Final report on heat pump developments in WP 4

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MacSheep - New Materials and Control for a next generation of compact combined Solar and heat pump systems with boosted energetic and exergetic performance

Dissemination Level: PU – public

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Executive Summary

In the MacSheep project three heat pump prototypes were developed by three different groups. These prototypes include several breakthroughs concerning advanced heat pump cycles, which have been identified and analyzed within phase 1 and phase 2 of the project. This document presents the status and results concerning the heat pump developments at the end of phase 3 of the project.

IWT, SPF and ESSA have developed a heat pump with a speed controlled compressor, a desuperheater and vapor injection (economizer cycle). A prototype has been built at IWT, which involves the above described breakthroughs and was equipped with measurement devices in order to allow an in-depth analysis of the refrigerant cycle. The heat pump has been optimized and tested under steady state and dynamic conditions, showing a good operating behavior and performance.

A semi-physical heat pump model in TRNSYS was extended with the functionality to simulate an economizer heat pump cycle. This new model was verified with the obtained measurement results and used for the annual system simulations of the MacSheep solar and heat pump system.

Ratiotherm and SERC have developed and built a dual stage heat pump with integral storage during phase 3 of the project. This was then tested at Ratiotherm's lab in Germany for a wide range of boundary conditions. However, the results of the techno-economic evaluation were not as promising as expected. Therefore, a completely new design was started in mid-2014. Due to this late re-start there was no time to build and test a new prototype before the end of 2014. Only the modelling process has been completed for this new development so far. The new design has an economizer cycle and variable speed compressor, and is designed for retrofit buildings with high heat load and higher temperatures for the space heating circuit. The annual simulation results for this new development are very promising.

CTU and Regulus have developed a ground source heat pump with one evaporator and three heat exchangers on the sink side (desuperheater, condenser and subcooler). Each sink has been used at a different temperature level: the desuperheater for DHW preparation, the condenser for space heating operation and the subcooler for cold water preheating.

Finally, it was decided that the heat pump unit for the MacSheep system of Regulus & CTU will have only a condenser and a desuperheater. The subcooler has been discarded due to low benefits for the combination with the solar thermal system and a higher complexity of control, pipe runs, and the additional pump, all leading to higher costs for the system. A prototype of the final heat pump with two heat exchangers on the sink side (condenser, desuperheater) was designed, built and tested.

A TRNSYS type for a heat pump with three heat exchangers at the sink side has been developed to allow the evaluation of the heat pump design and operation in the solar heat pump system. The TRNSYS type has been experimentally validated for the built prototype at CTU laboratories.

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1 Introduction

Within the MacSheep project, solar thermal and heat pump systems that achieve 25% energetic savings compared to the current state of the art are developed. These developments take place in four different development branches that are carried out by the following groups of partners:

- Energie Solaire SA & HSR-SPF & IWT TUG
- Ratiotherm GmbH & Co. KG & SERC
- VIESSMANN Faulquemont S.A.S., CEA INES
- Regulus spol. s.r.o., CTU

Within the first and second phase of the project in the year 2012, breakthroughs for materials, components and control that lead to higher energetic performance and/or lower cost of the system were analyzed and selected (see Figure 1). The selection was based on an analysis of the cost-effectiveness of the new development. The effect of potential breakthroughs on the energetic performance was determined by annual simulations. The cost difference compared to a system without this breakthrough was estimated based on the experience of the industrial partners on one hand, and on best guess for new products or methods for production on the other hand.

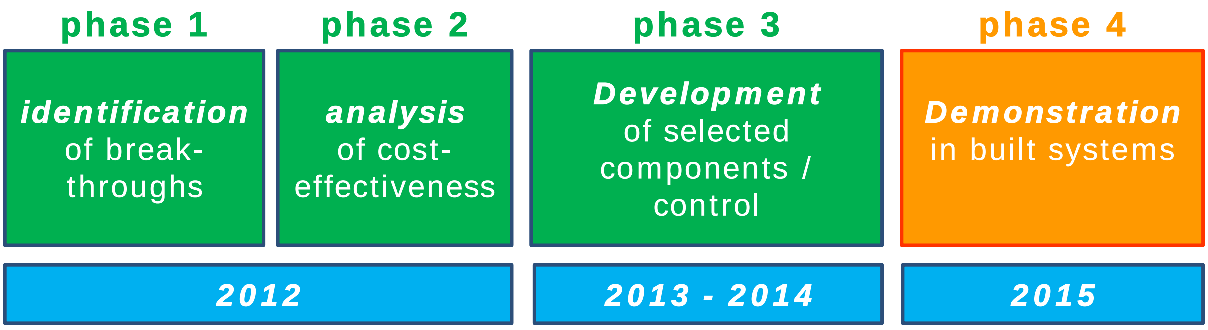

Figure 1: Phases and time-line of the MacSheep project.

Reports D3.4, D4.4, D5.4 and D6.4 give details of the developments in the project within the field of collectors, heat pumps, storage and control respectively while D7.3 gives information about the whole system and energy savings compared to a state of the art reference system.

The definition of the standard heat loads (SFH45 and SFH100) as well as of the climates (Zurich and Carcassonne) can also be found in report D7.3.

The breakthroughs that were selected for further development and prototyping within WP4 (heat pumps) are listed in Table 1. There were in total six different breakthroughs that had been identified as interesting for further development in phase 3, split between three development groups. However, as a result of the work within phase 3 new items were added (red X) while some developments had to be discarded (marked ~~X~~). Note that, as no compressors are developed within the project, the breakthrough of high efficiency motors is limited to selecting efficient compressors and the use of high efficiency pumps.

Table 1: Summary of breakthroughs for WP4 to be further developed during phase 3.

