Task 44/Annex 38
Solar and Heat Pump Systems

Solar and Heat Pump Systems Position Paper

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Contents

Aim of the Position Paper

The purpose of this document is to provide an inside view to energy policy makers on why and how solar and heat pump systems should be supported and promoted.

Executive Summary

Solar and heat pump systems (S+HP) are a combined technology that represent a market share in the building heating and cooling segment due to their following advantages: high renewable energy share, low electricity demand, low primary energy demand, and low CO_2 emission depending on the electricity mix feeding the heat pump.

The market share of S+HP systems could reach 100% for new houses in many countries where the heat pump technology is well-established and solar is mandatory for domestic hot water.

In the long term, S+HP could represent a significant market share in all IEA countries if electricity is produced CO_2 free and available. Solutions include increased use of solar PV and expansion of net zero houses and positive energy houses.

The S+HP components are mature, however, the combination of solar and heat pump needs international R&D work to better understand the optimal configurations under several criteria.

Solar and heat pump systems can be deployed for both small and large systems as there is no limitation on the size in this combination.

The combination of solar and heat pumps offer many advantages for the developing market, such as:

- Can cover all needs of a building: heating, DHW, cooling, dehumidification
- Specific combinations can be suited for different applications, climates, etc.
- Offers cooling (active or passive, if ground-coupled)
- Provides the capability of energy storing and supply-demand unbundling;
- Ventilation can be integrated in compact air units
- Solar and gas-driven heat pumps can be suitable for high-temperature distribution systems as boiler-replacement
- Part of the locally produced electricity (PV, wind) can be stored on site as thermal energy without stressing the grid

A supporting policy is needed for:

- Technological development
- Quality assessment of products
- Partnership between R&D teams and HVAC industries
- Sharing of knowledge among countries

- Communication to large audiences and customers
- Clean electricity production that would make S+HP solutions 100% renewables
- Thermal heat pump development
- Material and system testing platforms

It is anticipated that an obligation of a renewable share (for instance 70% or more over the years for the Primary Energy Ratio as asked by the RHC platform for EU) in national policies will help to develop S+HP systems that exhibit a high renewable energy fraction in regions where the electricity is produced by renewable. A CO_2 index could also be used to favor clean solutions and S+HP systems would certainly benefit from such a supporting scheme.

Introduction and Relevance

Over the past few years, systems that combine solar thermal technology and heat pumps have been marketed for space heating and domestic hot water production.

The IEA SHC Programme launched in 2010 Task 44: Solar and Heat Pump Systems, which was a joint effort with the IEA Heat Pump Programme under the name Annex 38. Over 4 years an international team of experts worked to contribute to better and higher performing S+HP systems.

More than 50 participants from 13 countries contributed to the Task effort.
This paper presents a vision of what could be the future of the combined technology solar collectors and heat pumps based on the work undertaken.

Why Is Heat Pump Technology Important?
Heat pumps have the ability of use low-grade heat from the environment (e.g., ambient or exhaust air, ground water, soil) and use it efficiently to produce heat for space heating and/or domestic hot water all year round, in most cases without an additional "back-up" system. Additionally, heat pump solutions can be used for space cooling.

Why Is Solar Thermal Technology Important?
The great advantage of solar collectors is that they can produce heat with little or no electricity input, and thus achieve considerable savings of electricity compared to direct electric systems and even compared to heat pump heating of sanitary water. The disadvantage of solar collectors on the other hand is that they produce heat only when there is enough solar irradiation, which does not always coincide with the times when heat is needed. Therefore, without large seasonal heat storage, a solar thermal system should always be combined with a heat pump or other backup heating system.

Relevance of Solar and Heat Pump Integration
Ground coupled heat pumps can have high performance and benefit from solar input. Air heat pumps are subject to the variation of the Coefficient of Performance (COP) due to variable evaporation conditions. The first advantage is that solar heat can help reduce this variation by raising the evaporation temperature in systems with

