SOLAR HEAT FOR INDUSTRIAL PROCESSES AND INDUSTRIAL ENERGY EFFICIENCY IN MALAYSIA AND EGYPT

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Abstract

Within two UNIDO-GEF5-projects industrial companies in Malaysia and Egypt are supported along the identification and implementation of energy efficiency and the optimized implementation of solar heat for industrial processes (SHIP). The main goal is to prove the feasibility of solar process heat in terms of technical and economic criteria and by this initiate a sustainable market penetration beyond the project. Based on the specific demands of industry as well as the status quo regarding awareness and capacity in the countries, a tailor-made program for training and involvement of relevant stakeholders was developed and implemented. Within this capacity building more than 1,100 trainees were trained on the identification of optimized solar integration concepts, applying a feasibility tool along the well-recognized methodology of IEA-SHC-Task 49/II. Real implementations of energy efficiency and SHIP were achieved (resp. initiated) and project findings implemented in a roadmap, expecting a maximized impact in both countries.

Keywords: Solar heat for industrial processes, SHIP, energy efficiency, tool, standardized methodology, innovative financing

1. Introduction

Objective of the UNIDO project „Green House Gas Emissions Reductions in Targeted Industrial Sub-Sectors through Energy Efficiency and Application of Solar Thermal Systems in Malaysia“ is to introduce a resource efficient production in the most energy relevant industry sectors as basis for the technical and economic feasible implementation of solar heat for industrial processes. The structure of Malaysia's energy consumption and distribution is, except residential heating demand, comparable to a typical European country. Malaysia is the third largest energy consumer in South-East Asia and according to the World Energy Outlook 2015[1] report, Malaysia will almost double its energy demand between 2015 and 2040. As per the National Energy Balance[2] 2016 figures, the energy consumption in Malaysia in 2016 was about 2,400 PJ (equivalent to 57,218 ktoe), of which 28 % are dedicated to the industry. The largest consumer is the transportation sector with a share of about 42 %. Accounting for a portion of 40.7 % of the primary energy supply, natural gas is the dominating energy carrier, followed by crude oil (29.7 %), coal and coke (20.2 %) and hydropower (4.8 %). The share of renewables is, although steadily growing, with 0.8 % at a very low level. In the industry sector, also natural gas (37.0 %) and electricity (33.6 %) are beside coal&coke (13.5 %) and petroleum products the most important energy sources. The Malaysian government has been proactive in discovering new thrust areas for development in the renewable energy space, especially after setting such enterprising targets for clean energy in alignment with its Nationally Determined Contribution (NDC) pledge. At the 21st COP summit in Paris, the country officials declared their INDC to reduce the country's greenhouse gas (GHG) emissions intensity of Gross Domestic Product (GDP) by 45% (35% unconditionally and 10% upon receipt of technology transfer and capacity building from developed countries) by the year 2030 relative to its emissions intensity of GDP in 2005. The most important industry sectors in Malaysia are "iron and steel", "petroleum products" and "production of food and beverages". Especially in the industry the share of renewable energy is, beside hydropower, negligible. At the same time the conditions for the integration of renewables and in detail solar process heat is excellent, as the solar irradiation of minimum 1,600 kWh/m².a is by far higher than in regions with

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[1] Data from World Energy Outlook- South-East Asia Energy Outlook 2015

[2] Malaysia Energy Statistics, 2016

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significantly lower solar irradiation but high number of SHIP implementations as e.g. in Central Europe. Also the share of diffuse radiation is due to the weather conditions comparable to Central Europe. As shown, the Malaysian industry (sectors, applied processes and energy demand) is comparable with Europe and by this has a high solar process heat demand in the low and medium temperature range (>100°C / 100..250°C). Addressing this demand is the objective of the above-mentioned project.

2. Methodology

Initiating solar heat for industrial processes (SHIP) has to start with awareness rising and capacity building. As in a lot of countries, terms as industrial energy efficiency and solar energy are linked to optimized electric utilities as pumps or fans and the use of solar for the generation of power via photovoltaic panels. Addressing these expectations is based on the awareness for the technical and economic potential and feasibility of thermal efficiency and solar process heat. Based on long-lasting experience identified relevant stakeholders are: (i) decision makers and industrial top management, (ii) production and energy managers in industrial companies, (iii) consultants and technology suppliers and (iv) training and capacity building. It is crucial to develop tailor-made communication and dissemination strategies. Key notes to decisions makers in half-day workshops, followed by 2-day-trainings for production and energy managers are the basis for detailed trainings for those who are finally doing the identification and design of real implementations. The objectives of the first strategies are to transfer knowhow and reduce barriers and address reservations. Very often, solar process heat is seen as new to the market including high technological and economic risks. Cost and risk reduction are by this the basis for the innovative training approach for consultants and energy managers.

