Implementation of the IEA SHC & HPP T44/A38 Boundary Conditions in Matlab/Simulink with CARNOT-blockset

A Platform Independence Check for the IEA SHC Task 44 / HPP Annex 38 – Subtask C

Date: 15.01.2014

Andreas Peter, Christian Winteler & Ralf Dott

Institut Energie am Bau - Fachhochschule Nordwestschweiz, IEBau - FHNW,
St. Jakobsstrasse 84, CH-4132 Muttenz, Switzerland

Phone: +41 61 467 45 74
Fax: +41 61 467 45 43
e-mail: ralf.dott@fhnw.ch

Introduction

This technical report shows the different results from the implementation of the IEA SHC Task 44 / HPP Annex 38 (T44A38) boundary conditions in simulink with the Reference results from TRNSYS. The climates and space heat loads that were used for this platform independence check are:

Climate(s)	***Building(s)***
☒ Strasbourg	☒ SFH 15
☐ Helsinki	☒ SFH 45
☐ Athens	☒ SFH 100
☐ Davos	
☐ Montreal	

Carnot Version 6.0 and Matlab 2013b were used to obtain the results presented here. Be aware that other versions might yield different results.

Climate of Strasbourg

The reference climatic data for Strasbourg are directly imported into Simulink. Therefore the simulation results are exactly the same as the results from the TRNSYS reference. An output check has been done and is shown in Figure 1 to verify the correct implementation.

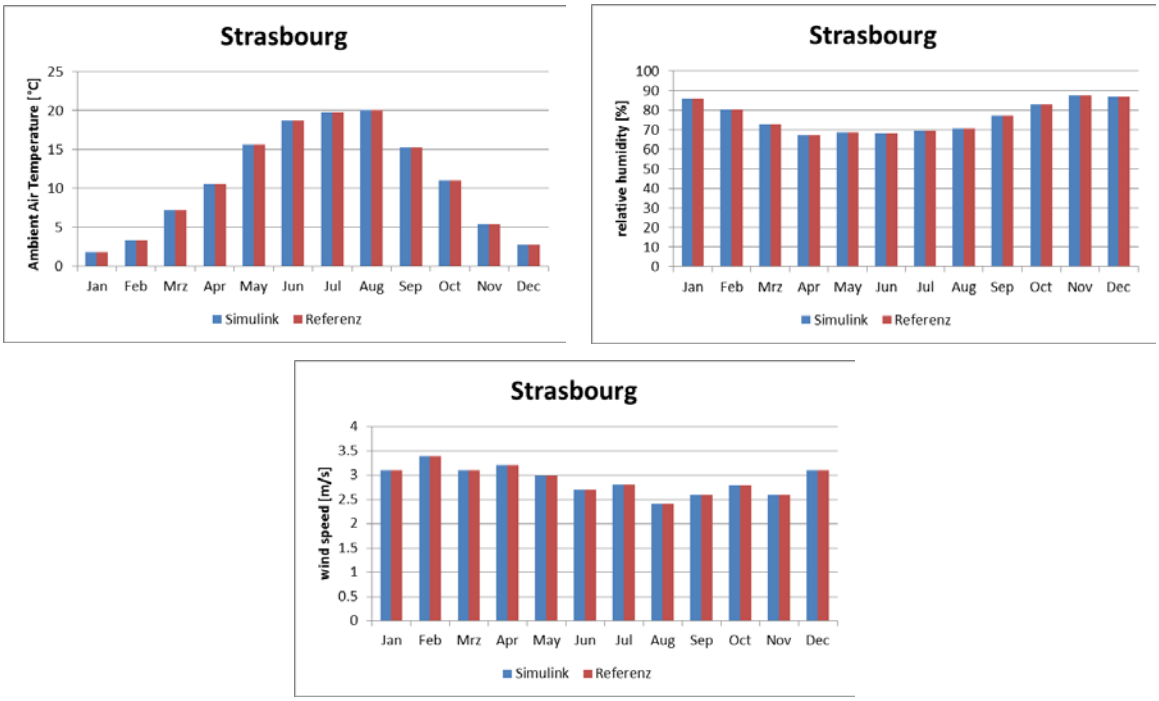
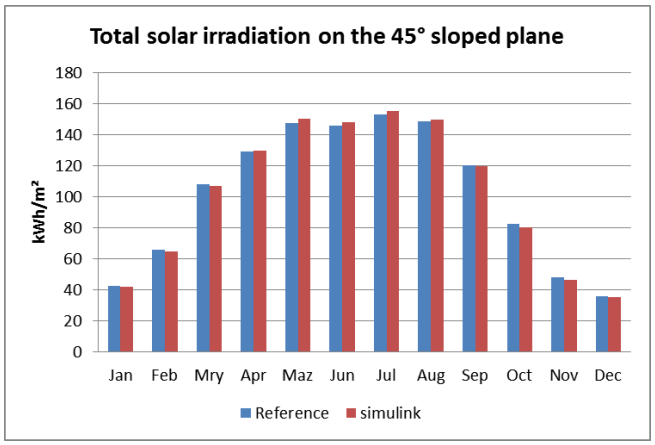
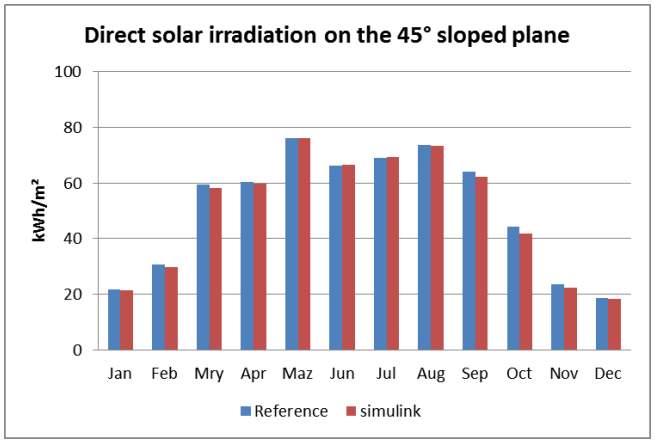