Description	***ESSA-IWT-SPF***	***Ratiotherm -SERC***	***Viessmann -INES***	***Regulus-CTU***
hydraulic optimized integration of heat pump	*X*			
desuperheater	*X*	~~*X*~~		*X*
vapor injection cycle	*X*	*X*		
subcooler				~~*X*~~
variable speed heat pump	*X*	*X*		~~*X*~~
high eff. motors for compressor and fan	*X*			
2-stage heat pump concept		~~*X*~~		

2 Heat pump development by IWT-TUG, SPF & ESSA

A novel brine-to-water heat pump system with integrated desuperheater, variable speed controlled compressor and an economizer injection cycle was developed by IWT. Furthermore a hydraulic optimized integration of the heat pump has been worked out by SPF and IWT. Using measured results from a heat pump prototype system, the new TRNSYS simulation model developed by IWT (T887) has been parameterized and validated. The TRNSYS type has been used for the annual system simulations of the whole combined solar heat pump system that are reported in D7.3).

2.1 Description of developed component

Hydraulic optimized integration of the heat pump (SPF)

Figure 2 shows the hydraulic concept of the system. The hydraulic connections to the storage and to the heating loop are shown only as a black box, because the design of the hydraulic in this part is confidential. An electric backup heater is added after the condenser outlet. All heat exchangers are external so the system can be easily adapted for other boundary conditions. Special for this system is that all hydraulic components (pumps, valves, and heat exchangers) are under the insulation. More details on the storage and its insulation can be found in report D5.4.

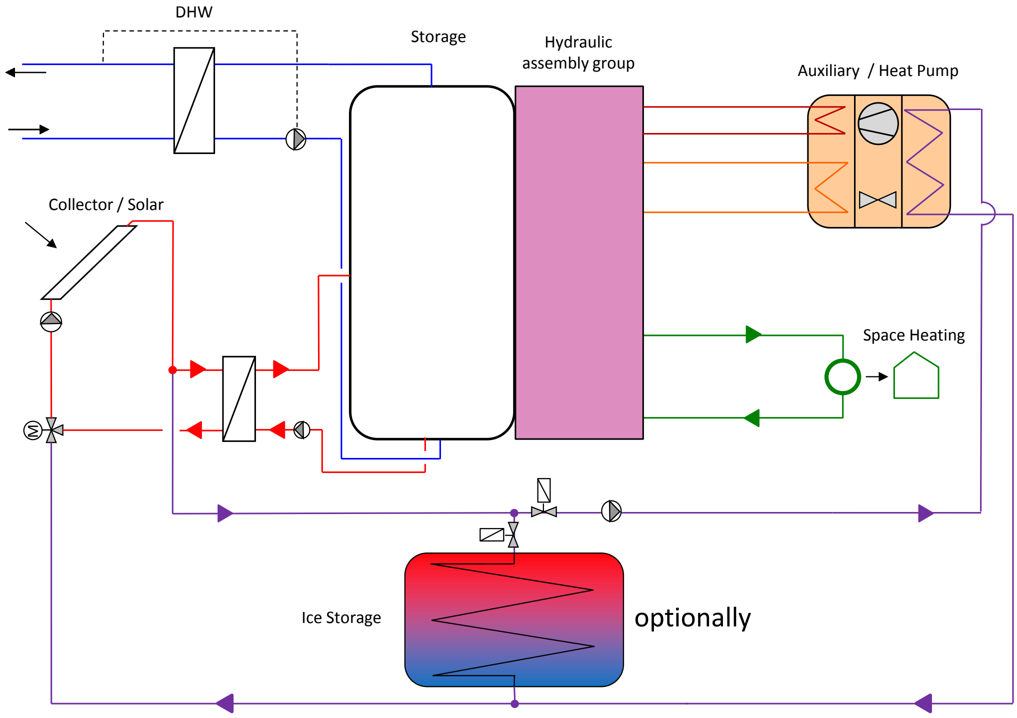

Figure 2: Schematic of the optimized system developed by ESSA, IWT and SPF.

Heat pump prototype (ITW-TUG)

A heat pump has been developed by IWT-TUG for the MacSheep system described above. The target application of the system and the heat pump is the area of new single family houses like the SFH45 building in MacSheep. Uncovered solar absorbers are used as the heat source of the system. These act as ambient air heat exchanger when no solar irradiation is available. Therefore the heat pump has to be able to provide enough heating capacity and a satisfactory COP also at quite low evaporation temperatures.

Figure 3 depicts a scheme of the heat pump system with all components and with the measurement equipment. The used refrigerant for the heat pump prototype is R410A. Figure 4 shows the heat pump prototype, which was assembled in the laboratory of IWT-TUG.

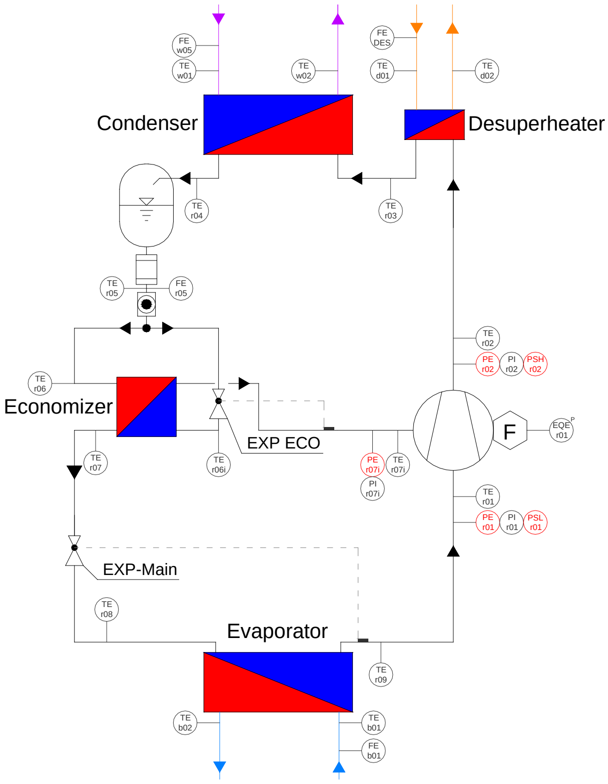

Figure 3: Scheme of the heat pump prototype with its measurement equipment.