In two 4-day trainings, the methodology for the optimized concept development is the core of the apprenticeship. It is seen crucial to have motivated industry on board with a high potential for energy efficiency and solar process heat. By this, the theoretical background trained in classrooms can be applied in so called host companies, acting as playground for the trainees. Standardized methodologies as the ISO 50001 or the European standard EN 16247 for industrial energy assessment and energy management systems are the basis for the training and more important the identification and the evaluation of possible integration of EE and SHIP in industrial energy systems. “Efficiency is the first fuel” is the slogan, so a very good overview of the status quo of the industrial energy system has to be achieved. This is mainly part of the first 4 days of training, followed by doing the job in the field. Normally, after 4 to 6 months the trainees come back to the classroom to focus on the solar integration with the second 4-day-training. Objective is to develop concepts for the optimized integration of SHIP without using detailed simulations or tools, in most cases not available and affordable in this project phase. Being able to evaluate different opportunities and having the basis for a further assessment decision was the starting point for the development of the SHIP tool at AEE INTEC. This is tailor-made on the one hand for the demand during a feasibility study and on the other hand available data after doing the performed assessment of the industrial status quo.

3. SHIP-Tool

The SHIP tool supports trainees and users along the identification and evaluation of solar concepts and finally the decision-making process in order to initiate real implementations. A guideline developed within IEA SHC Task 49/IV presents the overall necessary steps of an assessment methodology for solar process heat projects and leads the planner in detail through the following steps: 1) consideration of **process integration for solar process heat**; 2) specification of **integration concepts**; 3) planning of **solar process heat systems concepts;** and 4) **criteria for selecting most promising integration points**.

The starting point of the methodology is always a detailed assessment of the processes (load profile, energy demand, temperature, etc.) and the energy supply system to serve as a baseline for to evaluate the concept. This also includes possible excess heat recovery potentials (thermal energy efficiency), which is an important topic in industrial drying and depends on the drying temperature and system. Based on this assessment, the most efficient industrial process can be designed, followed by the solar energy system. There are several tools available supporting the planner in the system design (see IEA SHC Task 49).

Following this methodology, addressed features of the tool are:

- **Process integration:** based on yearly load profiles (hourly resolution), process and supply parameter (mass flow, temperatures), optimized integration concepts on process and system level are identified (design of heat exchanger, storage, losses, collector, etc.)

- **Solar concept:** collector type, climate data (solar irradiation, ambient temperature), collector placement and storage size included in evaluation of concepts based on a yearly simulation and defined key performance indicator
- **Technical and economic evaluation:** comparison of identified concepts as basis for optimized system design and feasibility studies

Starting point is the definition of industrial load profiles for the energy demand. It is important to identify day-to-day differences, weekend breaks or holiday season, especially in case these match with the highest solar availability. The user has to provide capacity rates, while the tool will generate the graphical output of these automatically (see Figure 1)