Figure 1: Comparison of the monthly average ambient air temperature, wind speed, and relative humidity for Strasbourg.

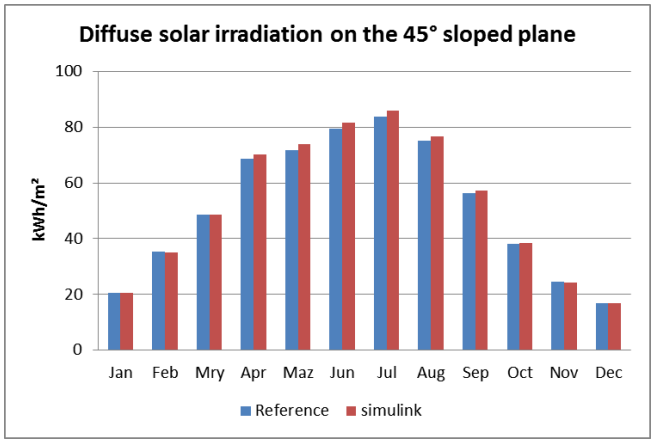
The solar irradiation on inclined surfaces is calculated by the simulation platform based on the climatic input data. Some minor differences are therefore possible as shown in Figure 2.



	Reference kWh/m²	*Simulink kwh/m²*	*Dev. kWh/m²*	*Dev. %*
Jan	42.5	42	-0.5	-1.1
Feb	66.1	64.9	-1.2	-1.9
Mry	108	106.9	-1.1	-1
Apr	129	129.9	0.9	0.7
Maz	147.7	150.1	2.4	1.6
Jun	145.7	148	2.3	1.6
Jul	152.8	155	2.2	1.5
Aug	148.8	150	1.2	0.8
Sep	120.4	119.5	-0.9	-0.7
Oct	82.4	80.2	-2.2	-2.6
Nov	48	46.6	-1.4	-2.9
Dec	35.7	35.1	-0.6	-1.6
SUM	1227.1	1228.2		