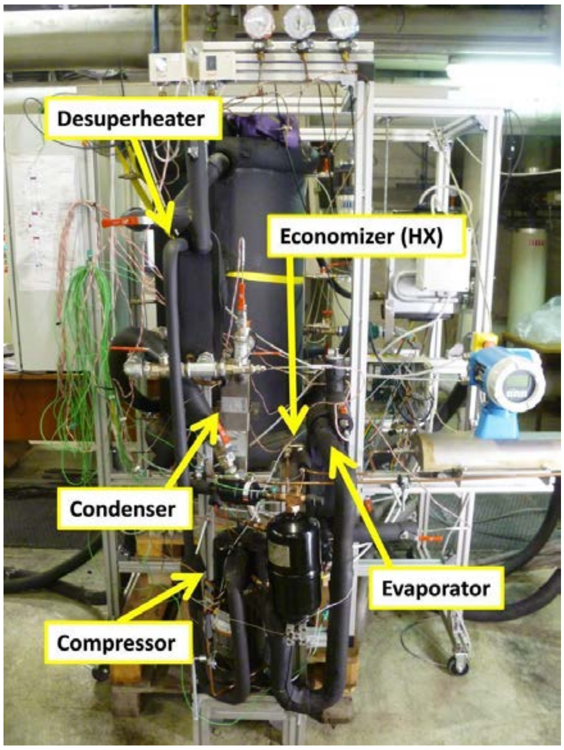

Figure 4: Photo of the final heat pump prototype.

The heat pump cycle is equipped with a speed controlled compressor equipped with an additional suction port for vapor injection (ZHW08, Copeland) via an economizer cycle with a plate heat exchanger. A Desuperheater is used to transfer heat from the superheated refrigerant vapor to water for DHW preparation at relatively high temperatures as a by-product of space heating operation. The water side of the condenser is connected to the space heating loop. A brine cycle, which is connected to the solar loop, is used as the heat source for the evaporator (compare Figure 2).

Extensive measurement equipment has been installed in the test rig in order to analyze the heat pump prototype. Figure 3 shows also the position of temperature sensors (TE), pressure sensors (PE), mass flow meters (FE) and the devices for measuring the electrical energy consumption (EQE^P). Table 2 provides an overview of the most important technical data of the developed heat pump system.

Table 2: Data of the developed heat pump system.

Type of heat pump	brine/water
Used heat sources	ambient air, solar collectors
Used heat sinks	heating system, storage tank
Compressor	
Type	Scroll (ZHW08 Copeland)
Vapor injection	Yes
Swept volume	15.56 cm³
Speed / Speed range	1800 – 7200 rpm
Refrigerant	R410A
Heating capacity sink side / COP @ B0W35[1] / 3600 rpm (without DES[2])	4.9 kW / 4
Heat exchangers high pressure side	
Desuperheater, SWEP B8Tx10	0.184 m²
Condenser, SWEP B8Tx40	0.874 m²
Economizer, SWEP B8Tx6	0.092 m²
Heat exchangers low pressure side	
Evaporator, SWEP B8Tx30	0.644 m²
Expansion device	electronic

2.2 Laboratory measurements and derived results

Steady state performance test results

The developed heat pump system was tested under steady state conditions, whereby 58 measuring points were recorded. For illustration, Figure 5 shows the heat pump process in the temperature-enthalpy-diagram for one operating point with detailed information on the right side.

Steady state tests were performed for three different inlet temperatures on the source side (-15 °C, 2 °C and 15 °C), three different inlet temperatures on the water side of the condenser (20 °C, 30 °C and 50 °C), and seven different compressor speeds (from 1800 rpm to 5400 rpm). The mass flow rate was set to a constant value. For the sink side it was 860 kg/h (5 K temperature difference), and for the brine side 1150 kg/h (3 K temperature difference under design conditions).

[1] Test condition according to ÖNORM (2013)
[2] Desuperheater

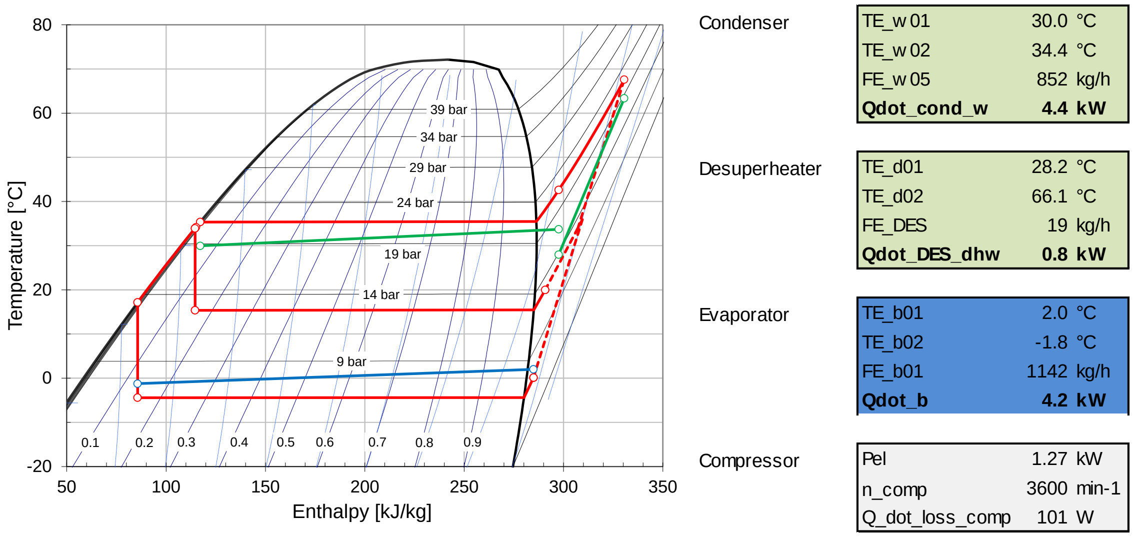

Figure 5: Measured result (example) of the final heat pump prototype in a temperature-enthalpy-diagram.

