Report on Solar Combisystems Modelled in Task 26

Appendix 9: Generic System #19: Centralised Heat Production, Distributed Heat Load

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 9: Generic System #19: Centralised Heat Production, Distributed Heat Load

by

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A technical report of Subtask C

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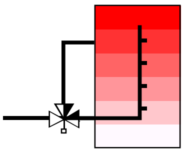
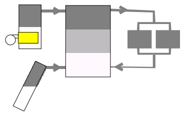
1 General description of System #19 Centralised Heat Production, Distributed Heat Load

Stratified Storage (Austria)



B/DMw



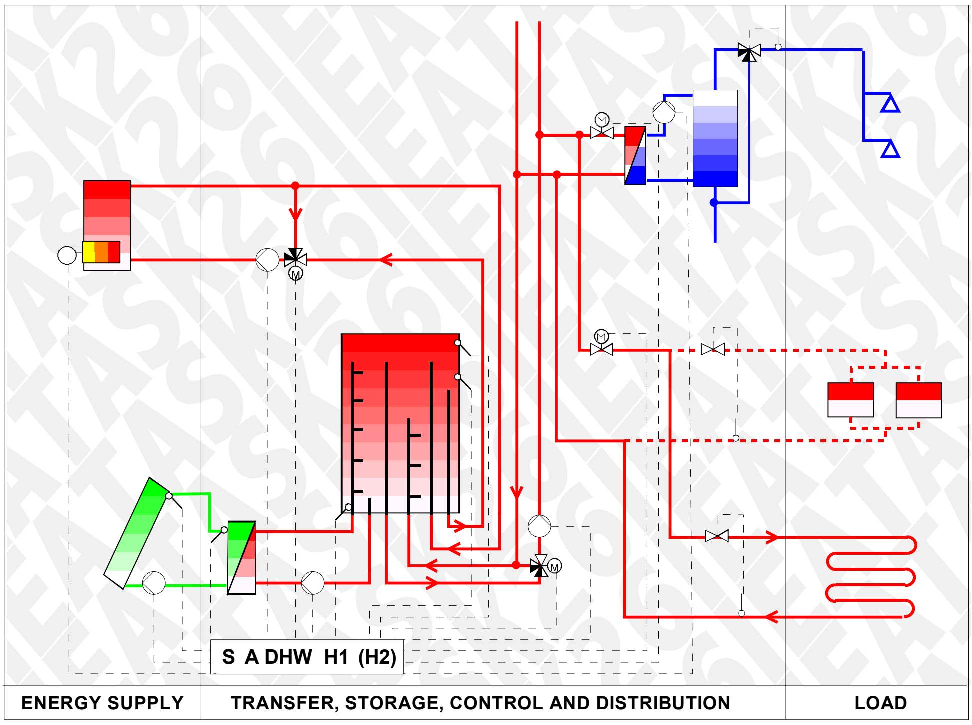
Main features

The system is meant to supply estates of terraced houses or multiple family houses. To operate the system in the best possible way, low temperature heating is required on the heat release side (wall or floor heating). The individual houses or flats are supplied by the central storage tank via a local heating network with a low temperature level of 40^{0}C (heating operation). To prepare hot water, the same local heating network is operated at a higher temperature level (65 - 70 ^{0}C). During this period the space heating is switched off and only the decentralised hot water storage tanks are loaded.

Heat management philosophy

Solar loop:

If the temperature at the collector outlet is higher than the one at the bottom of the tank, then the pump of the collector loop is started. The secondary circuit pump starts only when the temperature at the heat exchanger inlet, at the collector loop side, is higher than the one at the bottom of the tank. Both pumps are switched off when the temperature at the heat exchanger inlet drops below the one at the bottom of the tank.



The solar plant is operated in accordance with the Low-Flow principle.

Auxiliary boiler:

If the solar yields are not high enough, the auxiliary heating is switched on depending on the temperature state of the storage and heating requirements. A buffer temperature of 45 °C is acceptable in the upper part of the tank for the supply of heat to the rooms. If the temperature drops below this, the boiler switches on and heats the buffer up, until the temperature of the middle sensor is (to) approx. 70 °C. With regard to the preparation times for domestic hot water (one to two times each day - depending upon the volume of the boiler and consumption) this sensor has to have a temperature of 65 °C. Otherwise the boiler switches on and heats the buffer up to approx. 70 °C. The buffer volume required for the preparation of domestic hot water has to be selected in accordance with consumption, the boiler pipeline available and the time available until the domestic water has been prepared.

Space heating:

For approximately 20-22 hours - depending upon the loading time and the loading frequency of the domestic water storage tank - the outside temperature controlled supply of heat to the rooms is performed via a differential pressure regulated network pump.

Preparation of DHW:

The domestic hot water storage tank is charged one to two times (approx. 2 to 4 hours) each day at defined "DHW preparation times" to 60 °C. In this time the supply of heat to the rooms is interrupted and the temperature of the pipe network flow line is raised to approx. 65 °C.

Influence of auxiliary energy source on system design and dimensioning

Biomass (woodchips or pellets) is usually used as auxiliary energy. Oil, gas or district heating could be also used.

Cost (range)

Due to the wide variety of plants, the system cost should be related to the collector area: the additional cost (total system cost - reference system cost) is between 250 and 500 EUR/m² solar collector.

Market distribution

This system is marketed in Austria since 1997. 8 Systems have been sold so far, with a total collector area of 750 m². Two companies are manufacturing and marketing this system. So far the system is installed only in Austria.

Manufacturers: SONNENKRAFT, SOLID.

2 Modelling of the system

2.1 TRNSYS model

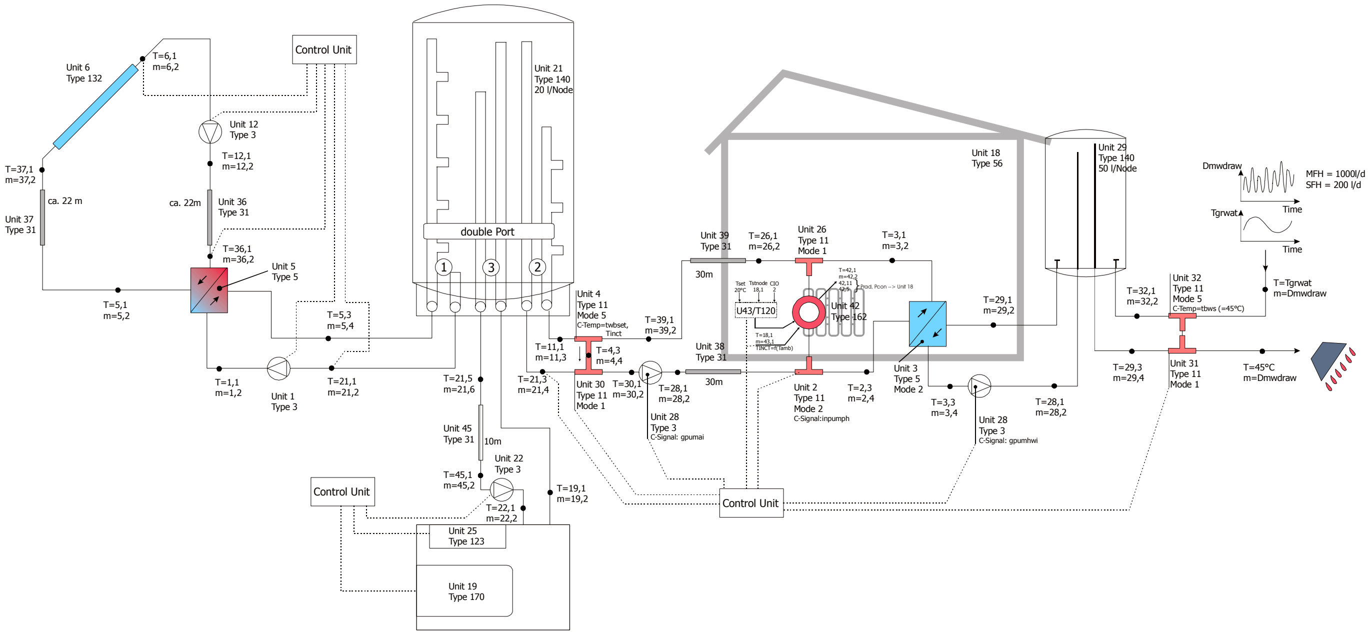


Figure 1. Modelling of System #19 in TRNSYS

2.2 Definition of the components included in the system and standard input data

2.2.1 Collector

Type: 132	Version Number: 1.03	
Collector	η_0	0.8 -
	a_1	3.5 W/m²-K
	a_2	0.015 W/m²-K²
	inc. angle modifier (50°)	0.9 -
	Area	100 m²
	Specific mass flow	15 l/m²h

Data defined in /2/

2.2.2 Pipes between Collector and Storage

Model: One Type 31 for hot side and one Type 31 for cold side
Pipes: Inner diameter[1]: 0.048 m   Total Length[2]: 52.78 m
Insulation: Thickness[3]: - mm (2.99 W/m²-K)   Thermal Conductivity: 0.042 W/m-K

Data defined by Heimrath (in agreement with the Austrian project "Solare Nahwärme" /1/)

[1] $d_i = 0.0064051 \cdot C_{AREA}^{0.43702}\ [m]$

[2] $l_{C,pipe} = 20.21 + 0.061824 \cdot C_{AREA}\ [m]$

[3] $U_{C,pipe} = 16.8433 - 1.7552 \cdot \ln(C_{AREA})\ [kJ/hm^2K]$

2.2.3 Storage

Type: 140 Version Number: 1.95

Storage tank	Total volume[4]	5.5 m³
	Height[5]	3.74 m
	Store volume for auxiliary	0.50 m³
	Number of nodes	150
	Medium:	Water
	Insulation thickness, thermal conductivity[6]	15 cm, 0.042 W/m-K
	Heat input system collector	Stratified
	Position of collector temperature sensor	0.05
	Start $\Delta\vartheta$, hysteresis, Collector loop	10 K, 8 K

Heat Exchanger N°1: Medium: Glycol (40%) / Water
Type of heat exchanger: external plate heat exchanger
Heat Transfer Coefficient[7]: 9185 W/K

Heat Exchanger N°2: Medium: Water / Water
Type of heat exchanger: external plate heat exchanger
Heat Transfer Coefficient: 1220 W/K

Data defined by Heimrath /1/

2.2.4 Boiler

Type 170 – Specific Type, data defined by Heimrath (in agreement with Task 26 /2/)

Aux. Boiler	Heating rate (MFH)	24 kW
	Mean efficiency	90 %
	Energy	24 kW
	Minimum running time	3 min
	Minimum stand still time	3 min
	Start $\Delta\vartheta$, hysteresis, auxiliary	10 K

2.2.5 Building

Type56 – One Zone Model, (Geometric Data defined in /**3**/)

4 $V_{E,Store} = V_{red} + \frac{C_{AREA} \cdot V_{spec}}{1000} \left[m^3\right]$ with store volume for auxiliary $V_{red} = 0.5 \left[m^3\right]$ and the specific volume $V_{spec} = 50 \left[l/m^2\right]$

5 $H_{st1} = \frac{1E^{-10}\left(V_{E,Store} \cdot 1E^3\right)^3 - 9E^{-6}\left(V_{E,Store} \cdot 1E^3\right)^2 + 0.4252\left(V_{E,Store} \cdot 1E^3\right) + 1630.6}{1000}$ $H_{st2} = 0.0930233 V_{E,Store} + 4.69767$

$H_{E,Store} = \min\left(H_{st1}, H_{st2}\right)\left[m\right]$

6 The heat losses are defined, using the geometrical data, and the correction factor defined in /2/ :

$C_{corr} = \max\left(1.2, \left(-0.1815 \ln\left(V_{E,Store}\right) + 1.6875\right)\right) \cdot 2.5$, that means a correction (imperfection) factor of 3.44.

7 $UA_C = \left(88.561 C_{AREA} + 328.19\right)\left[W/K\right]$

2.2.6 Heat distribution

Radiators – Heating Floor

Radiator	Radiator area (MFH)	31 m²
	Heat capacity (MFH)	5 x 1150 kJ/kg-K
	Set flow- and return temperatures (MFH)	40 / 35 °C
	Set flow rate	0.669 kg/s
Heating Floor	Thickness	-
unused	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 /**3**/)

2.2.7 Control strategy

The control strategy is realised with the standard Type 2 (Collector and DHW) and the non standard Type 120 (PID - Controller).

Controller 1: Type 2
Functions: Collector Controller
U_{db}=10 K L_{db}=3 K
$T_{upi}= T_{CollectorOut}$ $T_{loi}= T_{storeEnergy(r.h.=0.15)}$

Controller 2: Type 120
Functions: PID Controller / Radiator
Width of PID-band ± 3 K
Proportional gain 0.8
Integral gain 0.05
Differential gain 0.0

Controller 3: Type 2
Functions: DHW Controller
U_{db}=10 K L_{db}=0.7 K
$T_{upi}= T_{storeEnergy(r.h.=0.905)}$ $T_{loi}= T_{storeDHW(r.h.=0.1)}$

Data defined by Heimrath /1/

2.3 Validation of the system model

In the Austrian Project /1/ five promising solar concepts were selected and used for comparative and optimisation calculations. Three of the concepts selected comply with the 4-pipe-net category and two with the 2-pipe-net (including System #19) category. In order to take the influence of buildings into consideration (geometries and energy densities), the five hydraulic concepts were placed over three representative reference buildings of different sizes (5, 12 and 48 flats) and modelled together in the dynamic simulation program TRNSYS. A comparison of the large number of simulation and variation calculations was performed on the basis of the key system figures which were defined.

Dimensioning nomograms, the optimisation of system details and possible solutions for the integration of solar thermal systems in the existing building are other important results from the project.

The basic target functions for the comparison of the systems are the solar fraction SD,

$$SD = \frac{\text{Solar Energy}}{\text{Aux. Heating} + \text{Solar Energy}} \; [\%]$$

the specific collector yield SE,

$$SE = \frac{\text{Solar Energy}}{\text{Collector Area}} \; [\text{kWh}/\text{m}^2]$$

and the system efficiency SW.

$$SW = \frac{\text{Space Heating} + \text{Domestic Hot Water Demand}}{\text{Aux. Heating} + \text{Solar Energy}} \; [\%]$$

For a solar plant with space heating and domestic hot water preparation, the system load is defined as:

$$\text{Load II} = \frac{\text{used energy for DHW} + \text{SH(per year)}}{\text{Collector Area}} \left[\frac{\text{kWh/a}}{\text{m}^2}\right]$$

In Figure 1 the comparison between one built plant (low energy building settlement Sundays, Gleisdorf) for DHW-preparation and space heating with the concept shown in chapter 1 with the multifamily reference building with five apartments is shown.
With the usage of the specific Load II (Auslastung II) is it possible to compare the results from the measured plant with the simulated.
The accuracy agreement between the simulated and measured values is sufficient.

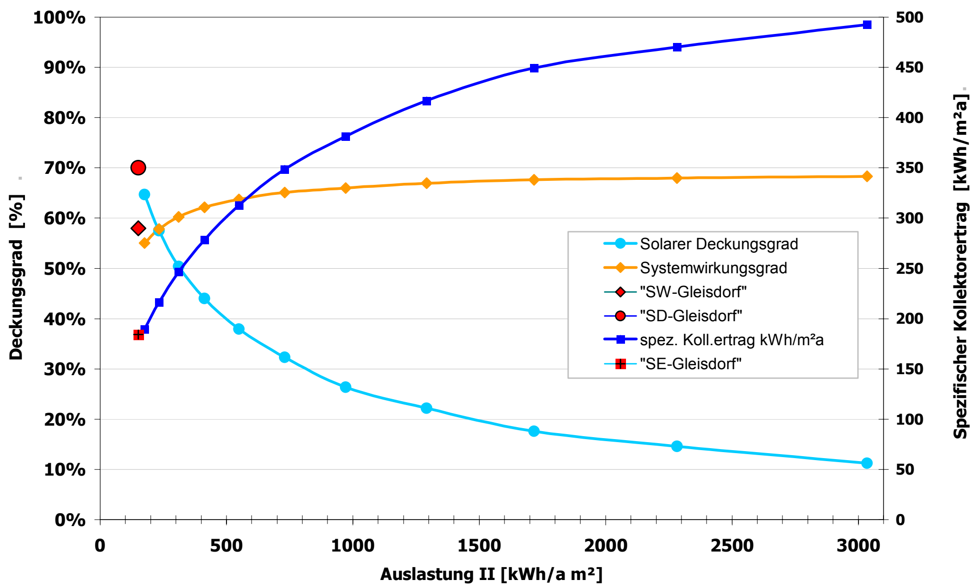


Figure 2. Simulated curves for the solar fraction (solarer Deckungsgrad), the system efficiency (Systemwirkungsgrad) and the specific collector yield (spez. Kollektorertrag) for the System #19 in comparison with one measured system (AEE-Intec Sundays, Gleisdorf)

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}	$Q_{penalty,SHLow}$	$Q_{penalty,SHUp}$	$Q_{penalty,DHW}$
Richard's Result (blend dll)	0.7900	0.7406	0.3006	9443	30	26480	0
Richard`s Result (AMD dll)	0.7896	0.7402	0.2969	9461	30.11	26640	0.077
Difference	0.0004	0.0004	0.0037	-18	-0.11	-160	-0.077

The differences between the two calculations depend on using two different dll's. The first dll is compiled in the "blend" mode (useable for all processor units) and the second dll is specially compiled for the AMD Athlon processor.