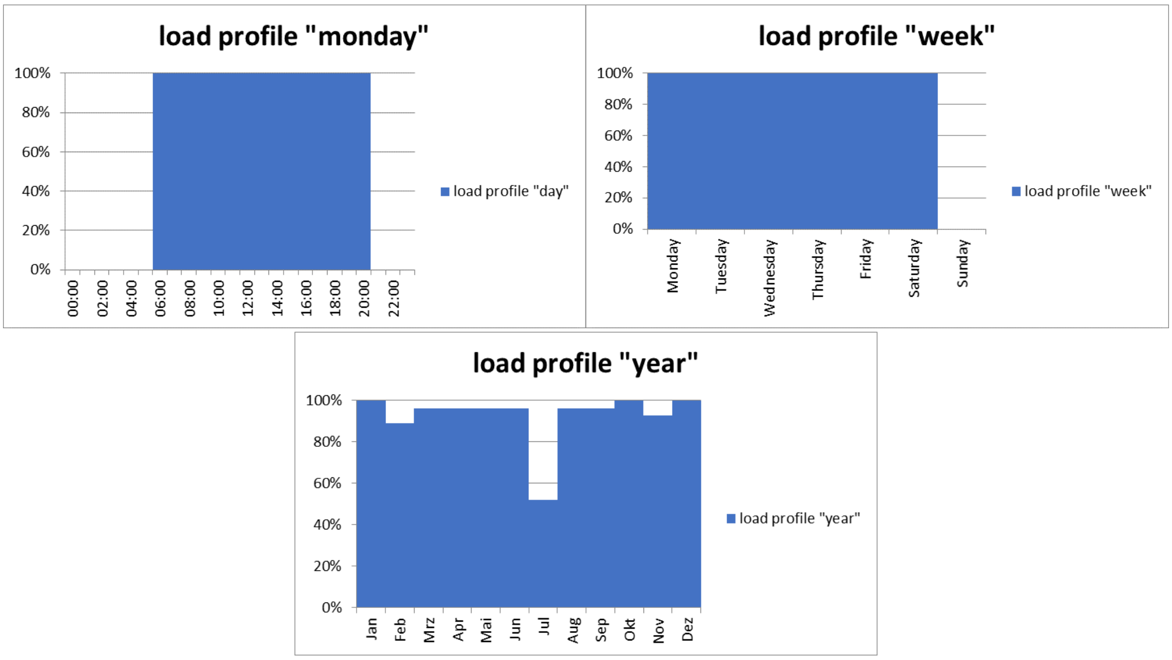

Figure 1: Automatically generated load profile for industrial energy demand based on user's input – weekly, monthly and yearly

The next step is the identification of an optimized integration point for solar process heat as this influences significantly the efficiency and complexity of the system, and by this its costs and economic feasibility. The way solar process heat is integrated in the industrial supply system significantly influences its technical and economic feasibility. Integration issues are becoming more important as the existing industrial supply and distribution system is much more complicated than in buildings due in part to the varying demand load profiles over a day, week, month and year. Therefore, several research projects have addressed this issue by developing methods to assist in the design and planning of solar process heat with an emphasis on feasibility. One of the most important projects is the International Energy Agency Solar Heating and Cooling Programme Task 49/IV (IEA SHC Task 49/IV) that contains three Sub-Tasks (A-C). In particular, Sub-Task B *Process integration and Process Intensification combined with solar process heat* has produced many resources to assist with integration issues. As a starting point, integration is possible at the “Supply Level” and “Process Level”. Supply level integration means integrating solar heat within the central heat distribution lines or central heat storages (see Figure 2 – pathway A: Integration on Supply Level, A1-A3), while process level means integrating solar heat to one specific process step or process heat storages (see Figure 2 – pathway B: Integration on Process Level, B1-B3).

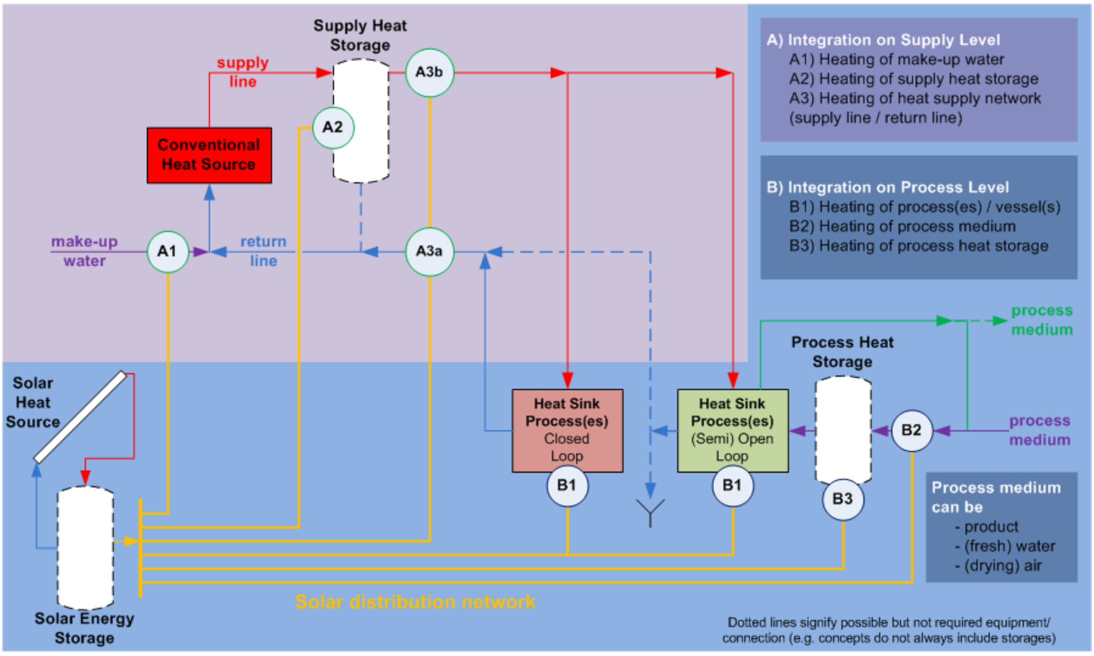

Figure 2: Integration of Solar Process Heat based on IEA SHC Task 49/IV

During the training the trainees learn how to apply available information by studying integration concepts appropriate for their cases studies. Overall, a system for solar process heat consists of up to 5 subsections as shown in Figure 3:

