European research school on large scale solar thermal – SHINE

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EUROPEAN RESEARCH SCHOOL ON LARGE SCALE SOLAR THERMAL - SHINE

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Abstract – The Solar Heat Integration NEtwork (SHINE) is a European research school in which 13 PhD students in solar thermal technologies are funded by the EU Marie-Curie program. It has five PhD course modules as well as workshops and seminars dedicated to PhD students both within the project as well as outside of it. The SHINE research activities focus on large solar heating systems and new applications: on district heating, industrial processes and new storage systems. The scope of this paper is on systems for district heating for which there are five PhD students, three at universities and two at companies. The PhD students all started during the early part of 2014 and their initial work has concentrated on literature studies and on setting up models and data collection to be used for validation purposes. The PhD students will complete their studies in 2017-18.

1. INTRODUCTION

The Solar Heat Integration NEtwork (SHINE) is a European research school in which 13 PhD students in solar thermal technologies are funded by the EU Marie-Curie program. It has five PhD course modules as well as workshops and seminars dedicated to PhD students both within the project as well as outside of it. It is the natural continuation of previous European activities for PhD students in solar thermal. In 2006 the SolNet network (Jordan et al., 2007) started with its first PhD scholarship project on “Advanced Solar Heating and Cooling for Buildings”, also funded by the Marie-Curie program of the EU. At that time, 10 PhD students were employed at nine different universities from all over Europe. The project included seven PhD courses, which were run bi-annually. After the end of the first SolNet scholarship project, a new course program was launched with annual PhD courses, supported by the two German industry federations “Bundesindustrieverband Deutschland Haus-, Energie- und Umwelttechnike.V.” (BdH) and “BundesverbandSolarwirtschaft” (BSW).

While the first SolNet PhD scholarship project covered components and system investigations of small solar heating systems, the focus of the new “SHINE”-project will be on large solar heating systems as well as new storage materials, i.e. sorption stores. Large solar heating systems are decisive to cover a major part of European low temperature heat demand by solar energy and therewith to meet European policy aims. However, at the moment only a small share of solar heating systems installed in Europe are large units due to manifold technical and socio-economic obstacles. The challenge of solar thermal technology, and the overall objective of the SHINE-project within the SolNet network, is to supply heat in larger solar heating systems for applications like industrial processes, to feed-in into district heating networks, or sorption drying and cooling. The SHINE project will tackle this with an innovative inter-disciplinary consortium, including scholarships for 13 PhD students. Six universities and five private sector participants from six different European countries will provide research and training in cooperation with four associated partners from the private sector.

The PhD students in the SHINE project started in early 2014 and their work covers detailed experimental material, component and system studies, system integration analysis and numerical optimization, as well as chemical investigations on storage materials. A close cooperation with industry should ensure fast exploitation of the results. Through the SHINE project, the SolNet network offers a specialized and structured PhD course program about large solar heating systems. The courses are open for all PhD-students in solar heating from all over the world.

The work is split into three different work packages: WP1, focusing on solar district heating (and the subject of this paper); WP2, studying solar heat for industrial processes; and WP3, focusing on sorption processes and materials. The overall research objectives within these three fields are:

- to reduce the large planning efforts (requiring expert knowledge) for systems integration into existing heating systems for new applications, especially for industrial processes,
- to optimize complex hydraulics in terms of flexibility to serve variable loads, overall collector efficiency, pressure drop and safety of collector stagnation for different boundary condition,
- to optimize operation strategies of the respective solar heating systems,
- to provide large, but inexpensive components like large stores and collectors,
- to detect errors within the complex hydraulics and controlling and to suggest suitable maintenance activities,
- to identify barriers within the supply chain and in the decision processes of the potential purchaser that limit the large scale implementation of the technology, and
- to improve the performance of sorption materials via chemical modification and combination of fluid solid hybrid materials.

2. PHD PROJECTS

Figure 1 shows a map with the participating organisations within SHINE and the preliminary title of their PhD study.