	Reference kWh/m²	*Simulink kwh/m²*	*Dev. kWh/m²*	*Dev. %*
Jan	21.9	21.4	-0.5	-2.2
Feb	30.6	29.7	-0.9	-3
Mry	59.5	58.1	-1.4	-2.3
Apr	60.2	59.9	-0.3	-0.6
Maz	76	76.2	0.2	0.3
Jun	66.3	66.5	0.2	0.3
Jul	68.9	69.1	0.2	0.4
Aug	73.7	73.3	-0.4	-0.6
Sep	64	62.3	-1.7	-2.7
Oct	44.2	41.9	-2.3	-5.1
Nov	23.6	22.4	-1.2	-4.9
Dec	18.8	18.3	-0.5	-2.6
SUM	607.7	599.2		

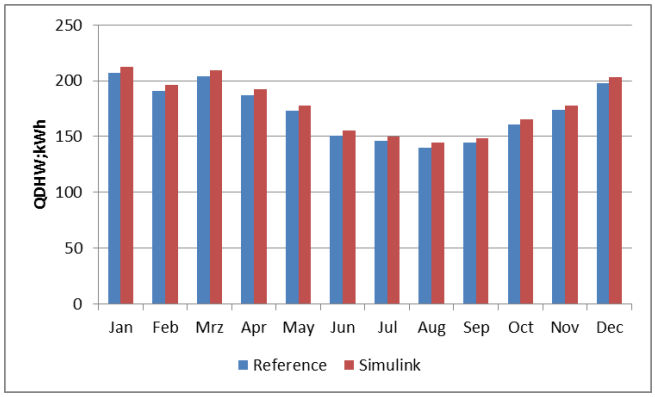


	Reference kWh/m²	*Simulink kwh/m²*	*Dev. kWh/m²*	*Dev. %*
Jan	20.6	20.6	0	0
Feb	35.5	35.2	-0.3	-0.9
Mry	48.5	48.8	0.3	0.5
Apr	68.8	70.1	1.3	1.8
Maz	71.7	73.9	2.2	3
Jun	79.4	81.5	2.1	2.7
Jul	83.9	85.9	2	2.4
Aug	75.1	76.7	1.6	2.1
Sep	56.4	57.2	0.8	1.5
Oct	38.2	38.3	0.1	0.2
Nov	24.4	24.1	-0.3	-1
Dec	16.9	16.8	-0.1	-0.4
SUM	619.4	629.1		

Figure 2: Comparison of the monthly and annual total, direct and diffuse solar irradiation on the 45° sloped southward facing plane and the percent deviation from the mean monthly value of the reference (right) for ***Strasbourg****.*

Domestic Hot Water Loads

The monthly domestic hot water loads is shown in Figure 3. The daily average hot water use is defined in TRNSYS with 140 L/d at 45°C.



	Reference kWh/m²	*Simulink kWh/m²*	*Dev. kWh/m²*	*Dev. %*
Jan	207	212.7	5.7	2.7
Feb	190.7	195.8	5.1	2.7
Mrz	204.1	209.6	5.5	2.7
Apr	187	192	5	2.7
May	172.8	177.4	4.6	2.7
Jun	151.1	155.1	4	2.7
Jul	145.9	149.8	3.9	2.7
Aug	140	144.6	4.6	3.3
Sep	144.3	148.2	3.9	2.7
Oct	160.9	165.2	4.3	2.7
Nov	173.9	177.8	3.9	2.2
Dec	197.9	203.2	5.3	2.7
SUM	2075.6	2131.7	56.1	2.7

*Figure 3: Comparison of the monthly domestic hot water load for **Strasbourg** and their percent deviation from the mean monthly value of the reference (right).*