- collector loop
- charge
- storage
- discharge
- integration point

In low-temperature SHIP systems with storage, usually all five sections can be distinguished but depending on the envisaged system design, specific components can be dropped (e.g. the storage) and/or a backup system may be included to ensure a trouble-free and continuous production irrespective of variations in solar resources.

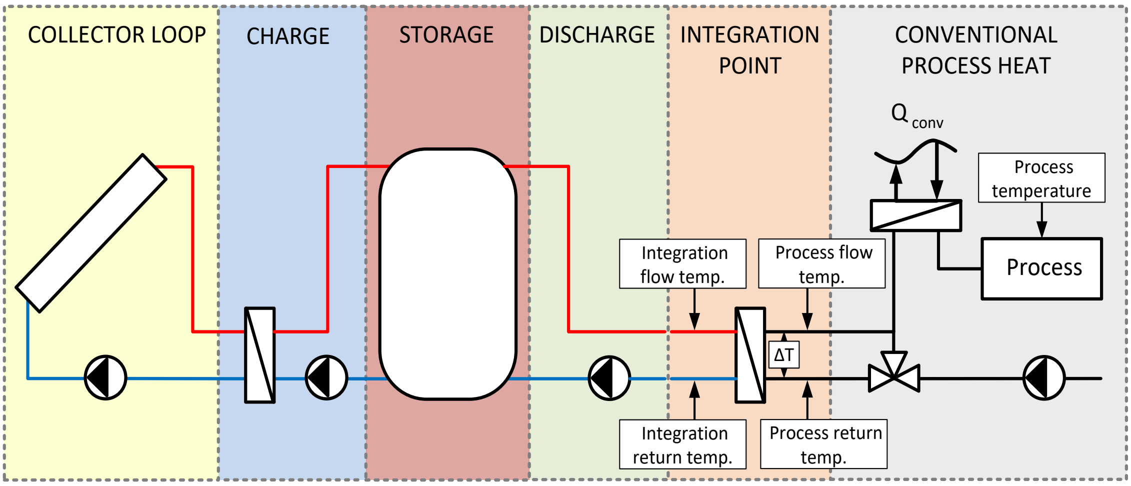

Figure 3 General SHIP system for pre-heating with five subsections supplying an industrial heat consumer (Helmke and Hess, in Muster-Slawitsch et al., 2015)

The key for reliable continuous energy supply to the energy demand is the design of the overall system including the collector, the storage, the integration point, the charging and discharging strategy and if needed a backup system.

- *Collector:* The selection of the most efficient and appropriate collector technology and the design of the collector field strongly depend on the process requirements (temperature, load profiles, capacity, production breaks, holiday breaks, etc.). Depending on the temperature levels needed, all collector technologies can be implemented as flat plate collector, evacuated tube collector and concentrating technologies as parabolic trough collector or others. An optimized system design increases the efficiency and yield of the collector by the interaction with charging and discharging strategies and components, the orientation and placement of the field. Finally, this influences the costs of the system and is a key not only in supplying drying technologies.
- *Storage and backup system:* Part of the system is in most cases also storage when the heating demand and the solar availability do not match in matters of time and load profiles. By the optimized integration and design of the storage (size, insulation, etc.) the economic feasibility can be significantly increased. Especially for industrial processes, an interruption-free supply is mandatory. Therefore, a backup system might be required. The use of existing systems and its best integration in the solar system (e.g. via the storage) is part of the overall design methodology.
- *Integration point:* This can be done on both levels, the supply and the process level. Going for the supply level means the (pre)heating of a supply medium or the drying gas delivering the heat to all industrial consumers, not only the dryer(s). On the process level, the solar energy would be designed specifically for the demand of one single process, the dryer. This is, in most cases more complex (hydraulic design) than the supply level integration. Supplying more processes means more heat exchangers and storages.On the other hand, the required temperature (to be delivered from the solar system) is in most cases lower on process level than on supply level, that is in most cases designed to supply energy to the whole system and therefore is operating at higher temperature levels. This also leads to higher distribution losses. Due to this fact, process integration is more efficient (higher specific solar yield) than supply integration. The whole energy system has to be designed in the most technical and economic optimized way, including possible excess heat recovery as well as a backup system (if necessary).

