Nexus Energy & Water: Integration concepts for solar energy in industrial water and waste water treatment

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Abstract

The main objective of IEA SHC Task 62 is to increase the use of solar thermal energy in industry, to develop new collector technologies and to open up industrial and municipal water treatment as a new area of application with high market potential for solar thermal energy. The nexus between solar thermal energy and water treatment enables the development of new and innovative technology combinations and the change to a sustainable, resource- and energy-efficient industry. For the best possible integration of solar energy in waste water treatment integration concepts incorporated into a decision-making tool provide a basis information platform for decision-making and system integration.

Keywords: Solar waste water treatment; industry; energy efficiency; resource recovery

1. Introduction

Based on data available, the industrial sector in EU member states accounts for ~21 % of the waste water demand, with only 36% of this amount being treated (5,293 million m^3 of industrial waste water generated vs. 1,927 million m^3 of industrial waste water being treated) (Alabaster et al., 2021). The collection and treatment of waste water plays an essential role within the transition towards circular value chains in industry, thus efforts need to be taken to increase treatment capacities. Within this transition, wastewater purification and recovery technologies take an essential role in augmenting water and valuables from wastewater streams without placing an excessive strain on limited energy supplies. The efficient supply of energy, the best possible integration of renewable energy sources and the recovery of resources in the sense of circular economy need to go hand in hand. Within this background the use of solar process heat represents a large, but so far largely untapped potential in industry. Innovative and concrete solutions are required for the long-term and successful introduction of solar thermal energy. The integration of solar process heat to supply technologies for water treatment and purification represents a new field of application with great technical and economic potential for solar energy. The efficient interaction, the nexus between solar energy and water, opens up new and innovative approaches to solutions, which are dealt with within the framework of the International Energy Agency’s Solar Heating and Cooling Task 62 (IEA SHC Task 62).

2. IEA SHC Task 62: Targets

IEA SHC Task 62 takes up selected focus areas and results from IEA SHC Task 49/IV (https://task49.iea-shc.org/) and research projects to address the opportunities, challenges and benefits of integrating solar energy into wastewater treatment in an industrial context. The main objectives are (1) to increase the use of solar thermal in industry, to (2) develop new collector technologies, and to (3) open up industrial as well as municipal water treatment as a new application area with high market potential for solar thermal. The nexus between solar thermal and water treatment enables the development of new and innovative technology combinations and the shift towards a sustainable, resource and energy efficient industry. By combining water treatment technologies with solar thermal collectors, an innovative and economically attractive overall solution can be created for the industry.

2.1. Thermally driven water separation technologies and recovery of valuable resources

One research focus of IEA SHC Task 62 is the combination of solar thermal collectors with technologies for the treatment of waste water to an innovative and economically attractive overall solution for industry. The use of thermally operated separation technologies such as membrane distillation in combination with solar process heat represents an energetically and economically promising alternative to conventional electrically operated separation technologies. Within the scope of the work, a technical and economic potential assessment for the use of solar-powered water treatment with a focus on membrane distillation will be carried out. The aim is to initiate

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new implementations and define further research and development issues.

2.2. Solar water decontamination and disinfection systems

In addition to thermal technologies, IEA SHC Task 62 focuses on processing technologies that use direct UV radiation. New industrial application areas for these solar water decontamination and disinfection systems will be identified, and by identifying technical, economic and political barriers to new decontamination and disinfection systems in industrial water and wastewater management, ongoing work can be better tailored to the needs of industry, integration facilitated and the number of implementations increased. The simultaneous utilization of heat and UV light in one technology represents new areas of application for solar energy (UV, photocatalytic applications, etc.) in industry.

2.3. System integration and decision support for end user needs

The developed concepts for the integration of solar energy in waste water and process water treatment will be available in a decision support tool to stakeholders (industrial companies, plant planners, technology providers, etc.) as a tool to support decision making and detailed planning of overall systems (further combination with waste heat, other renewables, etc.). This can overcome barriers to implementation due to a lack of user know-how and facilitate the market penetration of solar-based separation technologies.

3. Methodology

To deliver system integration and decision support for end user needs within the Nexus of Energy & Water, the methodological approach is structured as follows: (1) Identification of suitable industrial sectors and processes as well as other application areas (e.g., municipal waste water treatment) for the use of solar-driven separation technologies and definition of their requirements (e.g., components, concentrations [mg/L], amounts [m^3/day]). (2) Elaborating integration concepts, combining separation and purification technologies with energy supply from solar thermal technologies, other renewable energies and excess heat from industrial processes. (3) Setting up a decision-making tool based on Excel to identify most reasonable options for solar waste water treatment in industry from a technical and an economical point of view.

