Report on Solar Combisystems Modelled in Task 26

Appendix 8: Generic System #15: Two Stratifiers in a Space Heating Storage Tank with an External Load-Side Heat Exchanger for DHW

A Report of IEA SHC - Task 26
Solar Combisystems
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INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

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Appendix 8: Generic System #15: *Two Stratifiers in a Space Heating Storage Tank with an External Load-Side Heat Exchanger for DHW*

by

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A technical report of Subtask C

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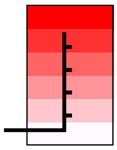
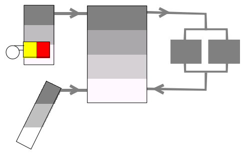
Contents

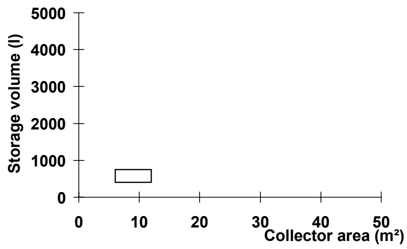
Preface

The report describes a sensitivity study performed on the solar combisystem called SolvisMax Gas manufactured and sold by Solvis GmbH & Co KG in Germany. A typically sized SolvisMax system serves as a base case for the parameter sensitivity analysis. The system that the TRNSYS model was validated for is a 750 l storage tank with an integrated condensing gas boiler.
Now the system is also available with an integrated oil burner. Except for the boiler characteristics (e.g. mean annual efficiency) the system is identical to the SolvisMax Gas system.

1 General Description of System #15 Two Stratifiers in a Space Heating Storage Tank with an External Load-Side Heat Exchanger for DHW





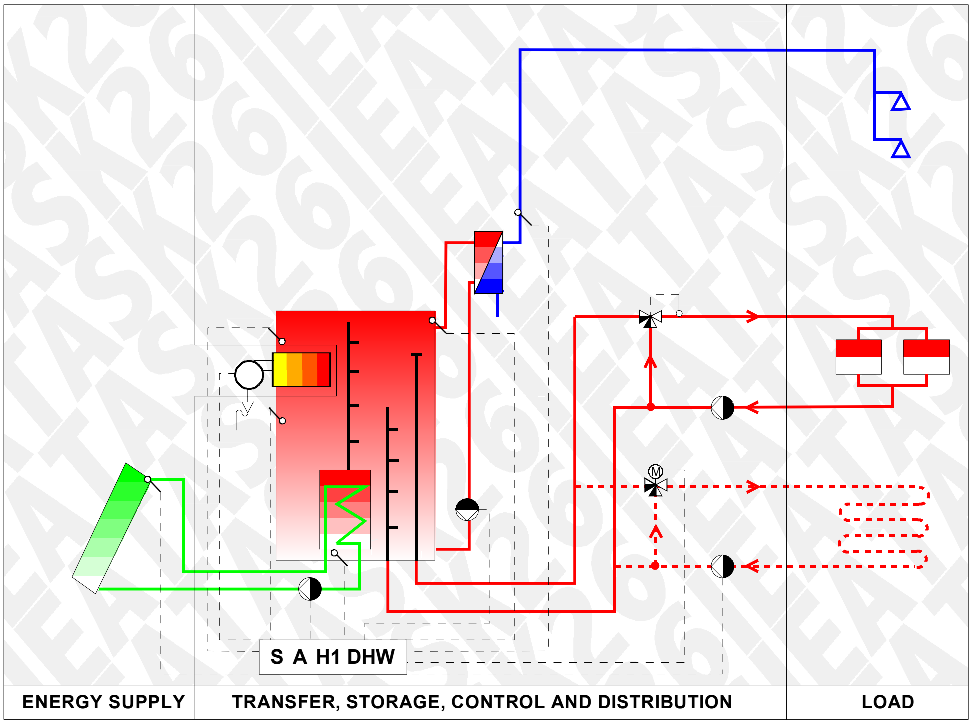


Main features

This system consists in a compact unit, in which all components (auxiliary condensing burner, DHW flat plate heat exchanger with its primary pump, solar heat exchanger, solar hydraulic unit) are integrated. Therefore, the installation time is reduced because of the reduction in the number of connections needed.

The solar storage tank works as an optimised energy-manager for all types of incoming (solar-energy, gas-burner, ...) and outgoing energy (domestic hot water, space heating water).

Heat management philosophy



The speed of the solar loop pump is controlled to reach an optimal loading temperature in the storage tank and a minimum flow rate in the collector to get a good heat transfer.

The DHW temperature is adjusted to the chosen setpoint temperature by controlling the speed of the pump located in the primary loop of the heat exchanger.

Heat delivered to the space heating loop is adjusted by a variable flow rate pump under selfcontrol of the valve position of the radiators (to save pump energy and ensure quiet operation of the radiator valves).

The power of the gas burner can be modulated between 5 and 20 kW, depending on the temperature in the tank and the requested temperature of the space heating loop (calculated from the ambient temperature, the room temperature and the time of the day).

Specific aspects

The input of solar energy in the storage tank is carried out by an internal low-flow heat exchanger in co-operation with stratifying tubes (low-flow technology). The system must be checked once a year, due to the condensing gas burner.

Influence of auxiliary energy source on system design and dimensioning
This system is designed with a gas condensing burner integrated in the storage tank. All other auxiliary energy can easily be connected to the storage tank without further heat exchangers (e.g. wood or pellet burners)

Cost (range)
The total costs of the system (space heating emission loop and mounting not included) is between 8040 EUR for a 5 m² collector area/ 400 l storage tank system and 11850 EUR. for a 12 m² collector area/ 750 l storage tank system.
(without taxes, collector mounted into the roof, including collector pipe with insulation, including solar unit (pump, valves, flow meters, ...), including solar fluid and solar controller as well as gas condensing burner controller)

Market distribution
This system is marketed in Germany since 1997. About 22 sales offices in Germany market this system directly to the plumbers, with more than 3000 units and 20,000 m² solar collector sold until now.
Manufacturer : SOLVIS GmbH & Co. KG

2 Modelling of the System

2.1 TRNSYS Model

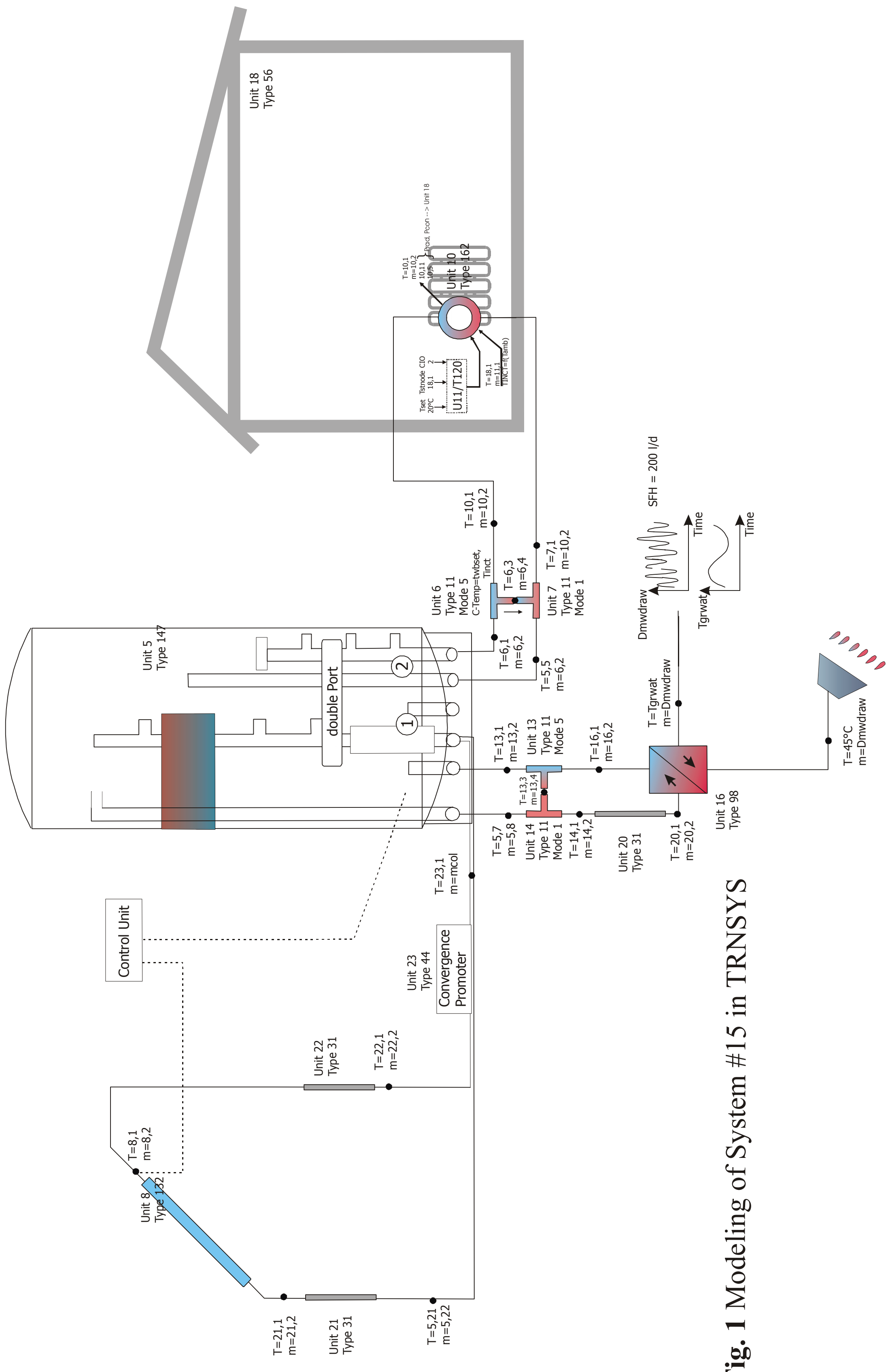


Fig. 1 Modeling of System #15 in TRNSYS

2.2 Definition of the Components Included in the System and Standard Input Data

2.2.1 Collector

The Task 26 standard collector as defined in [1] was used, not the Solvis collector that is actually sold with the system.

