

# Sustainable Building and Systems Modeling

## *Improvement of Building Performance by HAMBase Simulink*

Commissioned by:



University of Technology, Eindhoven  
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## TABLE OF CONTENTS

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<b>1. INTRODUCTION .....</b>	<b>3</b>
1.1 OBJECTIVES .....	3
1.2 METHODOLOGY .....	3
<b>2. CURRENT SITUATION.....</b>	<b>4</b>
2.1 GENERAL PARAMETERS.....	4
2.2 BUILDING SERVICES.....	4
2.3 ENERGY DEMAND .....	4
<b>3. BUILDING SYSTEM IMPROVEMENTS.....</b>	<b>6</b>
3.1 MODEL DESCRIPTION .....	6
3.1.1 <i>Air-to-water heat pump</i> .....	6
3.1.2 <i>PV panel</i> .....	7
3.2 SYSTEM CONTROL .....	7
<b>4. RESULTS .....</b>	<b>8</b>
4.1 TEMPERATURE SIMULATION .....	8
4.2 OPTIMIZATION ENERGY GENERATION PV PANEL.....	8
4.3 ENERGY SAVINGS .....	9
<b>5. CONCLUSION / DISCUSSION .....</b>	<b>9</b>
<b>6. APPENDICES .....</b>	<b>10</b>
APPENDIX A HAMBASE MODEL INPUT PARAMETERS .....	10
APPENDIX B CUMULATIVE ENERGY USE AND GENERATION .....	11
APPENDIX C MATLAB/SIMULINK FILES .....	12

# 1. Introduction

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In this case study, the HamBase model is built from scratch. This study is based on an existing building of a plumber company including its actual systems. The building consists of three zones:

- The office;
- The canteen;
- The workplace.

The study consists of two parts on the modeling and simulation of the energy usage, namely of the existing situation and of a new situation where improved and sustainable integrated measures for the building and systems are applied.

## 1.1 Objectives

The main objectives of this case study are:

- Modelling and simulation of the energy usage of an existing building;
- Integrating improved and sustainable measures for the building and systems;
- Gain knowledge about modelling a building in HAMBase in combination with Simulink.

## 1.2 Methodology

HAMBase is used for the simulation and optimization of the building of the plumber company. The HAMBase file includes all the building physical details, like the insulation values and the dimensions. Using Matlab / Simulink, the current system is modeled to compare the results of the energy demand with the literature and actual usage. This comparison is to validate and to adjust the model when necessary.

For the sustainable measures, the trias energetica is used. As a new sustainable measure for the building system, a heat pump in combination with PV panels is proposed. The system is further optimized by using a more intelligent control system instead of the on/off control.

The energy use after the optimization is compared with the energy use of the current systems to determine the amount of energy saved.

The report ends with a conclusion and a discussion which assesses the performances on reliability and usability.

## 2. Current situation

### 2.1 General parameters

The building used for the simulation is the premises of a plumber, consisting of three zones; an office, a canteen and a workplace. The model consists of only a ground floor, with no floors on it and a flat roof. The height of the exterior of the building is 3.500 mm. All windows are assumed to have a height of 1.200 mm.

A ground plan of the building is shown in Figure 2.1.

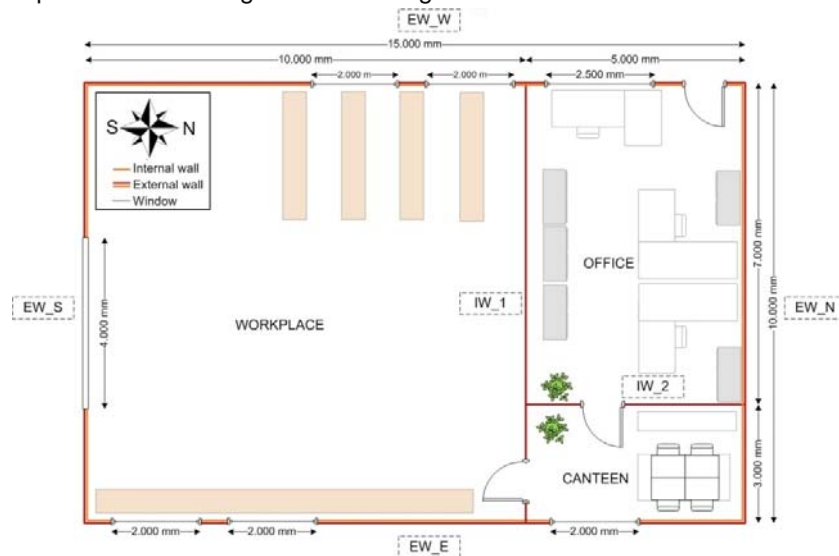


Figure 2.1 Ground plan of the simulated building

The overhead door in the south façade is assumed to have the same properties as the external south wall. The properties of the building and the construction are shown in Table 1 and Table 2 in appendix A.

### 2.2 Building services

In the current situation the office and canteen zone are heated by a boiler and cooled by air-conditioning. The workplace is only heated by the boiler. The installation is schematically shown in Figure 2.2.

The temperature of the office and canteen zone is kept between 20 and 23 °C. The workplace is not cooled, but is set at a minimum temperature of 15 °C.

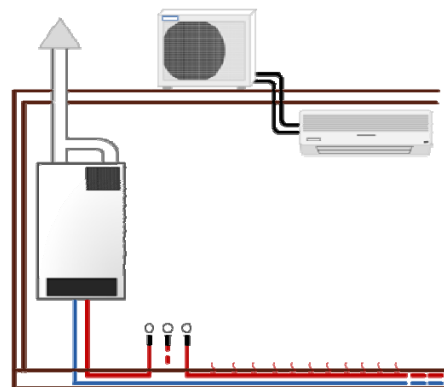


Figure 2.2 Schematic presentation of the current building services of the simulated building

### 2.3 Energy demand

The results of the simulation are compared with the energy demand calculated by literature and with the real data provided by the company.

The simulated energy demand by HAMBBase Simulink is 2.094 m<sup>3</sup> of gas for heating. The energy needed for cooling is 847 kWh. The cooling load is relatively small compared to the

heating load, because of the north facing orientation of the office and canteen. The profile of the heating and cooling load is shown in Figure 2.3.