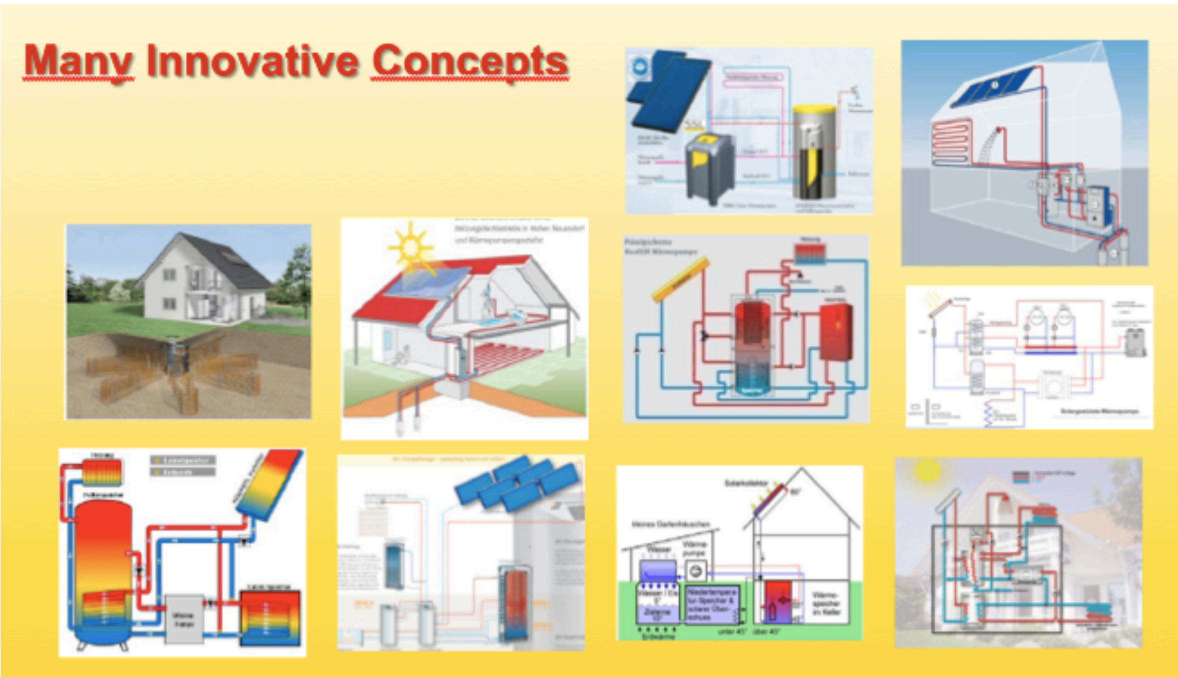
a serial arrangement where solar is coupled to the evaporator side.

Integrated solutions and well-designed installations can enhance, under certain design criteria, the system performance and consequently the efficient usage of primary energy. This, together with relevant economic and legislative aspects, is what a policy in this combination of technologies should aim for.

The second advantage is that solar heat can be stored and then further boosted in temperature by the heat pump if the temperature is not sufficient for direct use. Or the solar heat storage can be used directly for the load eventually reducing the need for peak electricity at some point of time during cold, but sunny days. This is a third advantage since electricity cannot be easily stored at present.

Status of the Technology/Industry

Even though there are a number of systems sold on the market, solar and electrical heat pumps are a very young combination when talking of "integrated" systems, and in many cases, it is rather juxtaposition than an optimal combination. There is still a lot to improve to increase seasonal performance factors (SPF), that is the overall annual efficiency to minimize the peak power required, to reduce the cost of heat, to increase the reliability of operation, to simplify the commissioning of an installation, to optimize the control strategies and to deliver the "standardized and proven industrial systems" as solar compact systems have done over the past 20 years.



Many systems combining solar and heat pump appeared on the market during 2000-2010.

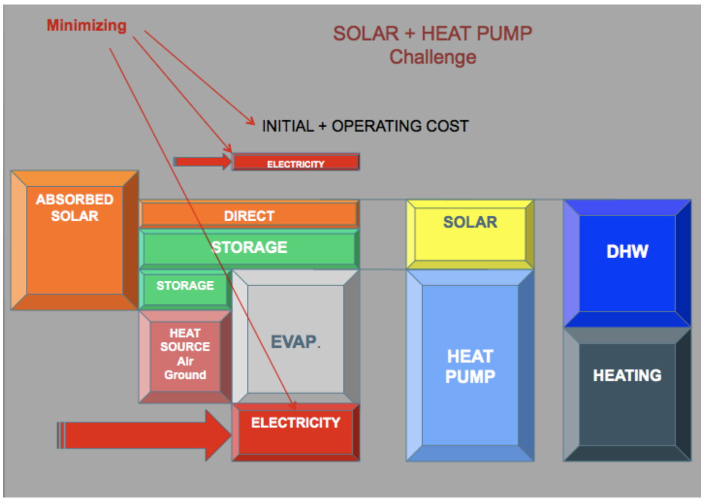
Solar PV can be installed to drive a heat pump or compensate for its electricity demand. At present, there are a few optimization challenges that are more a matter of total investment and customer willingness in the current framework with a feed-in tariff scheme. But running the heat pump on a sunny day with heat storage for the night represents an option to consider compared to a no storage solution. And, future decentralized and smart grids with many local electricity producers can further change the conditions for the optimal operation of solar and heat pump systems.

Solar PVT "hybrid" collectors still need to be developed as a true integrated product, and will be developed more and more in the future, primarily for areas where roof competition for solar tends to exist, as for instance in Germany.