3.2 Results of the accuracy and the timestep check

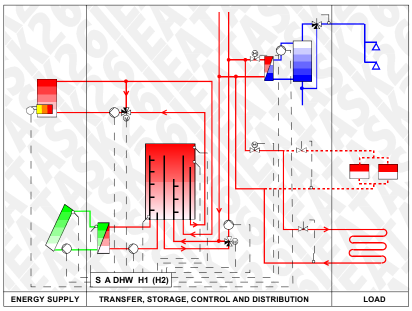
Table 1 Results of the accuracy and timestep check (according to /3/), getting the most practicable results for the simulation

Parameter			**Results**		
Convergence	Integration	Time Step	running	$f_{save,therm}$	Epsilon
0.1	0.1	1/16	yes	36.90%	-
0.01	0.01	1/16	yes	44.63%	0.209485
0.005	0.005	1/16	yes	45.91%	0.028680
0.001	0.001	1/16	no	-	-
0.0005	0.0005	1/16	no	-	-
0.005	0.005	1/16	yes	45.91%	-
0.005	*0.005*	*1/32*	*yes*	*45.30%*	*-0.013287*
0.005	0.005	1/64	yes	44.20%	-0.024283
0.01	0.01	1/32	yes	44.42%	-
0.005	0.005	1/32	yes	45.30%	0.019811
0.001	0.001	1/32	no	-	-
0.01	0.01	1/64	yes	43.44%	-
0.005	0.005	1/64	yes	44.20%	0.017495
0.001	0.001	1/64	no	-	-

The used simulation timestep is 1/32 [h] and the convergence and integration parameter 0.005.

4 Sensitivity Analysis and Optimisation

4.1 Presentation of results



#19 Centralised Heat Production, Distributed Heat Load, Stratified Storage (SCS-TH Austria)

Main parameters (optimised Base Case (BC)):			
Building:	*MFH 45*	Storage Volume:	*5.5 m³*
Climate:	*Zurich*	Storage height	*3.74 m*
Collectors area:	*100 m²*	Position of heat exchangers	*typical*
Collector type:	*Standard Flat Plate*	Position of in/outlets	*typical*
Specific flow rate (Collector)	*15 kg/m²-h*	Thermal insulation	*15 cm*
Collector azimuth/tilt angle	*0 / 45°*	Nominal auxiliary heating rate	*24 kW*
Collector upper dead band	*10 K*	Heat Exchanger:	*9185 W/K*
Simulation parameter:		Storage nodes	*20 l/Node Max. 150*
Timestep	*1/32 h*	Tolerances Integration Convergence	*0.005 / 0.005*

Summary of Sensitivity Parameters			
Parameter	Variation	[1]Variation in $f_{sav,ext}$	
Base Case (BC)	-	38.97%	
Collector size [m²] (fixed store size (5.5 m³)	25 – 250	16.85 – 50.91%	Figure 3
Collector Size [m²] (fixed store spec. vol. 0.05 m³/m²)	25 – 250	18.01 – 55.49%	Figure 4
Store Size [m³] (fixed collector area of 100 m²)	1.75 – 13.00	31.77 - 39.64%	Figure 5
Collector Azimuth [°] (fixed tilt of 60°)	-90 - 90	26.73 – 39.06%	Figure 6
Collector Tilt [°] (fixed azimuth of 0°)	15 – 90	29.46 – 39.45%	Figure 7
Specific Collector flow rate [kg/m²-h]	10 - 22	38.70 -39.22%	Figure 9
Climate (45 kWh MFH – Base Case (BC))	Carp. / Zur. / Stock.	67.0% / 39.0% / 34.4%	Figure 11
[2]Boiler Inlet Rel. Height [-]	0.940 – 0.999	38.97 – 39.10%	Figure 15
[2]Boiler Outlet Rel. Height [-]	0.87 – 0.98	38.48 – 40.37%	Figure 16
[2]Heating System Inlet Rel. Height [-]	0.00 – 0.60	31.04 – 38.97%	Figure 17
Collector Heat Exchanger UA [%] (variation from identified value)	-50 - +100	37.94 – 39.63%	Figure 19
DHW Heat Exch. UA [%] (variation from BC value)	-50 - +100	38.83 – 39.15%	Figure 20
[3]Store Insulation: top [cm]	4 – 34	36.84 – 39.45%	Figure 21
[3]Store Insulation: sides [cm]	4 – 34	28.69 - 41.21%	Figure 22
[3]Store Insulation: bottom [cm]	4 – 34	38.84 – 39.02%	Figure 23
[3]Store Insulation: whole store [cm]	4 – 34	25.59 – 41.73%	Figure 24
Collector Controller dT_{start} [K] (constant dTstart/dTstop)	4 – 12	38.94 – 39.06%	Figure 25
[4]Boiler Outlet Temperature [°C]	61 - 80	35.88 – 41.39%	Figure 26
[5]Store Charge Thermostat (off) [K]	0 - 2	38.80 – 38.97%	Figure 27
Store Charge Flow Rate [kg/h]	1500 - 5500	37.57 – 39.13%	Figure 28
Store Charge Controller Sensor Rel. Height [-]	0.85 – 0.96	36.85 – 38.97%	Figure 33
Collector Controller Sensor Rel. Height [-]	0.050 – 0.500	38.14 – 39.11%	Figure 34
DHW charge flow rate [kg/h]	100 - 200	38.24 – 42.00%	Figure 29
DHW Storage charging time (Day) [h]	9:00 – 13:00	38.90 – 39.14%	Figure 31
DHW Storage charging time (Night) [h]	0:00 – 4:00	38.80 – 38.97%	Figure 32
DHW Storage charging temperature [°C]	53 - 63	37.61 – 41.96%	N.N.
DHW Storage Volume [m³]	0.15 – 0.30	38.65 – 40.29%	Figure 30

[1] The variation of fractional savings indicated in the table does not represent the values for the extremes of the range, rather the minimum and maximum values for the range indicated.

[2] The thermostat settings for store charging and electrical heater were NOT changed for these variations. Adjusting the setting to just meet the demand of the period with the highest load would probably lead to different results.

[3] The insulation has a conductivity of 0.04 W/m-K and has a correction factor for "imperfection" of C_{corrE}=MAX(1.2,(-0.1815*LN(V_{maiST})+1.6875))*2.5.

[4] The settings for the controller for the charging of the store from boiler were kept constant for all variations (62°C start, 70°C stop).

[5] The boiler standby and supply set temperature were set to be 5K higher than the thermostat (off) setting. The thermostat had a constant hysteresis of 8K.

Sensitivity parameter:	Collector size [m²] (fixed store size 5.5 m³)	30 – 250 m²

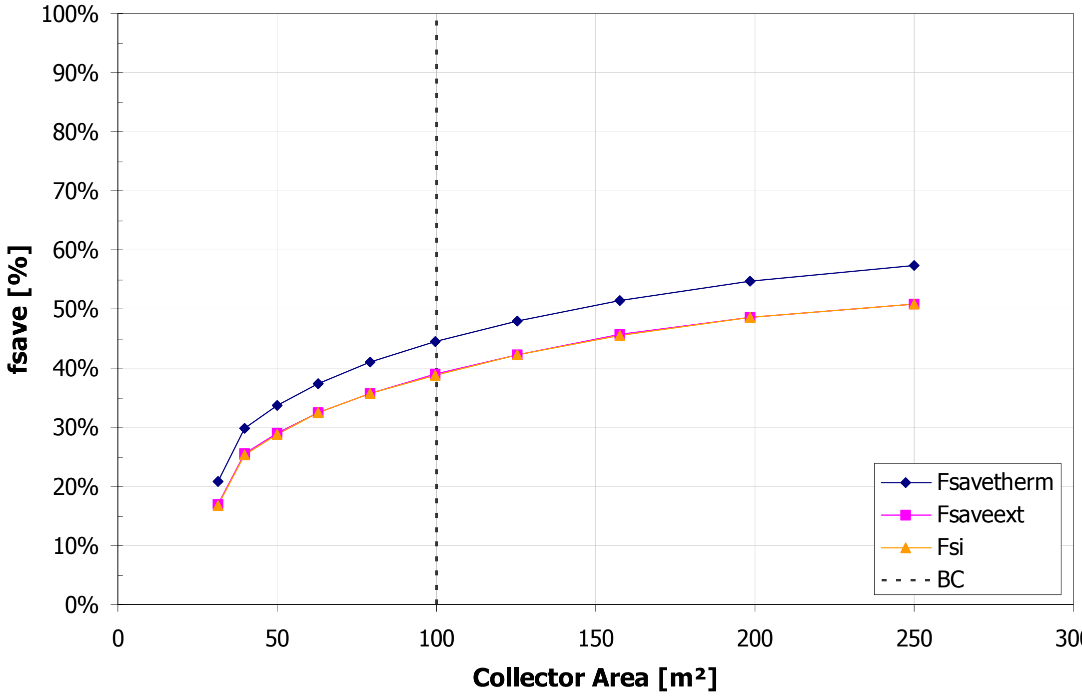


Figure 3. Variation of fractional energy savings with collector size with fixed store volume of 5.5 m^3.

Differences from Base Case (BC)
The heights for the inlet of the lower DHW heat exchanger, the electrical heater and boiler outlet were all fixed with the base case store volume.

Description of Results
As expected the increase of savings with increasing collector area decreases the larger the area. There are very few penalties incurred for the settings, so that $f_{si} \approx f_{sav,ext}$

Comments
None

Sensitivity parameter:	Collector Size [m^2] (fixed spec. store vol. 0.05 m^3/m^2)	25 – 250 m^2

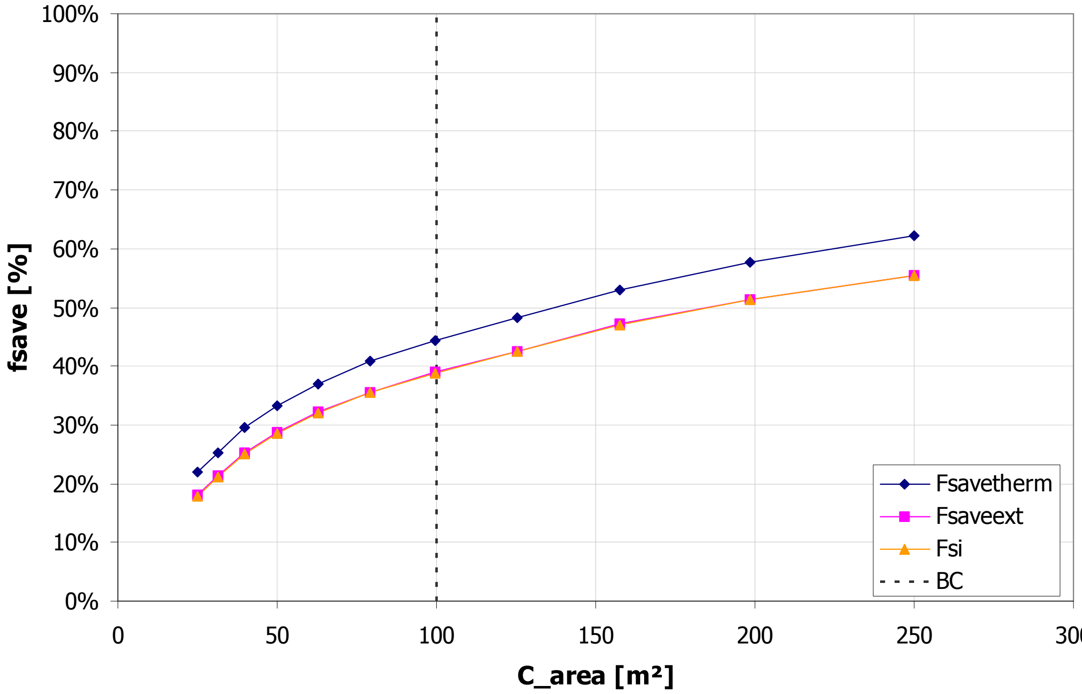


Figure 4. Variation of fractional energy savings with collector size with fixed specific store volume of 0.05 m^3/m^2.

Differences from Base Case (BC)
The heights for the inlet of the lower DHW heat exchanger, the electrical heater and boiler outlet were all varied with the store volume so that:

- The volume heated by the auxiliary was always the same (0.5 m^3).
- The sensors for the thermostats controlling the store charging were always on the same height, at the outlet of heater.
- The height of the store is calculated with the equation showed at (2.2.3).
- The heat loss coefficient for the store varied using equations for the area of the relevant section. In addition a volume sensitive "imperfection" factor was used to multiply the theoretical values.
  $UA_{loss,corr}$ = MAX(1.2,(-0.1815*LN(VmaiST)+1.6875))*2.5. (Values from Jenni /4/ multiplied with 2.5 – in agreement with the Austrian Project "Solare Wärmenetze" /1/)

Description of Results
As expected the increase of savings with increasing collector area decreases the larger the area. There are very few penalties incurred for the settings, apart from for the smallest store/collector area, so that $f_{si} \approx f_{sav,ext}$

Comments
None.

Sensitivity parameter:	Store Size [m³] (fixed collector area of 100 m²)	1.75 – 13.0 m³

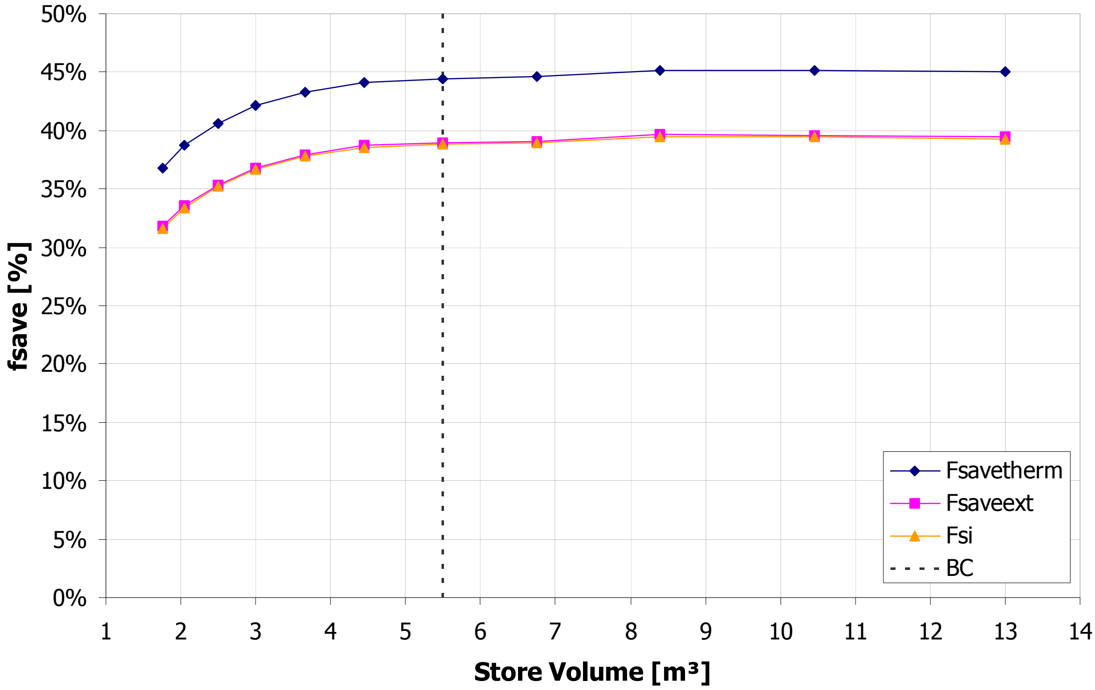


Figure 5. Variation of fractional energy savings with store volume with fixed collector area of 100 [m²].

Differences from Base Case (BC)
The heights for the inlet of the boiler outlet were varied with the store volume so that:

- The volume heated by the auxiliary was always the same (0.5 m³).
- The sensors for the thermostats controlling the store charging were always on the same height, at the outlet of heater.
- The height of the store is calculated with the equation shown in (2.2.3).
- The heat loss coefficient for the store varied using equations for the area of the relevant section. In addition a volume sensitive "imperfection" factor was used to multiply the theoretical values.
  $UA_{loss,corr}$ = MAX(1.2,(-0.1815*LN(VmaiST)+1.6875))*2.5. (Values from Jenni /4/ multiplied with 2.5 – in agreement with the Austrian Project "Solare Wärmenetze" /1/)

Description of Results
Here the savings show an optimum at around 10.45 m³ for the settings used. Below this value the store is too small to be able to utilise the solar in the best way, especially since the volume heated by the auxiliary is always the same. Above this value the heat losses from the store (year round) start to outweigh the gain in utilised solar heat and the overall savings decrease again.

Comments
None.