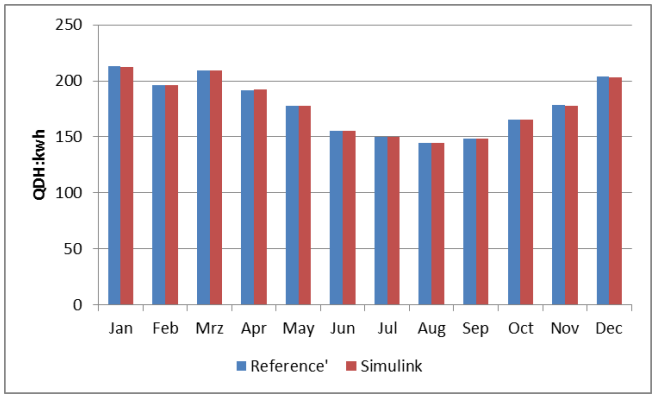
The sum for the Reference TRNSYS-simulation divided by the 365 days the simulation runs yields an average of 5.687 kWh/d while the written reference states an average daily DHW load of 5.845 kWh. The Simulink-simulation yields an average daily DHW load of 5.840 kWh and is thus much closer to the expected results from the reference which states that the average DHW load of a day is 5.845 kWh with a seasonal fluctuation modeled by

$$Q_{dhw,i} = Q_{dhw,loc}\left\{1 + \chi_{dhw,amp}\, COS\left(\frac{2\pi\left[\tau_i - \tau_{dhw,shift}\right]}{365d}\right)\right\}$$

With a modulation-amplitude $\chi_{dhw,amp} = 0.2$ for a 20% fluctuation of Heat demand over one year as specified in IEA SHC Task 4/ HPP Annex 38 Subtask C Report C1 Part A page 5.

The formula was implemented in an Excel-spreadsheet with timesteps equal to days and the first day set to Monday. Other starting days might yield different results since the number of Sundays in a given month might vary and Sundays have a bigger DHW load. The calculation yields a new reference, to which the simulink-implementation can be compared to as is shown in figure 4.

Figure 4 shows that the simulink values are much closer to the written reference than the implementation in TRNSYS with deviations in the magnitude of less than percent.

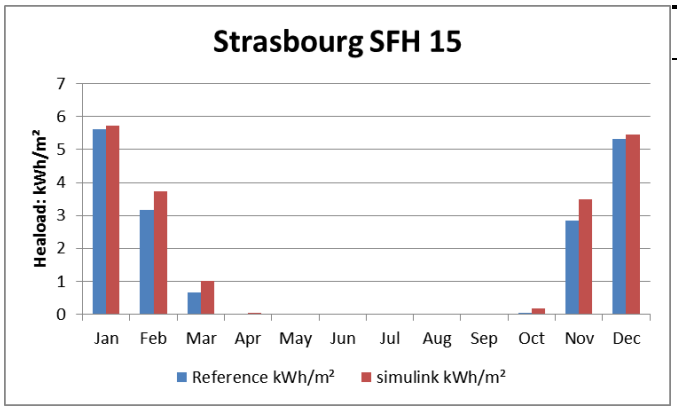


	Reference'	*Simulink*	*Dev. kWh*	*Dev. %*
Jan	212.9	212.7	-0.2	-0.1
Feb	195.9	195.8	-0.1	-0.1
Mrz	209.6	209.6	0	0
Apr	191.9	192	0.1	0.1
May	177.3	177.4	0.1	0.1
Jun	155.1	155.1	0	0
Jul	149.8	149.8	0	0
Aug	144.8	144.6	-0.2	-0.1
Sep	148.5	148.2	-0.3	-0.2
Oct	165.6	165.2	-0.4	-0.2
Nov	178.1	177.8	-0.3	-0.2
Dec	203.5	203.2	-0.3	-0.1
SUM	2133.1	2131.7	-1.4	-0.1

*Figure 4: Comparison of the monthly domestic hot water load for **Strasbourg** and their percent deviation from the mean monthly value of the calculated reference' (right).*