Autonomous combination of solar thermal + PV + heat pump could be looked at in regions where the electrical grid might be stressed.

Solar heat and its ability to be stored could also help to smooth the grid demand or to participate in smart grid options under development.

Solar and thermally driven heat pumps should be investigated too since the combination carries some potential at least theoretically. There is still work to be done internationally on this combined system.



The purpose of integrating solar and heat pumps is primarily to minimize the electricity needs and maximize the local renewable fraction. In recent low energy houses the heating load is often the same as the DHW load and even tends to be lower. This favors solar during the sunny season and warmer temperature from solar for heat pump during the heating season.

Combining solar and heat pumps is not valid only for small-scale systems. Large systems can benefit also from the combination. A dedicated IEA SHC Task (Task 45: Large Scale Solar Heating and Cooling Systems) has been working in this area since 2011.

More than 80 different systems have entered the market since 2000. Most are not yet optimized and the best performers are not yet known. Laboratory testing of systems are currently being done and will lead to improved systems. Testing and performance comparisons must be a continuous process to support market development.

For a **combined system solar + heat pump** there is no elaborated figure of merit yet: the Seasonal Performance Factor (SPF) is a powerful instrument, but as of yet is not generally calculated or supplied to customers. The SPF could be used as a basis for further figures of merit that rate the primary energy performance or the amount of CO_2 emissions of a heating technology. The SPF reached 5 to 6 in a well performing S+HP system monitored during SHC Task 44.

Potential

The combination of S+HP can lead to high renewable fractions by improving the heat pump seasonal performance factor, by improving the productivity of each square meter of collector or by doing both.

There is great potential for this technology in the new housing sector, mainly for detached houses. Renovation of single-family houses could also become a segment of choice for solar and heat pump combinations when a building owner wants to reduce its CO_2 exposure or fossil fuel dependency.

Up to 80 - 90% of the heating and DHW needs could be done "locally", that is in the house, with S+HP systems. If the source of electricity is 100% renewable, such as wind energy or hydropower or PV, 100% of the heating and cooling needs could be achieved using renewables.

There is high potential for improving solar and heat pump combinations both for the classical parallel systems where solar and heat pumps are working side by side, as well as for systems where solar thermal collectors are connected to the evaporator of the heat pump.

Some of the improvements that are currently in the focus of R&D and deserve national and international research support are:

- High efficiency heat pumps with variable evaporating temperatures.
- Storage integration of heat pump circuits to produce highly prefabricated compact systems that are easy and fail-proof to install and use little space.
- Highly stratifying thermal stores and hydraulic integration with the heat pump so as to limit the condensation temperatures of the heat pump process to the lowest possible value.
- De-superheater heat exchangers in the heat pump circuit that may – in combination with the solar thermal heat in summer – lead to almost no need to run the heat pump at the condensation temperature needed for DHW (60 to 65°C).
- Control strategies for using heat from solar thermal collectors for the evaporator of the heat pump or for a "direct to load" supply.
- Storage solutions for the cold side of the heat pump in order to store solar heat from the collectors before using it for the heat pump, for instance ice storages.
- Solar thermal collectors that can use ambient air as well as solar irradiation as a heat source.
- Solar thermal collectors that can be operated below the dew point without destruction of selective surfaces or insulation or even the roof underneath.
- Solar thermal collectors combined with photovoltaic (PV/T collectors).
- Smart control of the overall system including automatic fault detection and possibly also using demand and weather forecast.

Current Barriers

The initial investment cost is one of the main barriers for S+HP market expansion.

Current costs of a combined system reach 6,000 to 20,000 € for the solar installation (for 6 to 20 m2 of collectors and 500 to 1,000 liters of storage) and 10,000 to 15,000 € for a 6 to 15 kW heat pump air/water or some 5,000 to 10,000 € more for a ground coupled heat pump.

The cost of purchasing the components separately can reach 15,000 to 30,000 € for a single-family house.

Operating costs tend also to be higher than for a single system since two producers are present.

An optimal combination of the two technologies could reduce both the investment cost and the running cost if the system is designed for this purpose as in solar combisystems.

There is potential for improving the design and operation of solar and heat pump combinations in several aspects:

- Better performances.
- Shared controllers and remote controlling or monitoring for the customer ease.
- Shared installation time (volume effect).
- Shared maintenance plan.
- Innovative concepts for the combination.

Investment could be reduced by 10 - 30% by making these improvements. Running cost could be reduced by also 10 to 30%, but this will be more difficult to achieve without an integrated design.

All in all, this can lead to an anticipated cost reduction of the heat delivered by an estimated 10 to 30%. This is not a huge potential, but it might be enough to open a reasonable market share for S+HP solutions, which have the great advantage of reaching high renewable fractions and not being dependent on fossil fuel supply and prices.