Sensitivity parameter:	Collector Azimuth [°] (fixed tilt of 45°)	-90° - 90°

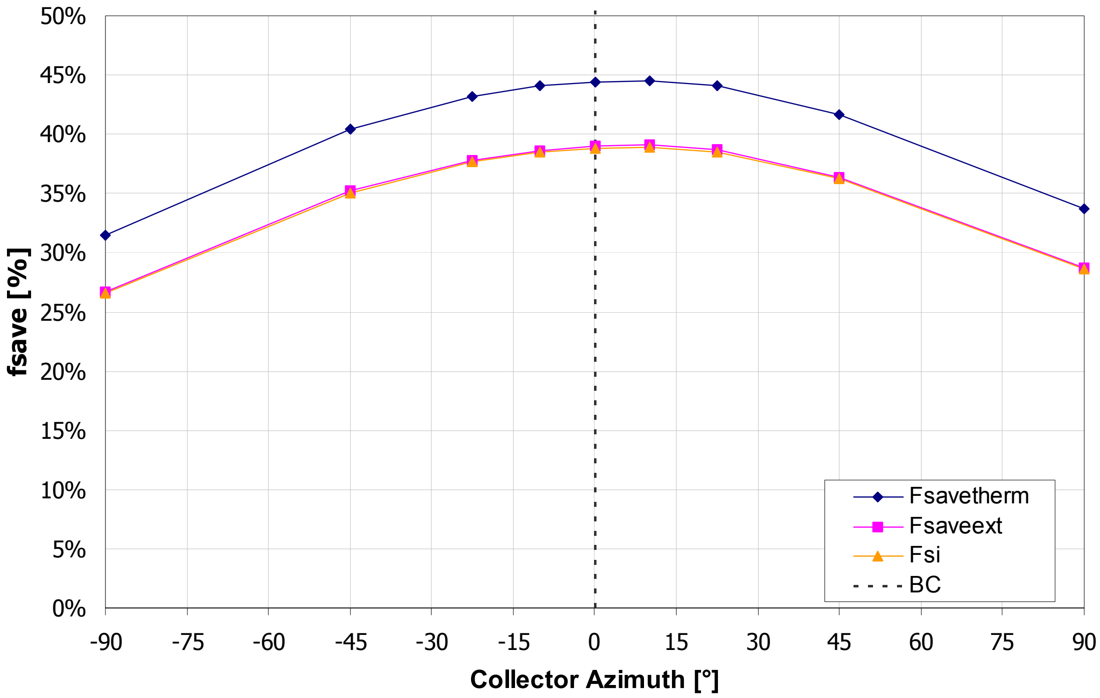


Figure 6. Variation of fractional energy savings with collector azimuth with fixed tilt angle of 45°.

Differences from Base Case (BC)
None

Description of Results
Here the savings show an optimum at around 10° west. This dependends on the climate data. Generally the ambient temperature is higher in the afternoon, improving collector performance, but this is often offset by reduced radiation for west facing collectors.

Comments
None

Sensitivity parameter:	Collector Tilt [°] (fixed azimuth of 0°)	15° - 90°

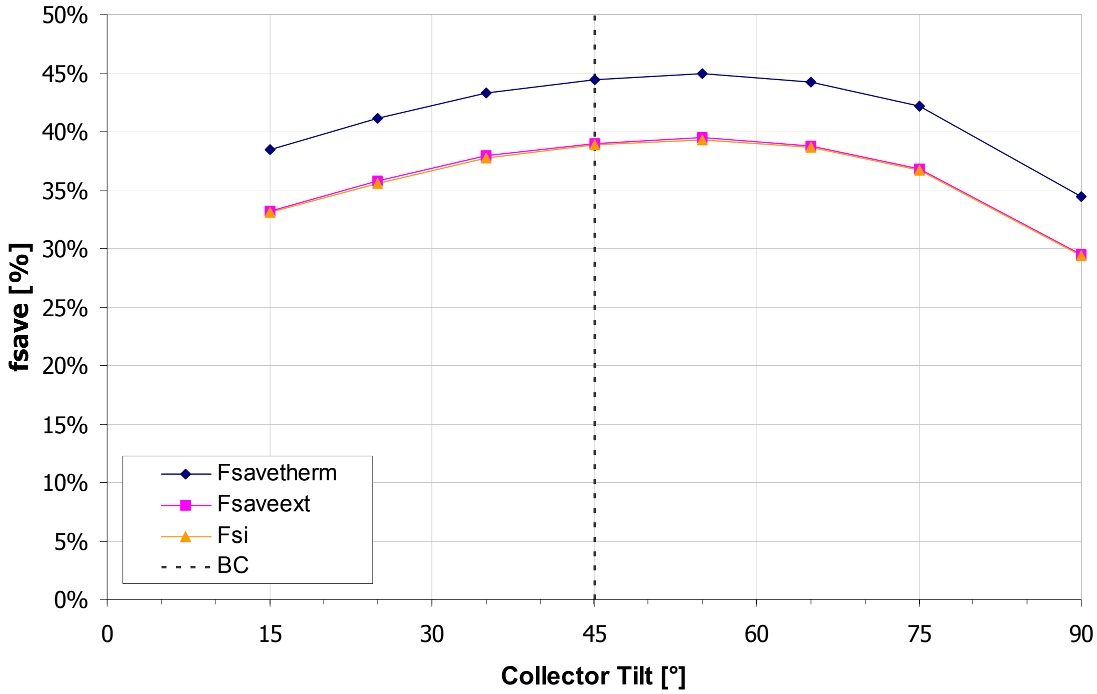


Figure 7. Variation of fractional energy savings with collector tilt, with fixed azimuth angle of 0°.

Differences from Base Case (BC)
None

Description of Results
Here the savings show an optimum at around 55° tilt. This is dependent on the climate and load data. Generally, the larger the space heating load in relation to the DHW loads, the higher the optimum tilt angle.

Comments
None

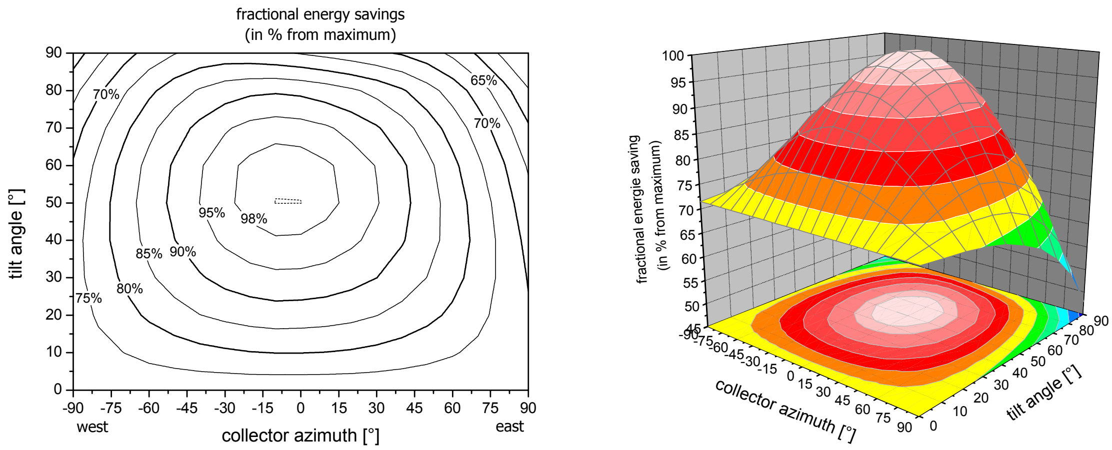


Figure 8. Variation of $f_{sav,ext}$ with collector tilt and azimuth angle. 100% ≅ 39.43% ($f_{sav,ext}$)

Sensitivity parameter:	Specific Collector Flow Rate [kg/m²-h]	10 – 22 [kg/m²-h]

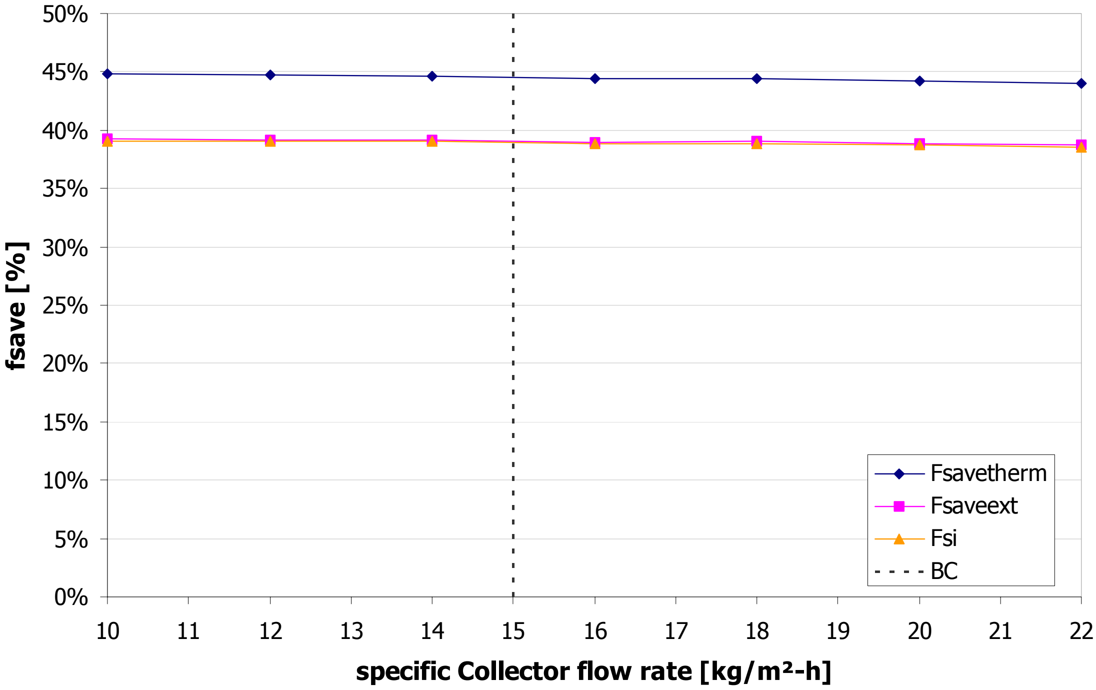


Figure 9. Variation of fractional energy savings with specific collector flow rate.

Differences from Base Case (BC)
None

Description of Results
The savings increase with a lower specific collector flow rate. Above the base case the savings start to decrease slowly.

Comments
None

Sensitivity parameter:	Climate	-

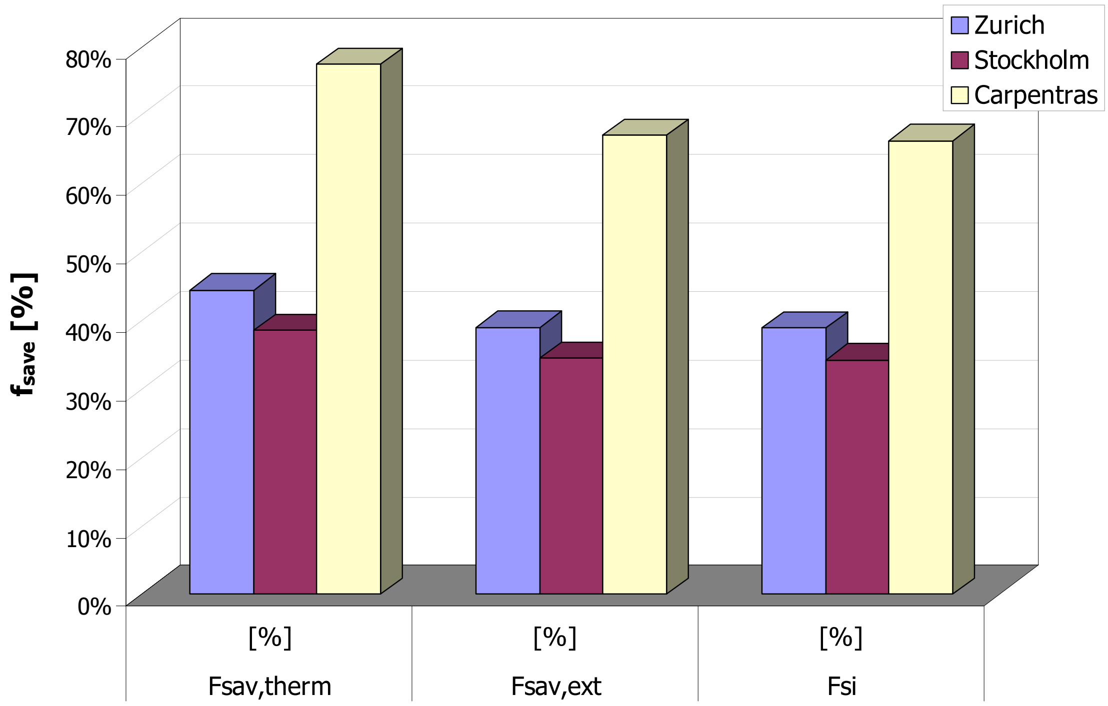


Figure 10. Variation of fractional energy savings with climate.

Differences from Base Case (BC)
None

Description of Results
The results show that the Carpentras climate is much better than the other two. Results for Stockholm and Zurich are quite similar despite the large geographic separation in latitude.

Comments
None.

Sensitivity parameter:	Climate and specific store volume [l/m²]	25 – 425 [l/m²]

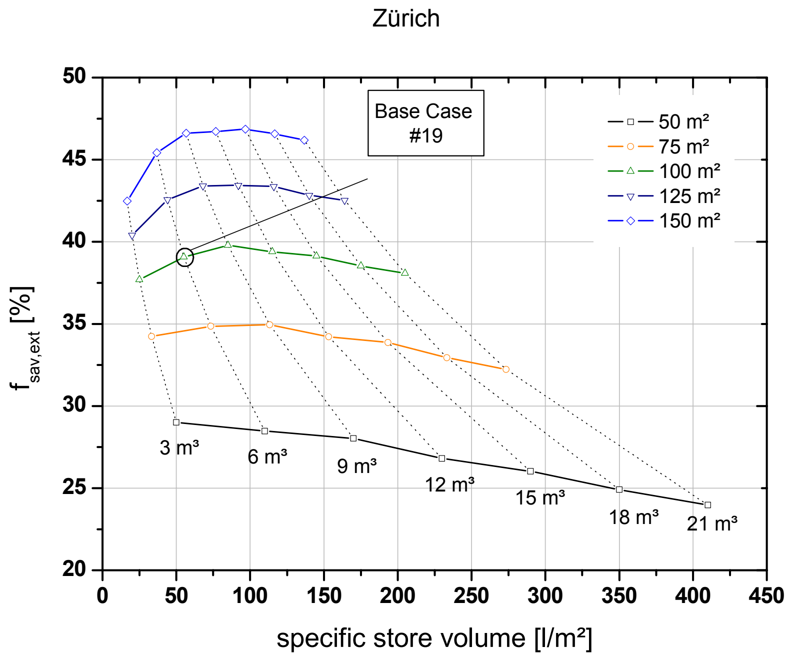


Figure 11. Variation of fractional energy savings with collector area and store volume (specific store volume) depending on the climate.

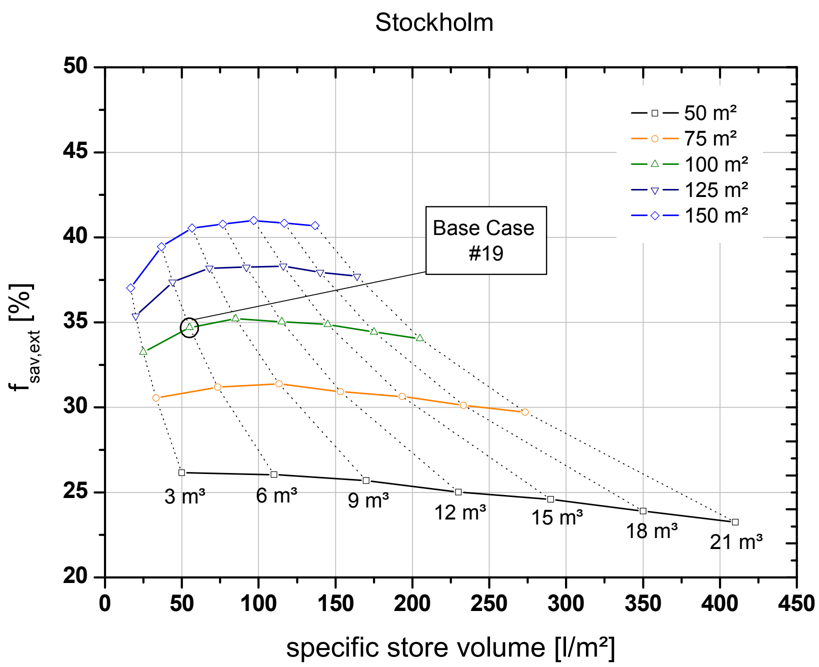


Figure 12. Variation of fractional energy savings with collector area and store volume (specific store volume) depending on the climate.

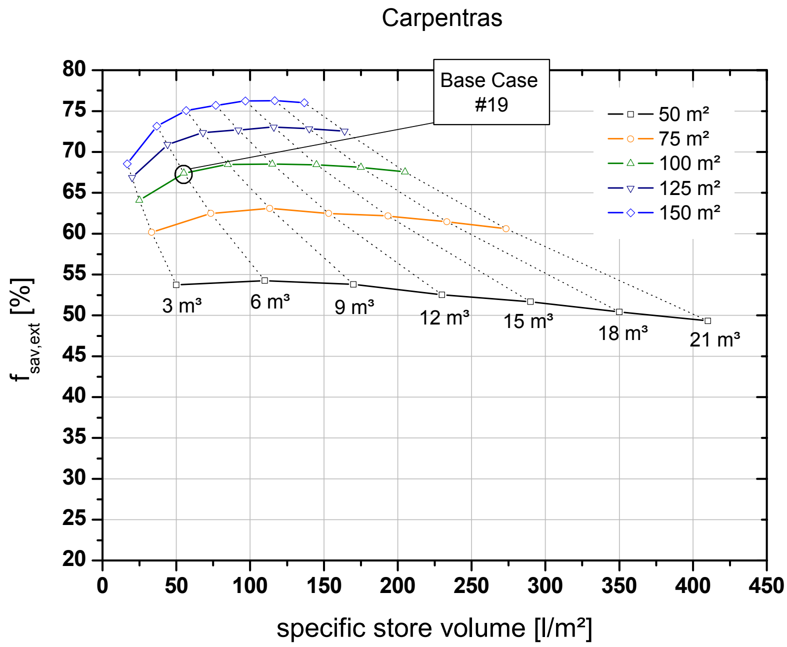


Figure 13. Variation of fractional energy savings with collector area and store volume (specific store volume) depending on the climate.