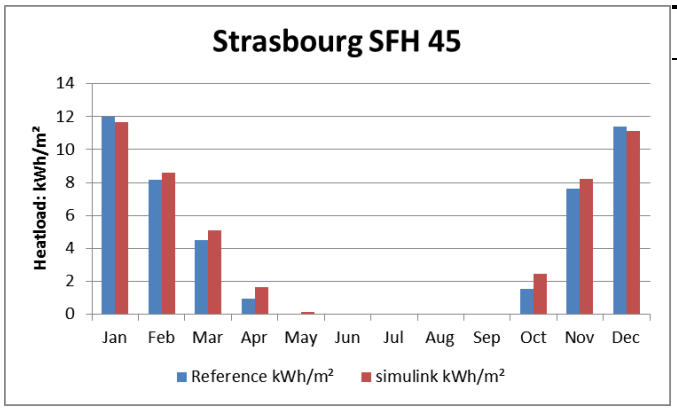
Monthly space heat loads

Next, the heatloads for the three reference buildings SFH 15,45 and 100 are shown for Strasbourg and divided into months.



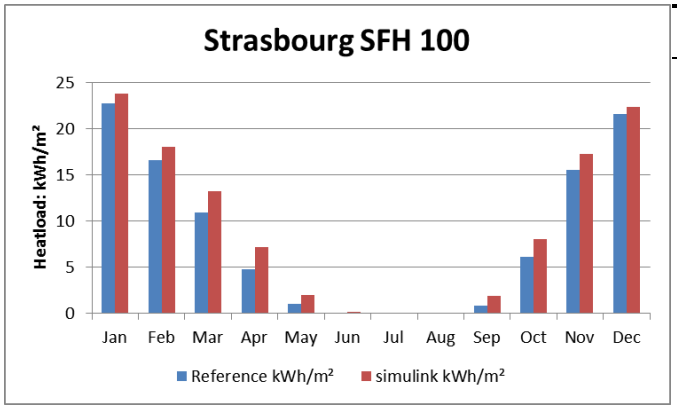
	Reference kWh/m²	*Simulink kWh/m²*	*Dev kWh/m2*	*Dev %*
Jan	5.6	5.7	0.1	1.8
Feb	3.2	3.7	0.6	17.8
Mar	0.7	1	0.3	50.7
Apr	0	0	0	0
May	0	0	0	0
Jun	0	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Oct	0	0.2	0.2	450
Nov	2.8	3.5	0.6	22.6
Dec	5.3	5.4	0.1	2.2
SUM	17.6	19.5		

Figure 5: The monthly space heat loads for SFH 15 in the simulink implementation and the TRNSYS reference and the percent deviation of simulink from the reference (table) in Strasbourg.



	Reference kWh/m²	*Simulink kWh/m²*	*Dev kWh/m2*	*Dev %*
Jan	12	11.6	-0.3	-2.9
Feb	8.2	8.6	0.4	4.8
Mar	4.5	5.1	0.6	12.5
Apr	1	1.6	0.7	69.9
May	0	0.1	0.1	
Jun	0	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Oct	1.6	2.5	0.9	59
Nov	7.6	8.2	0.6	8.1
Dec	11.4	11.1	-0.3	-2.4
SUM	46.3	48.8		

Figure 6: The monthly space heat loads for SFH 45 in the simulink implementation and the TRNSYS reference and the percent deviation of simulink from the reference (table) in Strasbourg.



	Reference kWh/m²	*Simulink kWh/m²*	*Dev kWh/m2*	*Dev %*
Jan	22.8	23.8	1	4.3
Feb	16.6	18	1.4	8.2
Mar	10.9	13.2	2.3	20.6
Apr	4.8	7.2	2.4	0
May	1	2	1.1	
Jun	0	0.2	0.1	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0.8	1.9	1.1	0
Oct	6.1	8	1.9	30.9
Nov	15.5	17.3	1.8	11.3
Dec	21.6	22.4	0.8	3.8
SUM	100.1	114		

Figure 7: The monthly space heat loads for SFH 100 in the simulink implementation and the TRNSYS reference and the percent deviation of simulink from the reference (table) in Strasbourg.