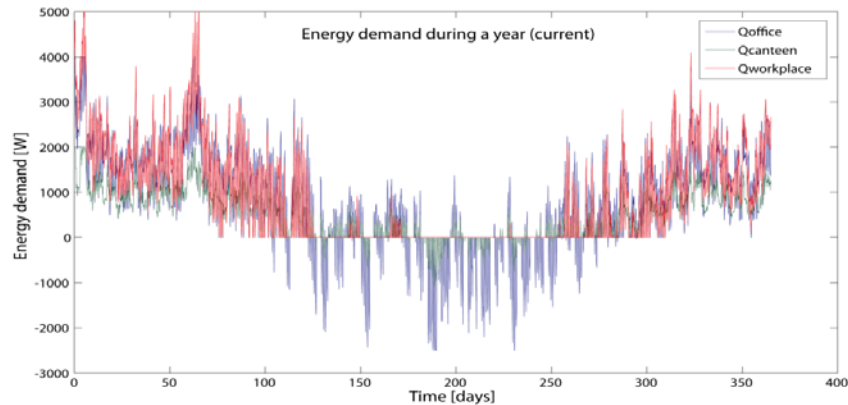


Figure 2.3 Energy demand during a year for the three zones

The energy demand by literature is calculated by multiplying the area of the office by normalized gas consumption. This is  $20 \text{ m}^3/(\text{m}^2 \text{ yr})$  for the office and the canteen and assumed to be  $10 \text{ m}^3/(\text{m}^2 \text{ yr})$  for the workplace [1]. The consumption is multiplied by  $35 \text{ MJ/m}^3$ . The cooling demand of an office is  $26.5 \text{ kWh}/(\text{m}^2 \text{ yr})$  [2]. This results in a cooling demand of  $1.325 \text{ kWh}$  per year. For the year 2009 and 2010 the plumber company had an average gas consumption of  $1.700 \text{ m}^3/\text{yr}$  and an indicated cooling demand of  $1.400 \text{ kWh/yr}$ .

The results of the heating and cooling load of the simulation by HAMBase Simulink, the literature and real data are shown in Figure 2.4.

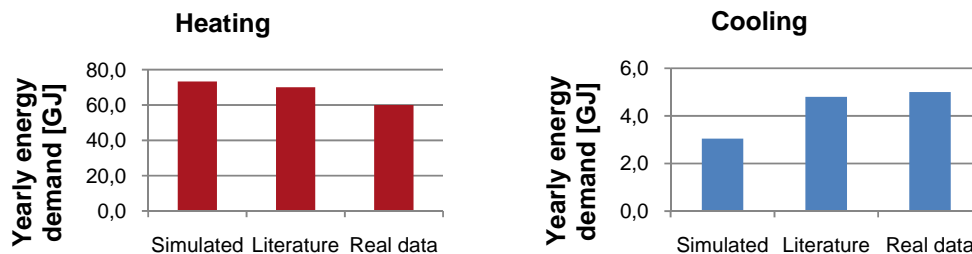


Figure 2.4 Yearly heating and cooling demand of the simulated building compared with data by literature and real data

The real heating demand is lower than given by the literature and the result of the simulation. There are several explanations for this difference:

- The plumber company uses a intelligent thermostat instead of an on/off controller as applied in the simulation, which reduces the energy heating demand;
- In the simulation the minimum temperature of the workplace was set to  $15^\circ\text{C}$ . This is probably lower in reality.

<sup>1</sup> Buitenhuis, H., Drissen, R., DWA installatie- en energieadvies; 'Installatieoptimalisatie Academie voor Engineering', VV+ maart 2007, 180-183

<sup>2</sup> Broekhuizen, H.J.; 'Optimale prijs/prestatie energie-opslagsystemen', TVVL 10, 30-34

### 3. Building system improvements

The improvements are based on the trias Energetic as shown in Figure 3.1; a concept with which the sequence of three steps towards the most sustainable energy is identified. Because of the relatively small energy demand for cooling compared to the heating demand (ca. 5 a 6%), the focus of the model improvement will be on the heating demand.

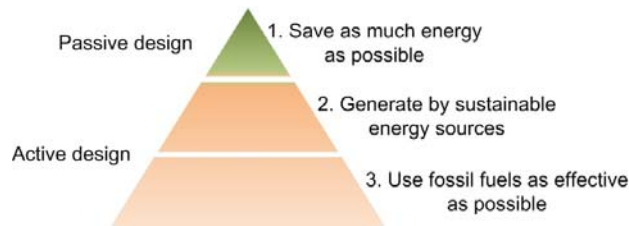


Figure 3.1 The three steps of the trias energetique

The applied measures according to the trias energetique:

1. Adjustments of the passive design:
  - Apply double glazing instead of single glazing in the workplace;
  - Insulate the internal wall between the workplace and office / canteen;
2. Electrical energy will be generated by PV panels on the roof of the building, which make use of a sustainable energy source: the sun.
3. Heating is generated by an air-to-water heat pump instead of the central boiler.

#### 3.1 Model description

The proposed improvements will be modeled to determine the new primary energy demand needed for building systems. The sustainable improvements are schematically shown in Figure 3.2.

##### 3.1.1 Air-to-water heat pump

The air-to-water heat pump will be used for space heating by diverting heat from the outside air (source) at a lower temperature to a higher temperature by adding mechanical work. The model consists of a mass flow/temperature based system with a dynamic Coefficient of Performance (COP). The COP value depends on the external air temperature and the condenser outflow temperature. The heat capacity of air ( $\sim 1000\text{J/kgK}$ ) is different from the heat capacity of water ( $\sim 4200\text{J/kgK}$ ). For this reason, the mass flow on the evaporative side will be much higher to provide enough energy for space heating. The simplified model description is shown below:

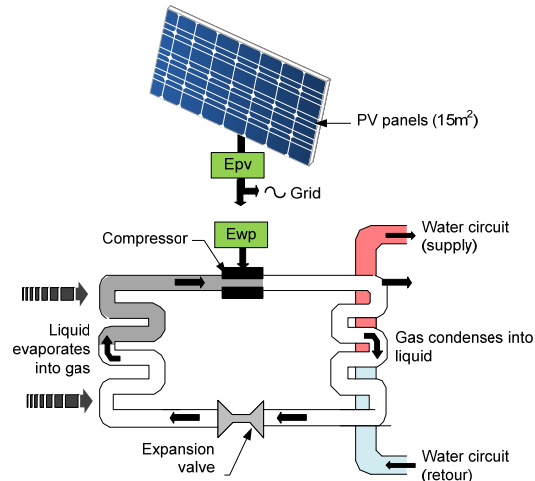


Figure 3.2 Schematic overview of sustainable building systems: Air-to-water heat pump and PV-panel.