Table 3 shows chosen measurements that represent a range of expected operating conditions of the heat pump prototype (incl. desuperheater) in the system described above. The COP is 2.8 at a quite low evaporator inlet temperature of -15 °C and condenser water outlet temperature of 34 °C, with parallel preparation of domestic hot water (DHW) with an outlet temperature of 80 °C. Even at higher condenser water outlet temperatures (48 °C) for DHW preparation only with condenser and desuperheater in series, the COP is 2.3. These good results can be attributed to the implementation of the economizer cycle. For higher brine inlet temperatures the heating COP is between 4.4 and 5.9.

Table 3: Results of the steady state heat pump measurements for different realistic operating points.

n_{comp} [rpm]	TE_{b01} [°C]	TE_{w01} [°C]	TE_{w02} [°C]	TE_{d01} [°C]	TE_{d02} [°C]	$Q_{cond,w}$ [kW]	$Q_{DES,dhw}$ [kW]	P_{el} [kW]	COP [-]
4800 a)	-15	45	48.1	29	92	3.0	1.9	2.20	2.3
5400 b)	-15	30	34	28.9	80	3.9	1.2	1.85	2.8
3000 b)	2	23	28	27	58	3.9	0.5	0.88	5.0
2400 b)	2	30	33	29	62	3.0	0.6	0.81	4.4
2400 b)	15	30	34	25.6	57	3.9	0.6	0.77	5.9

a) domestic hot water preparation

b) space heating mode with parallel preparation of domestic hot water (desuperheater)

Dynamic test results

Additionally to the steady state measurements, also dynamic tests with varying operating conditions were carried out. The objectives of these tests were:

- to analyze the stability of the superheating control as well as
- the dynamic behavior of the heat pump,
- to evaluate the performance factor over a longer period and
- to test the programmed control software.

Therefore three different days with representative characteristics were chosen from annual simulations from WP7 and used as input files for the heat pump test rig. One day represents a quite cold day, where the heat pump has to operate at high pressure ratios. The second day represents a day in the transitional period, where the HP is switched on and off several times. And the last of the three days is a day where domestic hot water preparation is done. This day is used to analyze high temperature changes at the inlet of the condenser.

The obtained results from the daily tests show a satisfying performance of the heat pump prototype and its control.

2.3 Component simulation models

2.3.1 Heat Pump Model Type 887

The semi-empirical standard refrigerant heat pump cycle TRNSYS model (Type 877), which was used for the simulations of the reference system, has been extended by IWT-TUG to a model with an economizer cycle. This model (Type 887) was validated with the measurements of the heat pump prototype as described in the following section.

2.3.2 Model parameters and verification

The obtained measurement results were used to analyze the performance of the used compressor. The used model requires data for the overall isentropic efficiency $\eta_{is,over}$, the volumetric efficiency η_{vol} as well as the heat losses $\dot{Q}_{comp,losses}$ of the compressor. For $\eta_{is,over}$ and η_{vol} polynomial functions were generated by means of linear regression with the evaporation temperature t_{evap}, condensation temperature t_{cond} and compressor speed n_{comp} as parameters. For the heat exchangers in the heat pump cycle, functions for UA [W/K] that depend on the refrigerant and secondary mass flow rate were established.

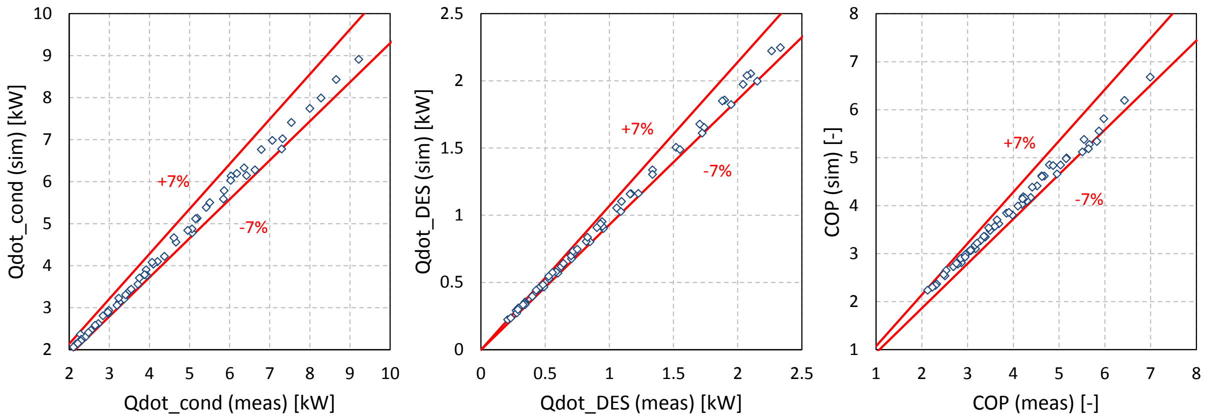

Figure 6: Simulation results from the heat pump model vs. experimental data from the heat pump test rig (58 measurement points).

A comparison of the measurements with the simulations was carried out using this data for the heating capacity on the sink side of the heat pump (condenser and desuperheater) $\dot{Q}_{sink}$ and the coefficient of performance COP (Figure 6).

The results of the heat pump model show a good agreement for $\dot{Q}_{sink}$ and for the COP compared to the experimental data and stay within a tolerance of ±7 % between measurements and simulations. With this validated model the annual dynamic system simulations presented in report D7.3 were carried out.