Collector	η0, a1, a2, inc. angle modifier (50°)	0.8, 3.5, 0.015, 0.9
	Area	10.1 m²
	Specific mass flow	12 l/(m²h)

2.2.2 Pipes between Collector and Storage

Model :	One type for hot side and one type for cold side			
Pipes :	Diameter:	10 mm	Total Length :	2 x 15 m
Insulation :	Thickness :	20 mm	Thermal Conductivity :	0.04W/m.K

Data defined by insulation manufacturer's specifications.

2.2.3 Storage

Type : 147 Version Number :1.21

Storage tank	Total volume	0.635 m³
	Height	1.44 m
	Store volume for auxiliary	0.170 m³
	Number of nodes	86
	Medium	Water
	Insulation thickness, thermal conductivity	10.7 cm, 0.035 W/(m K)
	Heat input system (collector)	Stratifier
	Position of collector temperature sensor	Attached to the absorber plate
	Start $\Delta\vartheta$, hysteresis, collector loop	10K, 3K

Solar heat exchanger: Medium: Propylene glycol (40%)
Type of heat exchanger: tubular
Average heat transfer coefficient: 415 W/K
Domestic hot water heat exchanger: Media: Water
Type of heat exchanger: flat plate
Average heat transfer coefficient: 6190 W/K

Data defined by parameter identification performed by ITW, University of Stuttgart, Germany

2.2.4 Boiler

Integrated in the store, model is part of Type 147 – Specific Type, data defined by parameter identification using test sequences by ITW, University of Stuttgart, Germany.

Aux. Boiler	Heating capacity	5-20 kW
	Mean efficiency	108 %
	Energy source	natural gas
	Minimum running time	N/A.
	Minimum stand still time	N/A.
	DHW mode: Start $\Delta\vartheta$, hysteresis, auxiliary	12K, 5K
	SH mode: Set temp., hysteresis	Tset for heating loop, 5K

2.2.5 Building

Type56 – defined in [2]

2.2.6 Heat Distribution

Radiators – Heating Floor

Radiator	Radiator area (SFH Zurich 60)	2.35 m²
	Heat capacity (SFH)	1150 kJ/(kg K)
	Set flow- and return temperatures (SFH) Maximum flow rate	40 / 35 °C 0.8526 kg/s
Heating Floor *not used*	Thickness	-
	Area	-
	Specific heat of floor material	-
	Heat conduction coefficient of floor material	-
	Density of floor material	-
	Space between two pipes	-
	Set flow- and return temperatures (MFH)	-

(Data defined in [1])

2.2.7 Control strategy

Solar loop:

TRNSYS Type 2

Functions: On/off of solar loop pump, cut-off when maximum tank temperature is reached. Flow rate increases if the temperature at the bottom of the tank reaches 40°C to ensure complete charging of the tank.

Burner:

integrated in TRNSYS Type 147

Functions: Auxiliary heating for space heating and domestic hot water. When in hot water mode, the burner runs on full power. In space heating mode, it modulates between 5 and 20 kW.

Heating loop:

TRNSYS Type 120

Functions: Set flow temperature as a function of ambient temperature

Domestic hot water preparation:

integrated in TRNSYS Type 98

Functions: Controls the rpm of the domestic hot water pump to ensure a constant water draw temperature.

2.3 Validation of the System Model

TRNSYS type 147, i.e. the storage tank including the integrated burner and solar and domestic hot water heat exchanger have been well validated by verification sequences performed at ITW, University of Stuttgart, Germany.

3 Simulations for Testing the Library and the Accuracy

3.1 Result of the TRNLIB.DLL Check

	$F_{sav,therm}$	$F_{sav,ext}$	F_{SI}	Q_{boiler}	$Q_{penalty, SHLow}$	$Q_{penalty, SHUp}$	$Q_{penalty, DHW}$
Reference Results	0.7900	0.7406	0.3006	9443	30	26480	
SOLVIS Results	0.7996	0.7498	0.3065	9012	29	26640	0
Difference	0.0096	0.0092	0.0059	-431	-1	-160	

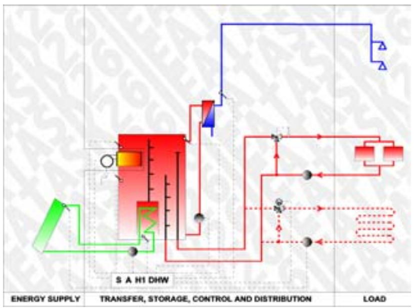
3.2 Results of the Accuracy and Timestep Check

The accuracy and timestep check was done for a system with 650 l of storage tank and 10.1 m² of collector area, Zurich climate and the 60 kWh/(m² a) building.

Convergence Tolerance	Integration Tolerance	Timestep	$F_{sav,therm}$	Epsilon (change in timestep)	Epsilon (change in tolerance)
0.1	0.1	6 min	0.3953		
0.01	0.01	6 min	0.3956		0.00076
0.1	0.1	3 min	0.3979	0.00658	
0.01	0.01	3 min	0.3900	-0.01416	-0.01985
0.005	0.005	3 min	0.3886		-0.00359
0.001	0.001	3 min	doesn't run	--	--
0.1	0.1	2 min	0.3922	-0.01433	
0.01	0.01	2 min	0.3905	0.00128	-0.00433
0.005	0.005	2 min	0.3887	0.00026	-0.00461
0.1	0.1	1 min	0.3928	0.00153	
0.01	0.01	1 min	0.3906	0.00026	-0.00560
0.005	0.005	1 min	0.3902	0.00386	-0.00102

4 Sensitivity Analysis and Optimisation

4.1 Presentation of Results



#15 Two Stratifiers in a Space Heating Storage Tank with an External Load-Side Heat Exchanger for DHW

Main parameters (base case) :			
Building :	*SFH 60*	Storage volume	*0.635 m³*
Climate :	*Zurich*	Storage height	*1.8 m*
Collectors area :	*10.1 m²*	Position of heat exchangers	*typical*
Collector type :	*Standard Flat Plate*	Position of in/outlets	*typical*
Specific flow rate (Collector)	*12 kg/(m² h)*	Thermal insulation	*11 cm*
Collector azimuth/tilt angle	*0 / 45°*	nominal auxiliary heating rate	*5-20 kW*
Collector upper dead band	*10 K*	Exhaust Gas Heat Exchanger	*integrated*
Simulation parameters:		Storage nodes	*86*
Timestep	*3 min*	Tolerances Integration Convergence	*0.01 / 0.01*

The base case is a system that is typically sold by Solvis for a family of 4 – 5.

There are a few parameters that can be decided on by the installer or user of the system. These parameters are called **system design parameters**. The parameters that are analysed here, are the storage volume, the collector area and the tilt angle of the collector.

In a second step, a sensitivity was performed on several parameters that include a change in the system itself, i.e. changing the control strategy, using a different heat exchanger, using a different insulation.

Summary of Sensitivity Parameters			
Parameter	Variation	[1]Variation in $f_{sav,ext}$	
Base Case	-	36.45%	
Collector size [m^2] (fixed store size (623 l)	5 - 12	32.06 – 37.71 %	*Figure 1*
Store size [l] (fixed collector size 10.1 m²)	377-1423	36.14 - 36.24 %	*Figure 2*
Collector tilt angle [°]	0 - 90	32.79 – 26.,51 %	*Figure 4*
Climate	Carpentras, Zurich, Stockholm	53.43, 36.45, 33.50 %	*Figure 5*
Building standard	30, 60, 100 kWh/(m² a)	42.68, 36.45, 31.49 %	*Figure 6*
Control strategy of heating loop pump	T_room, T_amb, etc.	36.45 – 38.57	*Figure 8*
Modulation range of burner	5-20 kW, 2-20 kW, 2-10 kW, 15 kW, 5 kW	36.33 – 37.23 %	*Figure 10*
UA value of solar hx	factor 0.8...2 from UA_basecase	36.11 – 37.12 %	*Figure 11*
Store insulation	0 – double the actual losses	33.76 – 38.83 %	*Figure 12*
Taux_set (dhw)	45 - 65°C	35.23 – 37.22 %	*Figure 13*
DHW hysteresis	0 – 10 K	36.26 – 36.48 %	*Figure 14*

