The Role And Potential For Solar Thermal In Future Energy Systems

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The necessary reductions in greenhouse gas emissions to the atmosphere need to occur within the next decades. During that period, significant renewable energy volumes will be installed, but the challenge is which technologies to prioritize. Currently, wind and solar power for electricity generation has gained momentum, but these technologies will not suffice when considering the heating sector. Experts have suggested the application of solar thermal technologies for heating purposes, but no studies have analysed this technology in details in the context of an entire national energy system. In addition, a variety of solar thermal types exists, for example for individual buildings, building blocks or for larger district network systems.

Filling in this knowledge gap is the purpose of the paper “Comprehensive assessment of the role and potential for solar thermal in future energy systems”, recently published in Solar Energy by authors Kenneth Hansen and Brian Vad Mathiesen. Four national energy systems were replicated in an advanced energy system analysis tool entitled EnergyPLAN with the purpose of analyzing the consequences of expanding solar thermal shares in future energy systems. The countries included Germany, Italy, Austria and Denmark, located in various regions of Europe and differing in terms of energy demands, resources and climates. These variations in conditions increased the likelihood that the findings can also be applied to other countries comparable with the example countries in the study.

The expansion of solar thermal technologies was investigated in future energy systems resembling the existing systems, but also in systems with reduced heat demands, expanded district heating networks and in energy systems dominated by renewable energy, excluding the transport and industrial sectors. The effect of expanding solar thermal energy were quantified for primary energy, energy system costs and CO_2-emissions.

Some findings contradicted what intuitively could be expected from integrating further solar thermal into these national energy systems. Most remarkably, installing a fluctuating renewable source such as solar thermal in certain scenarios increased the CO_2-emissions to the atmosphere due to the effects on the overall energy system. For example, in countries with cogeneration units for combined electricity and heating generation, solar thermal induced a reduction in the operating hours of these plants. Consequently, other plants producing solely electricity were forced to operate more, thereby reducing the energy system efficiency which caused higher fuel (i.e. coal) consumption.

Similarly, in energy systems with very high renewable energy penetrations, the integration of further solar thermal energy had mixed effects on the indicators. In certain scenarios, solar thermal generation started competing with other lower-cost or fluctuating technologies because of the limitations regarding how much fluctuating energy it is possible to integrate in these energy systems.

The effects on the total energy system costs when installing further solar thermal was rather negligible as some scenarios demonstrated small cost reductions while other scenarios indicated small cost increases. However, the general trend showed that it is more economical to install solar thermal in large-scale district network systems compared to installing a unit in each building. The integration of solar thermal reduced the consumption of solid fuels, which is crucial in a future where the entire energy system is transitioning towards 100% renewable energy. Concretely, the biomass resources are scarce and more vital in the transport and industrial sectors where less alternatives to fossil fuels are available. Hence, the role of solar thermal energy in a future energy system should be to reduce the reliance on biomass and other solid fuels to remain within sustainable thresholds.

Finally, limitations to the maximum solar thermal share in each country were identified by investigating the entire energy system. These limitations exist due to the alignment between energy generation and demand, which needs to be analysed in a high temporal resolution. Furthermore, limitations exist regarding the ability to store excess energy as the solar thermal generation peaks during summer periods where the heat demands are lowest. The maximum solar thermal share of the total heat generation is in the range of 3-12% for these countries, depending on the technology mix in the energy system, developments in energy demands and the number of buildings connected to the solar thermal generation, either directly or indirectly through a network.

These findings are significant, as little research has been conducted about the extent and consequences of solar thermal technologies today and in a future energy system with less carbon emissions. Solar thermal technologies should be part of future energy strategies by reducing the dependence on bioenergy and as an option in regions with limited alternative renewable resources. The study supports the prioritization of future energy investments and highlights the importance of investigating the entire energy system, rather than only the consequences in parts of the energy system.

These findings are described in further details in the article Comprehensive assessment of the role and potential for solar thermal in future energy systems, recently published in Solar Energy. This work was conducted by Kenneth Hansen and Brian Vad Mathiesen from the Sustainable Energy Planning Research group at Aalborg University in Denmark.