As a sidestep to be mentioned, for industrial processes and the used technologies, steady development is ongoing. New process technologies aim to enhance heat and mass transfer to “intensify” reactions, mixing or heating/cooling of process media, including mechanisms of drying. These intensification strategies can also increase the potential for solar thermal process heat by decreasing the process temperatures (higher system efficiency), increasing the process efficiency or smoothing the energy demand (reduction of peak loads). Strategies, also tackled within the training, used in new technologies with impacts on solar heat supply are:

- Heat transfer enhancement
- Batch to continuous
- Increasing selectivity in separation processes
- Intensification of electro hydrodynamics

In order to make this approach applicable to real cases and increase the technical understanding of the trainees, a direct link between the integration concepts of IEA SHC Task 49/IV and the training methodology is established. Trainees study these documents and identify the most suitable integration concept for their case study. In Figure 4 an exemplary scheme of a heat integration concept is presented, including solar heat as a utility. Simulations allow the designing of heat exchangers and storages to achieve best performances.

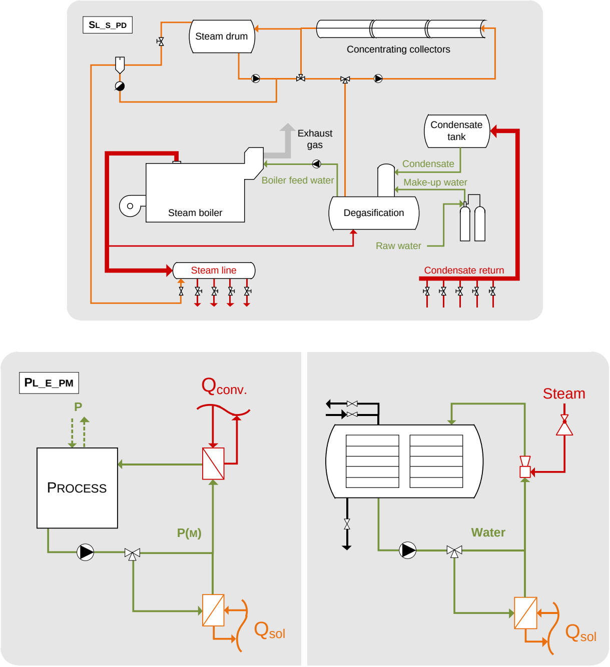

Figure 4: Integration concepts for direct solar steam generation based on Muster-Slawitsch et.al.

Based on the pre-studies, trainees learn how to apply this knowhow within the SHIP tool. First step is to identify the most appropriate collector type based on the requested process parameter (mainly temperature), the selected integration concept (number of heat exchanger and storage type) and the location (solar irradiation). Within the tool, the user can select one of the pre-defined collectors or add new ones by using available data of curve definition out of e.g. the certificates of Solar Keymarks. This is visualized in the tool (see Figure 5)

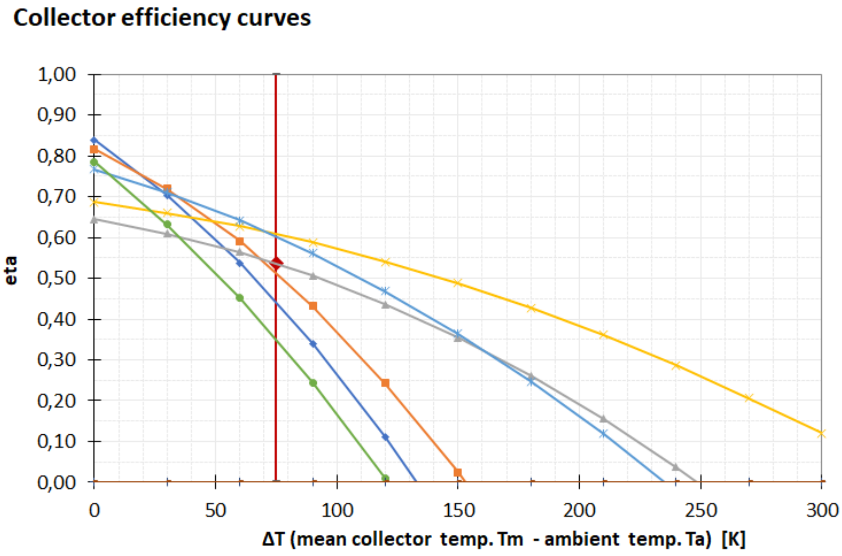

Figure 5: Selection of solar collector type based on input parameter and achievable efficiency