4. Results

4.1. Integration concepts

The elaborated integration concepts describe, how solar thermal energy can be integrated in combination with thermal separation technologies like Membrane Distillation (MD), to provide the thermal energy demand in a renewable way. The integration concepts are modular. Each concept has at least one base module for the renewable process heat supply, like solar thermal (illustrated in Figure 1) or heat pump. Also, the possibility for waste heat integration is available.

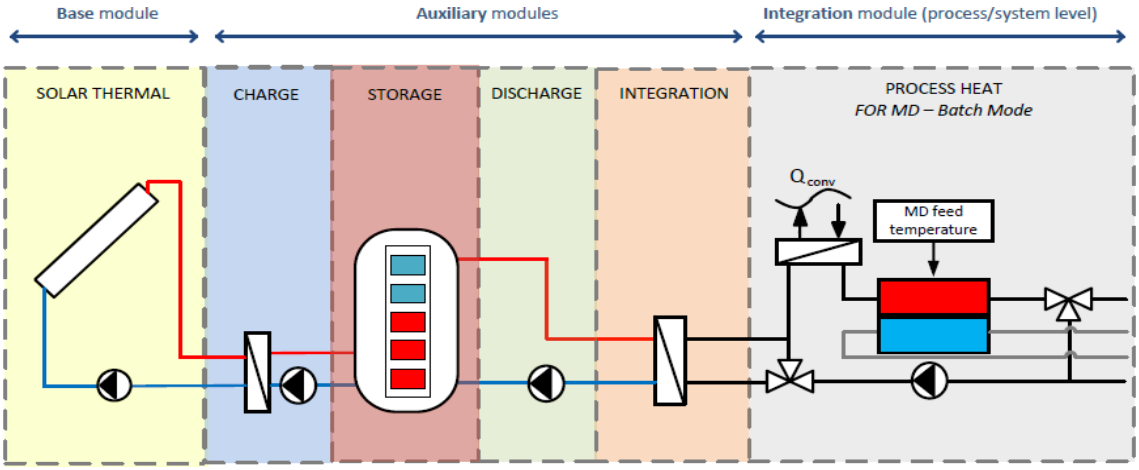

Fig. 1: Example for an integration concept combining solar thermal for the process heat supply of Membrane Distillation

In addition to the base modules, there is a large number of auxiliary modules (e.g., charge, storage, discharge, integration). Auxiliary modules enable the integration of renewable process heat modules to supply heat on process or system level and allow adaption of the concept depending on the specific requirements given. In Figure 2 exemplary the heat supply for MD on process level is illustrated. The MD process module changes based on requirements like batch or continuous operation as well as internal heat recovery (HR) realized.

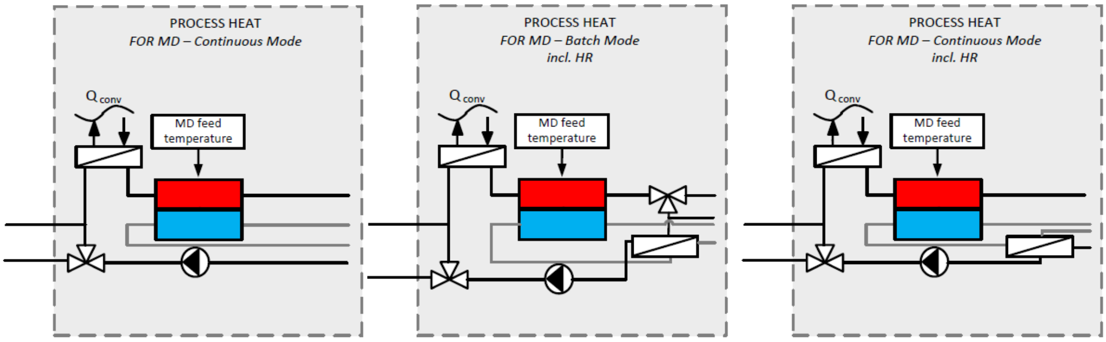

Fig. 2: Integration for MD supply on process level (batch mode with/without heat recovery, continuous mode with/without heat recovery)