2.4 Conclusions and outlook

A novel brine-to-water heat pump prototype with a speed controlled compressor, an economizer refrigerant cycle and a desuperheater has been designed, built and tested for integration into the MacSheep solar heat pump system. Furthermore an optimized hydraulic integration of the heat pump has been worked out by the IWT, SPF and ESSA working group. This hydraulic integration is reported in D5.4. The heat pump prototype was tested under steady state and dynamic conditions, showing a satisfying operating behavior and performance.

A semi-empirical heat pump model (TRNSYS Type 877; standard refrigerant cycle) was extended with the functionality to simulate an economizer heat pump cycle. This new model (Type 887) was verified with the obtained measurement results and used for the annual system simulations of the MacSheep solar heat pump system.

3 Heat Pump development by Ratiotherm & SERC

A first prototype using a dual stage heat pump was built and tested at Ratiotherm's lab in Germany. The basic concept was that an air source heat pump delivered heat to an intermediate cold storage and a water source heat pump discharged the cold storage to provide heat to the combi-tank as well as directly to space heating. This concept had to be discarded because the results of the techno-economic evaluation were not as promising as hoped and so a completely new design was started in mid-2014.

In the following sections, simulation models and model parameters are provided for the new prototype design that includes a variable speed compressor and an economizer cycle in order to achieve good COP at higher temperature levels. The effect of the new components on the seasonal performance factor of the system is reported in D7.3.

3.1 Description of developed component

Table 4 shows data of the second prototype developed by SERC. The heat pump uses ambient air as heat source and delivers heat to the heating system as well as to the storage tank. The heat pump is connected to the combi-store as in "four pipes" configuration similarly to the reference system described in report D7.3, but with all pipes connected to the bottom of the store and internally to a stratifier unit. Details about the storage unit and connections to the tank are provided in report D5.4. The compressor is variable speed controlled and has a vapor injection port. The economizer cycle is designed with plate heat exchanger (HX), solenoid valve and electronic expansion valve (EEV) as depicted in Figure 7. Condenser and evaporator were sized at nominal conditions (A-5W55 /104Hz) and heat surface areas are listed in Table 4.

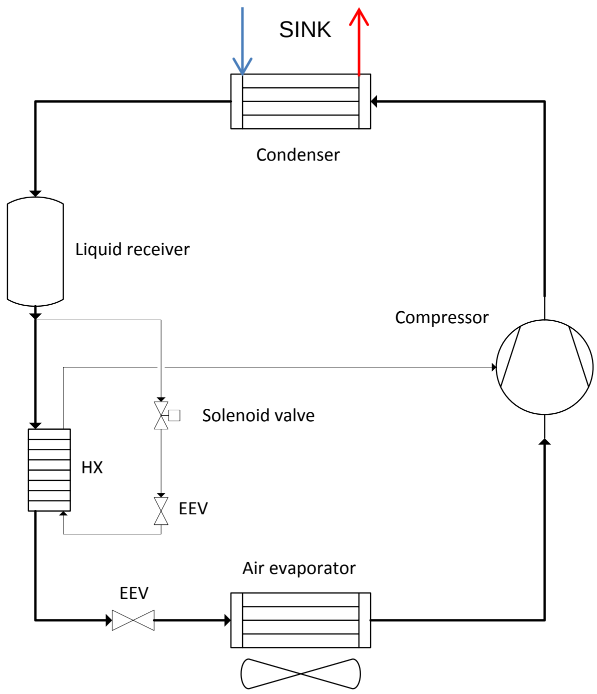

Figure 7: Scheme of the heat pump prototype.

Table 4: Data of the developed heat pump system.

Type of heat pump	air/water
Used heat sources	ambient air
Used heat sinks	heating system, storage tank
Compressor	
Type	scroll
Vapor injection	yes
Displacement at 50 Hz	2.8 m³/h
Frequency range	30 - 117 Hz
Heating capacity @ A2W35 / 30 Hz (SH= 5K; SC=0K) [a)]	3.41 kW
Heating capacity @ A2W35 / 117 Hz (SH = 5K; SC=0K)*	8.46 kW
Heat exchangers high pressure side	
Condenser, plate heat exchanger	0.902 m²
Heat exchangers low pressure side	
Evaporator, finned tube heat exchanger (ext. surface/int. surface)	104.5 / 4.46 m²
Expansion device	electronic
Vapor injection cycle	
Economizer, plate heat exchanger	0.276 m²
Expansion device	electronic

a) Heating capacity derived with type 887 with 5K superheating in the evaporator and 0K sub-cooling in the condenser.

3.2 Laboratory measurements and derived results

A first prototype using a dual stage heat pump was built at tested at Ratiotherm's lab in Germany. However, the results of the techno-economic evaluation were not as promising as hoped and so a completely new design was started in mid-2014. Due to this late start there was no time to build and test a new prototype before the end of 2014, and so only the modelling process has been completed.

3.3 Component simulation models

3.3.1 Simulation model

The heat pump was modeled using the semi-physical model Type 887 from IWT and SPF (Heinz and Haller, 2012). The full heat pump model was not validated against measurements in this development group, but it is the same model that has also been used and validated for the MacSheep heat pump of IWT (see section 2.2). With this model dynamic system simulations were carried out and results are shown in Deliverable 7.3.

3.3.2 Model parameters

The identification of model parameters was carried out with manufacturer data of the compressor and the heat exchangers.

The compressor was modelled with the approach that uses the overall isentropic efficiency and the volumetric efficiency by assuming same values for both stages of compression. As for the economizer, a fixed value for the efficiency of heat exchanger was considered.

Other heat exchangers (evaporator, condenser) were modeled by using the inlet conditions (mass flow rate, pressure, temperature) of the fluids on both sides for dependency of the UA-Values.