- **Coefficient of Performance**

$$COP_c = \frac{(T_{c,out} + 273.15)}{T_{c,out} - T_{e,out}}$$

$$\eta_c = 0.4 \text{ (for air)}$$

$$COP = \eta_c * COP_c$$

- **Heat flows**

$$q_c = COP * E_{wp} \text{ [W]}$$

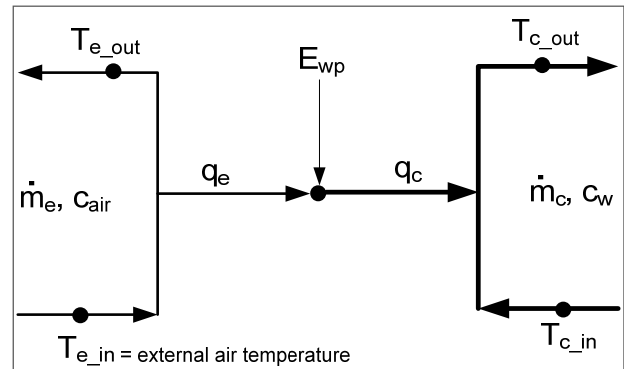
$$q_e = q_c - E_{wp} = (COP - 1) * E_{wp} \text{ [W]}$$

- **Outflow temperatures**

$$C \frac{dT_{c,out}}{dt} = \dot{m}_c * c_w * (T_{c,in} - T_{c,out}) + q_c \text{ [W]}$$

$$C \frac{dT_{e,out}}{dt} = \dot{m}_e * c_{air} * (T_{e,in} - T_{e,out}) - q_e \text{ [W]}$$

For a complete description of the air-to-water heat pump model parameters, the s-function is included in appendix C.



### 3.1.2 PV panel

PV panels are placed on the roof of the company for the generation of electrical energy for the heat pump. The panels are south oriented with an inclination of 35° and a total area of 15 m<sup>2</sup>. The electrical output of the panels depends on the solar irradiation (diffuse and direct) and of the temperature of the panels. It is assumed that the temperature of the cells in the panel is equal to the surface temperature of the panel. Figure 3.3 schematically shows how this surface temperature is determined.

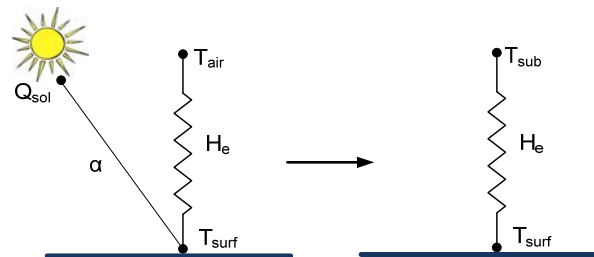


Figure 3.3 Schematic view of the calculation of the surface temperature of the PV panel

With the calculated surface temperature, the efficiency of the cells can be determined. It is assumed that there is a linear relationship between the cell temperature and the efficiency. The maximum efficiency is 20% at a surface temperature of -20°C and an efficiency of 15% at 80°C. The power output of the panels is determined by the scheme of Figure 3.4. The formula describes the efficiency of the cell depending on the surface temperature.

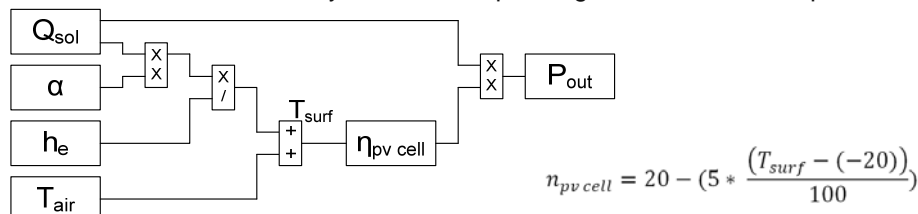


Figure 3.4 Calculation relationships to determine the power output of the solar panels

## 3.2 System control

The heating system is in the improved model controlled by a proportional controller instead of an on/off controller. The proportional relation for the office and canteen zone is shown in Figure 3.6.

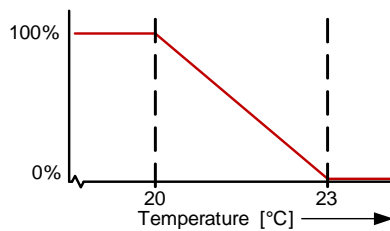


Figure 3.6 Heating power proportional determined by the inside temperature (as applied for the office and canteen)

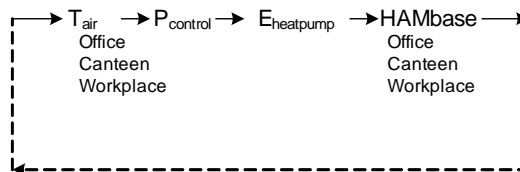


Figure 3.5 Schematic control loop for the heating system of the three zones in the HAMbase model

Figure 3.5 shows the control loop of the heating system of the HAMbase model. Based on the temperature ( $T_{air}$ ) in the different zones, the heating demand is determined by the proportional controller ( $P_{control}$ ). The controller sets the amount of electrical power ( $E_{heatpump}$ ) for the heat pump by summing up the request of the zones, because there is one heat pump for all the zones. The controller then divides the generated heat of the heat pump over the several zones in the HAMbase model (HAMbase).

## 4. Results

### 4.1 Temperature simulation

The temperature is simulated for the three zones to look whether the new sustainable system and the proportional control operate as intended, shown in Figure 4.1. At the time of ca.  $2.2 \times 10^4$  sec it is clear that the capacity of the system is insufficient. For the rest of the year the temperature of the workplace is above the  $15^\circ\text{C}$  as intended.

The air temperature of the office and canteen are above the  $20^\circ\text{C}$ , but does not stay below the maximum of  $23^\circ\text{C}$ . This is because there no cooling is applied in the improved model.