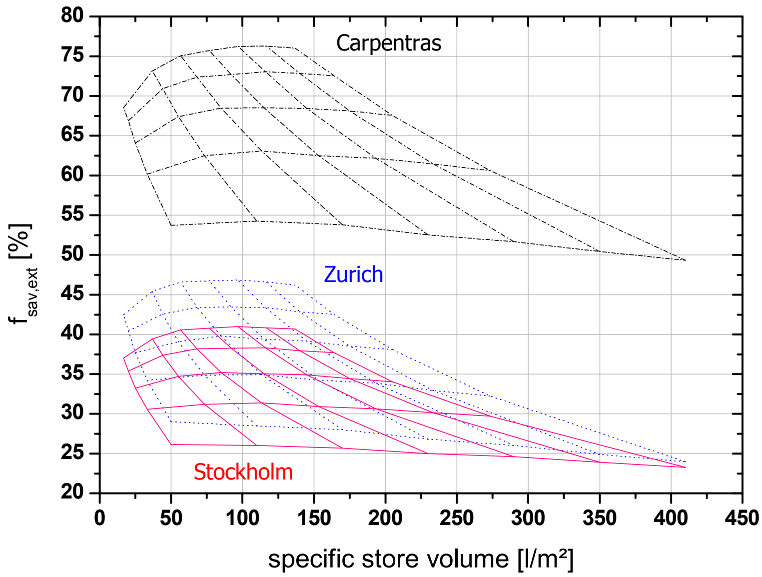


Figure 14. Variation of fractional energy savings with collector area and store volume (specific store volume) depending on the climate.

Differences from Base Case (BC)

The heights for the inlet of the lower DHW heat exchanger, the electrical heater and boiler outlet were all varied with the store volume so that:

- The volume heated by the auxiliary was always the same (0.5 m^3).
- The sensors for the thermostats controlling the store charging were always on the same height, at the outlet of heater.
- The height of the store is calculated with the equation shown in chapter 2.2.3.

- The heat loss coefficient for the store varied using equations for the area of the relevant section. In addition a volume sensitive "imperfection" factor was used to multiply the theoretical values. (see chapter 2.2.3)

Description of Results
The results for the 105 simulations, combinations of climate and specific store volume are shown, in Figure 11, Figure 12, Figure 13 and Figure 14, above. The results show that the Carpentras climate is much better than the other two. Results for Stockholm and Zurich are quite similar despite the large geographic separation in latitude. This net of results shows, in dependence of the collector surface and storage volume as well as the climatic data, how the optimal specific store volumes results.

Comments
The technical optimum for the combination storage volume and collector area is shown in the diagrams above. The point for the economical optimum must be to the left of the technical optimum.

Sensitivity parameter:	Boiler Inlet Relative Height [-]	0.94 – 0.999

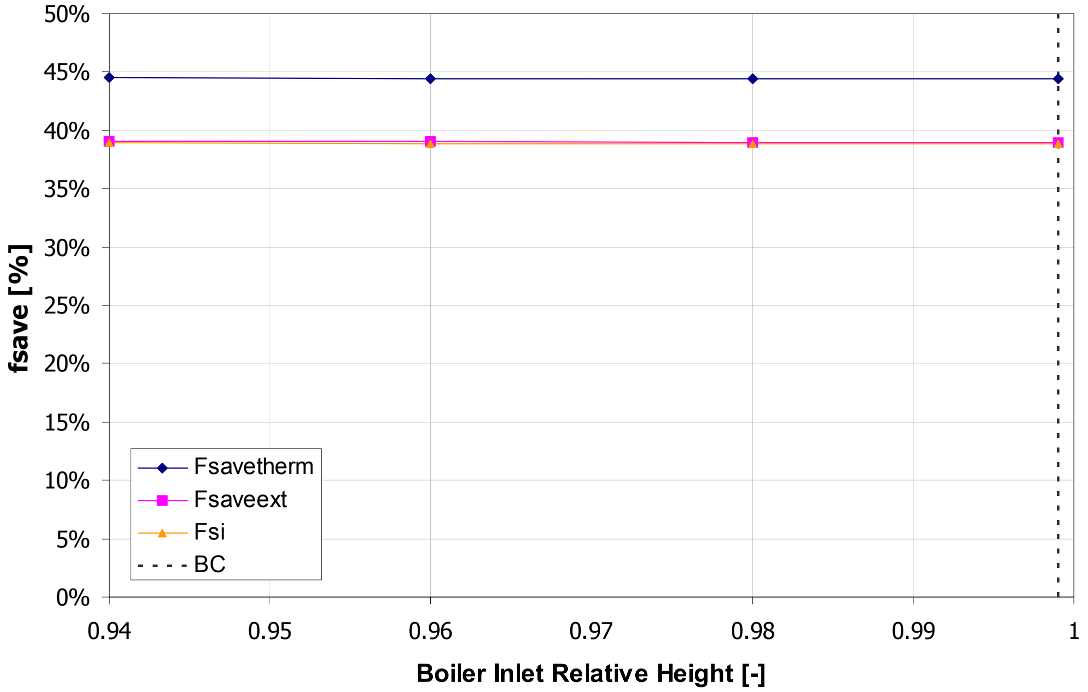


Figure 15. Variation of fractional energy savings with the position of the boiler inlet. Heights are relative heights (=actual height / total height of store)

Differences from Base Case (BC)
None

Description of Results
The savings vary insignificantly over the range of values simulated.

Comments
The thermostat/controller settings for auxiliary charging of the store were unchanged for these simulations.

Sensitivity parameter:	Boiler Outlet Rel. Height [-]	0.877 – 0.980

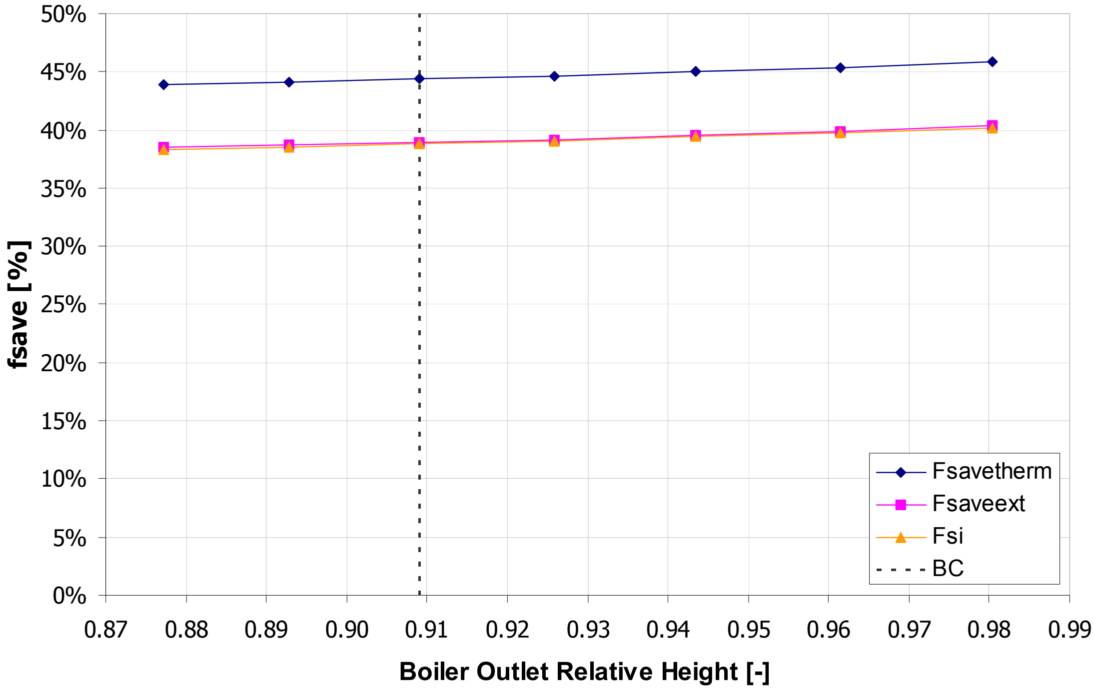


Figure 16. Variation of fractional energy savings with the position of the boiler outlet. Heights are relative heights (=actual height / total height of store)

Differences from Base Case (BC)
None

Description of Results
The savings increase significantly with a higher position of the outlet. Above a height of 0.96 the savings indicator levels off and would probably drop for even higher values as penalties start occurring for the DHW and SH load not being met in full.

Comments
The thermostat/controller settings for auxiliary charging of the store were unchanged for these simulations. Adjusting these settings so that the peak load is just covered would probably alter the results shown here and lead to a smaller variation in savings and maybe even an optimum.

The results are likely to be load dependent.

Sensitivity parameter:	Heading System Inlet Rel. Height [-]	0.000 – 0.500

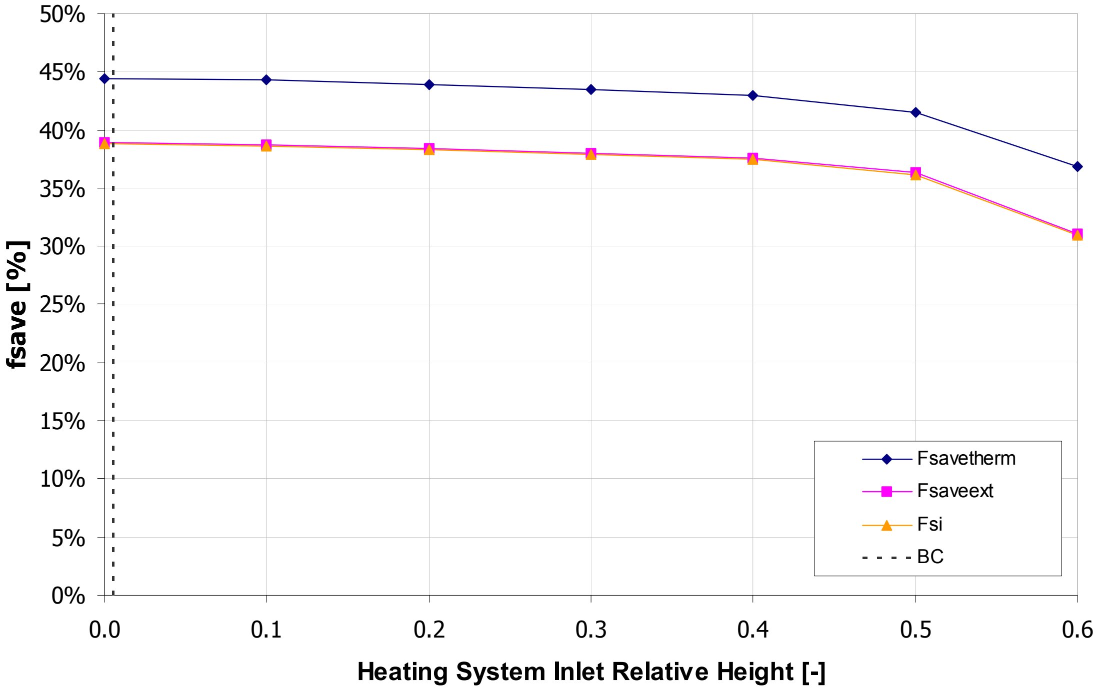


Figure 17. Variation of fractional energy savings with the range of the heating system inlet (return). Heights are relative heights (=actual height / total height of store)

Differences from Base Case (BC)
None

Description of Results
The savings decrease more and more rapidly if the useable storage volume is getting smaller (compare with comments).

Comments
The option "stratified discharging" is used in the Type 140 (Vers. 1.95). That means for example, the range for the stratified charging, for the simulation result 0.2 is from 0.2 up to 1.0.
The heating return is the only return into the energy storage and the range of the inlet temperature is between 15 up to 60 °C at domestic hot water loading sequence. Therefore it is necessarily to use the stratified return.

Sensitivity parameter:	Heading System Outlet Rel. Height [-]	0.8 – 1.0

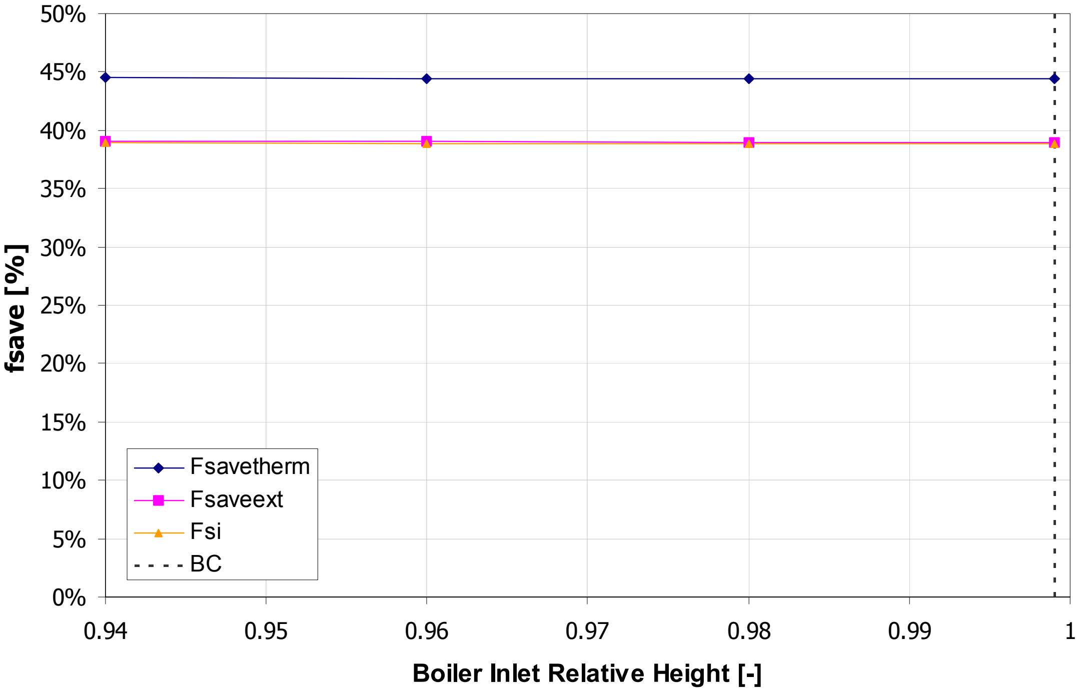


Figure 18. Variation of fractional energy savings with the position of the heating system outlet (forward). Heights are relative heights (=actual height / total height of store)

Differences from Base Case (BC)
None

Description of Results
The savings vary insignificantly over the range of values simulated.

Comments
None.

Sensitivity parameter:	Collector Heat Exchanger UA (variation from base case value)	-50% - +100%

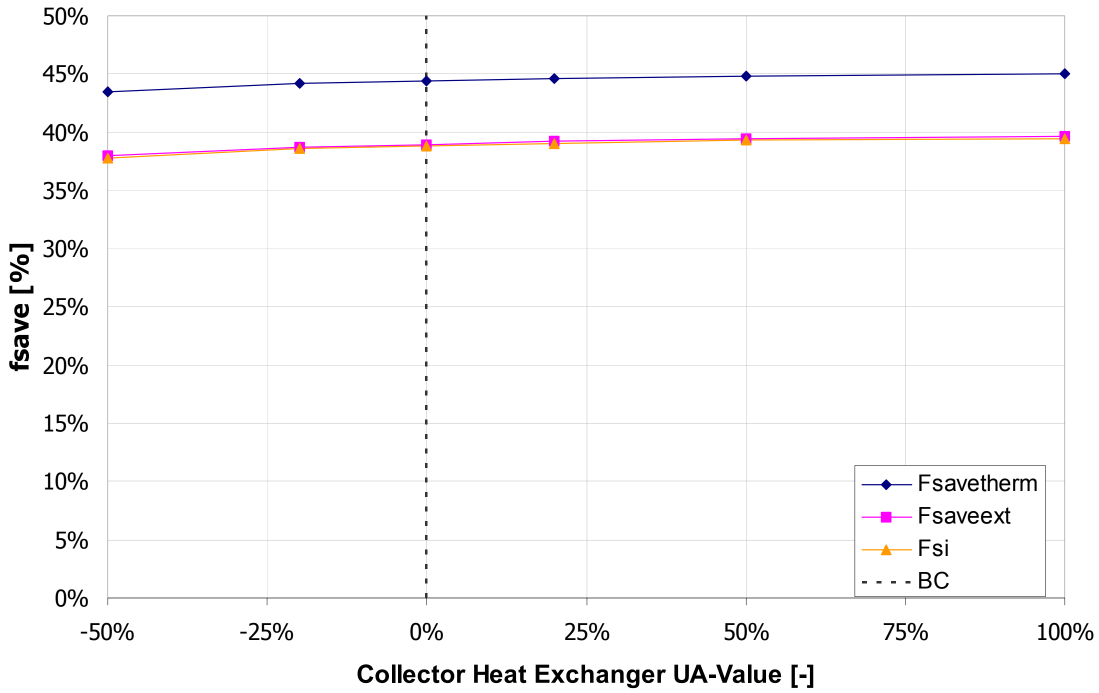


Figure 19. Variation of fractional energy savings with the UA-value of the collector heat exchanger. Parameter values are relative to that defined for the base case system.

Differences from Base Case (BC)
None

Description of Results
Below the base case value (designed with heat exchanger program), the savings decrease more and more rapidly. Above this value there is only a marginal improvement in the savings.

Comments
None.