4.1.1 System Design Parameters

Sensitivity parameter:	Collector size [m²] (fixed store size 623 l)	5-12

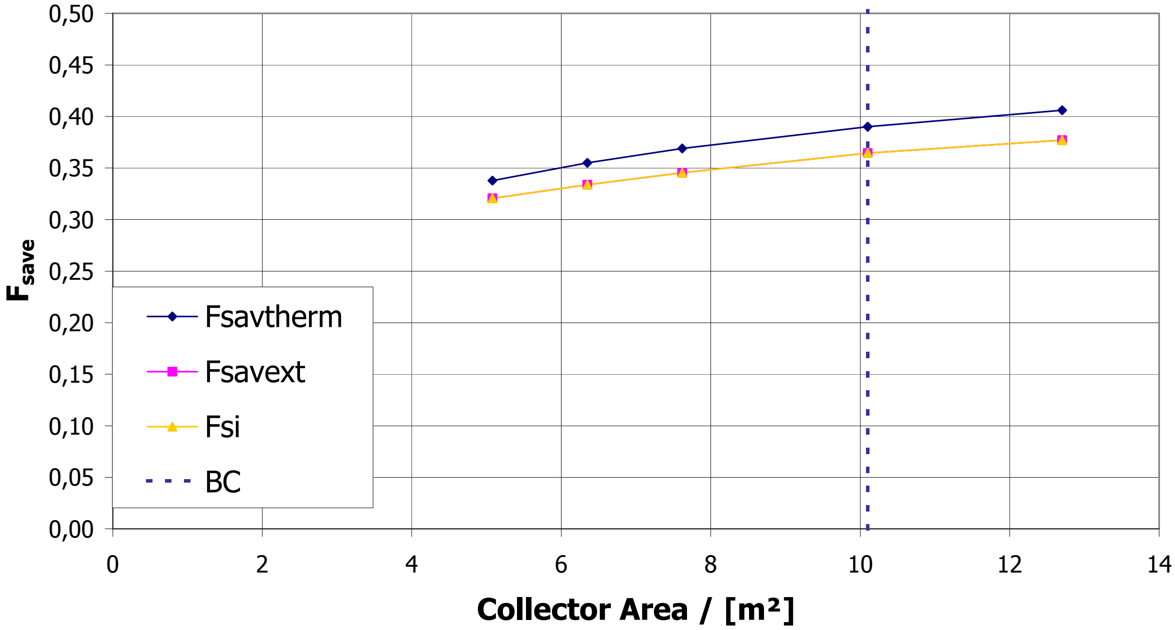


Fig. 1 Fractional energy savings vs. collector area for a constant store volume of 623 l.

Differences from Base Case
Collector area

Description of Results
Increasing the collector area from 10.1 m² to 12.6 m² increases the Fsav,ext value by 3.5%. But one can see in Figure 1 that the curves already flatten at this point. Increasing the collector area even more is not going to lead to the same improvements while increasing investments costs significantly.

Comments
None.

Sensitivity parameter:	Store size [l] (fixed collector size 10.1 m²)	377-1423

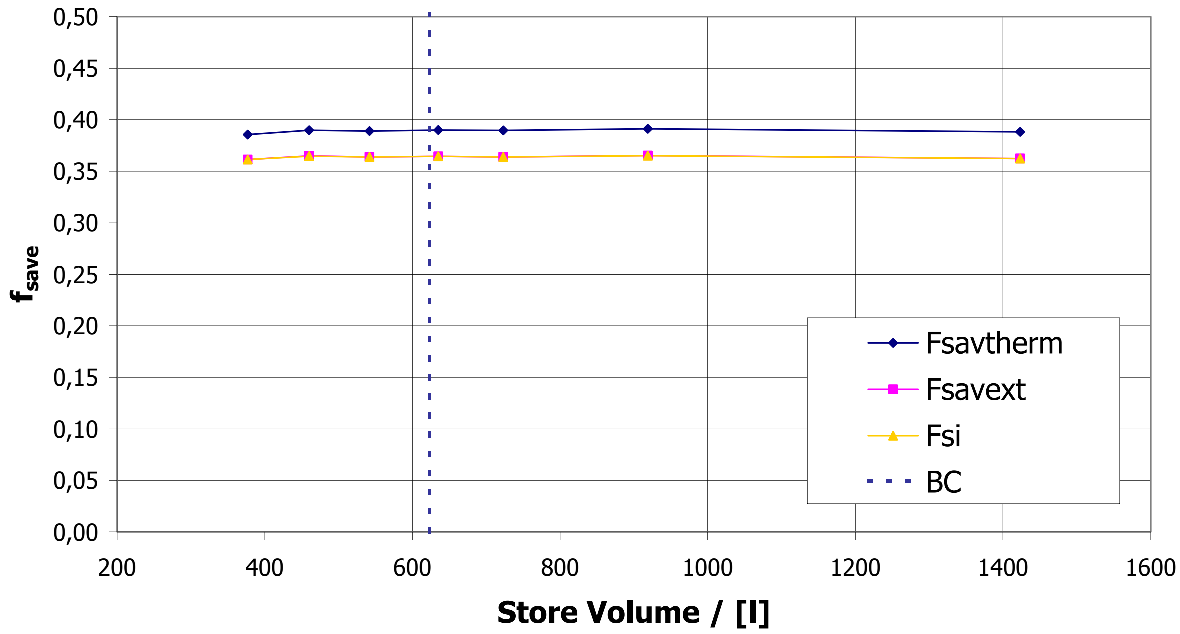


Fig. 2 Fractional energy savings vs. store volume for a constant collector area of 10.1 m²

Differences from Base Case
Store volume

Description of Results
The store volume has hardly any influence at all on the fractional energy savings if the collector area stays the same. However, it is important to choose a storage size that meets especially the domestic hot water needs of the consumers.

Comments
None.

Figure 3 is a combination of Fig. 1 and 2. It shows combinations of all collector and storage sizes Solvis sells in one graph as a function of the specific store volume (store volume/collector area). Some combinations don't make a lot of sense (like a small collector area with a very large storage tank) but were included to study the influence of the two parameters.

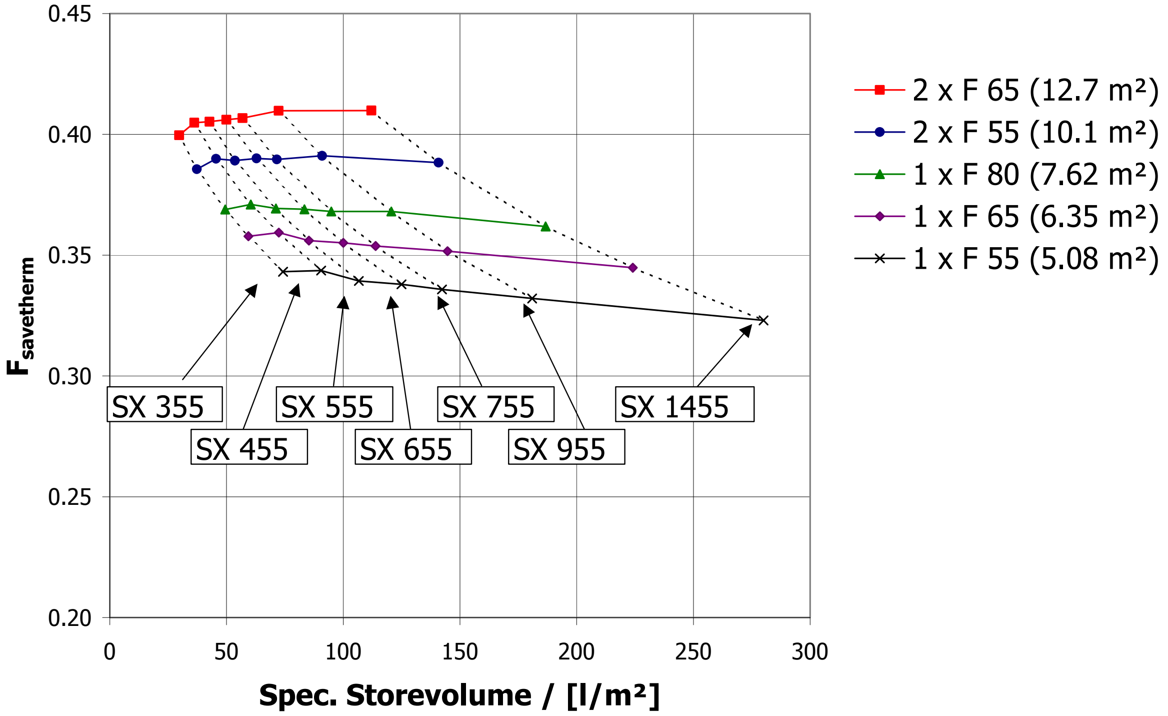


Fig. 3 Fractional thermal energy savings vs. specific store volume

For small collector areas a large storage tank leads to lower energy savings than a small storage tank due to additional heat losses from the tank. Only for larger collector areas it makes sense to choose a bigger storage tank.

This is only true for the specific domestic hot water demand that was chosen for the system comparison in IEA Task 26. The larger storage sizes that were simulated are usually sold only when there is a higher domestic hot water demand, for example for 2 or three family houses. A higher domestic hot water demand would also lead to higher energy savings.