4.2. Decision-Making process

4.2.1 Decision-making tool

To support the decision-making process, the integration concepts are part of the decision-making tool. The tool shows industrial companies (e.g., food and beverage industry, galvanic industry) and (municipal) waste water treatment plant operators which options/integration concepts are available to them for solar water treatment under certain framework conditions (location, land availability, waste water requirements, etc.) and which represents the most technically viable variant. The tool is available as an Excel tool to give a wide application possibility. Depending on the input (data basis) of the water treatment task (waste water characteristics, waste heat characteristics, location of industry, etc.) and selecting the treatment target (e.g., concentration or separation of specific compounds) as well as selecting the technology, the tool performs calculations (mass and energy balances) to present rough performance values (energy demand, solar yield, collector area etc.) and give recommendations for the integration. The waste water calculations are based on integrating membrane distillation as treatment technology. In terms of the energy supply solar thermal or waste heat in stand-alone mode or in a combined energy system can be selected. The basis set-up of the tool is presented in Figure 3.

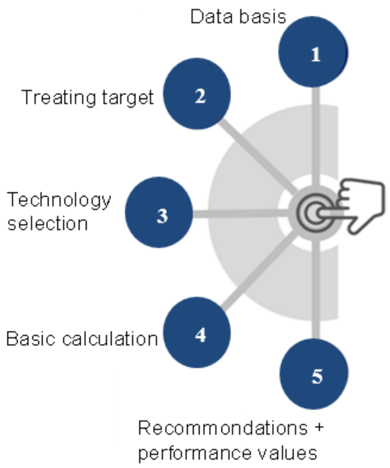

Fig. 3: Structure of the decision-making tool

4.2.1 Nomograms

Based on the calculated results from the tool, nomograms for the solar thermal and/or waste heat driven waste water treatment have been created to assist in evaluating the dependencies of a renewable supplied energy system for MD. Following parameters are included to the nomograms:

- Country: As local conditions influence the renewable energy potential (f.i. irradiation), nomograms are available for different countries. In a first step European countries Austria (Vienna) and Spain (Madrid) have been evaluated.
- Solar fraction [%]: The solar fraction is defined by the amount of energy provided by the solar thermal plant, referred to the total energy demand needed.
- GOR efficiency [-]: The Gained output ration (GOR) is defined as the ration of the latent heat of evaporation of the produced water to the total heat supplied to the system.
- Energy demand ext. [MWh/a]: The external energy demand given in MWh per year gives the remaining demand of energy needed for the MD process, depending on the solar fraction.

Exemplary nomograms are shown in Figure 4 and 5. Calculations are based on location Vienna (Austria) and a system of MD supplied by solar thermal and used for concentrating (concentration factor of 2) waste water via separating water from a waste water stream at 80°C operating temperature.

The total energy demand (calculated by the sum of the energy demand provided by solar thermal and energy demand external) to supply MD increases with an increased volume [L/h] to be treated. The energy demand of MD can be reduced, applying optimization like optimum operation conditions, module design and configurations etc. By reducing the energy demand an increase in GOR is possible. To show the influence of GOR on the whole systems energy demand, Fig. 4 illustrates that by keeping the solar fraction constant at 50% and increasing the efficiency of the waste water treatment system from GOR 0,5 to 2,5 an enormous reduction of the external energy demand is possible.