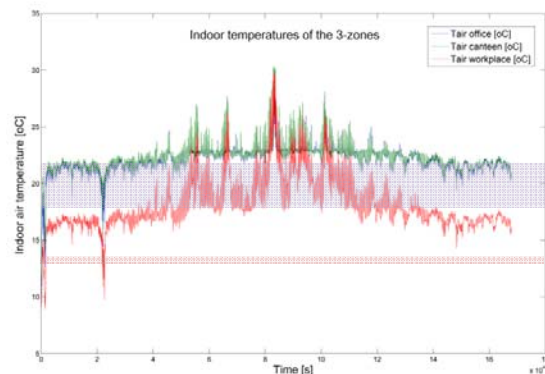


Figure 4.1 Simulated inside temperature during the year for the three zones

### 4.2 Optimization energy generation PV panel

The energy generation of the PV panel depends on the solar irradiation and the efficiency of the PV cell. As mentioned before, the efficiency is determined by the temperature of the solar cell. The solar irradiation varies during the year and is influenced by the inclination and azimuth.

Due to the simulation time, only the month July is simulated. For the month July, a south-east optimization with an inclination of  $20^\circ$  will generate the most energy (See Figure). However, over the whole year these results will not be valid because of different solar heights.

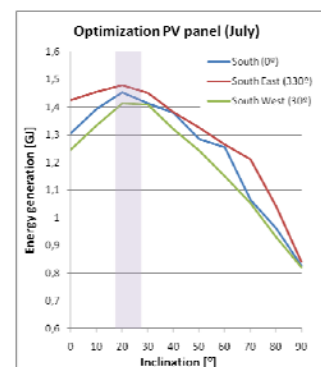


Figure 4.2 Energy generation of PV panel by orientation and inclination



### 4.3 Energy savings

The total energy demand of the system is determined for the current situation and after application of the sustainable measures. The decrease of the energy demand of the improved system is ca. 56%, as can be derived from Figure 4.4. However, it is interesting to look at the primary energy needed. For the actual system, the boiler, the primary energy demand is equal to the energy demand of the building system. The primary energy demand of the improved system depends of the efficiency of the power plant and the energy transport. An efficiency of 44% is assumed. Considered that a part of the energy is generated by PV panels, this energy does not have to be taken into account (equation 4.1).

$$Q_{\text{primair HP}} = \frac{E_{\text{HP}} - E_{\text{PV}}}{\eta_{\text{electric}}} = \frac{32.23 - 10.28}{0.44} \approx 50 \text{ GJ} \quad [4.1]$$

The primary energy usage of the building systems are shown in Figure 4.3. The decrease of the energy demand is ca. **32%**. The cumulative electrical energy usage of the heat pump and the generation of the pv panels is shown in Figure 6.1 in appendix B.

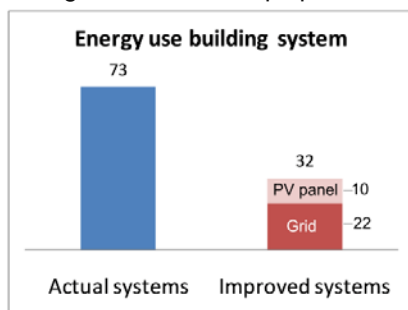


Figure 4.4 Building system energy demand [GJ] per year for the heating demand of the 3 zones

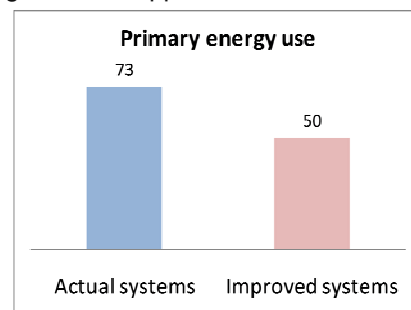


Figure 4.3 Primary energy demand [GJ] per year for the heating demand of the 3 zones

## 5. Conclusion / Discussion

From this research it can be concluded that:

- After the application of the sustainable measures, the primary energy demand of the building decreases with ca. 32%;
- The optimal orientation of the PV panel for the month July is south-east with an inclination of 20°. For the whole year an optimal inclination of 35° is assumed;
- With the appliance of the sustainable measures, the system operates as intended within the set temperature band;
- Since the results match with the real data and literature, the HAMbase model with Simulink can be applied to model and compare several options for sustainable measures.

Discussion:

- The optimized control is based on a P-controller. Using a PI-controller could lead to better results regarding the temperature fluctuations (and energy use);
- In the Simulink model no profiles are applied. E.g. allowing lower temperature during the weekend could lead to a decreasing energy usage;
- The efficiency of the PV panel is based on a simplified model. A more precise model could lead to different results, although this would not lead to significant differences;
- The capacity of the system is not sufficient enough to keep the temperature above the minimal desired temperature during the extreme cold period. Higher capacity would probably result in more energy demand.

## 6. Appendices

### Appendix A HAMbase model input parameters

Description	Unit	Value	Comments
<b>Volume office {1}</b>	[m <sup>3</sup> ]	123	
Heat gain 2 persons	[W]	300	Office work
Heat gain 2 computers	[W]	1000	
Lighting, etc.	[W]	600	
Moisture production 2 persons	[kg/s]	5,5E-05	Office work
Moisture production plant	[kg/s]	5,8E-06	
<b>Volume canteen {2}</b>	[m <sup>3</sup> ]	53	
Internal heat gain	[W]	250	
Moisture production plant	[kg/s]	5,8E-06	
<b>Volume workplace {3}</b>	[m <sup>3</sup> ]	350	
Heat gain 1 person	[W]	200	Physical work
Moisture production 1 person	[kg/s]	8,0E-05	Physical work