Sensitivity parameter:	Collector tilt angle [°]	0 - 90

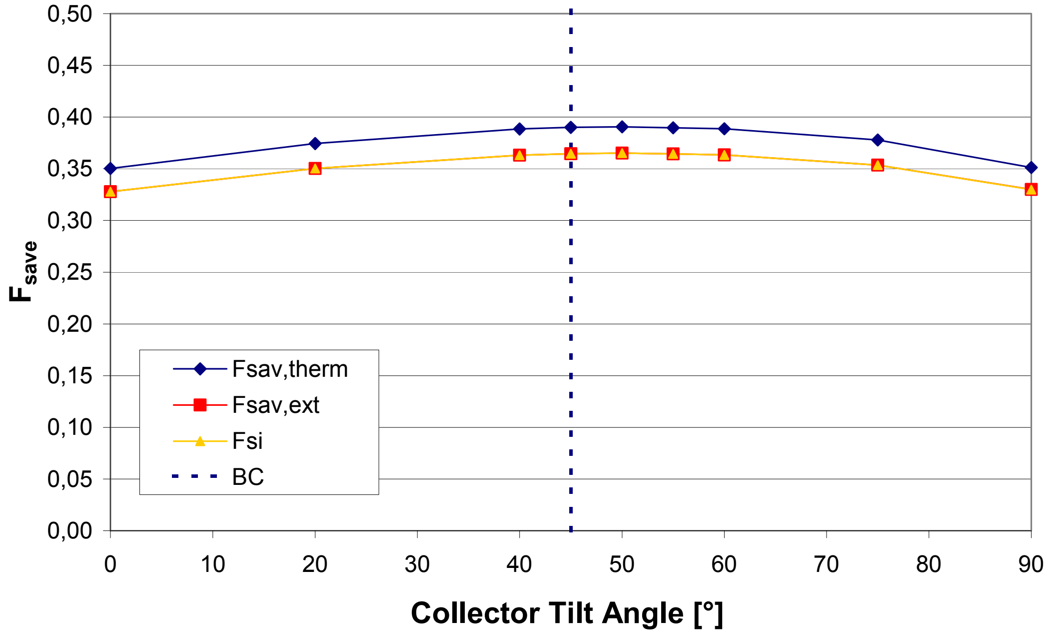


Fig. 4 Fractional energy savings vs. collector tilt angle

Differences from Base Case
Collector tilt angle varies from horizontal to vertical orientation.

Description of Results
The optimum collector tilt angle for the base case is 50°. Changing the collector tilt angle from the base case value of 45° to 50° increases the extended fractional energy savings by only 0.2%.

Comments
None.

Conclusion Optimum Design

The optimum design is therefore a slightly bigger collector area than the base case (12.7 m²) and a tilt angle of 50°. This leads to an improvement in extended fractional energy savings of 3.7%.

4.1.2 Climate and Building Standard

Sensitivity parameter:	Climate	Carpentras, Zurich, Stockholm

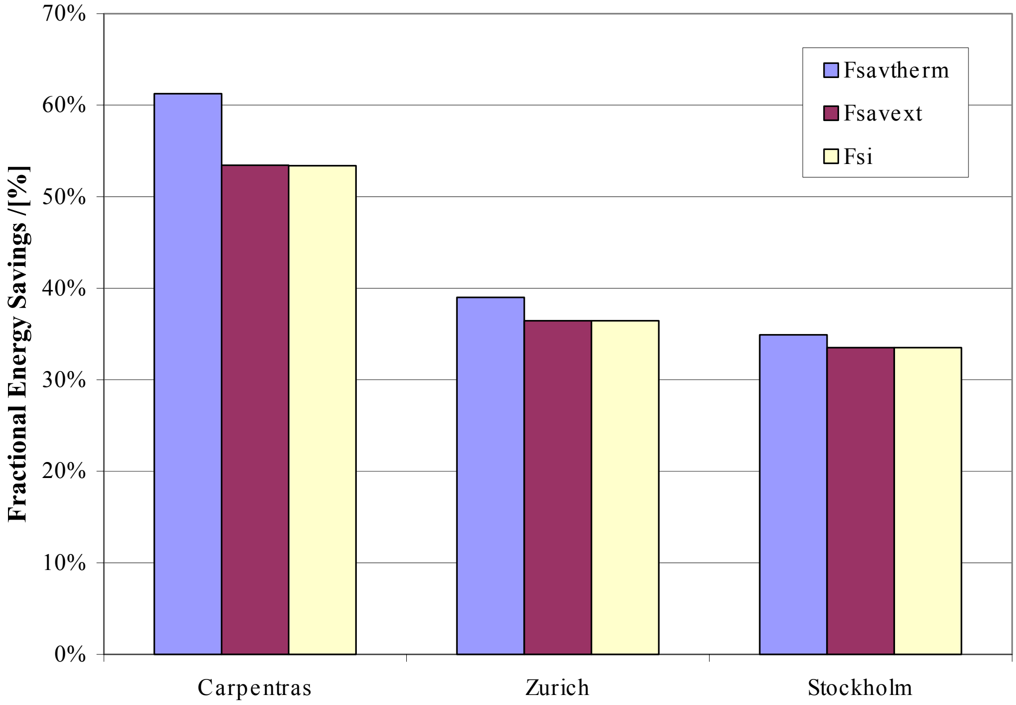


Fig. 5 Fractional energy savings for different climates

Differences from Base Case
60 kWh base case building was simulated in three different climates.

Description of Results
As expected, there is a big increase in fractional energy savings for the Carpentras climate.

Comments
None.

Sensitivity parameter:	Building standard	30, 60, 100 kWh/(m² a)

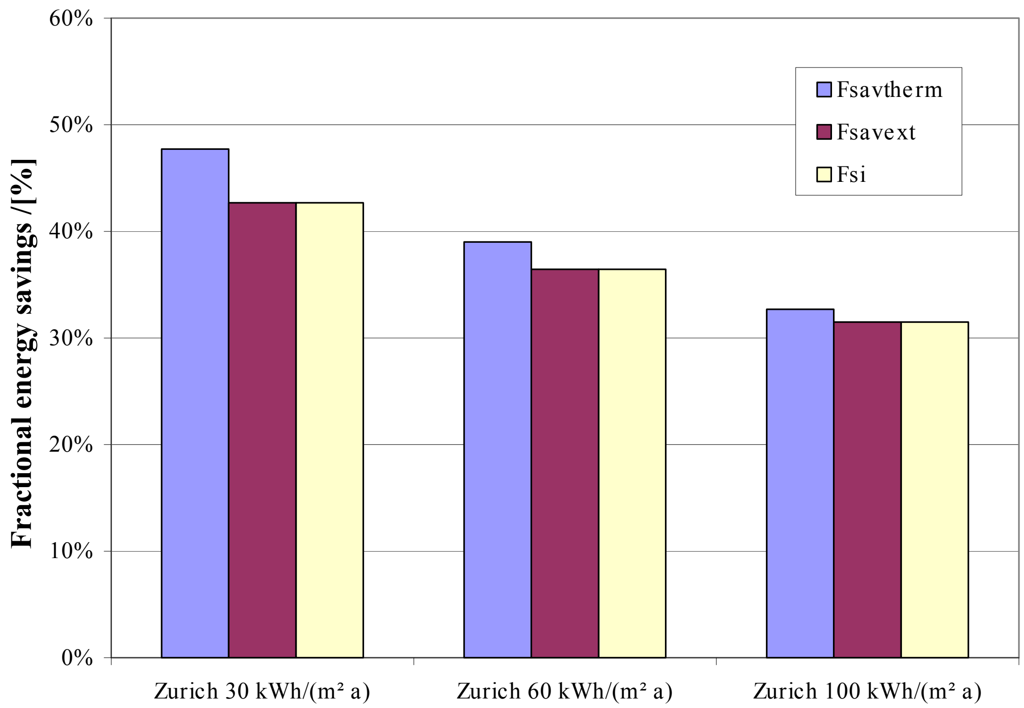


Fig. 6 Fractional energy savings for different building standards

Differences from Base Case
For the Zurich climate all three building standards were simulated.

Description of Results
The extended fractional energy savings are significantly higher for the 30 kWh/(m² a) building than for the 100 kWh/(m² a) building.

Comments
None.

4.1.3 Sensitivity Analysis

Sensitivity parameter:	Control strategy of heating loop pump	T_room, T_amb, etc.

Differences from Base Case

Several control strategies of the space heating loop pump have been simulated.

1) The space heating pump is ON when the ambient temperature is less than 20°C with a hysteresis of 1 K. This is the standard setting of the Solvis controller. The electricity consumption of the pump that was used is the actual one of pump that is being sold with the Solvis system.
2) The space heating pump is ON when the room temperature is less than 20°C with a hysteresis of 1 K. This is an option one can choose in the Solvis controller. Is saves you a considerable amount of electrical energy while delivering the same comfort level. For this option, the location of the room temperature sensor has to be chosen carefully to avoid that the sensor shows a significantly different temperature than in other rooms of the building.
3) The space heating pump is ON when the average ambient temperature over 24 hours is less than 20°C with a hysteresis of 1 K. The simulation showed that there is no big difference to case number 2 where the pump operation depends only on the current temperature.

4), 5) For these simulations the set temperature for the room was lowered to 15°C during the night. This saves a lot of electrical energy and pump running time. Because the room temperature goes below 20°C, penalties are high in these cases. Therefore, it's not part of the system comparison and optimisation.