Sensitivity parameter:	DHW Heat Exchanger UA (variation from base case value)	-50% - +100%

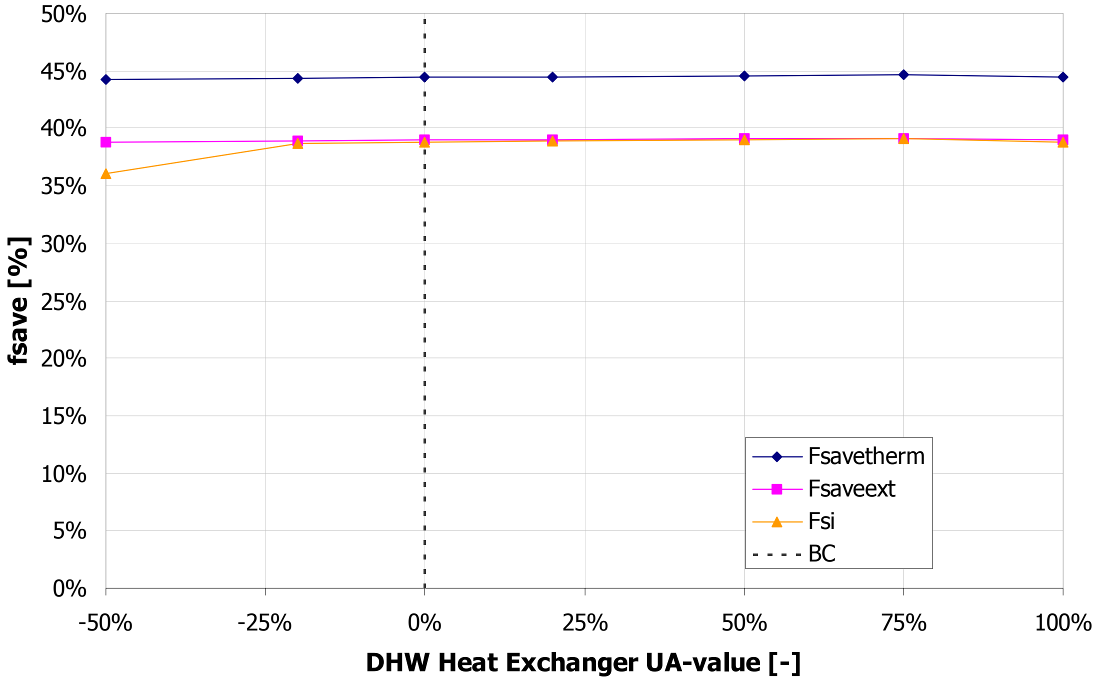


Figure 20. Variation of fractional energy savings with the UA-value of the DHW heat exchanger. Parameter values are relative to the base case UA-value.

Differences from Base Case (BC)
None

Description of Results
Below the base case value (designed with heat exchanger program), the savings decrease more and more rapidly. Above this value there is only a slight improvement in the savings. The reduced UA-value brings up problems with the DHW penalty.

Comments
The thermostat/controller settings for auxiliary charging of the store and the loading time window for the DHW store were unchanged for these simulations.

Sensitivity parameter:	Store Insulation: top [cm]	4 – 34 cm

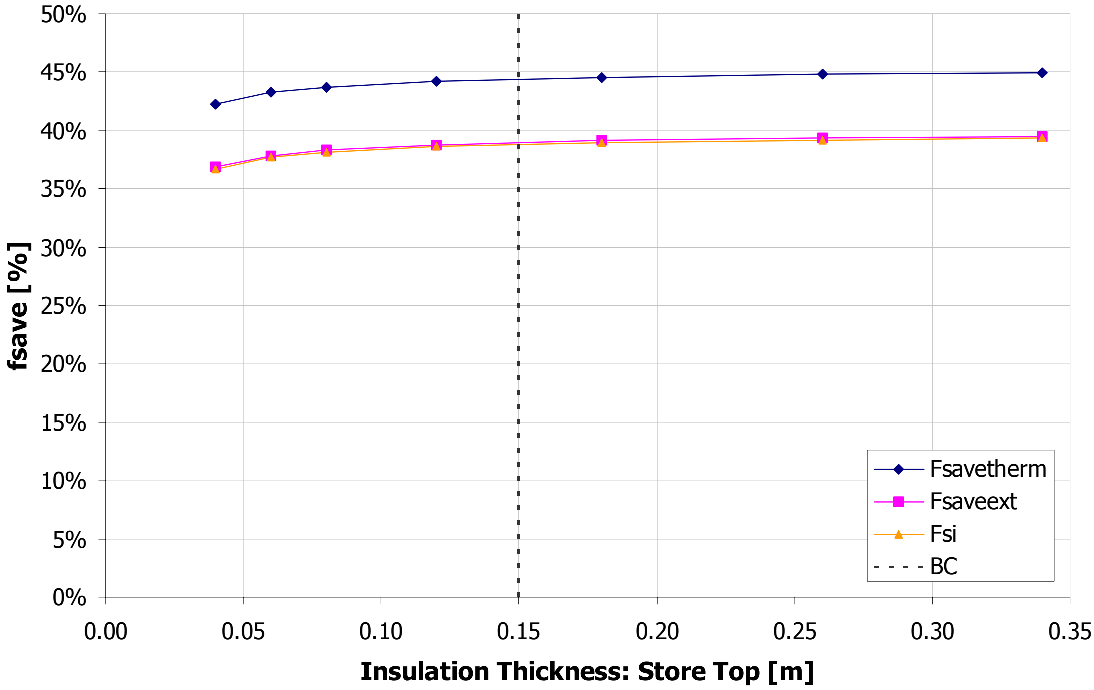


Figure 21. Variation of fractional energy savings with the thickness of insulation on the top of the store.

Differences from Base Case (BC)
None

Description of Results
Above the base case thickness of 15 cm there is only a slight increase in savings. Below this thickness however, and especially below 8 cm, the savings start to decrease significantly.

Comments
The insulation has a conductivity of 0.042 W/m-K and has a correction factor for "imperfection" with the factor $UA_{loss,corr}$ = MAX(1.2,(-0.1815*LN(Vstore)+1.6875))*2.5. This is 3.44 for the base case volume of 5.5 m^3.

Sensitivity parameter:	Store Insulation: sides [cm]	4 – 34 cm

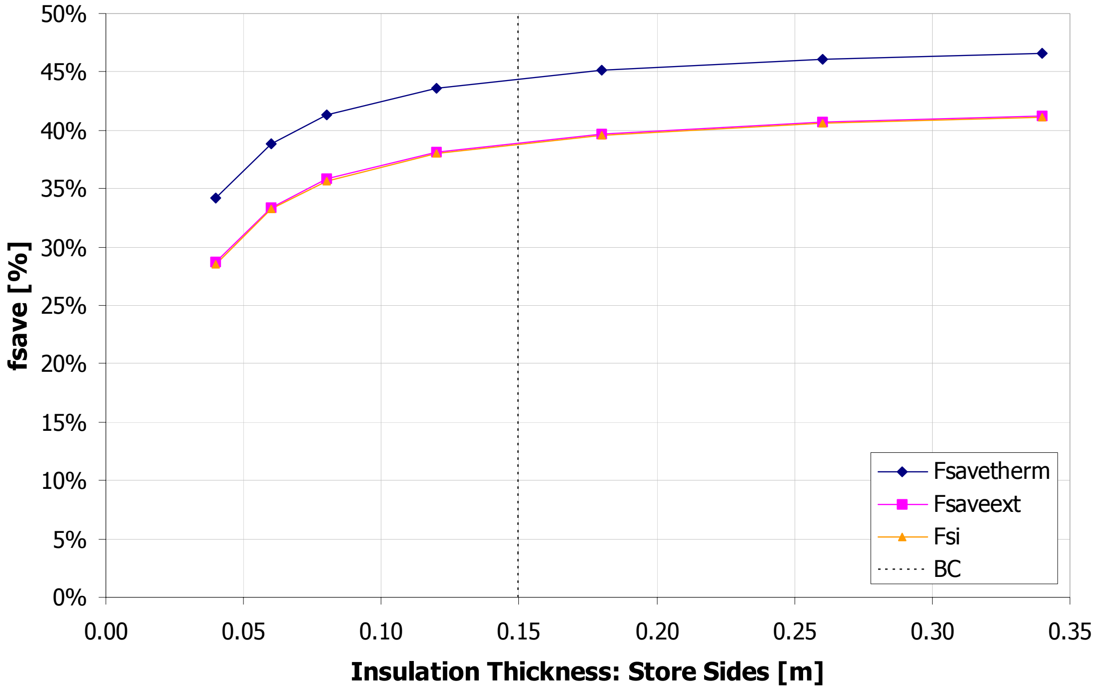


Figure 22. Variation of fractional energy savings with the thickness of insulation on the sides of the store.

Differences from Base Case (BC)
None

Description of Results
Here the variation of insulation thickness is highly significant over the whole range simulated.

Comments
The insulation has a conductivity of 0.042 W/m-K and has a correction factor for "imperfection" with the factor $UA_{loss,corr}$ = MAX(1.2,(-0.1815*LN(Vstore)+1.6875))*2.5. This is 3.44 for the base case volume of 5.5 m^3.

Sensitivity parameter:	Store Insulation: bottom [cm]	4 – 34 cm

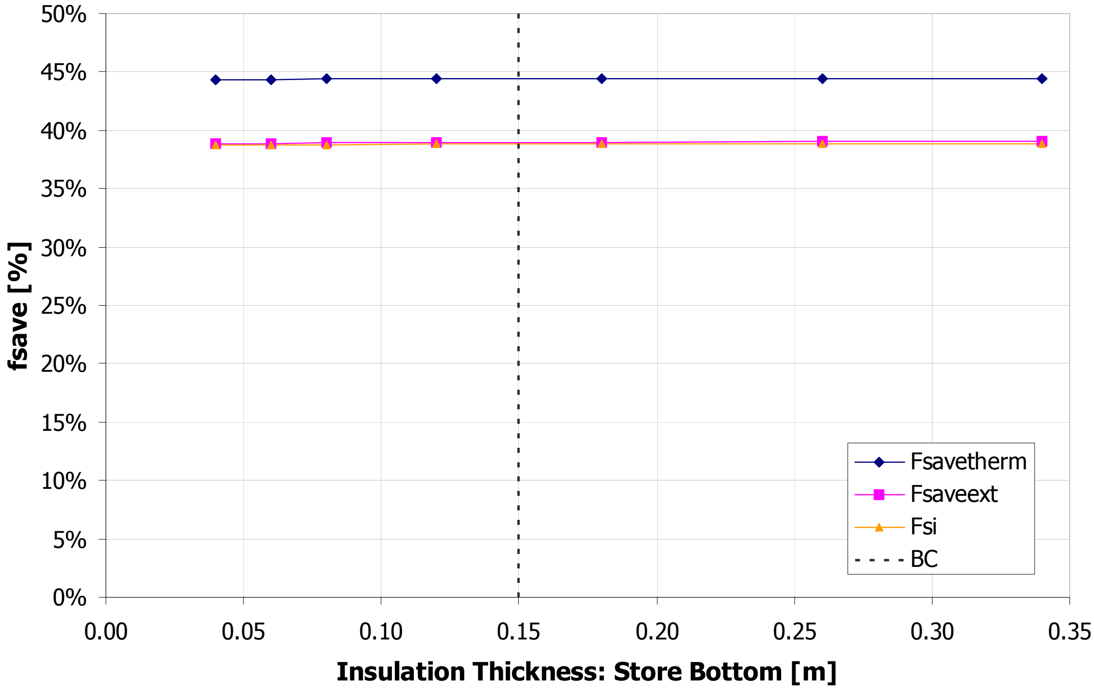


Figure 23. Variation of fractional energy savings with the thickness of insulation on the bottom of the store.

Differences from Base Case (BC)
None

Description of Results
The savings vary insignificantly over the range of values simulated. Because of the low temperature level at the bottom storage volume.

Comments
The insulation has a conductivity of 0.042 W/m-K and has a correction factor for “imperfection” with the factor $UA_{loss,corr}$ = MAX(1.2,(-0.1815*LN(Vstore)+1.6875))*2.5. This is 3.44 for the base case volume of 5.5 m^3.

Sensitivity parameter:	Store Insulation: whole store [cm]	4 – 18 cm

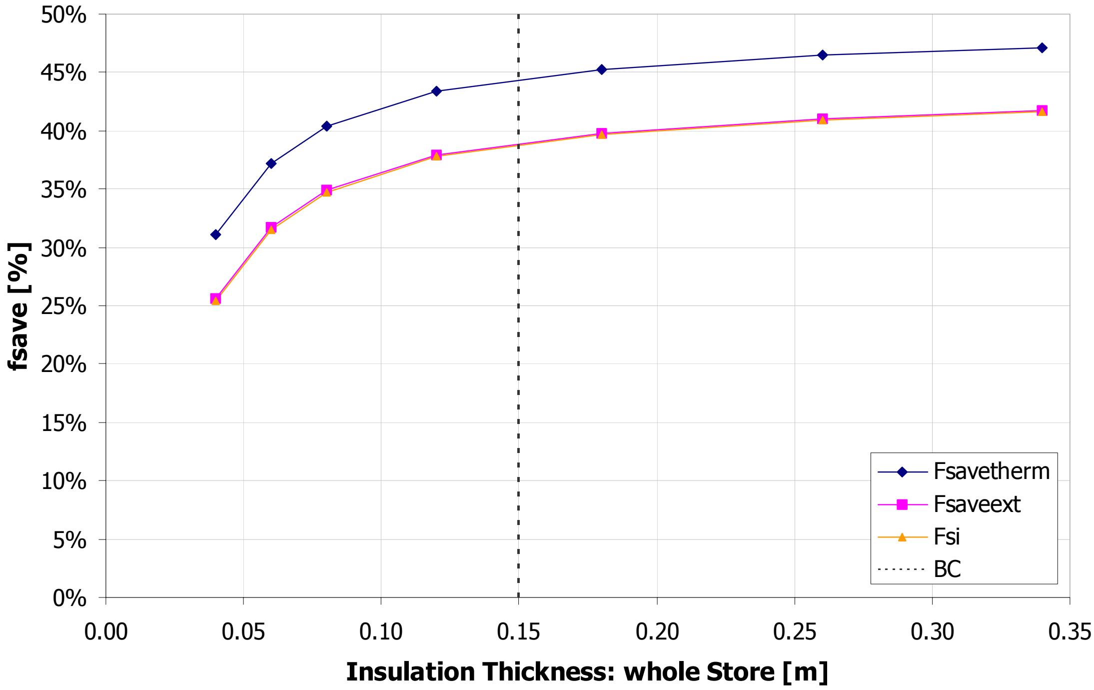


Figure 24. Variation of fractional energy savings with the thickness of insulation around the whole store.

Differences from Base Case (BC)
None

Description of Results
Here the variation of insulation thickness is highly significant over the whole range simulated.

Comments
The insulation has a conductivity of 0.042 W/m-K and has a correction factor for "imperfection" with the factor $UA_{loss,corr}$ = MAX(1.2,(-0.1815*LN(Vstore)+1.6875))*2.5. This is 3.44 for the base case volume of 5.5 m^3.

Sensitivity parameter:	Collector Controller dT_{start} [K] (constant dTstart/dTstop)	4 – 12 K

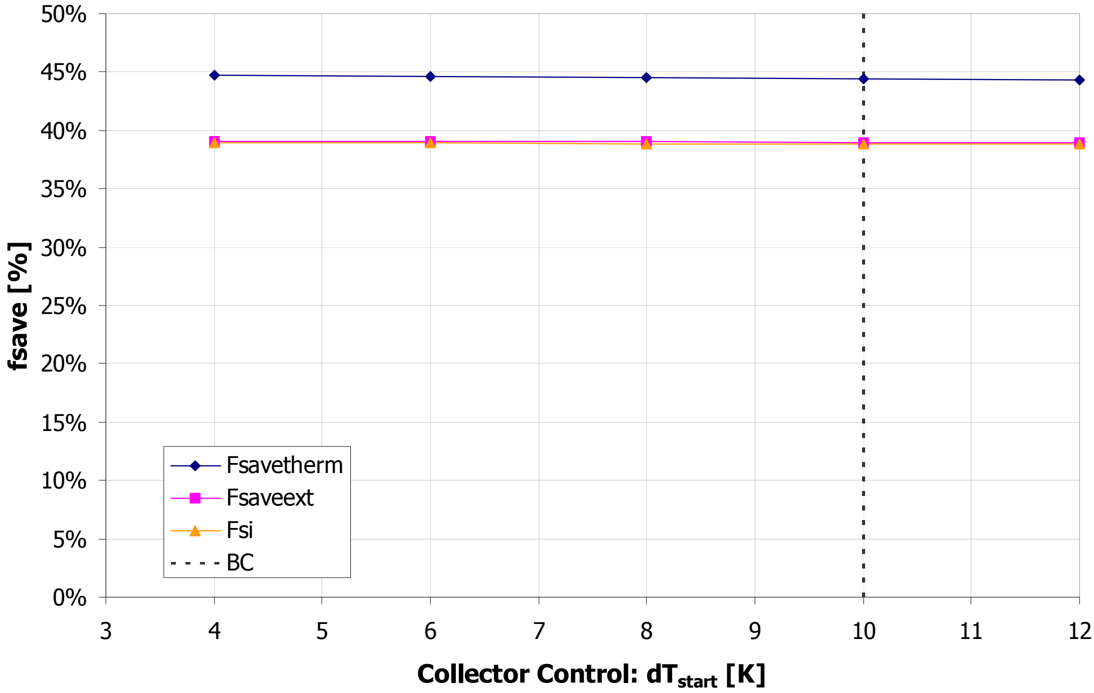


Figure 25. Variation of fractional energy savings with the collector controller settings.