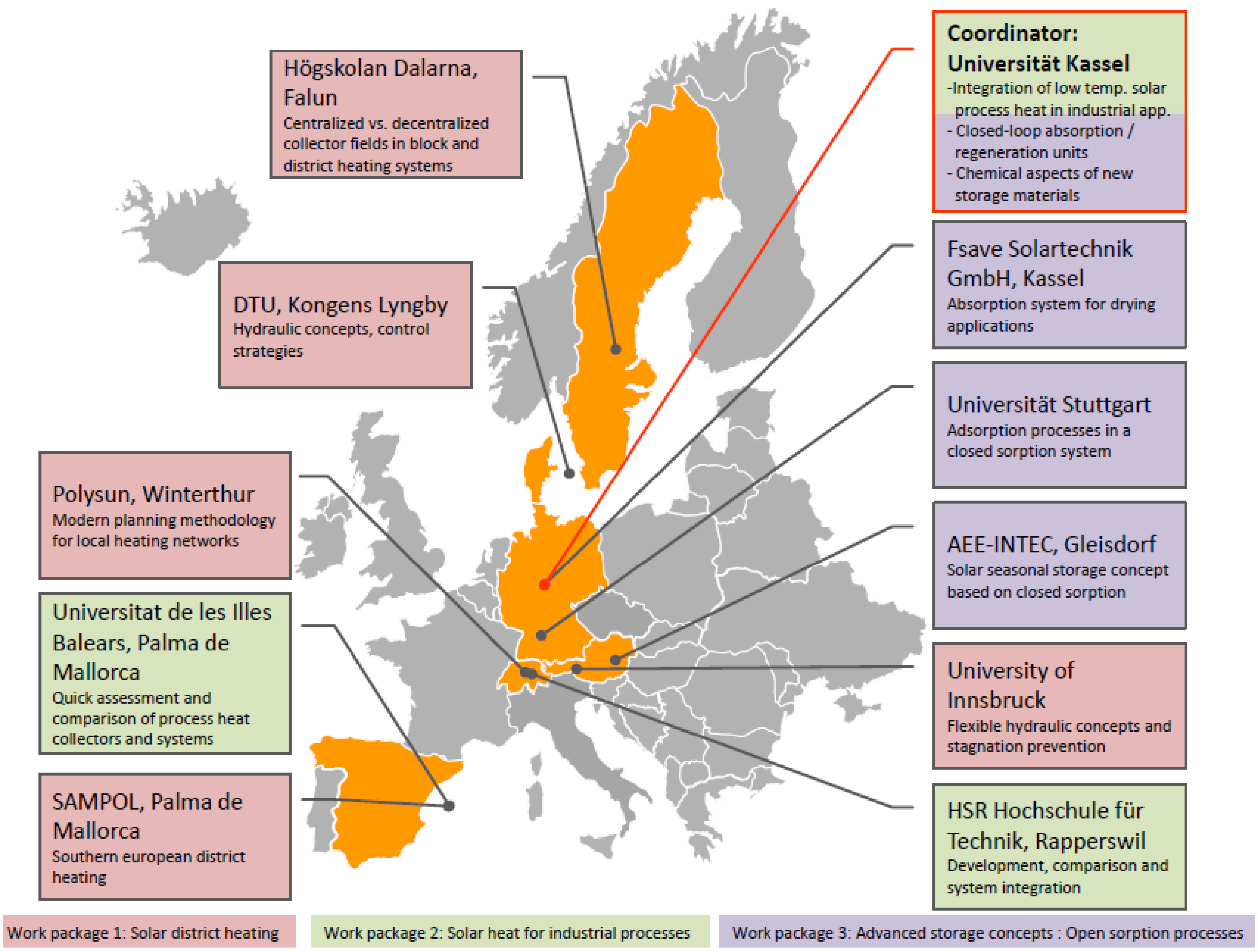

Figure 1. *Participating organizations and their PhD projects within the SHINE project showing the split into the three different focus areas (work packages).*

The PhD project at Högskolan Dalarna (SERC) will be made by Christian Nielsen, supervised by Chris Bales at Högskolan Dalarna and Jan-Olof Dalenbäck at Chalmers University of Technology. The main aims are to analyze the advantages and disadvantages of centralized and decentralized solar collector fields in district heating networks and to derive the technological and economic boundary conditions for profitable operation. Both de-centralized feed-in (connection on primary side) and district heat augmented systems (connection on secondary side) will be covered. The work will be coordinated with another PhD student in Sweden who is part of the national graduate school REESBE (REESBE, 2014), and who's aim is to derive detailed recommendations for feed-in systems covering design, control and safety aspects.