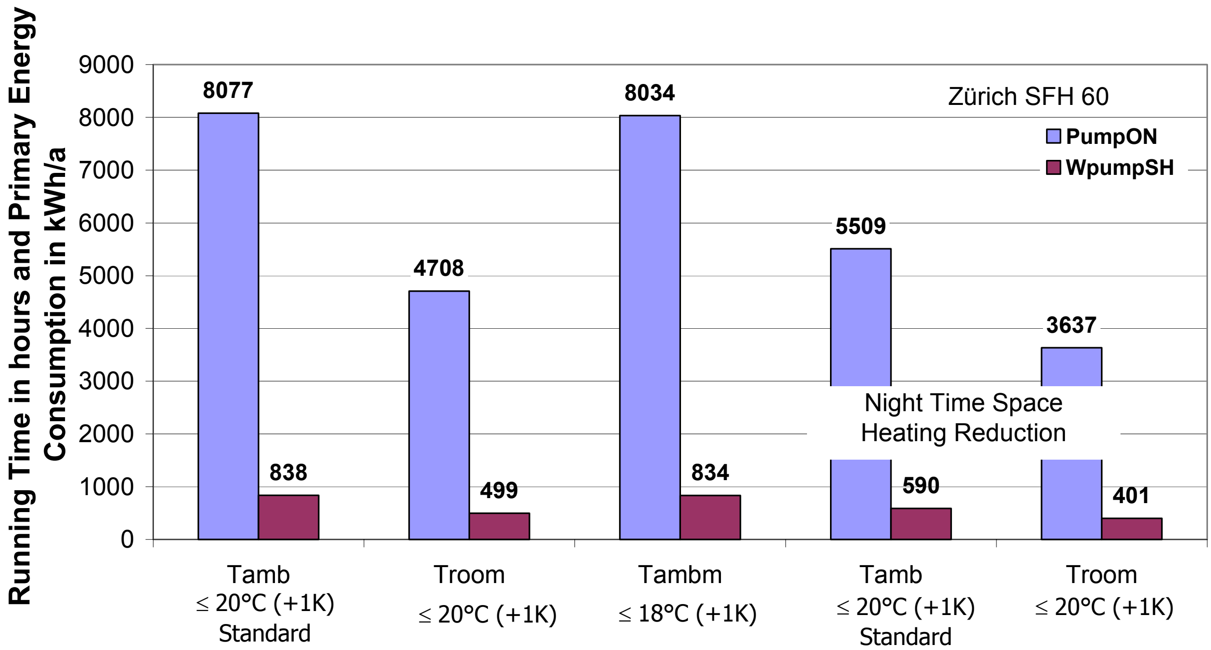


Fig. 7 Running time and primary energy consumption of the space-heating loop pump for different control strategies of the heating loop pump

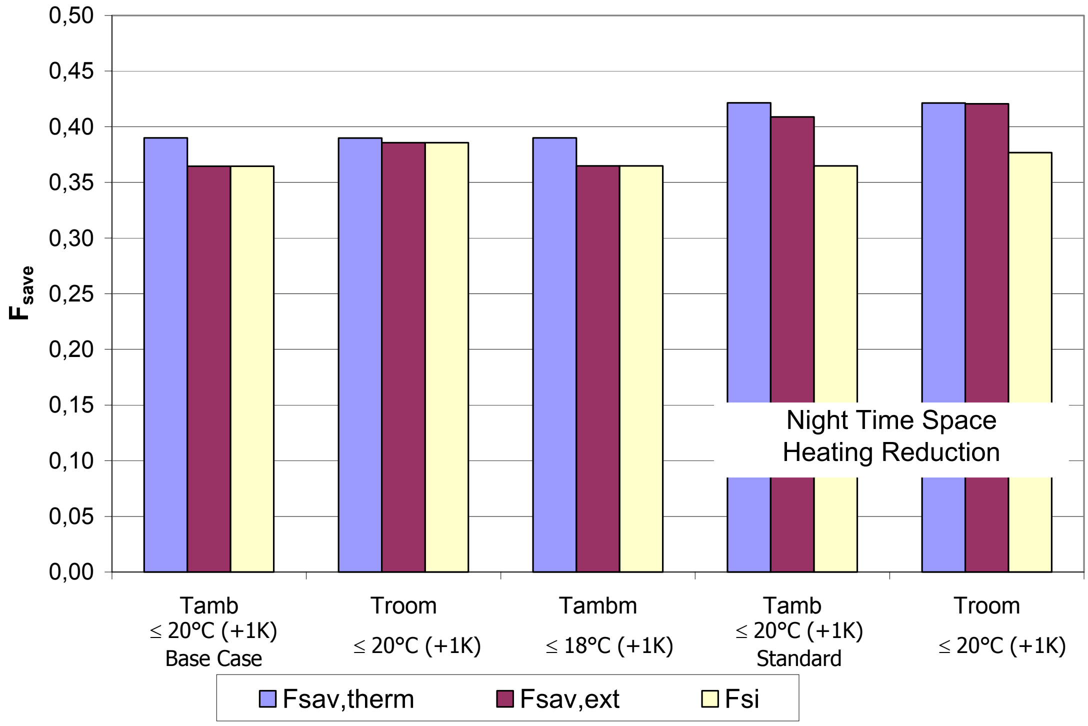


Fig. 8 Fractional energy savings for different control strategies of the heating loop pump

Description of Results

The thermal fractional energy savings are approximately the same for all three cases studied. However, case #2 (control by the room temperature) uses considerably less electrical energy. Therefore, $F_{save,ext}$ is 5.8 % higher than in the standard case #1.

Comments
None.

Sensitivity parameter:	Modulation range of burner	5-20 kW, 2-20 kW, 2-10 kW, 15 kW, 5 kW

Differences from Base Case
Different modulation ranges of the burner were studied here. The most interesting parameter to look at is the average running time of the burner per cycle.

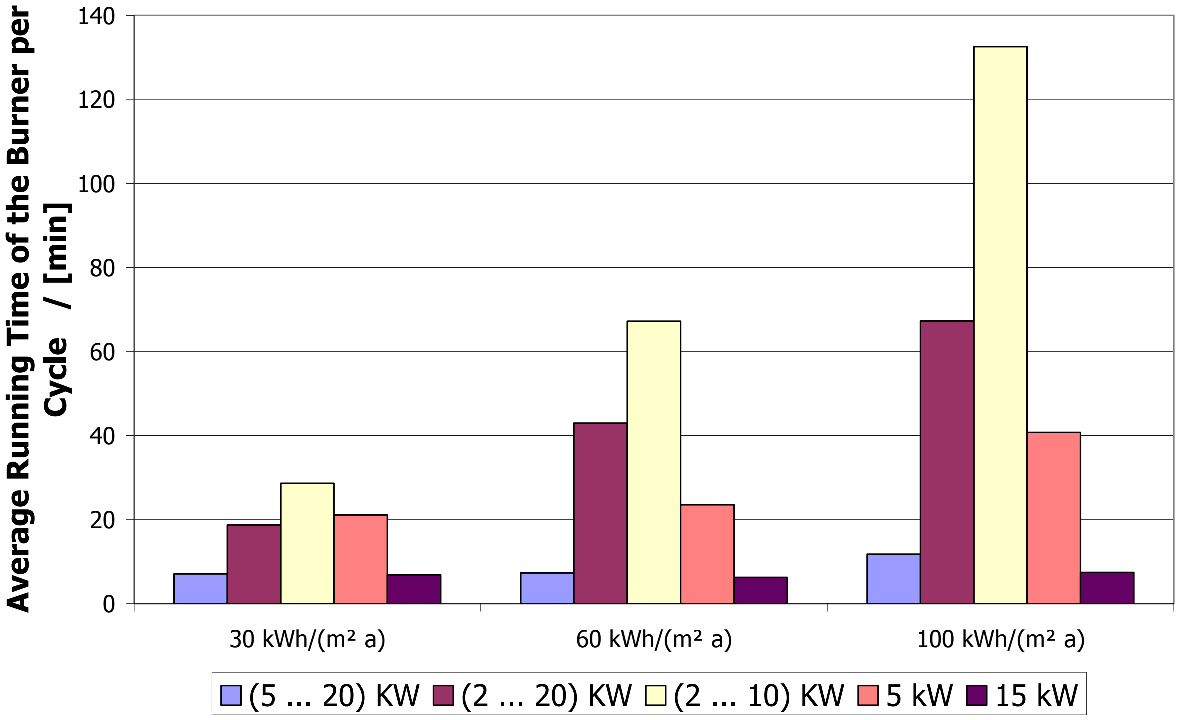


Fig. 9 Average running time of the burner per cycle vs. different modulation ranges and different building standards in Zurich

Description of Results

The current SolvisMax burner modulates from 5 to 20 kW. If the burner could modulate down to 2 kW instead of 5 kW, the average running time of the burner were much longer. This is especially true if the space heating demand of the building is large. For low energy buildings the burner runs mostly in domestic hot water mode and therefore on full power. Long running times of the burner are important to reduce start and stop emissions.

A burner that modulates from 2 to only 10 kWh would have even longer running times but when the domestic hot water part of the store is empty it would take longer to recharge it.

Non-modulating burners lead to fairly short running times. The 15 kW-version would also be less efficient than a modulating one.