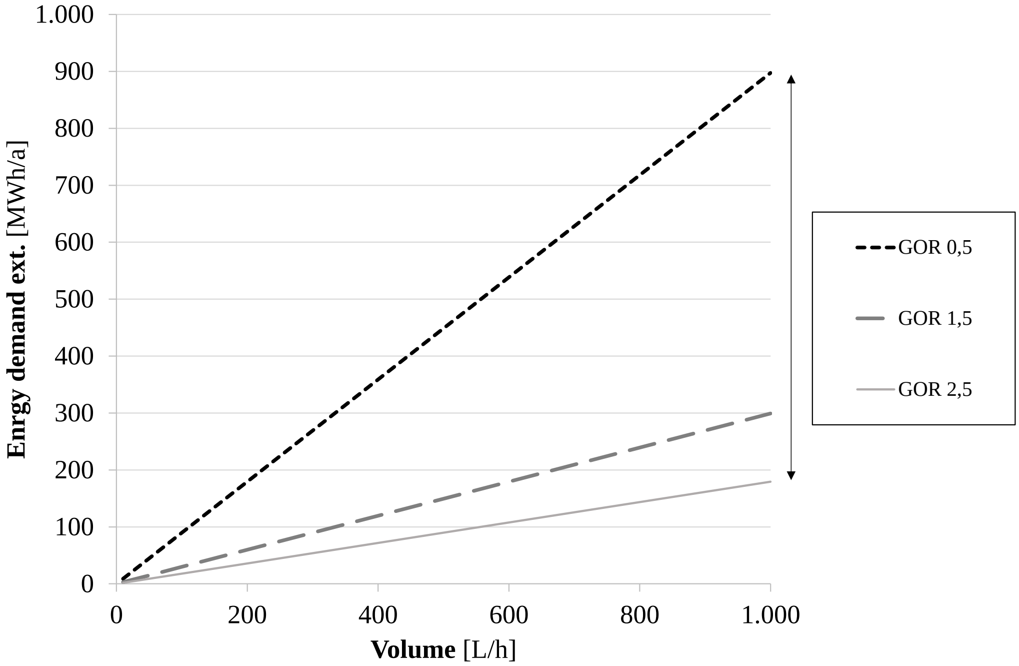

Fig. 4: Structure of the decision-making tool

Fig. 4. shows the correlation between the volume of waste water to be treated and external energy demand to be provided, depending on the given solar fraction at a constant GOR of 0,5. The external energy demand decreases by increasing the solar fraction – so the bigger the solar thermal plant the higher the coverage range of energy demand for MD.

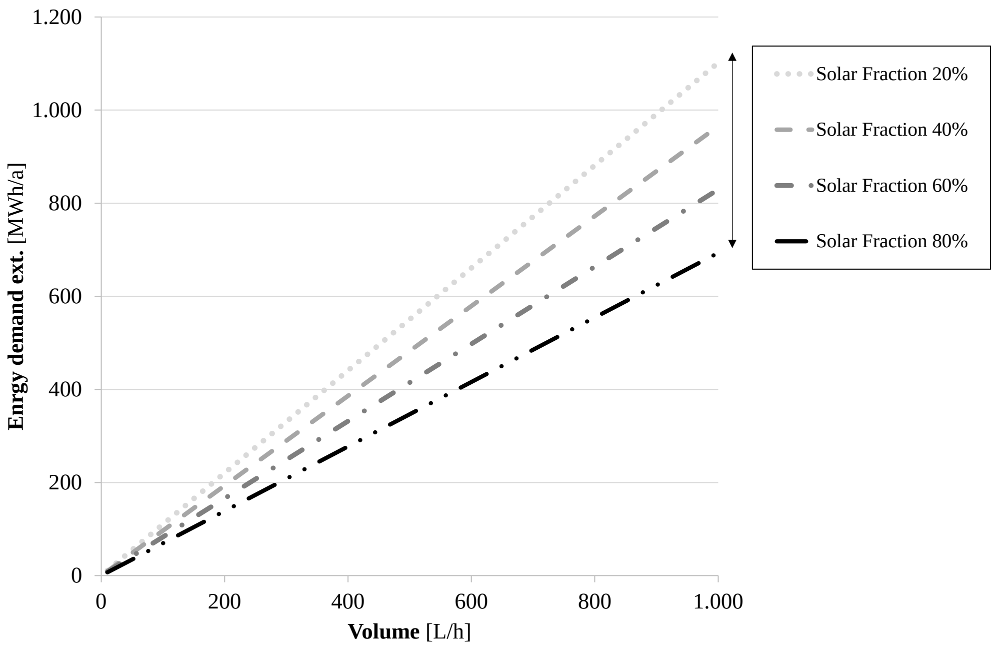

Fig. 4: Structure of the decision-making tool

5. Outlook

The use of solar wastewater treatment by solar thermal energy supply represents a large, but so far largely untapped potential in industry. Integration concepts offer a good possibility to show planners, technology providers and end-users the different options for integrating solar thermal driven water treatment technologies.
To further promote solar wastewater treatment, upcoming activities of the IEA SHC Task 62 include the completion of the decision-making tool, which is currently under validation, to show industrial companies which options/integration concepts are available for solar water treatment under certain conditions (energy demand, location, space availability, etc.) and which are the technically feasible variants.

6. Acknowledgement

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7. References

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