Table 1 Properties for the three different zones of the model

Description	Unit	Value	Comments
<b>External wall north [EW_N]</b>	[m <sup>2</sup> ]	35,0	Limestone, insulation, air gap, brick
Glazing	[m <sup>2</sup> ]	7,5	HR+ glass double glazing
Orientation		[90, 180]	
<b>External wall east [EW_E]</b>	[m <sup>2</sup> ]	52,5	Limestone, insulation, air gap, brick
Glazing canteen	[m <sup>2</sup> ]	2,4	HR+ glass double glazing
Glazing workplace	[m <sup>2</sup> ]	4,8	Single glazing
Orientation		[90, 270]	
<b>External wall south [EW_S]</b>	[m <sup>2</sup> ]	35,0	Limestone, insulation, air gap, brick
Orientation		[90, 0]	
<b>External wall west [EW_W]</b>	[m <sup>2</sup> ]	52,5	Limestone, insulation, air gap, brick
Glazing office	[m <sup>2</sup> ]	3,0	HR+ glass
Glazing workplace	[m <sup>2</sup> ]	4,8	Single glazing
Orientation		[90, 90]	
<b>Internal wall 1 [IW_1]</b>	[m <sup>2</sup> ]	35,0	Plaster, insulation, plaster
Orientation		[90, 0]	
<b>Internal wall 2 [IW_2]</b>	[m <sup>2</sup> ]	17,5	Plaster, insulation, plaster
Orientation		[90, 90]	
<b>Floor construction</b>	[m <sup>2</sup> ]	150,0	Covering, concrete (adiabatic)
Orientation		[0, 0]	
<b>Roof construction</b>	[m <sup>2</sup> ]	150,0	Plaster, air gap, concrete, insulation, PVC
Orientation		[0, 0]	

Table 2 Properties of the construction of the modeled building

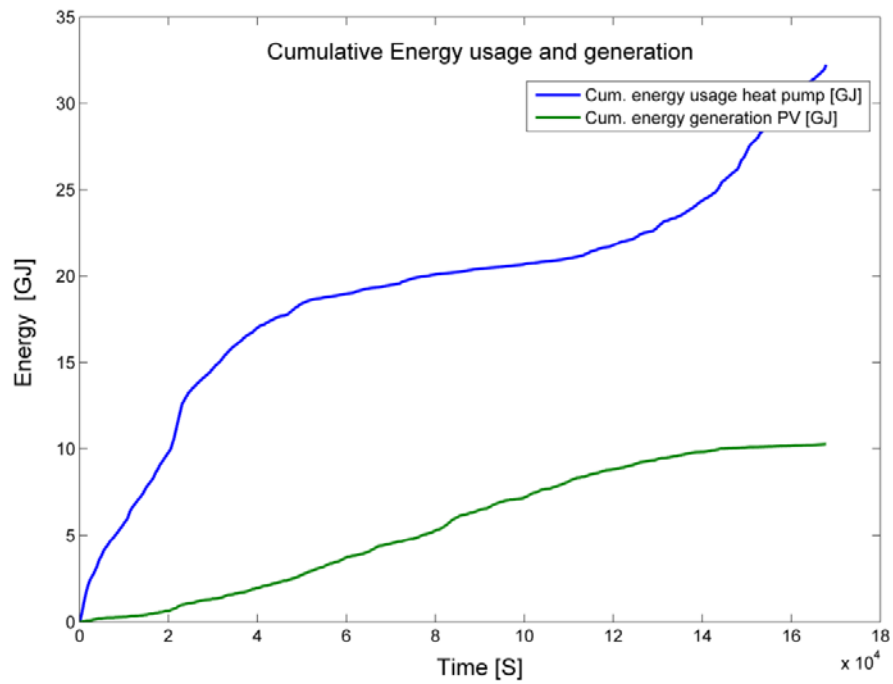
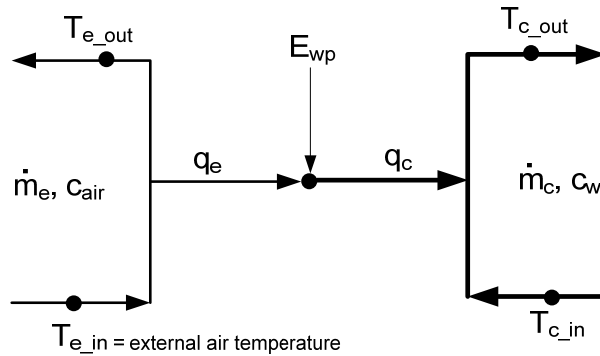
**Appendix B Cumulative energy usage and generation**

Figure 6.1 Cumulative electrical energy usage of the heat pump and generation of the PV panels [GJ]

## Appendix C Matlab/Simulink files

### Air-to-water heat pump model (heatpump.m)



```
function [sys,x0,str,ts] = heatpump(t,x,u,flag)
%Case study (7Y700)
%
%DV/RM 2011/June
%
%input u; output y
%u(1)=Ewp (electricity) [W]
%u(2)=mc (mass flow condensor) [kg/s]
%u(3)=Tc_in (temperature Condensor in) [oC]
%u(4)=me (mass flow evaporator)[kg/s]
%u(5)=Te_in

%y(1)=x(1)=Te_out [oC]
%y(2)=x(2)=Tc_out [oC]
%y(3)=COP [-]
%y(4)=Qcond [W]

switch flag,

    %%%%%%%%%%%%%%%
    % Initialization %
    %%%%%%%%%%%%%%%
    case 0,
        [sys,x0,str,ts]=mdlInitializeSizes;

    %%%%%%%%%%%%%%%
    % Derivatives %
    %%%%%%%%%%%%%%%
    case 1,
        sys=mdlDerivatives(t,x,u);

    %%%%%%%%%%%%%%%
    % Outputs %
    %%%%%%%%%%%%%%%
    case 3,
        sys=mdlOutputs(t,x,u);

    %%%%%%%%%%%%%%%
    % Unhandled flags %
    %%%%%%%%%%%%%%%
    case { 2, 4, 9 },
        sys = [];

    %%%%%%%%%%%%%%%
    % Unexpected flags %
    %%%%%%%%%%%%%%%
    otherwise
```

```

        error(['Unhandled flag = ',num2str(flag)]);

end
% end wpfun1

%
%=====
% mdlInitializeSizes
% Return the sizes, initial conditions, and sample times for the S-function.
%=====
%
function [sys,x0,str,ts]=mdlInitializeSizes

sizes = simsizes;
sizes.NumContStates = 2;
sizes.NumDiscStates = 0;
sizes.NumOutputs = 4;
sizes.NumInputs = 5;
sizes.DirFeedthrough = 1;
sizes.NumSampleTimes = 1;

sys = simsizes(sizes);
x0 = [10; 30];
str = [];
ts = [0 0];

% end mdlInitializeSizes
%
%=====
% mdlDerivatives
% Return the derivatives for the continuous states.
%=====
%
function sys=mdlDerivatives(t,x,u)

% input
Ewp=u(1); %W, electricity in
mc=u(2); %kg/s, mass flow condensor
Tc_in=u(3); %oC, temperature condensor in
me=u(4); %kg/s, mass flow evaporator
Te_in=u(5); %oC, temperature evaporator in

% modelparameters
cair=1000; %[J/kgK], heat capacity air
cw=4200; %[J/kgK], heat capacity water
C=100000; %[J/K], Capacity
Ce=C;
Cc=C;

% COP
COPc=(x(2)+273.15)./(x(2)-x(1)); %[-], coefficient of performance carnot
n=0.4; %[-], efficiency air/water heat pump
COP=n*COPc; %[-], real COP

% Heat flows
Qe=(COP-1)*Ewp; %[W], heat flow evaporator
Qc=COP*Ewp; %[W], heat flow condensor

% ODE's;
xdot(1)=( (me*cair*(Te_in-x(1))) - Qe) / Ce;
xdot(2)=( (mc*cw*(Tc_in-x(2))) + Qc) / Cc;

sys = [xdot(1); xdot(2)];

% end mdlDerivatives
%
%=====
% mdlOutputs
% Return the block outputs.
%=====