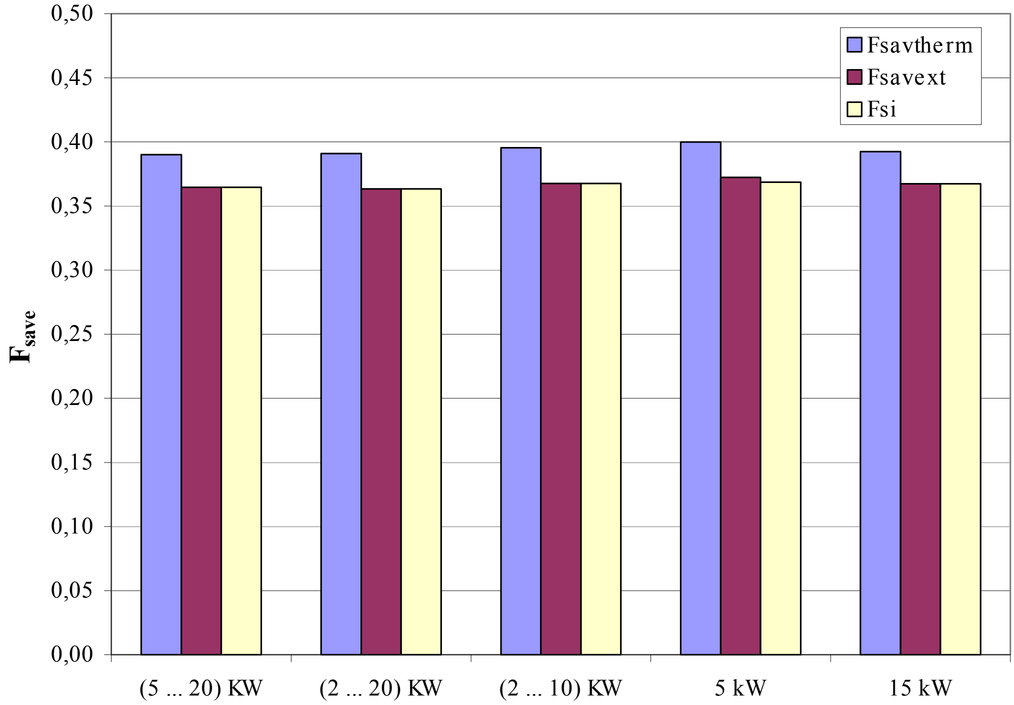


Fig. 10 Fractional energy savings vs. different modulation ranges for the Zurich 60 kWh (m²a) building

The fractional energy savings don't vary a lot for the different modulation ranges. The highest value is the one for the non-modulating 5 kW-burner. However, 5 kW is not enough to cover the average domestic hot water needs.
The burner modulating from 1 to 20 kW was chosen as the optimum case. The extended fractional energy savings are 0.3% lower than for the base case because of the total running time of the burner is much longer.

Comments
None.

Sensitivity parameter:	UA value of solar hx	***factor 0.8...2 from UA_basecase***

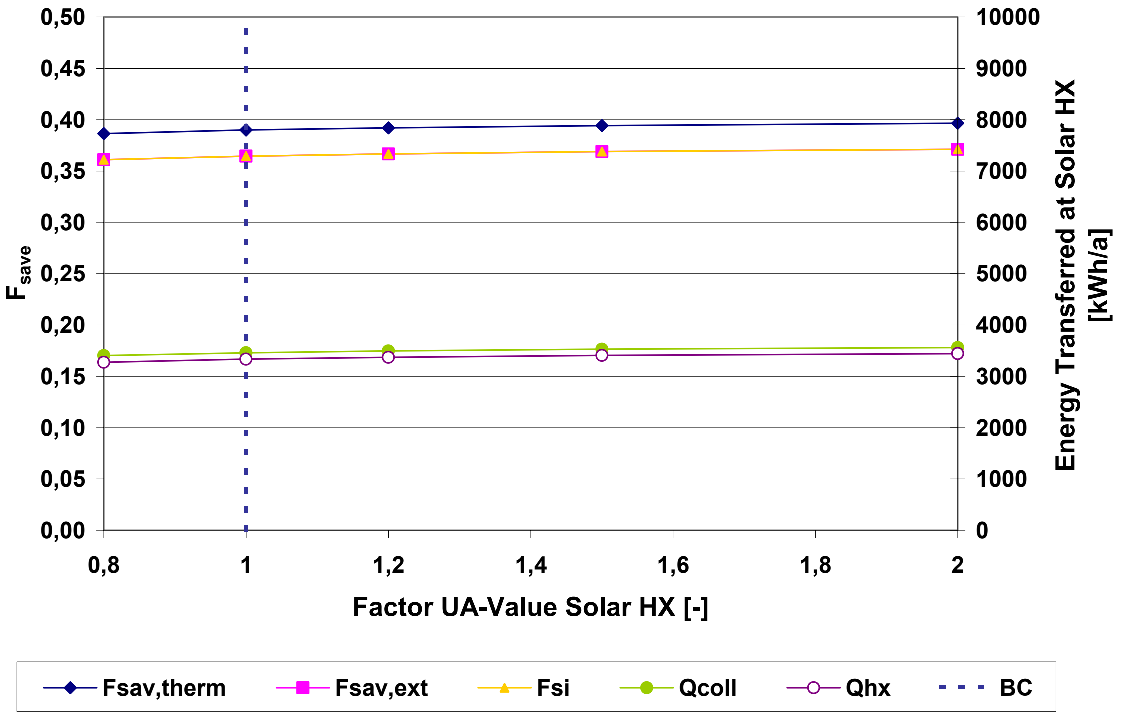


Fig. 11 Fractional energy savings vs. UA value of the solar heat exchanger

Differences from Base Case
To study the influence of the solar loop heat exchanger, the UA-value was multiplied by a factor of 0.8 to 2.

Description of Results
For the 10 m² collector area in the base case which is already close to the maximum sold with the system, the solar loop heat exchanger is well dimensioned. The improvements due to better UA-values are fairly small.
For the optimisation, a value of 1.5 was chosen which seems to be a fairly realistic value. This leads to a change in extended fractional energy savings of 1.2%.

Comments
None.

Sensitivity parameter:	Store insulation	0 – double the actual losses

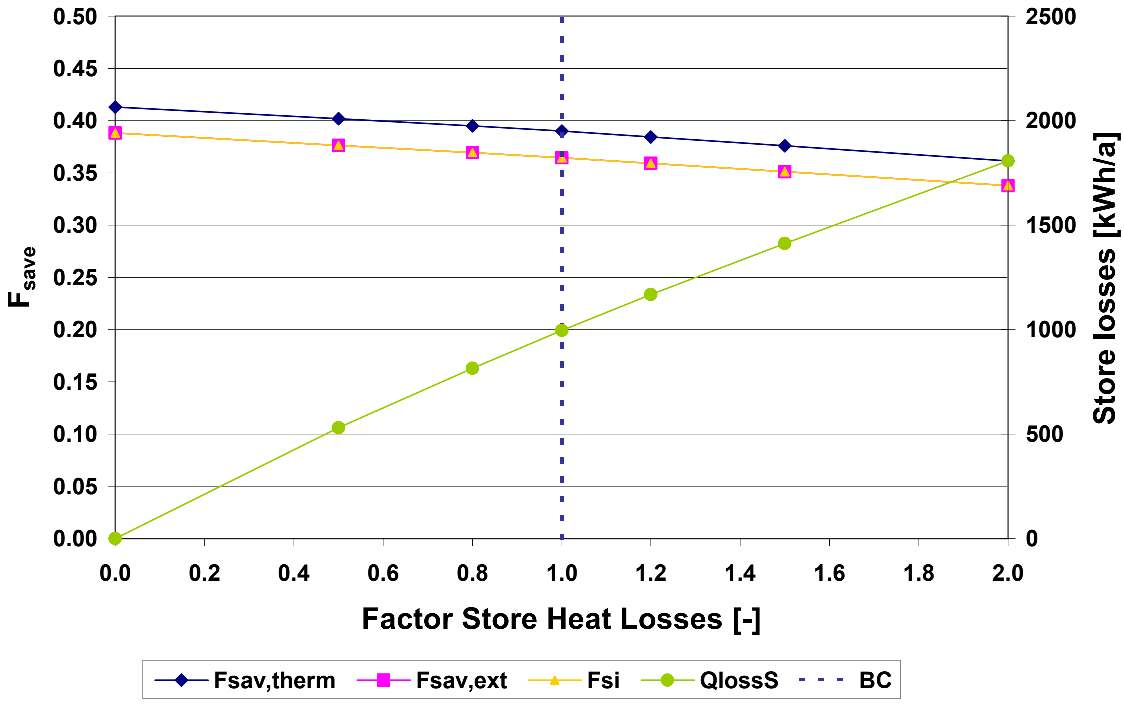


Fig. 12 Fractional energy savings vs. factor for the heat losses from the store

Differences from Base Case
The UA-value was varied by a factor of 0 (ideal insulation) to 2.

Description of Results
The store is already well insulated. A UA-value factor of 0.8 improves the extended fractional energy savings by only 1.3%. The maximum possible improvement is 6.5 % for an ideal insulation (no losses at all).

Comments
None.

Sensitivity parameter:	Taux_set (dhw)	45 - 65°C

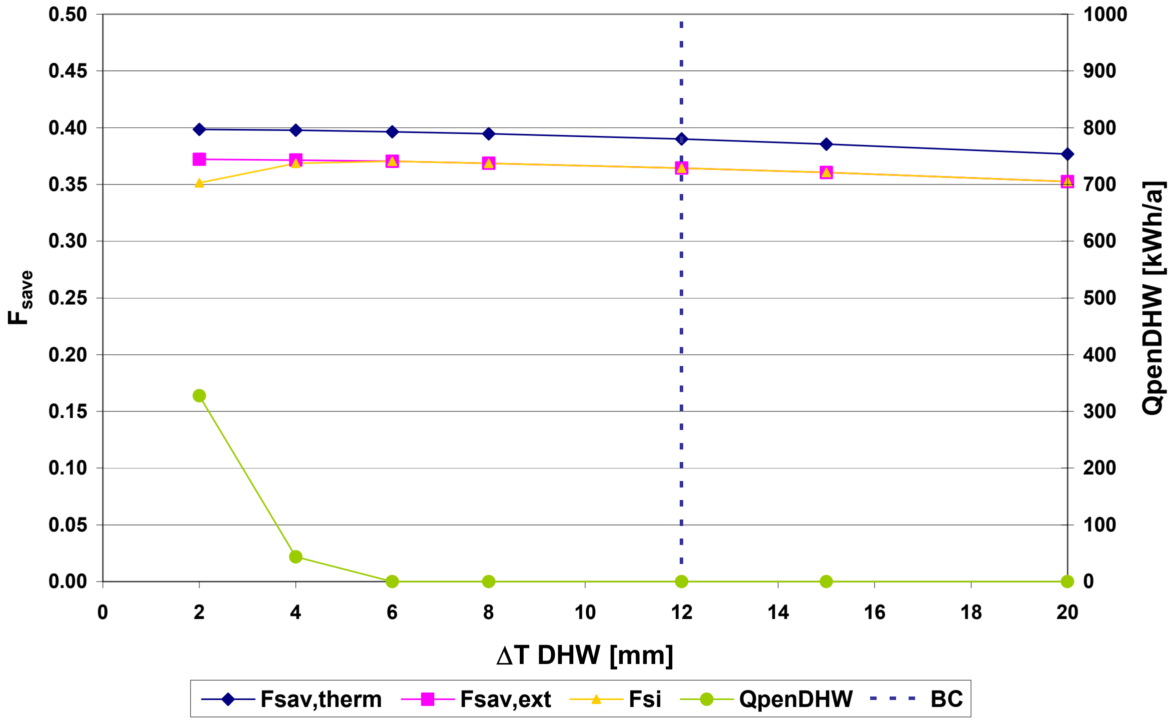


Fig. 13 Fractional energy savings vs. temperature difference between set temperature in the store and water draw temperature