Table 5 shows simulation results of some steady state points that were selected as representative of working conditions within the selected system. The air inlet temperature (TE_{a01}) varies from 10.0°C down to -10.0 °C and the water outlet temperature of the condenser (TE_{w02}) varies from 36.0 °C up to 51.3 °C. The COP is 2.6 at air temperature of -10.0°C and water outlet temperature of 51.3 °C. The highest value of COP is 3.88 at 5.0°C air temperature and 43.3 °C water outlet of condenser. For higher air inlet temperature (10.0°C) the COP is lower because of the poor isentropic efficiency due to low pressure ratio (high air temperature and low sink temperature in space heating mode).

Table 5: Results of the steady state heat pump simulations for different operating points.

F_{comp} [Hz]	TE_{a01} [°C]	TE_{a02} [°C]	TE_{w01} [°C]	TE_{w02} [°C]	$Q_{cond,w}$ [kW]	P_{el} [kW]	COP [-]
104	-10.0	-12.4	47.0	51.3	6.68	2.57	2.60
80	-5.0	-7.3	45.4	48.9	5.54	1.89	2.93
60	0.0	-2.1	40.5	43.3	4.55	1.28	3.55
47	5.0	3.1	40.9	43.3	3.84	0.99	3.88
30	10.0	8.2	33.5	36.0	4.02	1.41	2.85

3.4 Conclusions and outlook

SERC and Ratiotherm have recently started the development of a second heat pump prototype designed for relatively high heating demand building (SFH100). The new design includes an economizer cycle, a variable speed compressor and the connections to the storage tank are realized as a “four pipes” configuration. Due to the late start, only the modelling process has been completed so far. The modeled heat pump has a heating capacity that varies between 3.4 kW at A2W35 / 30 Hz and 8.5 kW at A2W35 / 117 Hz. The annual simulation results (see report D7.3) are very positive.

4 Heat pump development by Regulus & CTU

Regulus and CTU have originally developed a ground source heat pump with one evaporator and three heat exchangers on the sink side (desuperheater, condenser and subcooler). Each sink has been used at a different temperature level: the desuperheater for DHW preparation, the condenser for space heating operation and the subcooler for cold water preheating.

A new TRNSYS type for a heat pump with three heat exchangers at the sink side has been developed to allow the evaluation of the heat pump design and operation in the MacSheep solar heat pump system. The TRNSYS type has been experimentally validated for the built prototype at CTU laboratories (UCEEB Bustehrad).

Finally, it was decided that the heat pump unit for the Regulus & CTU solar heat pump system will not have a subcooler due to low benefits for the combination with the solar thermal system and a higher complexity of the control, more pipe runs, and an additional pump, leading to higher costs for the system.

The target application of the concerned heat pump is the area of new or retrofitted family houses with a design heat load around up to 6 kW.

4.1 Description of developed component

The developed ground source heat pump includes a ground loop pump, sink loop pump and controlled three-way valves. A scheme of the heat pump is shown in Figure 8. Several sensors are installed in the refrigerant loop to monitor the operation and for control.

Table 6: Data of the developed heat pump system.

Type of heat pump	brine/water
Used heat sources	ground
Used heat sinks	storage tank (DHW, SH zone)
Compressor	
Type	scroll
Vapor injection	no
Swept volume	3.96 m^3/h
Speed / Speed range	3000 rpm (50 Hz)
Heating capacity / COP @ B0W35 (condenser only)	5.52 kW / 4.31
Heat exchangers high pressure side	
Desuperheater	0.41 m^2
Condenser	1.76 m^2
Heat exchangers low pressure side	
Evaporator	1.76 m^2
Expansion device	electronic

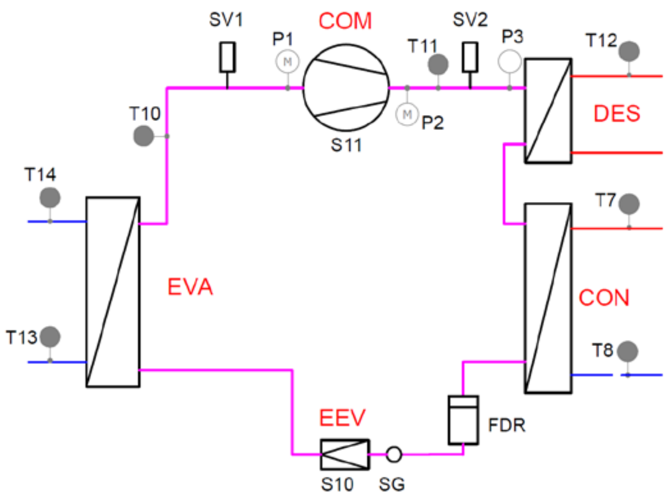

Figure 8: Hydraulic scheme of heat pump and front view.

4.2 Laboratory measurements and derived results

The final prototype design has been tested in standard heat pump mode (without the desuperheater) and additionally using the desuperheater (independently operated temperature and flow rate). The measurement procedure for the standard heat pump mode has been performed in accordance with EN 14 511. The measurements with desuperheater have followed the EN procedure.

Standard heat pump mode

The flow rate for nominal conditions 30/35 °C at the condenser side has been set and maintained for the other measurements. Table 7 shows selected results from heat pump testing.

Table 7: Performance data of the heat pump in condenser only mode.

Water outlet temperature [°C]	**35**	45	55	45	45	35	50	60
Brine inlet temperature [°C]	**0**	0	0	-5	5	5	10	10
Heating capacity [kW]	**5.52**	5.30	5.13	4.57	6.07	6.33	6.69	6.43
Cooling capacity [kW]	**4.08**	3.65	3.18	3.02	4.32	4.80	4.69	4.07
Power input [kW]	**1.28**	1.57	1.92	1.53	1.61	1.30	1.82	2.23
COP [-]	**4.31**	3.37	2.67	2.98	3.77	4.87	3.68	2.88

Desuperheater mode

The measurement of the heat pump with more than one heat exchanger on the high pressure side is not currently in the scope of the standard EN 14 511 for heat pump testing. Nevertheless, the general rules have been followed.