Differences from Base Case (BC)
None

Description of Results
Here there is slight decrease in performance with increasing dT_{start}, however the difference between the values for 4 and 10 K is very small.

Comments
The ratio of the upper and lower dead bands for the controller was kept constant at 10 for these simulations so as to avoid instability.

Sensitivity parameter:	Boiler Internal Standby Temperature [°C]	61 - 80°C

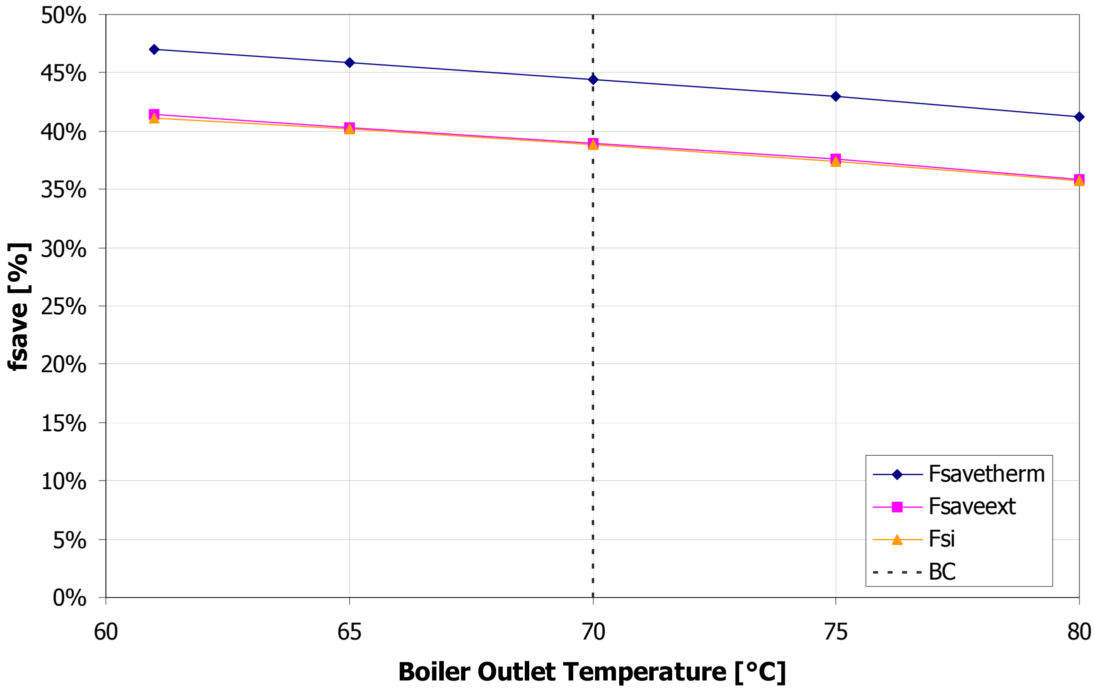


Figure 26. Variation of fractional energy savings with the internal standby temperature of the oil boiler. This is also the set outlet temperature of the boiler.

Differences from Base Case (BC)
None

Description of Results
Here there is significant deterioration in performance with increased standby temperature. This is due to increase losses during standby as well as during combustion.

Comments
The settings for the controller for the charging of the store were kept constant for all variations (62°C start, 70°C stop).

Sensitivity parameter:	Store Charge Thermostat (off) [°K]	0 – 2°K

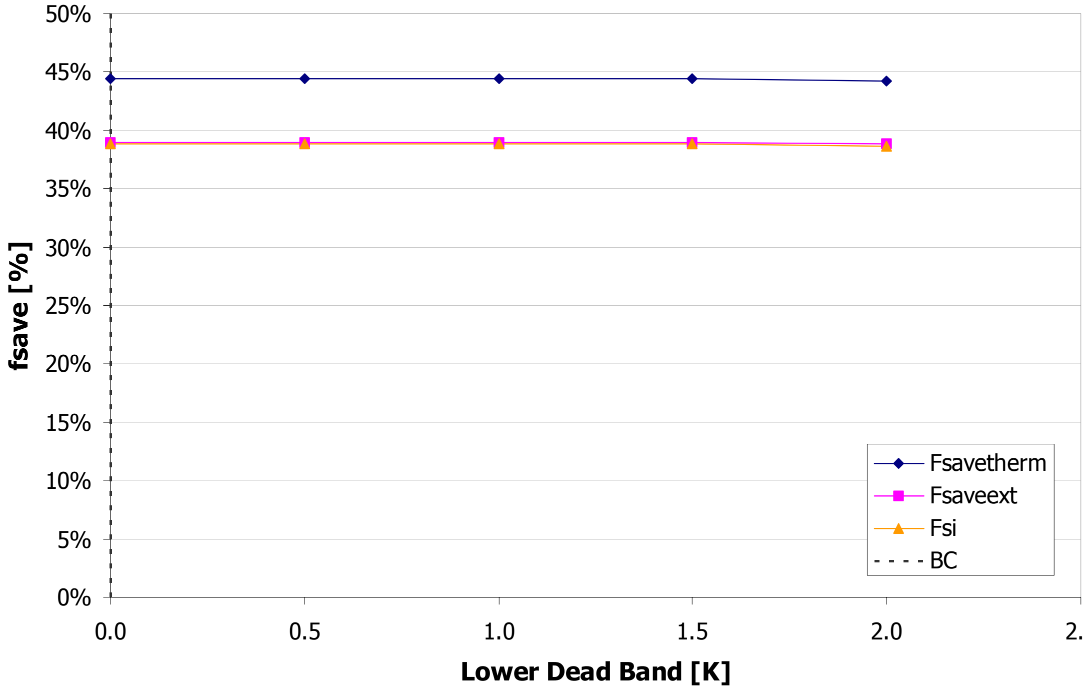


Figure 27. Variation of fractional energy savings with the store charge controller settings.

Differences from Base Case (BC)
None

Description of Results
The savings vary insignificantly over the simulated range of values.

Comments
None

Sensitivity parameter:	Store Charge Flow Rate [kg/h]	1500 – 5400 kg/h

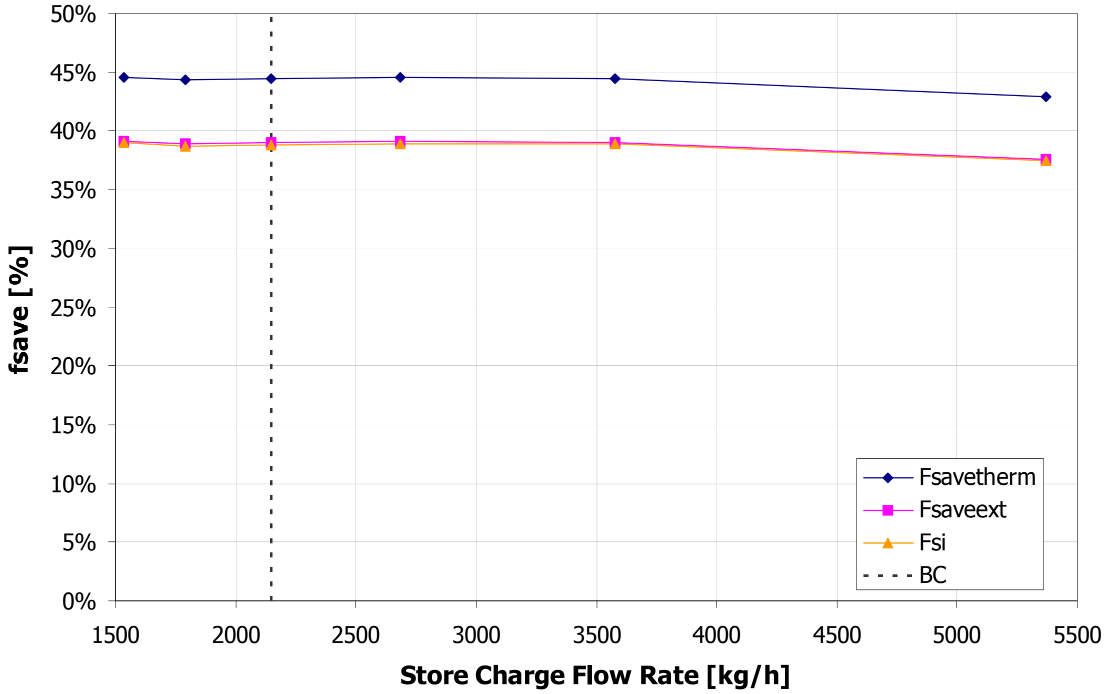


Figure 28. Variation of fractional energy savings with the store charge flow rate.

Differences from Base Case (BC)
None

Description of Results
The store charge flow affects the annual savings slightly. The trend is for larger flows to give larger savings, but there are slight variations due to the variability in convergence of the simulation (see below).

Comments
Due to the allowed tolerance of convergence in the simulations, the energy balance for the boiler (heat supplied to the water – heat supplied to the store – standby losses from the boiler) varied by ±20 kWh which is enough to make the trend non-smooth.

Sensitivity parameter:	DHW Store Charge Flow Rate [kg/h]	100 - 200 kg/h

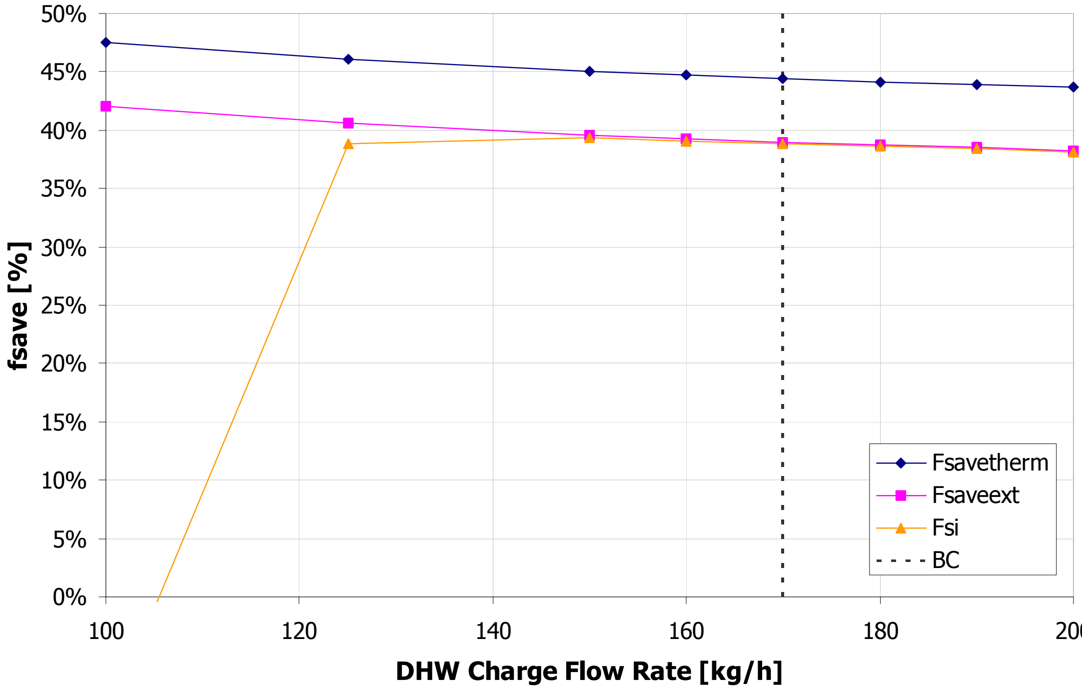


Figure 29. Variation of fractional energy savings with the store charge flow rate.

Differences from Base Case (BC)
None

Description of Results
The store charge flow affects the annual savings slightly. The trend is for lower flows to give larger savings (lower flows means reduced mixing effects in the energy storage).

Comments
The DHW penalty is increasing at small flow rates. The DHW loading time is getting to small for charging the whole DHW store.

Sensitivity parameter:	DHW Storage Volume [m³]	0.15 – 0.3 m³

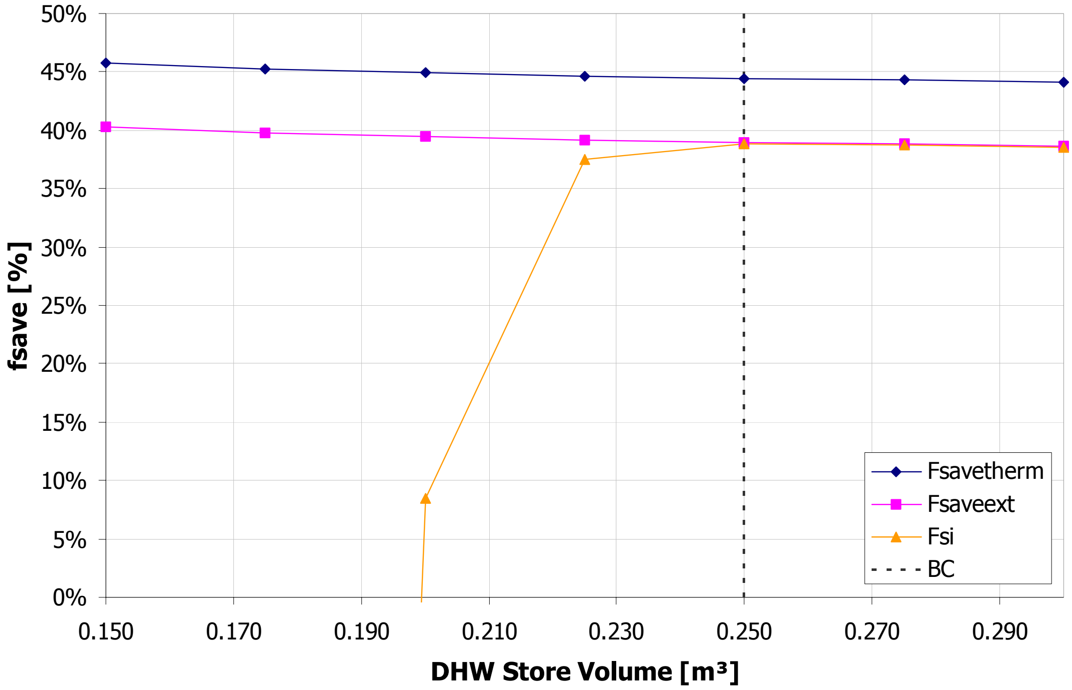


Figure 30. Variation of fractional energy savings with the DHW storage volume.

Differences from Base Case (BC)
None

Description of Results
The DHW storage volume affects the annual savings slightly. The trend is for lower volumes to give larger savings.

Comments
The DHW penalty is increasing with small DHW store volumes. There must be more then two times a day for charging the small DHW store.

Sensitivity parameter:	DHW Storage charging time [h]	$9_{AM} – 13_{PM}$ h

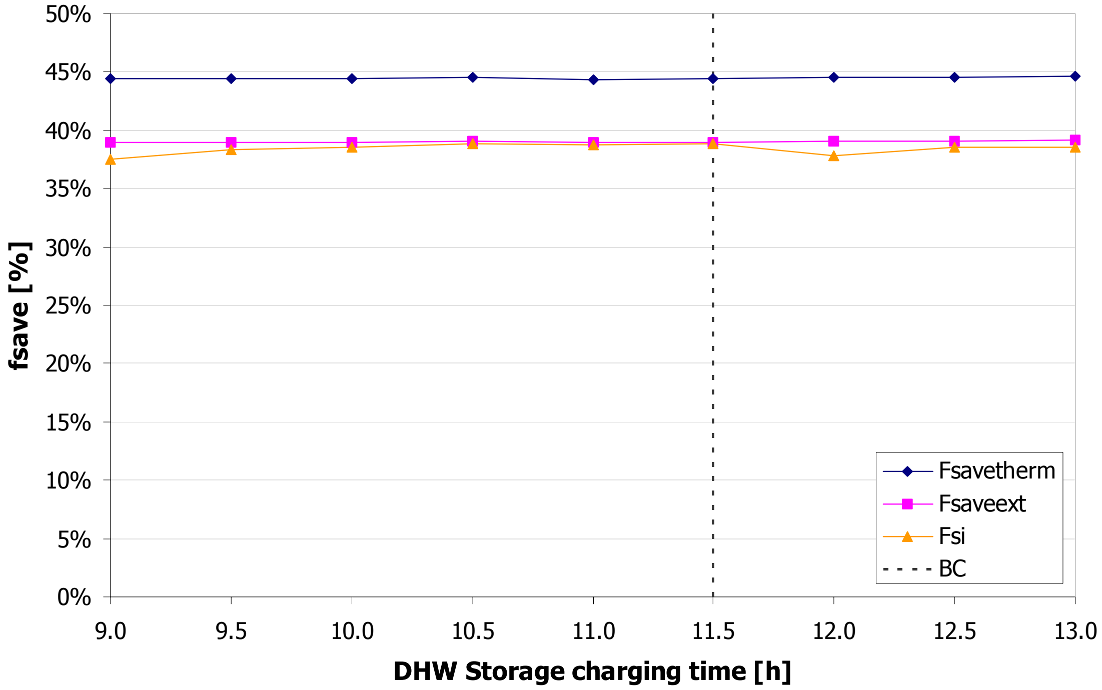


Figure 31. Variation of fractional energy savings with the DHW storage charging time (Day – charging)

Differences from Base Case (BC)
None

Description of Results
The DHW storage charging time affects the annual savings slightly. The trend is for earlier charging time to give slower savings, but there are slight variations due to the variability in convergence of the simulation.

Comments
The FSI has a non-smooth trend depending on the DHW load profile peaks.