Differences from Base Case

Figure 13 shows the difference between the water draw temperature (in this case 45°C) and the set temperature of the store. The standard temperature difference for the SolvisMax system is 12 K. That means that the temperature in the store is kept at 45 + 12 = 57°C plus a hysteresis of 5 K.

Description of Results

If the temperature is lowered, there are less energy losses from the store. Therefore the fractional energy savings increase. However, the amount of hot water in the store decreases. It depends on the domestic hot water profile at which point the demand cannot be met anymore. This is the case at a temperature difference of 4 K for the profile chosen for Task 26.

To be on the safe side, a temperature difference of 8 K was chosen as the 'optimum' case which is an improvement of 1.1% in extended fractional energy savings.

Comments

None.

Sensitivity parameter:	DHW hysteresis	0 – 10 K

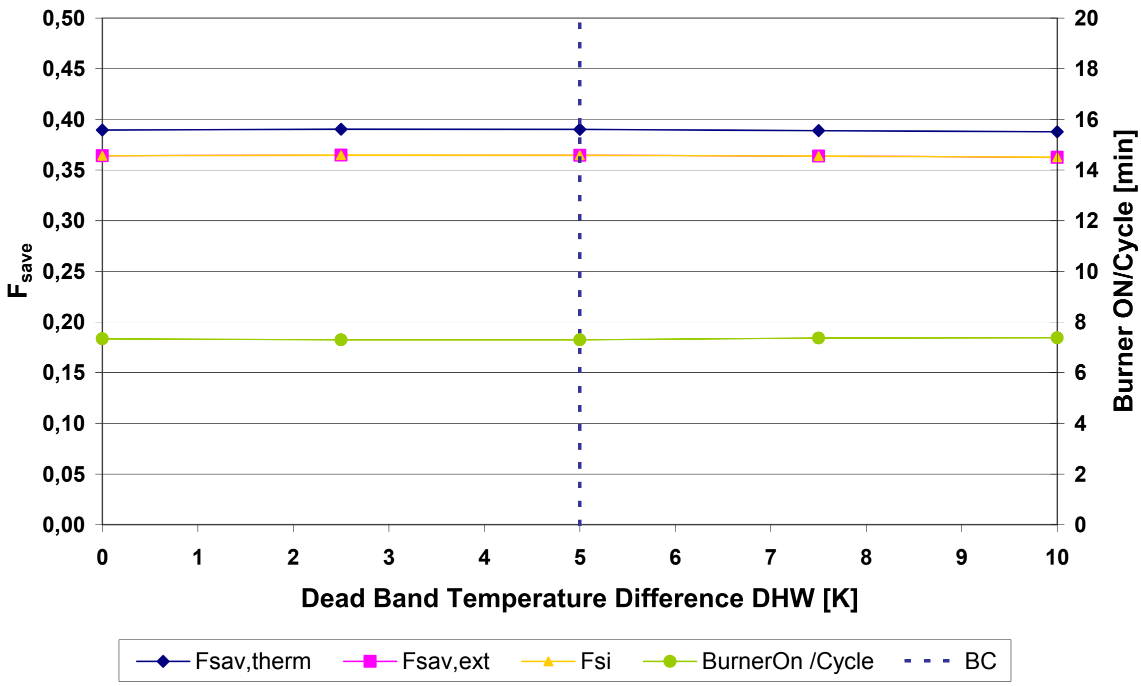


Fig. 14 Fractional energy savings vs. dead band temperature difference (dhw)

Differences from Base Case
The dead band temperature difference for charging the domestic hot water portion of the thank has been varied from 0 to 10K.

Description of Results
The dead band temperature difference for charging the domestic hot water portion of the storage tank has hardly any influence at all on the fractional energy savings of the system.

4.2 Optimisation

In the sensitivity analysis, the influence of several parameters has been studied. The optimum value was chosen for each parameter and a final simulation carried out using these optimum values.

The optimised system is:

Control strategy heating loop pump:	$T_{room} \leq 20°C$
Store insulation factor:	0.8
Modulation of burner:	2-20 kW
Solar loop hx factor:	1.5
Temperature difference DHW:	8 K

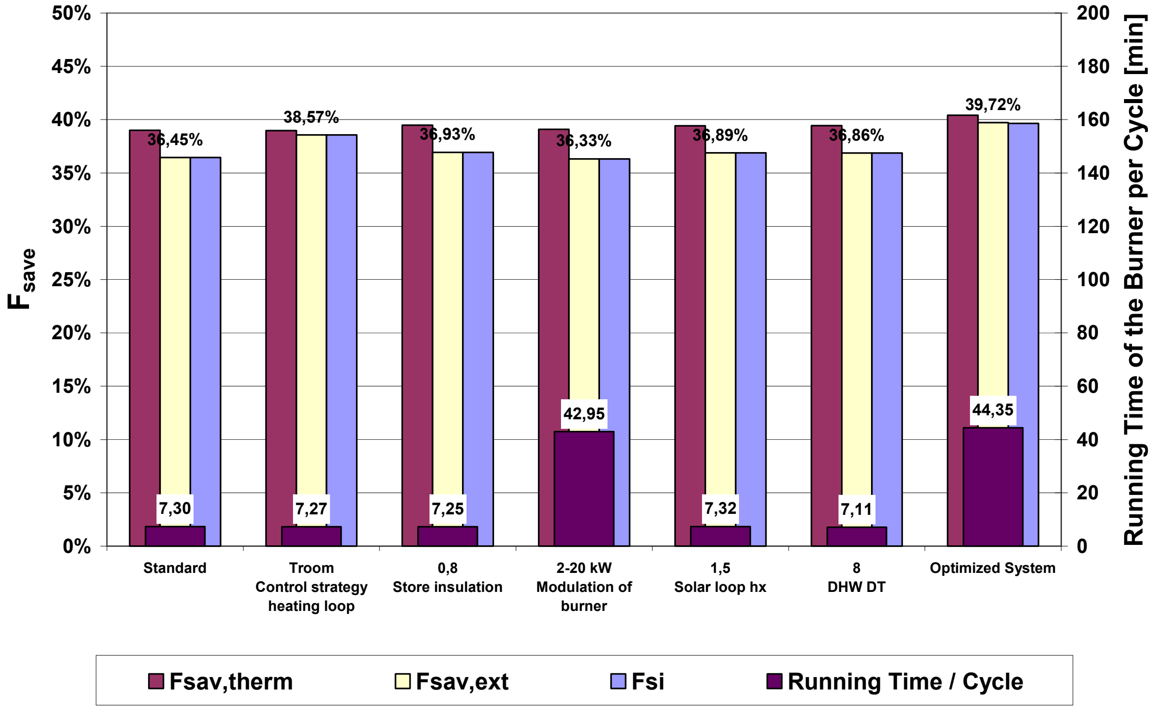


Fig. 15 Optimisation

The first column in figure 14 shows the results of the base case. The following 5 columns show the results of the separate sensitivities for each parameter. The last column represents the optimised system which is 9.0 % better (in terms of Fsav,ext) than the base case.

The biggest change are the savings in electrical energy due to the new control strategy of the space heating loop pump.

5 Analysis using FSC

The optimised system was simulated for all three climates and buildings. The results have been plotted on the FSC chart shown in Figure 16.