```

```
%  
function sys=mdlOutputs(t,x,u)  
Te_out=x(1);  %[oC], temperature evaporator out  
Tc_out=x(2);  %[oC], temperature condensor out  
  
% COP calculation  
COPc=(x(2)+273.15)./(x(2)-x(1));  %[-], coefficient of performance  
n=0.4;  %[-], efficiency air-to-water heat pump  
COP=n*COPc;  %[-], real COP  
  
% heatflow condensor  
cw=4200;  %[J/kgK], heat capacity water  
Qcond=u(2)*cw*(x(2)-u(3));  %[W]  
  
sys = [Te_out; Tc_out; COP; Qcond];  
  
% end mdlOutputs
```

**HAMBase file (casestudysim2.m)**

```

% CASE STUDY H.N.MAAIJEN & D.R. VISSERS - Building of a plumber
% -----
%           HAMBASE
%
% HEAT And Moisture Building And Systems Evaluation
% -----
%
% -----
% PART 1 : THE CALCULATION PERIOD
% -----

% The available climate data of De Bilt are of the years 1971 till 2000.
% FORMAT BAS.Period=[yr,month,day,ndays]
%
BAS.Period=[1971,1,1,364];

% If BAS.DSTime=1 the EU daylight-savings time is taken into account. It starts on the
% last Sunday of March and ends on the the last Sunday of October (the total
% duration is 30 or 31 weeks). If there is no daylight-savings period BAS.DSTime=0
% If the daylight-savings period is different from the EU the starting and ending days
% must be given:
% BAS.DSTime(1,:)=[year,starting month,day,ending month,day];
% BAS.DSTime(2,:)=[year+1,starting month,day,ending month,day]; etc.

%BAS.DSTime(1,:)=[1987,4,28,4,29];
%BAS.DSTime(2,:)=[1988,4,3,4,3];
BAS.DSTime=1;

% -----
% PART 2 : THE BUILDING
% -----
%
% FORMAT BAS.Vol{zonenumber}=volume (m3);
BAS.Vol{1}= 123;    %Office zone
BAS.Vol{2}= 53;    %Canteen zone
BAS.Vol{3}= 350;   %Workplace zone

% ** CONSTRUCTION COMPONENTS DATA **
%
% FORMAT BAS.Con{conID}=[Ri,d1,matID,...,dn,matID,Re,ab,eb].
% dn    = material layer thickness [m]
% matn  = material ID-number.
% Ri    = internal surface heat transfer resistance (for example Ri=0.13) [Km2/W]
% Re    = surface heat transfer resistance at the opposite site (for example Re=0.04) [Km2/W]
% ab    = external solar radiation absorption coefficient [-] e.g.light ab=0.4, dark ab=0.9.
% eb    = external longwave emmissivity [-]. Almost always: eb=0.9

% BAS.Con{conID}=[Ri, d1,matID,..., dn,matID, Re,
ab, eb].
BAS.Con{1} = [0.13,    0.214,235,  0.120,409,  0.050,003,  0.100,234,    0.04,
0.9,    0.9];
BAS.Con{2} = [0.13,    0.013,381,  0.074,409,  0.013,381,    0.13,
0.5,    0.9];
BAS.Con{6} = [0.13,    0.020,512,  0.240,002,  0.370,316,  0.200,453,0.005,601,  0.04,
0.8,    0.9];

% Comments
% 1: limestone,insulation,air gap,brick (external wall)
% 2: plaster,insulation,plaster (internal wall)
% 6: roof construction

% ** GLAZING SYSTEMS DATA**
%
% FORMAT BAS.Glas{glaID}=[Uglas,CFr,ZTA,ZTAw,CFrw,Uglasw]
%
% Uglas = U-value without sunblinds [W/m2K]
% CFr   = convection factor without blinds [-]