Sensitivity parameter:	DHW Storage charging time [h]	$0_{AM} - 4_{AM}$ h

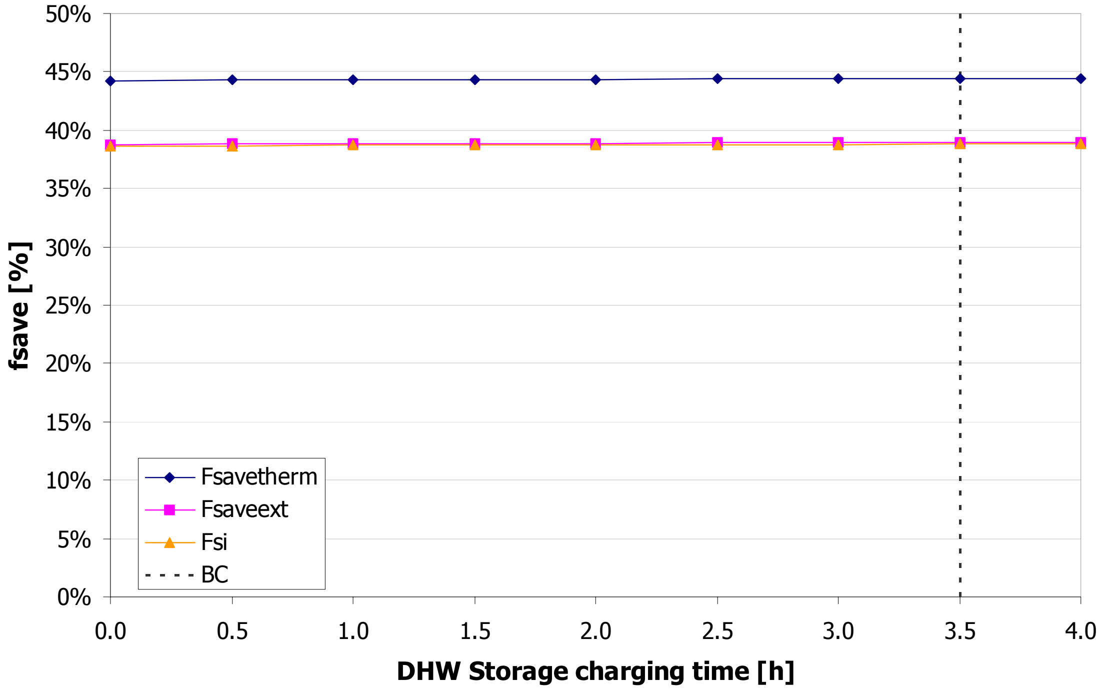


Figure 32. Variation of fractional energy savings with the DHW storage charging time (Night - charging).

Differences from Base Case (BC)
None

Description of Results
There is no significant improvement in savings, at changing the DHW charging start time.

Comments
None

Sensitivity parameter:	Store Charge Controller Sensor Rel. Height [-]	0.85 – 0.96

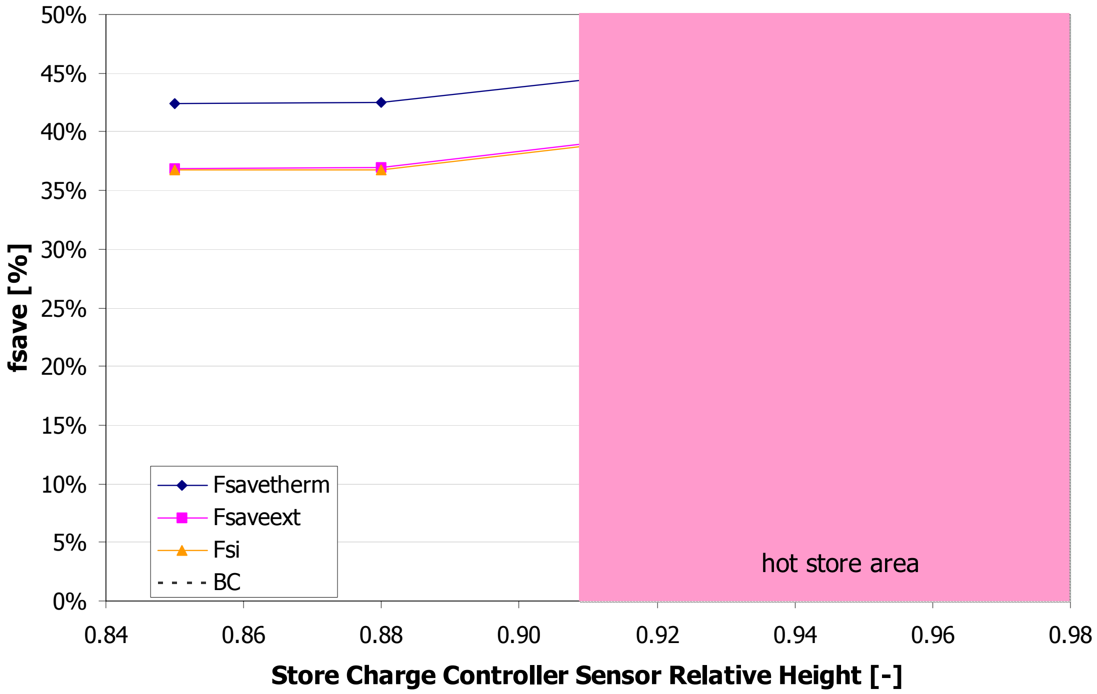


Figure 33. Variation of fractional energy savings with the boiler store charge controller sensor position.

Differences from Base Case (BC)
None

Description of Results
Here there is a trend for the savings to improve with decreasing sensor height (within the hot store area), but below the base case the improvements rate decrease with height.

Comments
The boiler inlet position is constant at the relative height of 0.91. The fractional savings reach a maximum, if the sensor relative height is nearby the boiler inlet position.

Sensitivity parameter:	Collector Controller Sensor Rel. Height [-]	0.050 – 0.500

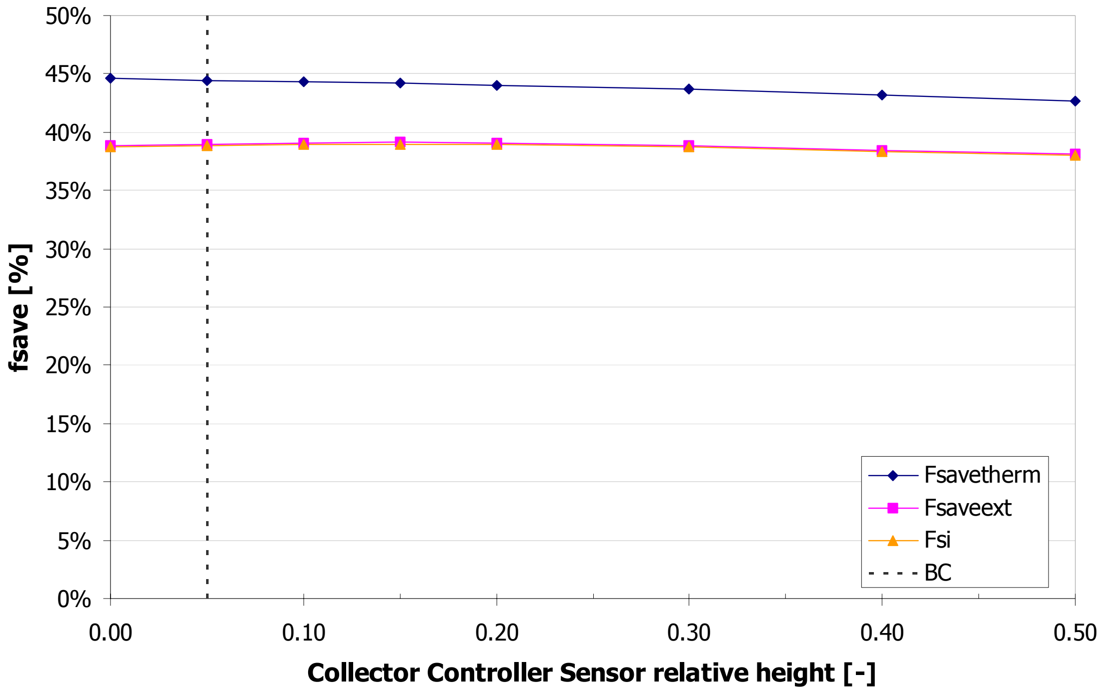


Figure 34. Variation of fractional energy savings with the collector controller sensor position.

Differences from Base Case (BC)
None

Description of Results
Above a height of approximately 0.15 the savings start to decrease. Below this height there is little influence on the savings from the collector controller's position.

Comments
Using lower heights for the collector controller, the running time for the collector loop pumps is increasing. This effect can be seen at the $f_{sav,ext}$ curve, decreasing at lower collector controller heights.

4.2 Definition of the optimised system

That's only the first draft – some more work would be necessary but the financing is missing at the moment.

Summary of Sensitivity Parameters	
Parameter	Variation
Collector size [m^2]	30 – 250 m^2
Collector Size [m2]	25 – 250 m^2
Store Size [m3]	1.75 – 13.0 m^3
Collector Azimuth [°]	-90° - 90°
Collector Tilt [°]	15° - 90°
[2]Climate	Carp. / Zur. / Stock.
Boiler Inlet Rel. Height [-]	0.94 – 0.999
Boiler Outlet Rel. Height [-]	0.88 – 0.98
Heating System Inlet Rel. Height [-]	0.000 – 0.500
Collector Heat Exchanger UA	-50% - +100%
DHW Heat Exch. UA	-50% - +100%
Store Insulation: top [cm]	4 – 34 cm
Store Insulation: sides [cm]	4 – 34 cm
Store Insulation: bottom [cm]	4 – 34 cm
Store Insulation: whole store [cm]	4 – 34 cm
Collector Controller dT_{start} [C]	4 – 12
[5]Boiler Outlet Temperature [C]	61 - 80°C
[6]Store Charge Thermostat (off) [C]	60 - 80°C
Store Charge Flow Rate [kg/h]	1500 - 5500
Store Charge Controller Sensor Rel. Height [-]	0.85 – 0.96
Collector Controller Sensor Rel. Height [-]	0.050 – 0.500
DHW charge flow rate [kg/h]	100 - 200
DHW Storage charging time (Day) [h]	9:00 – 13:00
DHW Storage charging time (Night) [h]	0:00 – 4:00
DHW Storage charging temperature [°C]	53 - 63
DHW Storage Volume [m³]	0.15 – 0.3

- **Sensitivity Analysis**
  - ✓ done with 26 Parameters
- **first optimization Step**
  - ✓ Base Case for all cost parameters
  - ✓ all non cost parameters for the energy store are at optimized value
- **second optimization Step**
  - ✓ Base Case for all cost parameters
  - ✓ Base Case for the energy store values
  - ✓ all non cost parameters for the DHW store are at optimized value
- **third optimization Step**
  - ✓ Base Case for all cost parameters
  - ✓ All non cost parameters at optimized value

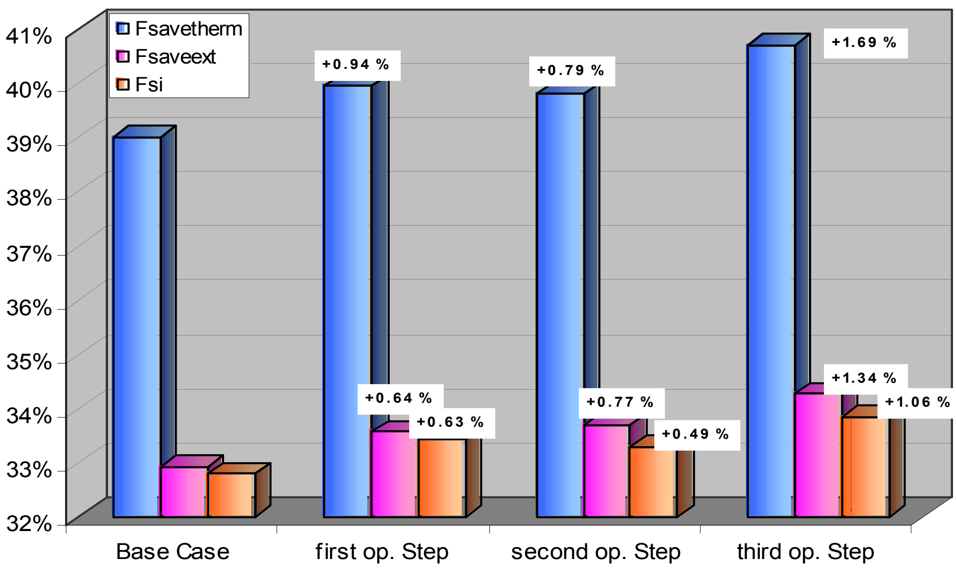


Figure 35. First optimisation results for some non cost parameters

5 Analysis using FSC

For the optimised system the analysis based on FSC /5/ should be carried out for each system.

Table 2 Results of System #19 simulations for the climate Zurich

Building Climate		MFH 45 Zurich											
A_{Coll}	[m²]	25	31	40	50	63	79	100	125	158	199	250	
V_{STORE}	[m³]	1.75	2.05	2.50	3.00	3.65	4.45	5.50	6.75	8.40	10.45	13.00	
Qburner/η_{burn}	[kWh/a]	39000	37300	35210	33330	31460	29540	27770	25900	23450	21170	18920	
Wel	[kWh/a]	3371	3396	3442	3501	3592	3737	3772	3784	3826	3930	4085	
QpenSH19_5	[kWh/a]	29.39	29.39	29.40	29.39	29.37	29.37	29.39	29.39	29.39	29.39	29.40	
QpenSH24	[kWh/a]	5623	5622	5622	5622	5623	5622	5622	5622	5623	5623	5622	
QpenDHW	[kWh/a]	44	43	43	43	42	42	42	42	42	42	42	
Qsol	[kWh/a]	29444	36528	47111	58889	74222	93056	117778	147250	186111	234417	294444	
Qcoll	[kWh/a]	11475	13531	16181	18733	21625	24819	28306	32056	36444	41444	46861	
Qsol_pipe_loss	[kWh/a]	922	1103	1375	1675	2042	2486	3042	3611	4278	5222	6417	
Qst_in	[kWh/a]	10553	12428	14806	17058	19583	22333	25264	28444	32167	36222	40444	1
Qaux	[kWh/a]	36917	35333	33417	31694	29833	27917	25981	23939	21594	19269	17022	2
Qstout	[kWh/a]	44361	44361	44361	44361	44361	44361	44361	44361	44361	44361	44361	3
Qhds_pipe_loss	[kWh/a]	10811	10811	10808	10808	10808	10808	10806	10806	10806	10806	10806	
Qheat	[kWh/a]	22500	22500	22500	22500	22500	22500	22500	22500	22500	22500	22500	
Qhwin	[kWh/a]	18306	18306	18308	18308	18308	18308	18311	18311	18311	18311	18311	
Qhwout	[kWh/a]	15244	15244	15244	15244	15244	15244	15244	15244	15244	15244	15244	
Qstloss I	[kWh/a]	3106	3394	3858	4369	5036	5856	6864	8006	9381	11092	13075	4
Qstloss II	[kWh/a]	2861	2861	2861	2864	2864	2864	2864	2864	2864	2864	2864	
E_balance	[kWh/a]	3	6	3	22	19	33	19	17	19	39	31	=1+2-3-4
FSC	**[%]**	**36.7%**	**41.2%**	**47.0%**	**52.0%**	**57.3%**	**62.2%**	**66.4%**	**70.0%**	**73.6%**	**77.2%**	**80.9%**	
Fsav,therm	**[%]**	**22.0%**	**25.4%**	**29.5%**	**33.3%**	**37.0%**	**40.9%**	**44.4%**	**48.2%**	**53.1%**	**57.6%**	**62.1%**	
Fsav,ext	**[%]**	**18.0%**	**21.3%**	**25.2%**	**28.7%**	**32.2%**	**35.6%**	**39.0%**	**42.6%**	**47.2%**	**51.4%**	**55.5%**	
Fsi	**[%]**	**17.9%**	**21.1%**	**25.1%**	**28.6%**	**32.0%**	**35.5%**	**38.8%**	**42.4%**	**47.1%**	**51.3%**	**55.4%**	