The desuperheater has been operated separately from the condenser at different temperatures and flow rates. The flow rate for the desuperheater has been set to 120 kg/h in the measurements.

Table 8: Performance data of the heat pump in desuperheater mode.

Condenser inlet/outlet temperature [°C]	30/33	30/33	40/43	30/34	**30/34**	40/43	30/35	30/36	40/45
Desuperheater inlet/outlet temperature [°C]	40/46	50/54	50/57	40/46	**50/54**	50/58	40/46	50/54	50/59
Evaporator inlet temperature [°C]	-5	-5	-5	0	**0**	0	10	10	10
Condenser heating capacity [kW]	3.72	3.90	3.26	4.37	**4.60**	3.95	5.95	6.32	5.38
Desuperheater heating capacity [kW]	0.81	0.62	1.07	0.93	**0.60**	1.16	0.97	0.58	1.27
Evaporator cooling capacity [kW]	3.39	3.33	2.80	3.92	**3.92**	3.52	5.42	5.40	4.88
Power input [kW]	1.24	1.24	1.50	1.27	**1.27**	1.55	1.29	1.30	1.61
COP [-]	3.66	3.64	2.89	4.17	**4.11**	3.30	5.36	5.30	4.12

4.3 Component simulation models

A new type for TRNSYS simulations has been developed for the triple sink heat pump in order to evaluate the original development of the heat pump with desuperheater and subcooler. An experimental validation of the semi-physical heat pump model has been done. The triple sink prototype heat pump has been assembled in the laboratory of UCEEB (CTU). Selected results are shown in the graphs in Figure 9 to Figure 11 below.

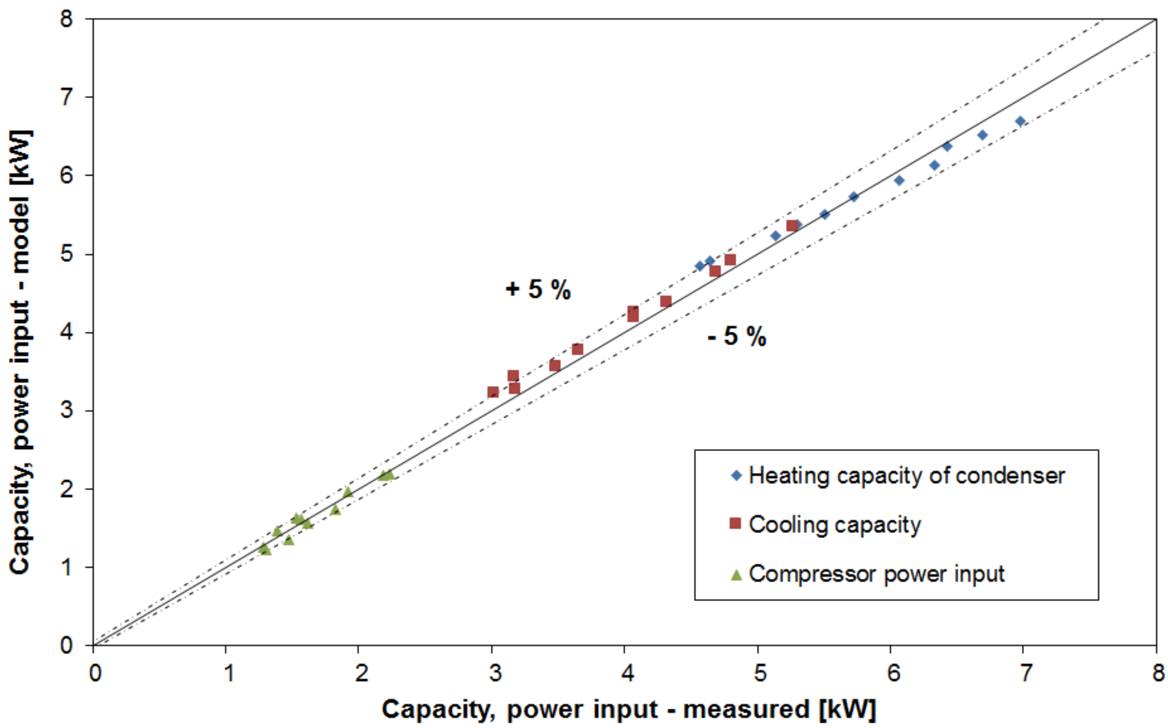

Figure 9: Verification in condenser mode only.

