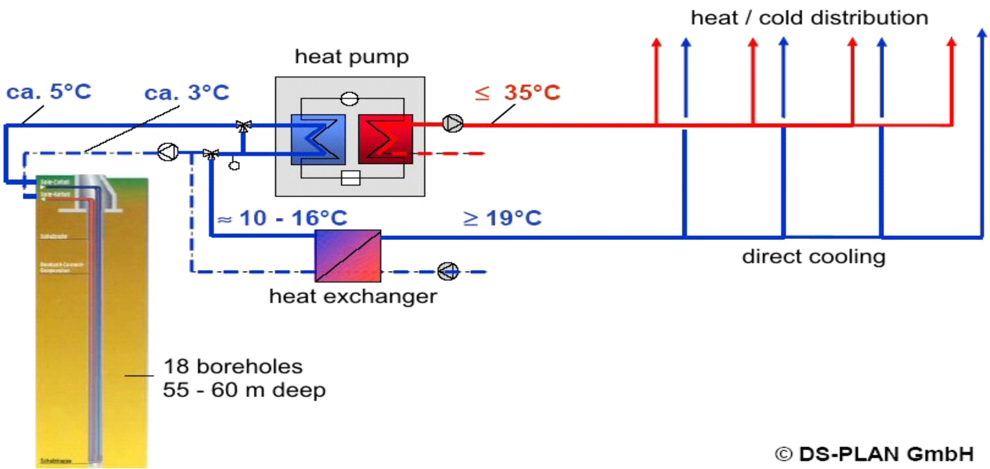

Figure 5: Project for an office building's heating and cooling in Stuttgart (source: SoilCool/Rekyl project, Pre-design guide for ground cooling systems with thermal energy storage, 2004)

2.3. Examples of realized projects

Themes	Learning objectives
• **Project development**	o Example of the development of a project o Example of a construction cycle (photos)
• **Practical issues**	o Lessons learned from pilot projects o Technical, organizational issues encountered
• **Performances**	o Measured performances of one or more pilot projects / comparison with planned performance

2.3.1. Project development

Example in Crailsheim, Germany

Figure 6:Drilling the boreholes

Figure 7: pipe installation in the boreholes and foam glass gravel insulation

Figure 8: Coverage of the insulation layer

2.3.2. Performances

It is important to monitor the performances of built storages, to collect information, compare to the previsions made when planning and designing the storage, and finally gain new knowledge on the technology. To evaluate and check the performance of a storage, the following criteria can be used:

- Heat storage capacity in kWh/m³.
- Storage efficiency: to evaluate the heat losses due to storing the heat
- Operation temperatures/pressure
- Number of cycles (full charging and discharging) per year

Of course, all these values have to be considered in relation to the investments costs, the additional costs to the heat delivered and also the production costs saved by using the storage.

2.4. Industry presentations

Themes	Learning objectives
• **Materials and products**	o Materials and products available on the market and their costs
• **Technical solutions**	o Discover technical solutions offered by industy on the market

2.5. Applications

Themes	Learning objectives
• **Applications of the technology to different energy production systems**	o Overview of some of the possible applications of large storages and their advantages in the different energy production systems o The concept of Smart District Heating (example of the Sunstore 4 project in Denmark) o Possibility of CHP optimization

2.5.1. Smart district heating (Sunstore 4)

Smart district heating is combining renewable energy technologies and thermal storages in such way that the district heating system is linked in a very flexible and constructive way with the liberal electricity market. Main features of a smart district heating system are long term storage, solar collectors, heat pumps and combined heat and power units.

More and more electricity is produced from wind and solar. This means more and more variation - both short and long term - in the electricity production and more difficult conditions for the traditional CHP units. The “smart district heating” concept is developing to assist in solving the problems connected to these two issues.

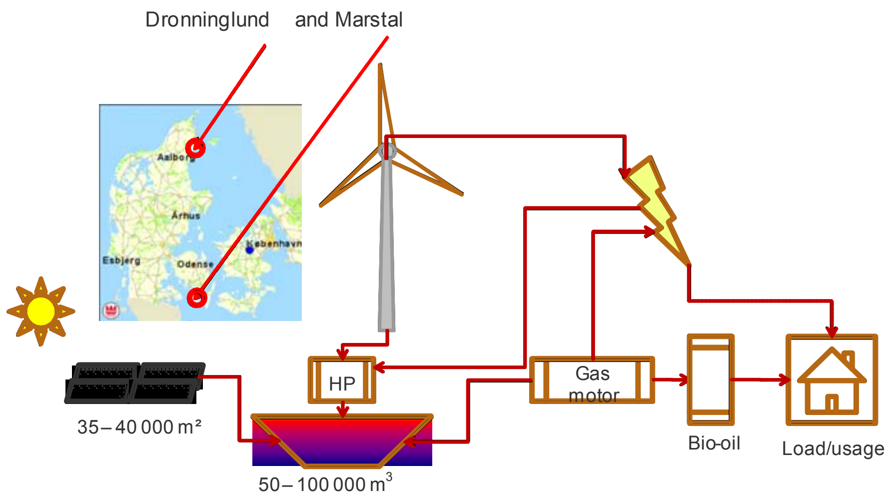

Figure 9: Example of Smart district heating system in Denmark (source: Planenergi, DK)