For the detailed simulation and calculation of the collector efficiency as well as the yield and solar fraction, more data on solar irradiation and ambient temperature is necessary. The SHIP tool is by this linked to a platform of the European Commission “PHOTOVOLTAIC GEOGRAPHICAL INFORMATION SYSTEM”, provided by JRC the European Joint Research Centre[1]. By clicking on any location world wide the necessary data can be downloaded and implemented in the SHIP tool. A detailed guidance is provided in the tool (see Figure 6).

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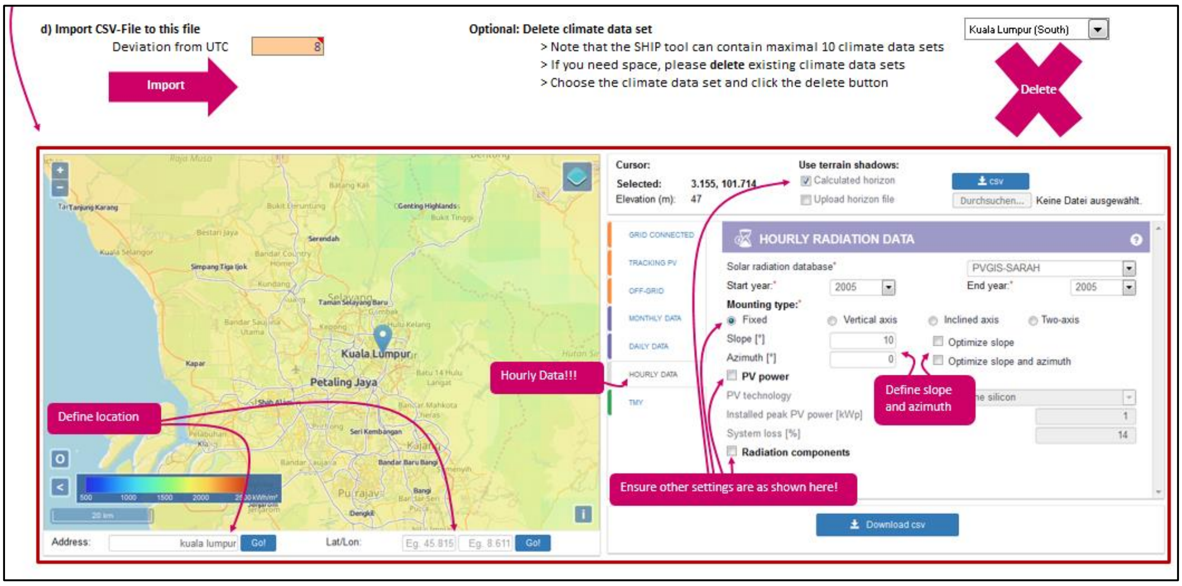
[1] https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#HR



d) Import CSV-File to this file

Deviation from UTC: 8

Optional: Delete climate data set

> Note that the SHIP tool can contain maximal 10 climate data sets
> If you need space, please **delete** existing climate data sets
> Choose the climate data set and click the delete button

Kuala Lumpur (South)

Cursor:

Selected: 3.155, 101.714

Elevation (m): 47

Use terrain shadows:

☑ Calculated horizon

☐ Upload horizon file

Durchsuchen... Keine Datei ausgewählt.