***Figure 2**. Building integrated collector field for the studied district heat augmented solar heating system at Högskolan Dalarna.*

The first study has been on a decentralized solar DHW system with district heating as back-up (see Figure 2), where monitoring data and TRNSYS simulations have been used to improve the system in terms of system design and control. Monitoring data have shown that the load assumed during the design phase was inaccurate, leading to a non-optimal design. Thus one of the outcomes is the need for good planning for such systems. The second study will be on the recently implemented block heating system at Vallda Heberg in southern Sweden (Dalenbäck et al., 2014), in which the system will be simulated in TRNSYS.

The PhD project at the University of Innsbruck will be made by Alireza Shantia, supervised by Wolfgang Streicher. The main aims are to develop and validate a detailed modular tool for the calculation of fluid flow and pressure drop as well as thermal losses/gains in hydraulic systems with series and parallel or mashed grids including the control characteristics of pumps and valves. With this tool the possibility for adaptive hydraulics for solar thermal systems as well as for space heating systems will be evaluated. The validation will be made for smaller scale hydraulic systems as well as full scale collector arrays. A simpler hydraulic layout was simulated in TRNSYS using models for pressure drop characteristics for valves, pumps and other components and the resulting flow rate could be determined. However, TRNSYS is not suited for this problem, so the current models are in Matlab® Simulink® using components from the Carnot blockset (Wemhöner et al., 2000) – see Figure 3.

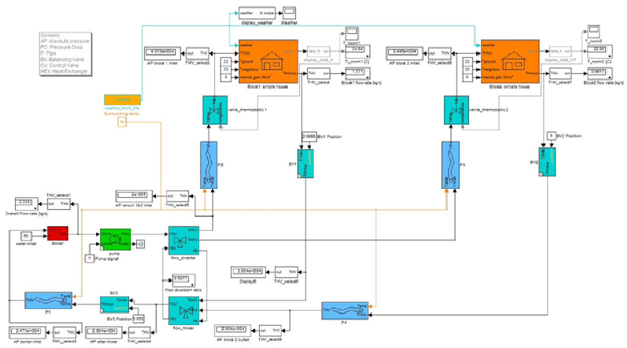

***Figure 3**. Example layout in Matlab® Simulink® of hydraulic scheme for test of model with pressure drops and flow rates using pressure characteristics of components (source: A. Shantia, 2014 ,Univ. of Innsbruck).*

The PhD project at the Technical University of Denmark (DTU) will be carried out by Federico Bava with Simon Furbo as supervisor. The main aims are to develop and validate a detailed model for large collector fields with the possibility of several different collectors in the same array. It will take into account the detailed flow distribution based on the hydraulic design, shadow effects, pipe losses and thermal capacity and will be used for studies on collector field control with dynamic boundary conditions. This project will be made in close collaboration with Arcon Solar A/S, one of the major suppliers of large scale solar collector fields. The first work has been to enhance an excel tool that calculates the overall pressure drop and flow distribution in the kind of large scale collectors that are used in large scale collector fields at centralized solar district heating systems. The tool has been verified for one collector product (see Figure 4), but showed some differences to the pressure drop reported by the manufacturer for another product. More detailed measurements at the lab of DTU are planned, both with water and water/glycol mixture, so that the tool can be verified for a range of conditions.

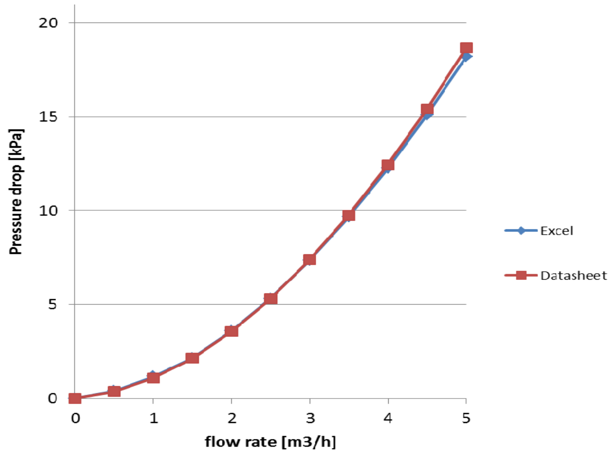

Figure 4. *Comparison of pressure drop characteristic of a collector derived using the excel tool developed at DTU and that given in the data sheet by the manufacturer (source: F. Bava, 2014, DTU).*

The PhD project at the utility Sampol Ingenieria y Obras S.A. will be carried out by Nicolás Pérez de la Mora, supervised by Pau Joan Cortés Forteza at Sampol and Victor Martinez Moll at Universitat de les IllesBalears. The PhD focuses on forecast baseline modeling (thermal/electric) of the different sources present in a tri-generation plant equipped with solar thermal support to the cooling production. From the forecast baseline models a set of proprietary computer tools will be developed that will work together with thermal simulation software TRNSYS in order to estimate the smart-district agents' energy demand, in order to determine the forecast energy production mix that minimizes the energy cost and optimize the electricity production. This will lead to an optimization of the plant operation and integration of the solar field. The first study has focused on the modeling of the existing "Parc Bit" plant and its control strategy in TRNSYS (see Figure 5).