2.5.2. CHP optimization

Advantages of adding a storage to a CHP system:

- Flexibility: the electricity production can become independent from the heat distribution through the storage, for example in summer time

- Cost- efficiency: by increasing the possible peak electricity production and increasing the efficiency of the CHP system

- Future adaptability: a storage also makes the CHP systems using renewable energies (as biomass) more efficient.

2.6. Visit

Themes	Learning objectives
• **Guided tour of a large storage installation**	o Practical experience

3. TWO-DAY COURSE PROGRAM

In the following an exemplary program for a two-day training course on large thermal energy stores is presented.

Day 1

½ hour	**Introduction** - Role of heat storages in heat supply - Politics and strategy, national and international
2 hours	**State of the art** - Working and building principles of large heat stores (on ground level as well as underground) - Cold storage - Criteria of decision during project development
1 hour	**Presentations of related industries or service providers**
2 hours	**Examples of realized projects, analyze** - Example of a realized steel storage, cold storage - Examples of realized underground storages, e.g. Crailsheim, München

Day 2

1 hour	**Heat storage application: CHP optimization** Technical influences on the CHP systems and current penetration of the heat storage technology in district heating systems
1 hour	**Heat storage application: Seasonal storage in solar district heating systems, smart district heating** - Presentation of the concept - Examples Solarthermie2000 - Example Sunstore4, Marstal, DK
3 ½ hour	**Technical presentation and site visit of a realized large thermal energy storage.**

Example: Program of the course held by AGFW and Solites in July 2012 in Hamburg:

Anmeldung zum Seminar
"Große Wärmespeicher und Speicherkonzepte"
Für die vorgenannte Veranstaltung melden wir verbindlich folgende Teilnehmer an:

Name, Vorname | E-Mail des Teilnehmers

Unternehmen

Straße, Postleitzahl, Ort

Der Seminarbeitrag von EUR 825,- (AGFW-Mitglieder)/EUR 1.650,- (Nichtmitglieder) zzgl. 19 % MwSt. pro Teilnehmer wird von uns nach Erhalt der Anmeldebestätigung und Rechnung überwiesen, Kennzahl: 14229

Bitte buchen Sie für mich ☐ ein Nichtraucherzimmer ☐ ein EZ für meine Voranreise: 02.-03.07.2012 (auf eigene Kosten)

Ort, Datum | Unterschrift, Stempel

Veranstaltungstermine

Zeit: 3.-4. Juli 2012

Veranstaltungsort:
Arcotel Rubin
Steindamm 63
20099 Hamburg
Tel. +49 40 241 929-0
Fax: +49 40 241 929-2550
rubin@arcotelhotels.com

Teilnehmer: Maximal 30 Personen

Leistungen: Vortragsunterlagen, 1 Übernachtung, Begrüßungsimbiss, Mittagessen, Abendessen, Kaffeepausen, Tagungsgetränke

Hinweis: Voranreisen (EZ-Preis: EUR 109,-) buchen wir gern für Sie. Bei Bedarf nehmen Sie bitte eine Anmerkung auf dem Anmeldeformular vor.

Gebühr: EUR 825,- zzgl. 19 % MwSt. pro Teilnehmer (AGFW-Mitglied), EUR 1.650,- zzgl. 19 % MwSt. pro Teilnehmer (Sonstige)

Bestätigung u. Rechnung: Erhalten Sie zusammen nach Eingang Ihrer Anmeldung.

Anmeldung: Mit beiliegender Antwortkarte. Die Anmeldungen werden in der Reihenfolge des Eingangs berücksichtigt. Eine telefonische Reservierung oder Anmeldung ist nicht möglich.

Abmeldung: Bei Abmeldung wird eine Bearbeitungsgebühr von EUR 100,- berechnet. Die Nennung eines Ersatzteilnehmers ist kostenlos.

Weitere Programmhinweise

Stornierung: Falls dieses Seminar aus wichtigen Gründen storniert werden muss, erhalten Sie sofort Nachricht und wir erstatten ggf. bereits gezahlte Gebühren zurück. Sonstige Ansprüche entstehen nicht.