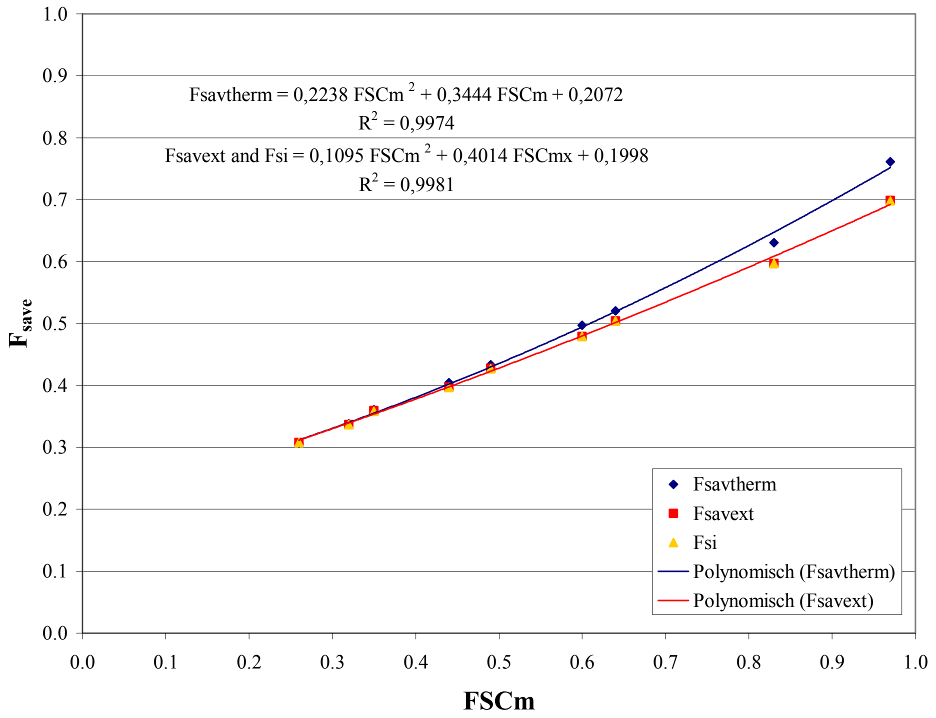


Fig. 16 Fractional energy savings corrected with the storage volume correction factor vs. FSCm for 3 climates (Carpentras, Zurich, Stockholm) and 3 loads (30, 60, 100 kWh/(m²a) single family buildings (optimised case).

The results of all simulations for different storage sizes and collector areas, Zurich climate and the 60 kWh/(m² a) building were plotted on an FSC chart with and without applying the storage size correction factor. The results are shown in Figure 17 and 18.

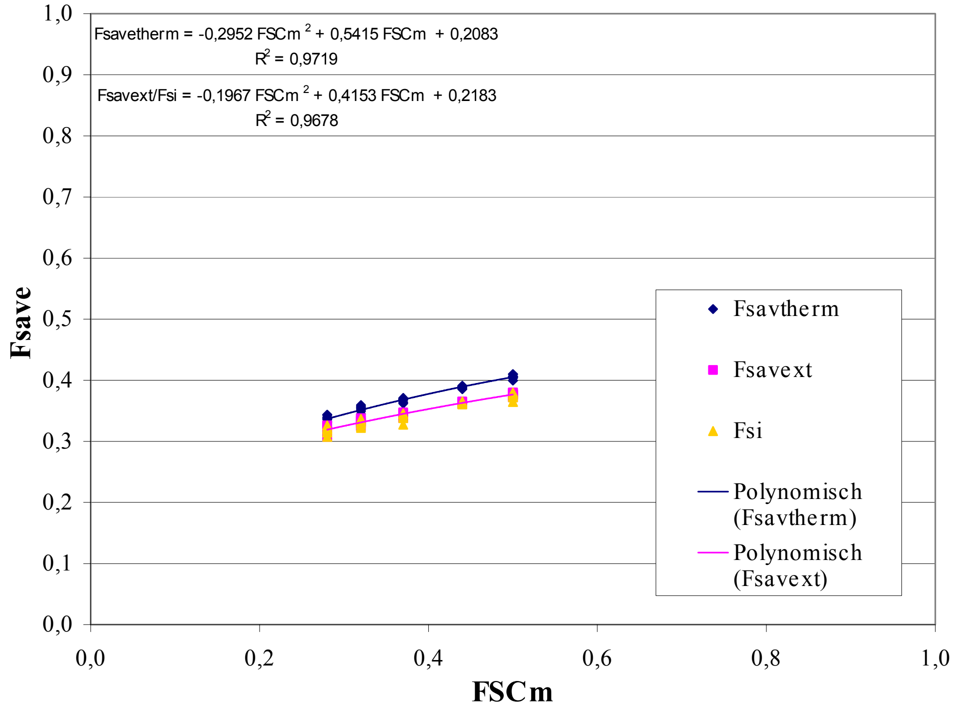


Fig. 17 Fractional energy savings vs. FSCm for a range of collector sizes and storage volumes (see figure 3) without applying the storage size correction factor. Sensitivity parameters are those of the base case.

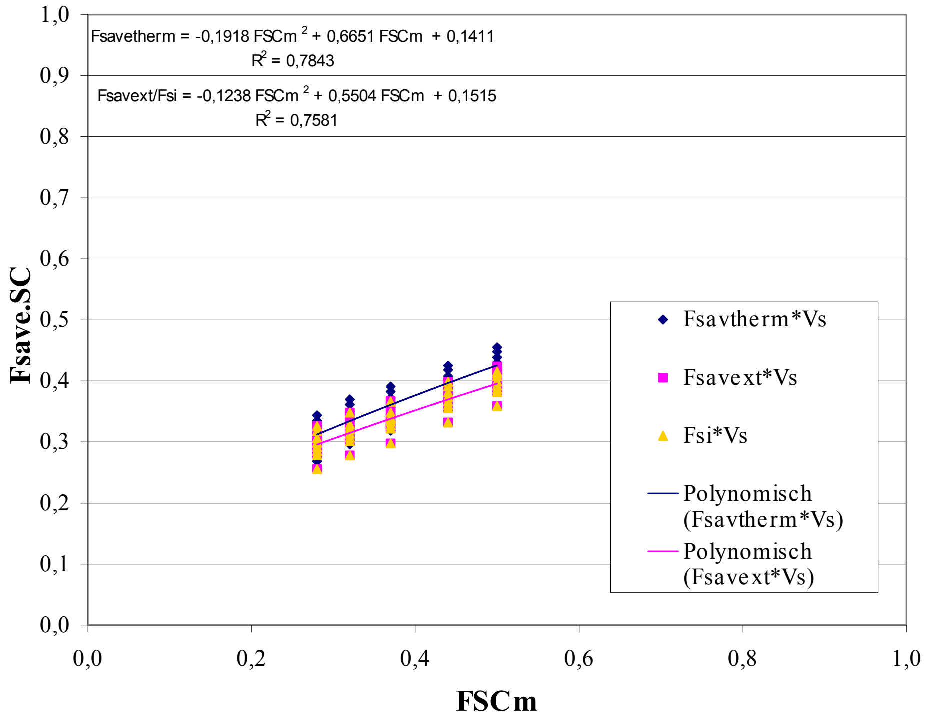


Fig. 18 Fractional energy savings vs. FSCm for a range of collector sizes and storage volumes (see figure 3) corrected with the storage size correction factor. Sensitivity parameters are those of the base case.

The regression factors show that the results fit much better on a curve without the storage size correction factor.

6 Lessons Learned

6.1 Concerning Simulation

1) To simulate a flow and return pipe in the solar loop, a convergence promoter (TRNSYS Type 44) had to be added to make the simulation converge.

2) Type 147 is very sensitive to changing the number of nodes in the store if the internal gas boiler is used. Already small changes in temperature of a store layer will change the exhaust gas temperature and therefore the efficiency of the burner significantly. Therefore, for the different storage sizes, the number of nodes had to be adjusted so that the number of nodes within the exhaust gas heat exchanger was kept constant.

6.2 Concerning the System

1) The system is already quite well optimised so that the improvements found in the sensitivity analysis are quite small.

2) System Design: Very large storage tanks combined with fairly small collector areas lead to high thermal losses from the store and decreasing fractional energy savings.

3) The mean annual efficiency of the integrated condensing gas burner is very high. This is mainly due to the very good efficiency in domestic hot water preparation mode. The reason for this is the design of the store with the external domestic hot water preparation unit that ensures very low return temperatures in the store. Therefore, the lower portion of the tank is kept at a low temperature which leads to very low exhaust gas temperatures even when operating at full load.
The efficiency in domestic hot water mode becomes even more important if the space heating load of the building is small and therefore the domestic hot water load becomes dominant.

4) The electricity consumption of the system has the highest potential for energy savings (electricity consumption of pumps or gas burner, different control strategies to optimise running time of pumps).

5) A new design of the exhaust gas heat exchanger is being introduced in autumn 2002. It increases the efficiency of the burner by about 1.5 %-points.

6) Cost reduction is also an important topic that is being worked on:
- The new exhaust gas heat exchanger reduced the cost of that component by approximately 40%.
- A new integrated controller is also being introduced. This unit can manage two temperature controlled space heating loops without additional control equipment which reduced the cost of the system significantly.

7) Improved collectors (low reflection glass covers, improved heat transfer to the fluid) is also a potential that should be worked on.

7 References

[1] Weiss, W. (ed.): Solar heated houses – A design handbook for solar combisystems, James & James Science Publishers, 2003.

[2] Streicher, W., Heimrath, R.: Structure of the Reference Buildings in Task 26, Technical Report, IEA SHC Task 26 Solar Combisystems, http://www.iea-shc.org, 2003.

8 Appendix 1: Description of Components Specific to this System

These are components that are

a) not part of the TRNSYS standard library AND
b) not part of the types used as "standard" by Task 26.

8.1 Type 147: Multiport- Storage Tank with Integrated Gas Burner

Version 1.21

Parameters : 144
Inputs : 38
Outputs : 97+number of nodes

Please refer to TRNSYS Description of Type 147 – SolvisMax by Harald Drück, ITW, Stuttgart, Germany

Availibility : ITW

8.2 Type 98: External Domestic Hot Water Preparation Unit

Version 1.5

Type was written by Thomas Pauschinger and modified by Harald Drück (ITW, Stuttgart, Germany). A small modification was made by Dagmar Jaehnig (Solvis, Braunschweig, Germany) to allow for a UA value that varies with mass flow rate and to choose the maximum primary mass flow rate as a parameter.

Parameter: 2
Inputs: 5
Outputs: 5