```

```

% ZTA = Solar gain factor [-] without blinds
% ZTAw = Solar gain factor [-] with blinds
% CFW = convection factor with blinds [-]
% Uglasw = U-value with blinds [W/m2K]
%
%BAS.Glas{glaID}=[Uglas, CFW, ZTA, ZTAw, CFW, Uglasw]
BAS.Glas{1}=[1.309, 0.047, 0.308, 0.072, 0.116, 1.253];
BAS.Glas{2}=[5.7, 0.01, 0.80, 0.31, 0.34, 5.7];
BAS.Glas{3}=[4, 0.03, 0.78, 0.78, 0.03, 4];
BAS.Glas{4}=[1.4, 0.03, 0.65, 0.3, 0.4, 1.4];

% Comments
% Glazing 1 saint-roch skn 165
% Glazing 2 single glazing with interior sunblinds
% Glazing 3 double glazing with interior sunblinds
% Glazing 4 HR glazing with interior sunblinds

% ** ORIENTATIONS **
%
% For each surface of the building envelope (exterior walls) the tilt and the
% orientation with respect to the south has to be known. Each different
% orientation gets a different orientation-ID-number: orID.
%
% FORMAT BAS.Or{orID}=[beta gamma]
% beta = tilt (vertical=90, horizontal=0)
% gamma = azimuth (east=-90, west=90, south=0, north=180)
%
%BAS.Or{orID}=[beta, gamma];
BAS.Or{1}=[90.0, 135.0]; % west wall EW_W
BAS.Or{2}=[90.0, -45.0]; % north wall EW_N
BAS.Or{3}=[90.0, 135.0]; % east wall EW_E
BAS.Or{4}=[90.0, 0.0]; % south wall EW_S
BAS.Or{5}=[0.0, 0.0]; % horizontal roof

% **SHADOWING DATA**
%
BAS.shad{1}=[
1 0.07 5 1.6 0 0.5000 0.7 3;...
2 0.1 5.1 3.0000 17.00 0.0000 0 0;...
2 17.00 0.1 3.0000 0 5.1000 0 0;...
2 17.00 0.1 2.0000 0 0.0000 0 0;...
2 0.5 24.00 9.2000 34.10 -9.0000 0 0;...
3 1.25 1.25/7 2.75 15.50 0.0 0 0;...
3 1.50 1.50/7 1.50 12.70 1.50 0 0;...
4 0 10 20 30 50 60 90;...
5 1 0.9 0.8 0.7 0.6 0.5 0.4];

BAS.shad{2}=[
4 20 30 40 50 60 70 80 ;...
5 787/789 784/789 775/789 754/789 700/789 563/789 302/789];

% Changing below '0' into '1' below, gives a drawing of the
% obstacle geometry for ShaID.
if l==0
shaID=1;
figure(1)
shaddrawf1101(BAS.shad,shaID);
end

% -----
% I. EXTERNAL WALLS
%
% For each wall ID-number exID=1,2,...
%
% FORMAT BAS.wallex{exID} = [zonenr,surf,conID,orID,bridge];
% zone nr = select zone number from ZONES section
% surf = total surface area[m2] including the windows surface area.
% conID = select construction ID-number from CONSTRUCTION section.
% orID = select orientation ID-number from ORIENTATIONS section
% bridge= the heat loss in W/K of the thermal bridges (choose 0 if unknown)

```



```

%BAS.wallex{exID}=      [zonenr, surf, conID,   orID,   bridge]
BAS.wallex{1} =      [3,      35.0,   1,       1,       0]; % west wall of workplace
BAS.wallex{2} =      [1,      17.5,   1,       1,       0]; % west wall of office
BAS.wallex{3} =      [1,      24.5,   1,       2,       0]; % north wall of office
BAS.wallex{4} =      [2,      10.5,   1,       2,       0]; % north wall of canteen
BAS.wallex{5} =      [2,      17.5,   1,       3,       0]; % east wall of canteen
BAS.wallex{6} =      [3,      35.0,   1,       3,       0]; % east wall of workplace
BAS.wallex{7} =      [3,      35.0,   1,       4,       0]; % south wall of workplace
BAS.wallex{8} =      [1,      100.0,  6,       5,       0]; % roof of workplace
BAS.wallex{9} =      [2,      35.0,   6,       5,       0]; % roof of workplace
BAS.wallex{10} =     [3,      15.0,   6,       5,       0]; % roof of workplace

% II. WINDOWS IN EXTERNAL WALLS
%
% FORMAT window{winID} = [exID, surf,glaID, shaID];
% exID = select external construction ID-number from CONSTRUCTIONS section
% surf  = surface area of the glazing [m2]
% glaID = select glass ID-number from GLAZING section
% shaID = select ID-number of shadow from SHADOW section, no shadow: shaID=0

%BAS.window{winID}= [exID,      surf,      glaID,      shaID]
BAS.window{1} =      [1,          4.8,      3,          0]; %windows in west wall
workspace
BAS.window{2} =      [2,          3.75,     3,          0]; %windows in west wall office
BAS.window{3} =      [5,          3,         3,          0]; %windows in east wall
canteen
BAS.window{4} =      [6,          4.8,      3,          0]; %windows in east wall
workspace

% III. CONSTANT TEMPERATURE WALLS
%
% Each constant temperature wall gets an ID: i0ID=1,2,...
%
% FORMAT walli0{i0ID} = [zonenr, surf, conID ,temp];
% zonenr = select zone number from ZONES section
% surf   = total surface area [m2]
% conID  = select construction ID-number from CONSTRUCTION section.
% temp   = constant temperature [oC],e.g ground = '10'
% bridge = the heat loss in W/K of the thermal bridges (0 if unknown)

%BAS.walli0{i0ID}= [zonenr, surf,   conID,      temp,   bridge]
BAS.walli0{1} =      [1,      0,      1,          10.0,   0];

% IV ADIABATIC EXTERNAL WALLS
%
% Each adiabatic wall gets an ID: iaID=1,2,...
%
% FORMAT wallia{iaID} = [zonenr,surf,conID];
% zonenr = select zone number from ZONES section
% surf   = total surface area in m2
% conID  = select construction ID-number from CONSTRUCTION section.

%BAS.wallia{iaID}= [zonenr, surf,      conID]
BAS.wallia{1} =      [1,      0,      2   ];

% V. INTERNAL WALLS BETWEEN AND IN ZONES
%
% FORMAT wallin{inID} = [zonenr1,zonenr2,surf,conID];
% zonenr1 = select zone number from ZONES section
% zonenr2 = select zone number from ZONES section
% surf    = total surface area [m2]
% conID   = select construction number from CONSTRUCTION section.

%BAS.wallin{inID}= [zonenr1,   zonenr2,   surf,      conID   ]
BAS.wallin{1} =      [1,      3,      30,      1   ]; %wall between office and
workspace
BAS.wallin{2} =      [1,      2,      15,      2   ]; %wall between office and
canteen
BAS.wallin{3} =      [2,      3,      9,      2   ]; %wall between canteen and
workspace