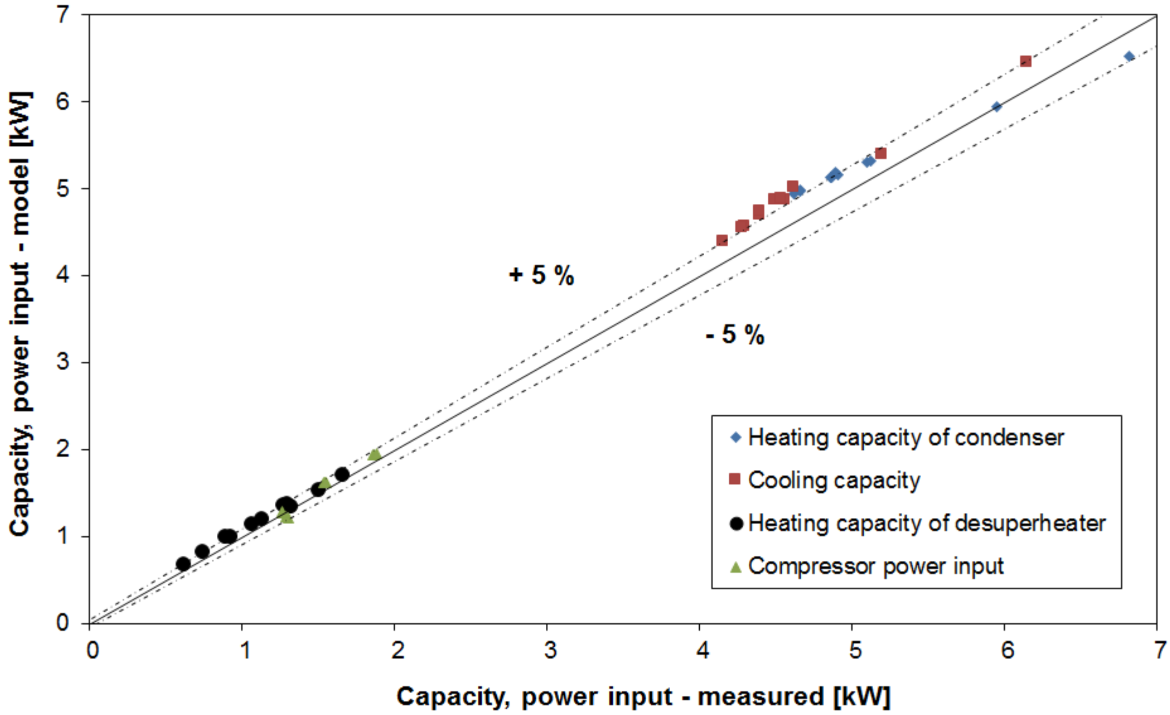

Figure 10: Verification in condenser/desuperheater mode.

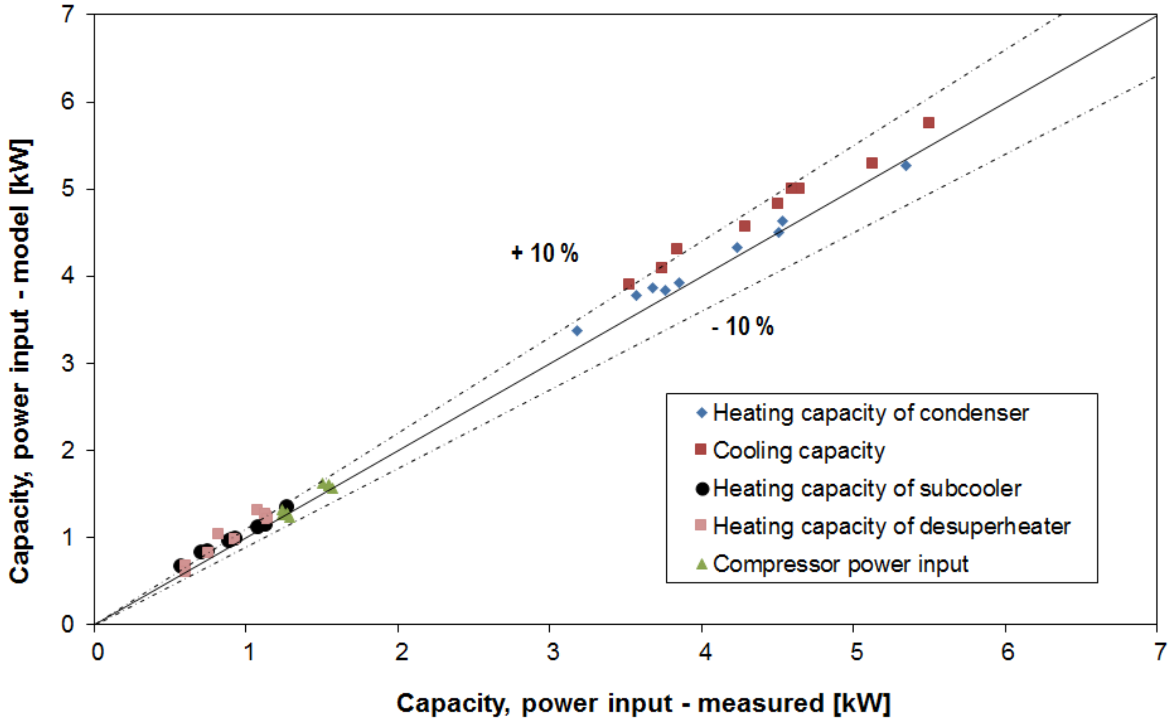

Figure 11: Verification in triple sink mode

While the conventional condenser mode and condenser/desuperheater mode result in an acceptable uncertainty of the model, the complex triple sink mode with subcooler results in a higher uncertainty. The reason could be mainly due to the problem with an exact definition of U-values of the heat exchangers (condenser, subcooler).

4.4 Conclusions and outlook

A ground source heat pump with condenser and desuperheater at the sink side has been designed, built and tested for the integration into the MacSheep solar heat pump system developed by Regulus & CTU. The nominal heating capacity of the heat pump (B0W35) is 5.5 kW and the COP is 4.3.

A new semi-physical model for a triple sink heat pump has been developed and validated for the use in the TRNSYS environment. Despite that the subcooler has been discarded in the final design of the Regulus & CTU heat pump, the concept could be further developed and used in heat pump systems without solar heating, especially in applications with a high portion of DHW load.

5 Conclusion

Within the MacSheep project three heat pump prototypes were developed by three different development groups. The target application of two of the concerned heat pumps is the area of new or retrofitted low energy single family houses (SFH45); one is designed for higher heat loads with a relatively high operating temperature for a radiator distribution system (SFH100).

These prototypes include five different breakthroughs concerning advanced heat pump cycles, which have been identified and analyzed within phase 1 and phase 2 of the project. This document presents the current status and results concerning the heat pump developments at the end of phase 3 of the project.

Two development groups have built up prototypes of the heat pump and have performed laboratory measurements. The third group has discarded their initial plans, has redesigned their system, and is therefore currently in the phase of assembly of their heat pump prototype.

In parallel the groups are working on simulation models for their heat pump systems. Two groups are developing semi-physical component models for the heat pump cycle, which have been adapted, parameterized and verified with the performed measurements. One group is using existing component models, which are combined to a heat pump system and parameterized in a way to fit measured data. These heat pump component models are used in the whole system simulations described in report D7.3.

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