HOURLY RADIATION DATA

Solar radiation database*: PVGIS-SARAH

Start year:* 2005

End year:* 2005

Mounting type:*

● Fixed ○ Vertical axis ○ Inclined axis ○ Two-axis

Slope [°]: 10

☐ Optimize slope

Azimuth [°]: 0

☐ Optimize slope and azimuth

☐ PV power

PV technology

Installed peak PV power [kWp]: 1

System loss [%]: 14

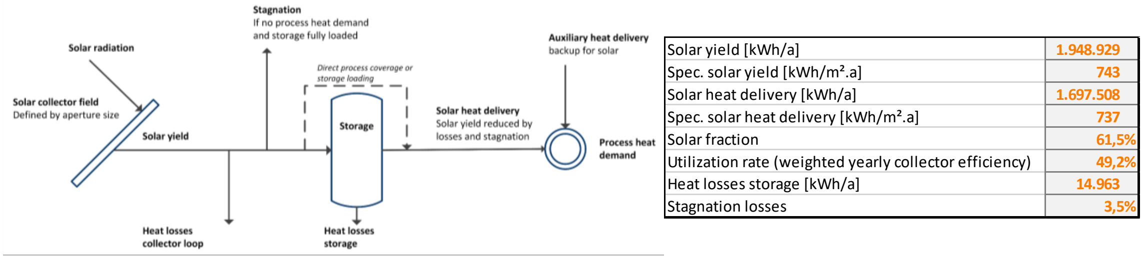
☐ Radiation components

Address: kuala lumpur

Lat/Lon: Eg. 45.815 Eg. 8.611

Figure 6: Guidance to import data on solar irradiation and ambient temperature necessary for the solar simulation in the SHIP tool

Using this information, the user has to finalize the collector field in terms of sizing and placement (inclination and azimuth) as well distance between rows to consider possible shading. Based on this, the size of the storage is adapted to the demand (half-day, day, 2- or more day storage). These adaptations finally influence the performance of the overall system, evaluated based on specific key performance indicators (see Figure 7).



Solar yield [kWh/a]	1.948.929
Spec. solar yield [kWh/m².a]	743
Solar heat delivery [kWh/a]	1.697.508
Spec. solar heat delivery [kWh/m².a]	737
Solar fraction	61,5%
Utilization rate (weighted yearly collector efficiency)	49,2%
Heat losses storage [kWh/a]	14.963
Stagnation losses	3,5%

Figure 7: Example of system evaluation based on design variations and defined key performance indicators in the SHIP tool

The performance of the system in terms of solar delivery, storage loading and unloading and necessary backup system is visualized within the tool (see Figure 8).

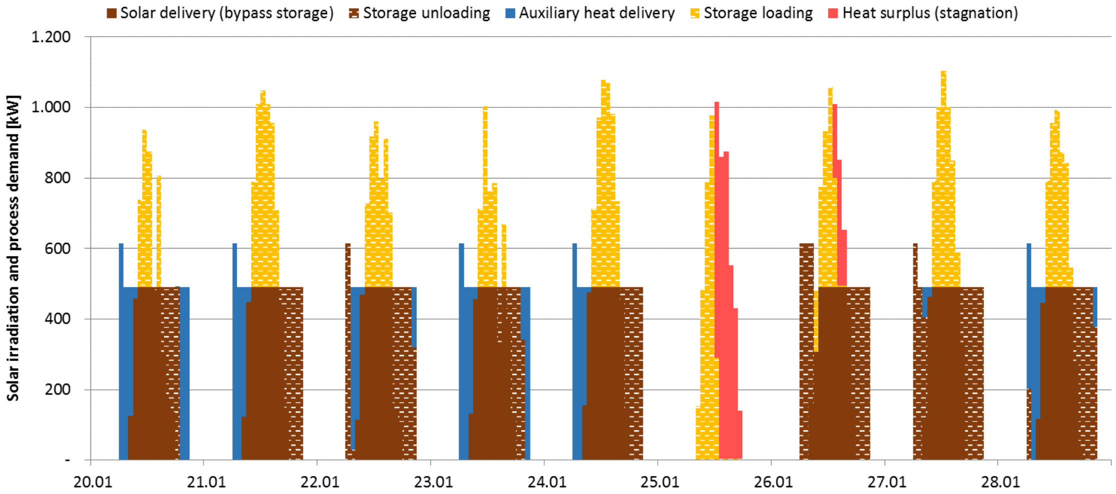


Figure 8: Visualization of system performance in the SHIP tool

Finally, the different selected and designed system scenarios are compared to each other and by this evaluated based on technical and economic parameter as following:

- Technical KPIs: solar yield, specific solar yield, solar heat delivery, installed area (gross aperture), storage volume, solar fraction and utilization rate
- Economic KPIs: investment costs, subsidy, annual O&M costs, levelized costs of substituted final energy supply, levelized costs of solar system, project lifetime, simple payback, dynamic payback, annual final energy savings and net present value

Based on this assessment the user has the chance to identify the most feasible option including variations of specific parameter.