```

```

%-----
% PART 3 : profiles for internal sources, ventilation, sunblinds and free
% cooling
%-----
%
% **PROFILES**
%
%
% BAS.Ers{proID}      = irradiance level for sun blinds [W/m2]
% BAS.dayper{proID} = [hrnr1,hrnr2,hrnr3], the starting time of a new period
% BAS.vvmin{proID} = [. . . ], the ventilation ACR [1/hr], for each period
% BAS.vvmax{proID} = [. . . ], the ventilation ACR [1/hr] in case free cooling
% BAS.Tfc{proID}    = [. . . ], threshold [oC] for free cooling, for each period
% BAS.Tsetmin{proID}= [. . . ], setpoint [oC] switch for heating, (in case of
%   no heating choose -100)
% BAS.Tsetmax{proID}= [. . . ], setpoint [oC] switch for cooling, (in case
%   of no cooling choose 100)
% BAS.Qint{proID}   = [. . . ], internal heat gains [W]
% BAS.Gint{proID}   = [. . . ], moisture gains [kg/s]
% BAS.RVmin{proID}  = [. . . ], setpoint [%] switch for humidification,(in case of no
%   humidification choose -1)
% BAS.RVmax{proID}  = [. . . ], setpoint [%] switch for dehumidification,(in case
%   of no dehumidification choose 101)
%
% proID=1 for office during week
BAS.Ers{1}=300;
BAS.dayper{1}= [ 0,          8,          18 ];
BAS.vvmin{1}= [ 3,          3,          3 ];
BAS.vvmax{1}= [ 3,          3,          3 ];
BAS.Tfc{1}= [ 100,         100,         100 ];
BAS.Qint{1}= [ 200,        1000,        200 ];
BAS.Gint{1}= [ 5.8e-6,     6.35e-5,     5.8e-6 ];
BAS.Tsetmin{1}= [ 19,       20,        19 ];
BAS.Tsetmax{1}= [ 23,       23,        23 ];
BAS.RVmin{1}= [ -1,        -1,        -1 ];
BAS.RVmax{1}= [ 100,       100,       100 ];

%proID=2 for canteen during week
BAS.Ers{2}=300;
BAS.dayper{2}= [ 0,          8,          18 ];
BAS.vvmin{2}= [ 3,          3,          3 ];
BAS.vvmax{2}= [ 3,          3,          3 ];
BAS.Tfc{2}= [ 100,         100,         100 ];
BAS.Qint{2}= [ 100,        250,         100 ];
BAS.Gint{2}= [ 5.8e-6,     5.8e-6,     5.8e-6 ];
BAS.Tsetmin{2}= [ 19,       20,        19 ];
BAS.Tsetmax{2}= [ 23,       23,        23 ];
BAS.RVmin{2}= [ -1,        -1,        -1 ];
BAS.RVmax{2}= [ 100,       100,       100 ];

%proID=3 for office and canteen in the weekend
BAS.Ers{3}=300;
BAS.dayper{3}= [ 0,          8,          18 ];
BAS.vvmin{3}= [ 2,          2,          2 ];
BAS.vvmax{3}= [ 2,          2,          2 ];
BAS.Tfc{3}= [ 100,         100,         100 ];
BAS.Qint{3}= [ 100,        100,         100 ];
BAS.Gint{3}= [ 5.8e-6,     5.8e-6,     5.8e-6 ];
BAS.Tsetmin{3}= [ 19,       19,        19 ];
BAS.Tsetmax{3}= [ 24,       24,        24 ];
BAS.RVmin{3}= [ -1,        -1,        -1 ];
BAS.RVmax{3}= [ 100,       100,       100 ];

%proID=4 for workplace whole week
BAS.Ers{4}=300;
BAS.dayper{4}= [ 0,          8,          18 ];
BAS.vvmin{4}= [ 1,          1,          1 ];
BAS.vvmax{4}= [ 1,          1,          1 ];
BAS.Tfc{4}= [ 100,         100,         100 ];
BAS.Qint{4}= [ 0,          500,         0 ];

```

```

BAS.Gint{4}=      [  0,          5.8e-6,      0   ];
BAS.Tsetmin{4}=   [  15,          15,          15   ];
BAS.Tsetmax{4}=   [  100,         100,         100   ];
BAS.RVmin{4}=     [  -1,          -1,          -1   ];
BAS.RVmax{4}=     [  100,         100,         100   ];

% THE PROFILES OF THE BUILDING
%
% FORMAT BAS.weekfun{zonenr} = [upnrmon, upnrtue, upnrwed, upnrthu, upnrfri,
% upnrsat, upnrsun]
% for each zone n=1.. number of zones, select profiles ID-numbers for each
% day
%
% BAS.weekfun{zonenr} =[upnrmon,      upnrtue,      upnrwed,      upnrthu, upnrfri, upnrsat,
upnrsun]
BAS.weekfun{1}=    [1,          1,          1,          1,          1,          3,
3];
BAS.weekfun{2}=    [2,          2,          2,          2,          2,          3,
3];
BAS.weekfun{3}=    [4,          4,          4,          4,          4,          4,
4];

%-----
% PART 4 : Heating, cooling, humidification, dehumidification
% -----

% FORMAT BAS.Plant{zonenr}=[heating capacity [W], cooling capacity [W],
% humidification capacity [kg/s],dehumidification capacity [kg/s]];

BAS.Plant{1}=[5000,-5000,0.001,-0.001];
BAS.Plant{2}=[5000,-5000,0.001,-0.001];
BAS.Plant{3}=[5000,0,0.001,-0.001];

% FORMAT BAS.convfac{zonenr}=[CFh, CFset, CFint ];
% CFh =Convection factor of the heating system: air heating CFh=1,
% radiators CFh=0.8 floor heating CFh=0.5, cooling usually CFh=1
% CFset= Factor that determines whether the temperature control is on the air
% temperature (CFset=1), or comforttemperature (CFset=0.6),Tset=CFset*Ta+(1-CFset)*Tr
%
% CFint= is the convection factor of the casual gains (usually CFint=0.5)

BAS.convfac{1}=[0.8, 1, 0.5 ];
BAS.convfac{2}=[0.8, 1, 0.5 ];
BAS.convfac{3}=[0.8, 1, 0.5 ];
BAS.convfac{4}=[0.8, 1, 0.5 ];

% FORMAT BAS.heatexch{zonenr}=[etaww, Twws];

BAS.heatexch{1}=[0 24];
BAS.heatexch{2}=[0 24];
BAS.heatexch{3}=[0 24];
BAS.heatexch{4}=[0 22];

% FORMAT BAS.furnishings{zonenr}=[fbv, CFfbi];
% fbv = Moisture storage factor
% CFfbi= The convection factor for the solar radiation due to furnishings.

BAS.furnishings{1}=[1, 0.2];
BAS.furnishings{2}=[1, 0.2];
BAS.furnishings{3}=[1, 0.2];
BAS.furnishings{4}=[1, 0.2];

%***** END OF INPUT*****
%
[Control,Profiles,InClimate,InBuil]=Hambasefun0309(BAS);

% Wavoooutput

```

## Simulink model (casestudy2.mdl)

HAMBase/Simulink model D.R.Vissers / H.N. Maaßen - Case study - Sustainable building system improvements