There is no premium for these advantages at present, but this might change in the future.

This cost reduction can, however, be offset by high electricity prices for the heat pump. Then the compensation of the electricity needed by the HP with solar PV might become a cost effective option.

To be fair, when comparing alternatives, it is recommended to compare S+HP combinations to heat pump-only solutions or solar-only solutions so that the value added of the mix is considered prior to any other criteria.

It is to be noted that EU legislation will ban non-efficient boilers from the market starting in 2015 – and this could change the economical barriers.

A second barrier is the complexity of a heating system when two producers are combined.

One key point when integrating systems is to understand that there is some relation between increasing complexity and increasing the Seasonal Performance Factor of the entire system. However, the relation is most often not linear, and for the sake of maintenance and repair, the best advice for a good combined system is still to keep it simple.

The two identified barriers noted above, however, are rather low since in some countries solar and heat pumps systems are the preferred choice for heating new single-family houses.

A third barrier is the lack of a certification system for S+HP combinations. There is on-going work in this area, but more is needed to establish an international standard.

Actions Needed

Technology Development: Actions that should be undertaken:

1. Quality of systems should be independently certified/labeled. There is currently a lack of knowledge on system quality and this is a great drawback for customer confidence.

We propose that a new label be created: the **S+HP Keymark** similar to the Solar Keymark, but for the combination of technologies.

During the Keymark assessment specific features needed in S+HP systems should be investigated, such as:

- Solar: solar collector certification of ability to operate at temperatures below ambient.
- HP: variable speed testing, partial load testing, extrapolation to yearly SPF and not only steady state conditions to record the machine coefficient of performance (COP).
- Visits with manufacturers would also help to avoid possible cheating with good one-shot prototypes sent for testing.

2. Independent testing of systems is also information that the customer and the decision maker should have access to. For this to be done, it is necessary to achieve the testing of the overall system. An international testing procedure should be agreed upon and testing platforms set up at research institutes for side-by-side testing of solar collectors or heat pumps.

3. Simulation model of S+HP standards should be part of a standardization effort

4. Research efforts should be conducted to understand the best combinations in several configurations (new housing, renovation), in different climates and in different cost environments.

5. Topics that the industry should tackle include:

- HP with possibly higher temperature on the evaporator side.
- HP optimized for variable temperature inlet from -10 to 30 C on the evaporator side.
- Storage strategy: is charging one common combi-store with solar and HP a better option than two or more different stores?
- The cycling of heat pump is to be reduced.
- Variable conditions for the heat pump (mass flow rates and power) should be possible with modern efficient compact heat pumps.
- Compact systems with few outside connections should be developed.
- Reducing heat losses in compact design should be searched for.

Market Development: Measures that should be undertaken:

1. Quality certification by independent bodies.

2. Transparent, “fair” calculation methods for comparison between different technologies.

3. Reliable scenarios regarding the decarbonization of power production as an argument in favor of S+HP systems.

4. Pilot and demonstration projects are needed to show the potential, but also to optimize and improve the systems.

5. The value of storage should be taken into account. Some S+HP systems can store solar energy and thus reduce the need for peak electricity. A careful policy should promote figure of merits for storing renewable energy.

6. Teaching of installers should be supported and facilitated by simple black box systems and prefabricated systems.

7. Public support, such as incentives or financing schemes should be correlated to the renewable energy share of a system not only to the seasonal performance factor.

A policy favoring S+HP systems and other renewable energy systems would set a law for an obligation to ensure a minimum renewable yearly share value in any system. This share would depend upon on the local electricity mix. For EU countries, a road map to reach “**75% renewable**” in 2021 with European mix of electricity should be set for S+HP. The renewable energy share should be based on the total seasonal or annual performance factor of any system.

IEA Solar Heating and Cooling Programme

The IEA Solar Heating and Cooling Programme members have been collaborating since 1977 to advance active solar and passive solar and their application in buildings and other areas, such as agriculture and industry. Under the management of an Executive Committee representing the members, the Programme carries out a strategy to enhance collective knowledge and application of solar heating and cooling through international collaboration.

More information can be found on the website of the IEA Solar Heating and Cooling Programme, www.iea-shc.org

IEA Heat Pump Programme

The IEA Heat Pump Programme members cooperate in projects in the field of heat pumps and related heat pumping technologies such as air conditioning, refrigeration and working fluids (refrigerants). Under the management of an Executive Committee representing the member countries, the Programme carries out a strategy to accelerate the use of heat pumps in all applications where they can reduce energy consumption for the benefit of the environment.

More information can be found on the website of the IEA Heat Pump Programme, www.heatpumpcentre.org