4. Implementations

The main objective of the project is the real implementation of identified and developed concepts, both on thermal energy efficiency and solar heat for industrial processes. Out of the Malaysian UNIDO project by now, more than 50 measures were implemented to increase the industrial efficiency. Examples are the so-called low-hanging fruits as the reduction of losses by insulation, optimization of process and system control but also the recovery of waste heat based on performed Pinch analysis, being a major part of the first 4-day-training. The first realized SHIP-plant in Malaysia was done in a food processing company. PPNJ Poultry & Meat Sdn. Bhd.is located in the region of Johor, producing poultry for selling in supermarkets and restaurants. Slaughtered chickens have to be cleaned in a water bath at 80°C, originally supplied by electrically-produced steam. The described SHIP tool was used for the feasibility study and design of the solar system respectively the optimized integration on process level. Linked to the comparable high costs for electricity and the inefficient process of heating the water bath with steam, the study for solar thermal supply has proven the technical and economic feasibility. The system (see Figure 9) supplies direct hot process water at a temperature of 91°C, by implementing 119 m² collector area and a hot water storage of 8 m³. The electric backup system also supplies the storage, seen as the energy switch in the system. Due to relatively high temperature needed vacuum tube collector were selected and evaluated to be economically more efficient than flat plate collectors. The optimized system achieves a solar fraction of approximately 80 % and by this CO2 savings of more than 260 t per year. By implementing the first industrial application of SHIP in Malaysia the awareness on solar thermal increased significantly. The whole project was by this awarded with the „ASEAN ENERGY AWARD 2018“ and solemnly inaugurated by the Malaysian ministry. The objective of the project is a high number of SHIP implementations achieved as a result of the training and by the high multiplication initiated a sustainability of the project.

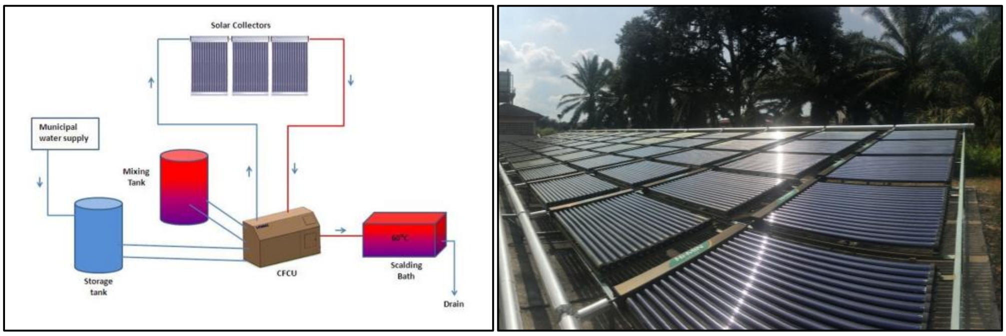


Figure 9: Implementation PPNJ Poultry & Meat SN.BHD. (Source: PPNJ, SIRIM)

A recently drafted roadmap for the Malaysian industry showed the market potential of more than 6,100,000 m² collector area supplying more than 7,000 GWh per year. Following a conservative market penetration strategy about 20 % of this potential could be realized, leading to a work force requirement of more than 6,000 jobs created. This highlights the rentability of green investments, including hotels and hospitals (and also the potential for solar cooling). By an optimized financing and funding scheme these figures could be even increased significantly. Besides this tailor-made policy and regulatory, technology and R&D, testing and certification as well a sustainable awareness and capacity building program were identified as crucial for the achievement of the set potential and objectives.

5. Outlook

The project in Malaysia focuses on the set potentials and their realisation in the upcoming years. This includes the official release of the roadmap and its implementation in Malaysian policies and climate targets. In Egypt the project recently started phase 2 including at least 2 more batches of trainings and design of solar systems for the industry, expecting a high number of implementations based on the already gained interest of companies. As the identified market potential, respectively its realisation, cannot be initiated and supported "just" by funding schemes, the economic feasibility has to be proven to the companies themselves as well as investors. Companies are still more willing to invest available capital in the extension of production capacities instead of energy supply systems, so it is seen crucial to gain interest and willingness on investors side. For a fast-track procedure and to reduce technical and financial risks, a standardised project assessment is the key for the reduction of transaction costs and to increase the number of externally financed projects significantly. The outcome of the H2020 funded project "TrustEE" (GA no 696140) and its standardised, semi-automated technical and financial project assessment based on high level system simulations are applied in Malaysia and Egypt. Specific workshops in the financing sector are planned.

Further information, project outline and the free accessible SHIP database on implemented plants on solar process heat can be found following these links: www.ship-plants.info / IEA SHC Task 49/IV http://task49.iea-shc.org/, project information: http://bit.ly/AEE_SHIP

6. Acknowledgments

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