Auskunft: AGFW-Geschäftsstelle
Marion Schäfer
(organisatorisch)
Tel.: +49 69 6304-415
Fax: +49 69 6304-391
E-Mail: m.schaefer@agfw.de

Dr. Heiko Huther
(fachlich)
Tel.: +49 69 6304-206
Fax: +49 69 6304-391
E-Mail: h.huther@agfw.de

Wissenschaftliche Begleitung:
Steinbeis Forschungsinstitut für solare und zukunftsfähige thermische Energiesysteme, Stuttgart, info@solites.de, www.solites.de

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Veranstalter: AGFW | Der Energieeffizienzverband für Wärme, Kälte und KWK e. V.

Organisation: AGFW-Projekt-GmbH

Es gelten die Allgemeinen Geschäftsbedingungen der AGFW-Projekt-GmbH.

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Große Wärmespeicher Konzepte und Anwendungsbeispiele

3.-4. Juli 2012
in Hamburg

SDH solar district heating

Gefördert durch:
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit
INTELLIGENT ENERGY EUROPE

www.agfw.de

Seminar

Große Wärmespeicher Konzepte und Anwendungsbeispiele

Die Referenten

Dipl.-Ing. Martin Ebel
HGC, Hamburg Gas Consult GmbH, Hamburg

Dr. Heiko Huther,
AGFW - Der Energieeffizienzverband für Wärme, Kälte und KWK e. V., Frankfurt

Dipl.-Ing. Dirk Mangold
Solites - Steinbeis Forschungsinstitut für solare und zukunftsfähige thermische Energiesysteme, Stuttgart

Dr. Thorsten Urbaneck
Technische Universität Chemnitz
Fakultät für Maschinenbau
Chemnitz

Dipl.-Ing. Roland Ziegler
GEF Ingenieur AG
Leimen

Dipl.-Wirtsch. Ing. Stefan Kirsch
Rehau AG + Co.
angefragt

Dipl.-Ing. Christian Arnold
DNV KEMA
Dresden

Programmablauf

Moderation
Dr. Heiko Huther,
AGFW | Energieeffizienzverband für Wärme, Kälte und KWK e. V., Frankfurt am Main

Dienstag, 3. Juli 2012

10:00 Uhr	**Begrüßungsimbiss**
10:30 Uhr	**Einführung** - Rolle der Wärmespeicher in der Wärmeversorgung - Politische Rahmenbedingungen, nationale und internationale Strategien
11:00 Uhr	**Freistehende Wärmespeicher** - Stand der Technik - Auslegung, Planung und technische Einbindung - Vorstellung und Analyse von Projekten einschließlich Kältespeicher - Kosten und Wirtschaftlichkeit
13:15 Uhr	**Mittagspause**
14:15 Uhr	**Erdvergrabene und Untergrund-Wärmespeicher** - Stand der Technik - Bauarten: Tank-, Erdbecken-, Erdsonden- und Aquifer-Wärmespeicher - Vorstellung und analyse von Projekten (Crailsheim, München, Eggenstein-Leopoldshafen) - Kosten und Wirtschaftlichkeit
15:45 Uhr	**Industriebeitrag zu Erdsonden-Wärmespeichern**
16:30 Uhr	**Fragen und Antworten**
17:00 Uhr	**Ende des 1. Veranstaltungstages**
19:00 Uhr	**gemeinsames Abendessen und Erfahrungsaustausch**

Mittwoch, 4. Juli 2012

09:00 Uhr	**Wärmespeicher in der Anwendung: KWK-Optimierung** Systemtechnische Bedeutung und aktueller Stand des Einsatzes von Heißwasserspeichern in Fernwärmenetzen
10:00 Uhr	**Wärmespeicher in der Anwendung: Saisonale Wärmespeicher in solaren Nah- und Fernwärmesystemen, Smart District Heating** - Präsentation des Konzeptes - Beispiel Sunstore 4-Projekt in Marstal, DK
11:00 Uhr	**Vorstellung von innovativen Speicherkonzepten der E.ON Hanse Wärme GmbH durch den Planer**
12:30 Uhr	**Besichtigung des Multifunktionsspeichers in Hamburg Karlshöhe** Mittagsimbiss
15:00 Uhr	**Ende der Veranstaltung**

Absender

Name
Unternehmen
Straße
PLZ, Ort
Telefon
E-Mail
Telefax

AGFW-Projekt-GmbH
Marion Schäfer
Stresemannallee 30
60596 Frankfurt am Main

Bitte mit EUR 0,45 freimachen