Table 3 Results of System #19 simulations for the climate Stockholm

Building Climate		MFH 45 Stockholm											
A_{Coll}	[m²]	25	31	40	50	63	79	100	125	158	199	250	
V_{STORE}	[m³]	1.75	2.05	2.50	3.00	3.65	4.45	5.50	6.75	8.40	10.45	13.00	
Qburner/□$_{burn}$	[kWh/a]	49300	47600	45540	43590	41680	39770	37910	35990	33750	31630	29380	
Wel	[kWh/a]	3373	3394	3434	3485	3566	3698	3737	3759	3802	3893	4054	
QpenSH19_5	[kWh/a]	72.13	72.13	72.12	72.12	72.10	72.10	72.10	72.10	72.10	72.10	72.10	
QpenSH24	[kWh/a]	4066	4065	4065	4065	4066	4065	4065	4066	4066	4065	4066	
QpenDHW	[kWh/a]	40	40	40	40	40	40	40	40	40	40	40	
Qsol	[kWh/a]	30361	37667	48611	60750	76528	95972	121500	151861	191972	241778	303611	
Qcoll	[kWh/a]	11731	13764	16414	18906	21750	24803	28167	31778	35861	40528	45694	
Qsol_pipe_loss	[kWh/a]	867	1042	1314	1575	1925	2333	2842	3417	4083	5000	6139	
Qst_in	[kWh/a]	10864	12722	15100	17331	19825	22469	25325	28361	31778	35528	39556	1
Qaux	[kWh/a]	46222	44639	42722	40944	39083	37194	35250	33278	31167	29083	26869	2
Qstout	[kWh/a]	54083	54083	54083	54083	54056	54056	54056	54056	54056	54056	54056	3
Qhds_pipe_loss	[kWh/a]	3586	3586	3583	3583	3556	3553	3553	3553	3553	3553	3553	
Qheat	[kWh/a]	31750	31750	31750	31750	31750	31750	31750	31750	31750	31750	31750	
Qhwin	[kWh/a]	18747	18747	18750	18750	18750	18753	18753	18753	18753	18753	18753	
Qhwout	[kWh/a]	15694	15694	15694	15694	15694	15694	15694	15694	15694	15694	15694	
Qstloss I	[kWh/a]	3019	3294	3747	4208	4831	5586	6519	7594	8872	10533	12356	4
Qstloss II	[kWh/a]	2847	2847	2850	2850	2850	2850	2850	2850	2850	2850	2850	
E_balance	[kWh/a]	-17	-17	-8	-17	22	22	0	-11	17	22	14	=1+2-3-4
FSC	**[%]**	**30.1%**	**33.5%**	**37.8%**	**41.9%**	**46.3%**	**51.1%**	**56.5%**	**61.8%**	**66.3%**	**71.1%**	**75.3%**	
Fsav,therm	**[%]**	**20.0%**	**22.8%**	**26.1%**	**29.3%**	**32.4%**	**35.5%**	**38.5%**	**41.6%**	**45.2%**	**48.7%**	**52.3%**	
Fsav,ext	**[%]**	**17.1%**	**19.7%**	**22.9%**	**25.9%**	**28.8%**	**31.6%**	**34.4%**	**37.4%**	**40.9%**	**44.1%**	**47.4%**	
Fsi	**[%]**	**16.9%**	**19.5%**	**22.7%**	**25.7%**	**28.6%**	**31.4%**	**34.3%**	**37.2%**	**40.7%**	**43.9%**	**47.2%**	

Table 4 Results of System #19 simulations for the climate Carpentras

Building Climate		MFH 45 Carpentras											
A_{Coll}	[m²]	25	31	40	50	63	79	100	125	158	199	250	
V_{STORE}	[m³]	1.75	2.05	2.50	3.00	3.65	4.45	5.50	6.75	8.40	10.45	13.00	
Qburner/□$_{burn}$	[kWh/a]	18310	16260	14000	12060	10370	8768	7194	5841	4424	3171	2069	
Wel	[kWh/a]	3395	3414	3448	3500	3594	3735	3763	3761	3789	3858	3995	
QpenSH19_5	[kWh/a]	3.39	3.38	3.38	3.38	3.38	3.38	3.39	3.39	3.38	3.38	3.38	
QpenSH24	[kWh/a]	39300	39310	39310	39310	39310	39310	39310	39310	39310	39310	39310	
QpenDHW	[kWh/a]	273	273	272	272	273	272	271	270	270	270	270	
Qsol	[kWh/a]	43028	53361	68833	86056	108444	135972	172111	215139	271944	342500	430278	
Qcoll	[kWh/a]	17719	20344	23519	26522	29556	32694	36333	40000	44139	48806	53861	
Qsol_pipe_loss	[kWh/a]	1514	1783	2172	2608	3117	3667	4389	5222	6194	7500	9139	
Qst_in	[kWh/a]	16206	18561	21347	23914	26439	29028	31944	34778	37944	41306	44722	1
Qaux	[kWh/a]	16981	15064	12928	11092	9419	7808	6181	4761	3347	2081	1028	2
Qstout	[kWh/a]	29361	29361	29361	29361	29361	29361	29361	29333	29333	29333	29333	3
Qhds_pipe_loss	[kWh/a]	3481	3481	3481	3481	3478	3478	3478	3450	3450	3450	3450	
Qheat	[kWh/a]	9308	9308	9308	9308	9308	9308	9308	9308	9308	9308	9308	
Qhwin	[kWh/a]	16572	16572	16572	16572	16575	16575	16575	16575	16575	16575	16575	
Qhwout	[kWh/a]	13600	13600	13600	13600	13600	13600	13600	13600	13600	13600	13600	
Qstloss I	[kWh/a]	3814	4256	4906	5636	6483	7475	8753	10175	11936	14039	16394	4
Qstloss II	[kWh/a]	2792	2792	2792	2794	2794	2794	2794	2794	2794	2794	2794	
E_balance	[kWh/a]	11	8	8	8	14	0	11	31	22	14	22	=1+2-3-4
FSC	**[%]**	**66.6%**	**71.7%**	**76.8%**	**80.4%**	**84.0%**	**87.0%**	**89.8%**	**92.4%**	**94.5%**	**96.1%**	**97.4%**	
Fsav,therm	**[%]**	**42.4%**	**48.8%**	**55.9%**	**62.1%**	**67.4%**	**72.4%**	**77.4%**	**81.6%**	**86.1%**	**90.0%**	**93.5%**	
Fsav,ext	**[%]**	**34.6%**	**40.7%**	**47.4%**	**53.1%**	**57.9%**	**62.3%**	**67.0%**	**71.1%**	**75.3%**	**78.8%**	**81.7%**	
Fsi	**[%]**	**33.8%**	**39.9%**	**46.6%**	**52.3%**	**57.1%**	**61.5%**	**66.2%**	**70.3%**	**74.5%**	**78.0%**	**80.9%**	

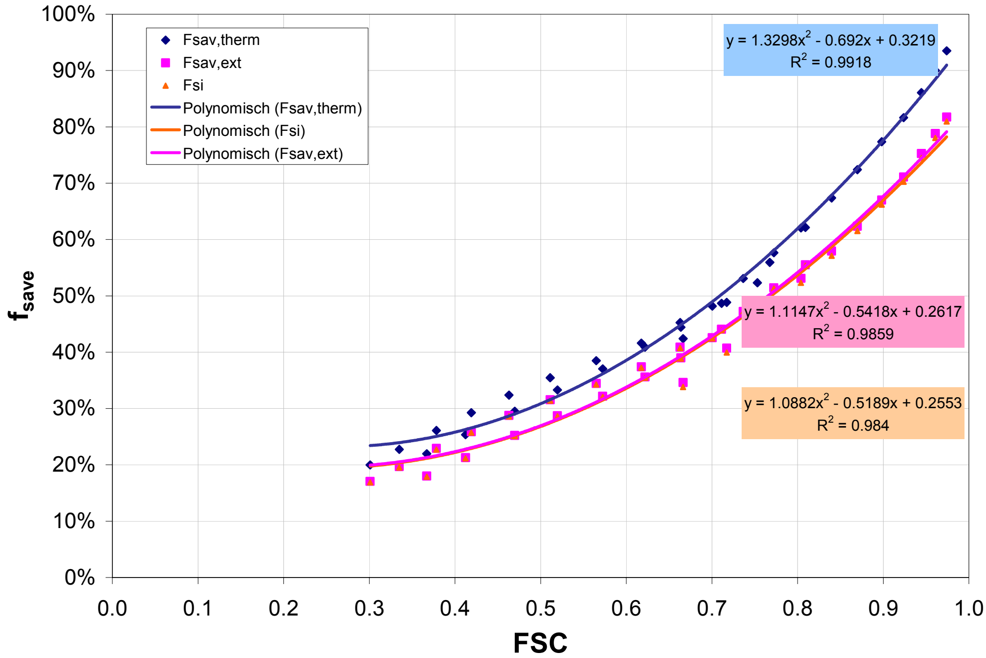


Figure 36. Variation of fractional energy savings with the fractional solar consumption (FSC) for 3 climates (Carpentras, Zurich and Stockholm) and one load (45 kWh/m²a multi-family building).

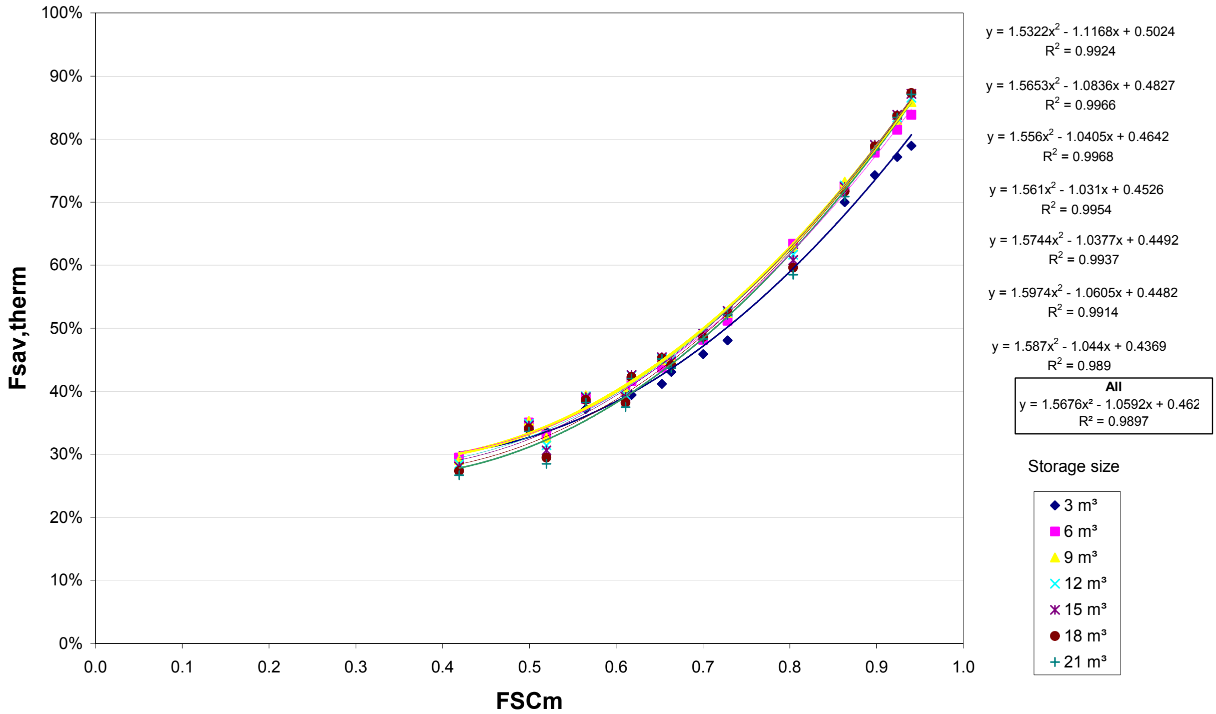


Figure 37. Variation of fractional energy savings with the fractional solar consumption (FSC) for 3 climates (Carpentras, Zurich and Stockholm) and one load (45 kWh/m²a multi-family building) varying the energy store volumes.

According to the proposal from T. Letz /5/ the following Diagram gives the range for the collector area related to the storage size.

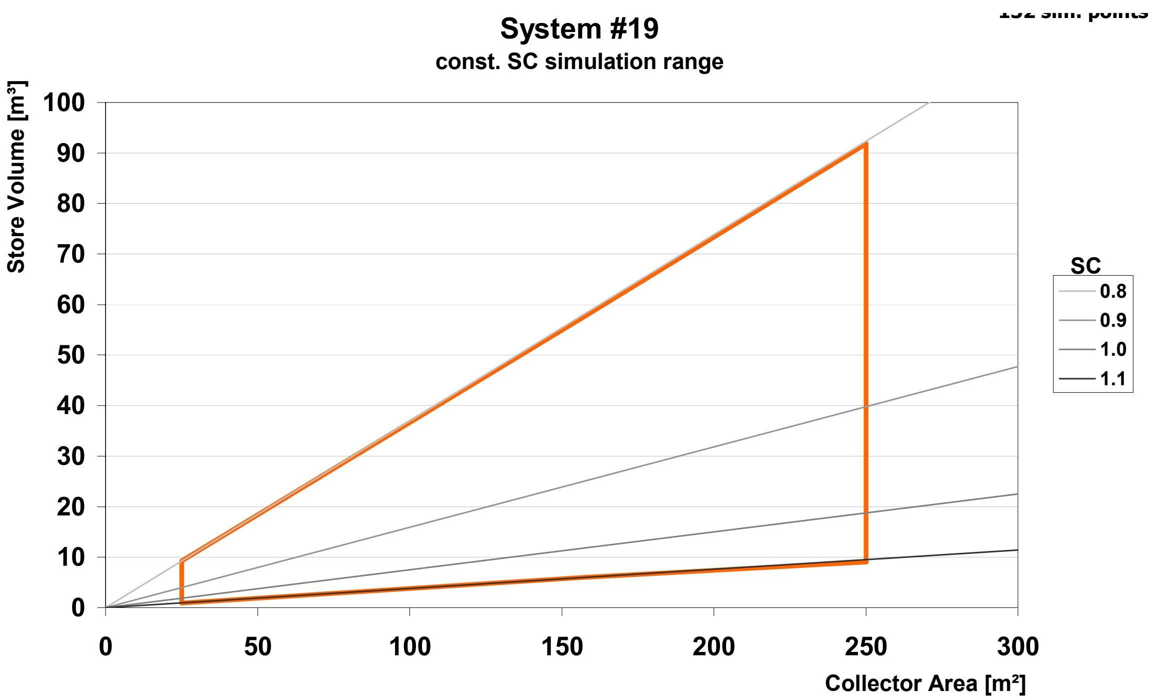


Figure 38. Storage size / collector area diagram for System #19 (compare with T. Letz /5/).

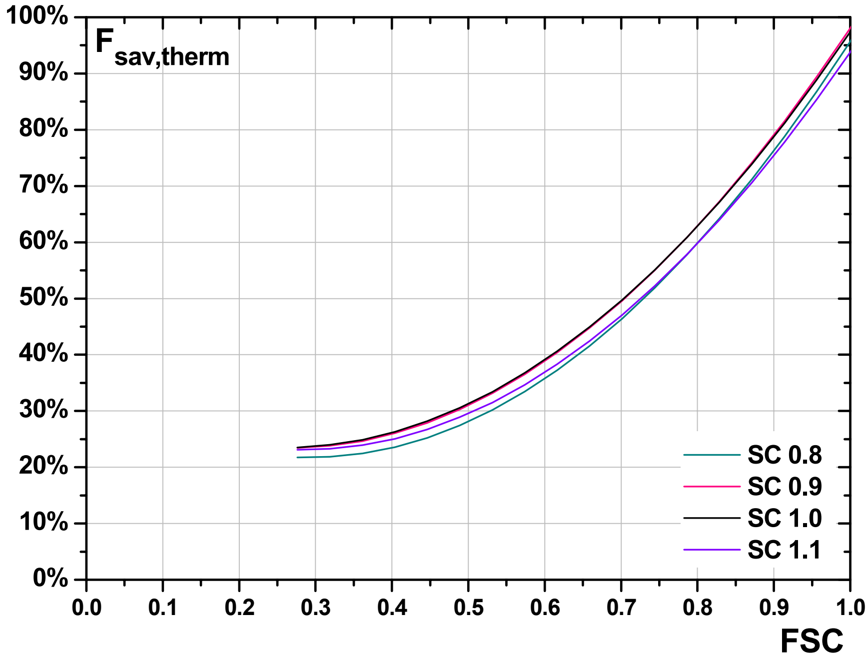


Figure 39. $f_{sav,therm}$ according to FSC, including the SC (compare with T. Letz /5/).

6 Lessons learned

Concerning simulation

- For distributed work, as it was performed in Task 26, it is necessary that the same reference conditions, the same revisions of TRNSYS modules and the same compilers with identical settings have to be used. Otherwise results are not comparable.
- The three target functions defined offer a quick understanding of the system performance.
- Energy balances have to be made for each hydraulic loop and element in order to check the simulation model.
- Sensitivity analysis offers a nice way to learn about the simulated system.
- The simulation-models of every TRNSYS Type should be known in detail, when they are used in a simulation. Otherwise there may be unrealistic results.
- The results of the simulation (slightly) are dependent on computer type and compiler settings. Therefore at least the same compiler settings have to be used, when different systems are to be compared.
- The TRNSED surface of TRNSYS offers a convenient possibility to change between different buildings, climates etc without forgetting changes to be made in the DEK file
- For complex simulations the IISBAT surface is not very attractive. It is better to use standard editors to produce and change the DEK files.

Concerning system

- For the multi-family building higher losses for the heat distribution system occur compared to the single-family house.
- The domestic hot water tanks in each apartment may be not the best solution because they have relatively high heat losses and need space which is normally very limited in apartments.
- The DHW-tank should be not smaller than 250 litres for the defined DHW draw off volume of 200 litres/day.

- For System #19 the store insulation should be not thinner than 15 cm at top and sides. Otherwise the fractional savings drop significantly. The insulation at the bottom of the store is not very significant, because this region of the store is mostly cold.
- The volume heated by the auxiliary should be kept as small as possible to leave a high store volume to the solar heating system.
- The supply temperature from the auxiliary heater should be as low as possible to leave a temperature “reserve” for the solar heating system for the whole storage volume.

7 References

/1/ Heimrath R., Fink C., Riva R., Solarunterstützte Wärmenetze - Projektteil Thermische Solaranlagen für Mehrfamilienhäuser, Endbericht, 2002

/2/ Weiss, W. (ed.), Solar heated houses – A design handbook for solar combisystems, James & James Science Publishers, 2003

/3/ Streicher W., Heimrath R.,. 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.

/4/ Jenni J., Speicher in Theorie und Praxis, Verlag Jenni Energietechnik, CH-3414 Oberburg, 2000

/5/ Letz T., Validation and Background Information on the FSC Procedure, 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
not part of the TRNSYS standard library AND
not part of the types used as "standard" by Task 26.

For the System #19 are only "standard" TRNSYS Types used.