Figure 5. *Picture of the Parc Bit plant comprising 900 m^2 collectors, 2 x 1.4 MW$_e$ co-generation units and 1.3 and 0.43 MW$_{cool}$ absorption chillers and associated hot and cold stores.*

The PhD project at the software company Vela Solaris AG will be made by Artem Sotnikov, supervised by Andreas Witzig at Vela Solaris and Wolfgang Streicher at the University of Innsbruck. The main aims are to develop and validate a powerful and user-friendly tool which supports the planning of solar district heating networks based on the well-known tool Polysun (see Figure 6). This means that newer models will be developed to broaden and extend the capabilities of the current version of the tool. This will include modeling of the demand in the network with several buildings being possible, more complicated borehole fields and cogeneration. This work will be in close collaboration with the other SHINE PhD students both in terms of the modelling aspects but also for obtaining data for model validation. In the early stage of the project, the extension of the building model has been specified and a reference simulation setup has been provided. In a next step, implementation will start in the source code of Polysun.

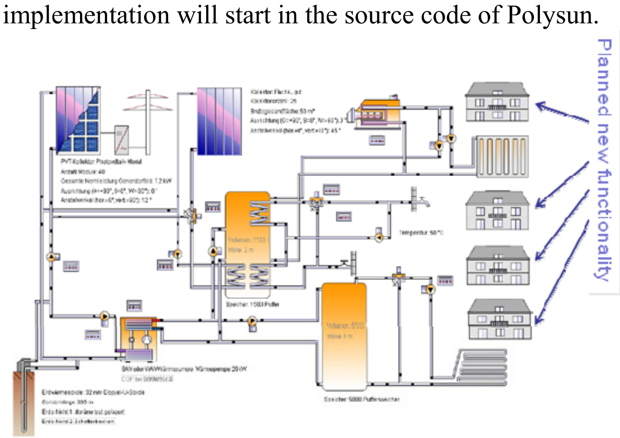

Figure 6. *Example system in Polysun showing the planned extra functionality with several buildings.*

Table 1. *Courses hosted within the SHINE project together with their dates, hosts and locations.*

Year	Host (location)	Title
February 2014	Universität Innsbruck (Innsbruck, AT)	**System Integration of Solar Thermal Plants**: Characterization, Guidelines, Analysis of Applications, Hydraulics, Control Systems, Dimensioning and Optimisation, Design Exercise
February 2014	Högskolan Dalarna (Innsbruck, AT)	**Dynamic simulation of energy systems**: Simulation tools, assumptions and simplifications at component and system level, planning of simulation studies, individual project.
May 2014	Technical University of Denmark (Lyngby, DK)	**Heat storage for solar heating systems**: Modelling, Experimental Investigations, Seasonal storage, Stratification in water stores, PCM, Thermo-Chemical.
Spring 2015	Universitat de les IllesBalearsares (Mallorca, ES)	**Solar collectors**: Heat Transfer and Optics, Solar Collector Modelling and Testing, High Temperature Flat-Plate Collectors, Building Integration of Solar Collectors.
Spring 2016	Kassel University (Kassel, DE)	**Applications for large solar heating systems**: District heating, industrial Process Heat and Sorption Processes

The financing for the PhD projects is 3 years through the SHINE project and is in some cases supplemented with additional third party funding. The thesis projects will thus be completed in 2017-18.

3. TRAINING PROGRAM

Table 1 shows the courses within the SHINE project as well as the dates, hosts and location. Before the start of the SHINE project, nine PhD level courses had been carried out at member universities. During the project, five more will be completed. Of these, three have already taken place in the first half of 2014. These are open to all PhD students, although only SHINE students are guaranteed places. The number of students generally ranges from 20 to 30 and the courses act as a perfect networking forum for young researchers in solar thermal.

ACKNOWLEDGEMENTS

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