Figure 8 shows the annual cumulated energy vs. temperature of the flow and return temperatures of the heating system, for the three different buildings in Strasbourg.

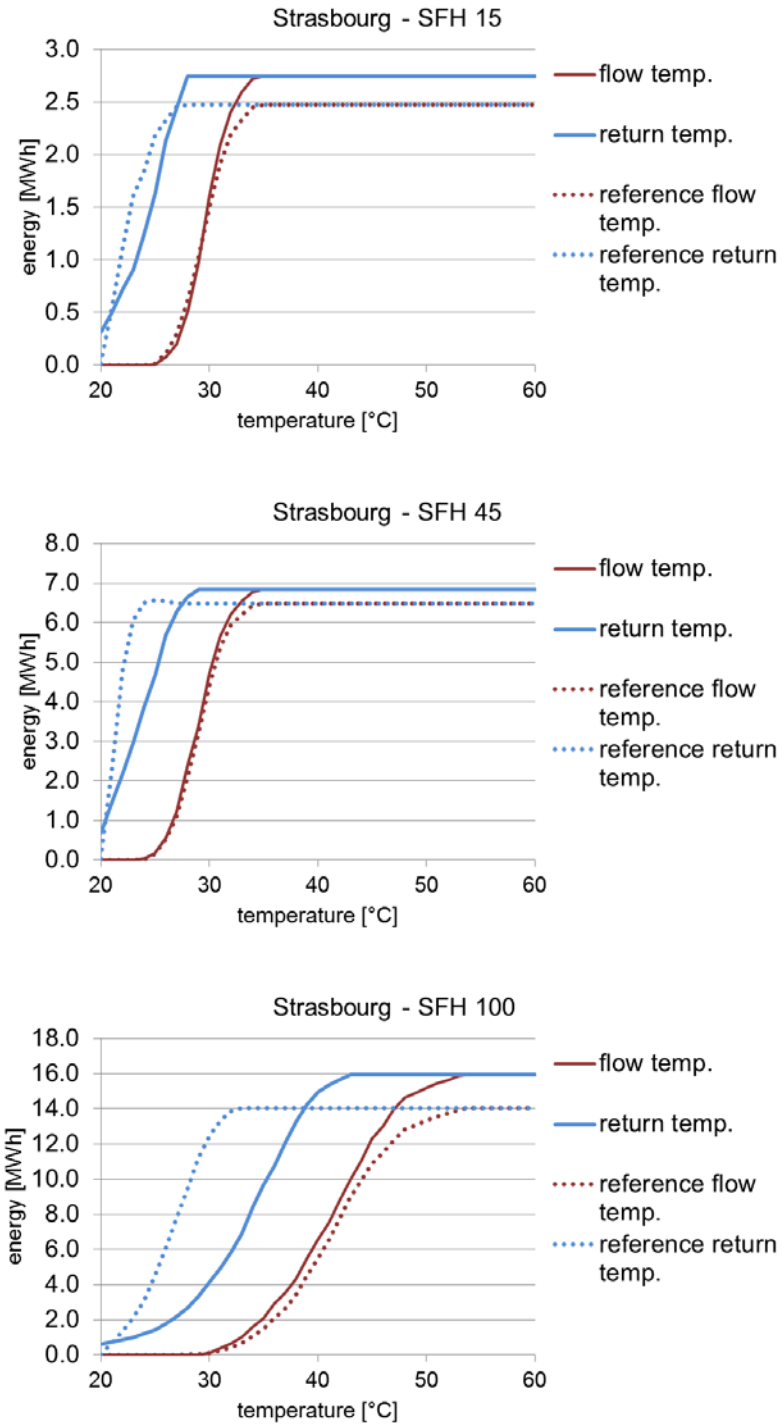


Figure 8: Annual cumulated energy vs. temperature of the flow and return line of the space heat distribution, SFH45 with the three different heating systems a b and c in Strasbourg.