Annex 60 New generation computational tools for building and community energy systems based on the Modelica and Functional Mockup Interface standards

Task 2: Validation and Demonstration
Activity 2: Design of district energy systems

Definition of Common Exercise: reference "Annex 60 Neighborhood Case"

Introduction

During the expert meeting in Lund (08-09 March 2014) it was proposed to start a common exercise on neighborhood level.

The aim is to define a reference "Annex 60 Neighborhood Case" on which different modeling approaches developed in Subtask 1 and the other activities can be tested. The following main research questions regarding district energy systems were identified during the breakout session:

- Interconnection of electrical and thermal grids
- Control strategies
    - what benefits can it provide for the networks
    - how will the consumer be impacted
    - controllers in Modelica, Simulink, or…?
    - common exercise required: different solutions to be tested
- Available flexibility can be provided by thermal networks for the electrical networks and vice versa, DSM: how to use the flexibility
- Hydraulic balancing: drive heat correctly to the consumption
- Change from consumers to prosumers, what is the influence of distributed energy supply

The modeling environment should be able to analyze all of these aspects. As this activity does not focus on actually solving these questions but rather on analyzing whether the models that are developed in Subtask 1 provide suitable modeling approaches. To find this out, a reference "Annex 60 Neighborhood Case" will be gradually developed. The case will gradually incorporate features which are necessary to analyze the identified issues.

The definition of the "Annex 60 Neighborhood Case" will consist of three consecutive steps.

In a **first step** participants will be asked to model the behavior of buildings and their installations in a given neighborhood. They will be asked to report on predefined performance indicators representative for the building energy use. The buildings have to be treated stand-alone (not coupled), the participants are free to choose the way they model the buildings.

While the main aim of this first step is to come up with a common library with building models, an additional aim of this first step is to demonstrate the consequences of some modeling decisions and to illustrate the effect of different levels of complexity. By analyzing the results, the level of understanding in modeling buildings of all participants will level out. Depending on the outcome, it is possible that several sets with different complexity will be developed for use in the further steps.

In a **second step** participants will be asked to connect the buildings (developed in the previous step) with distribution grids and to describe how they input energy from centralized renewable sources and how they exchange energy. Both electrical and thermal connections as well as input/outputs have to be explored. Again participants will be asked to individually solve a common exercise. They will be encouraged to explore the tools that are developed in the other activities (f.i. direct integration of the grid in Modelica, use of FMU/FMI, co-simulation, …). Based on a discussion on the different approaches used, a SWOT analysis will be carried out and the most promising solutions will be worked out into (a) reference model(s) that will be used in the next step.

In a **third step** participants will be asked to use the reference model from step 2 (with the buildings coupled) to integrated control strategies and to attempt (to do) an optimization exercise. Similarly as for step 2 a SWOT analysis will be carried out and the most promising solutions will be integrated into a reference model. At some point it is possible that the definition of the reference is too complex for f.i. optimization. At that point a less complex definition of the building stock or other solutions will have to be investigated.

Note that at any time participants from other activities are encouraged to participate in one or more of the common exercises.

Definition of first common exercise

Definition of typical typology for the neighborhood:

- A street with houses and some tertiary buildings
- Mixing residential and commercial buildings: heat transfer between buildings (simultaneous H/C demands)
- Level of insulation: different insulation levels to define different load profiles
- Include different occupancy profiles/heating strategies: will impact the part load profile. We should see the effect of oversizing of the DHN,
- Change progressively the complexity: boilers can be replaced by heat pumps, low temperature district heating, variable mass flow rate, add cooling …
- Adjust the emission systems to the type of buildings (radiators, radiant floor, cooling)

As results of the simulations, we will gather:

- The annual heating (and cooling) demand of the buildings and neighborhood
- The peak heating (and cooling) demand of the buildings and neighborhood, and the moment at which they appear in the year.
- The peak temperatures, and the moment at which they appear in the year.

Planning

To do

- Definition of CE instruction document (6 - 8 weeks)

EPB 2010 in Flanders and (#2) denoting a level of insulation similar to the one found on buildings of the period 1946-1970 in Flanders, based on the IEE TABULA project.

The given five dwelling typologies D, S, T, A and O and levels of thermal insulation #1 and #2 are combined into a street design of 24 buildings as follows:

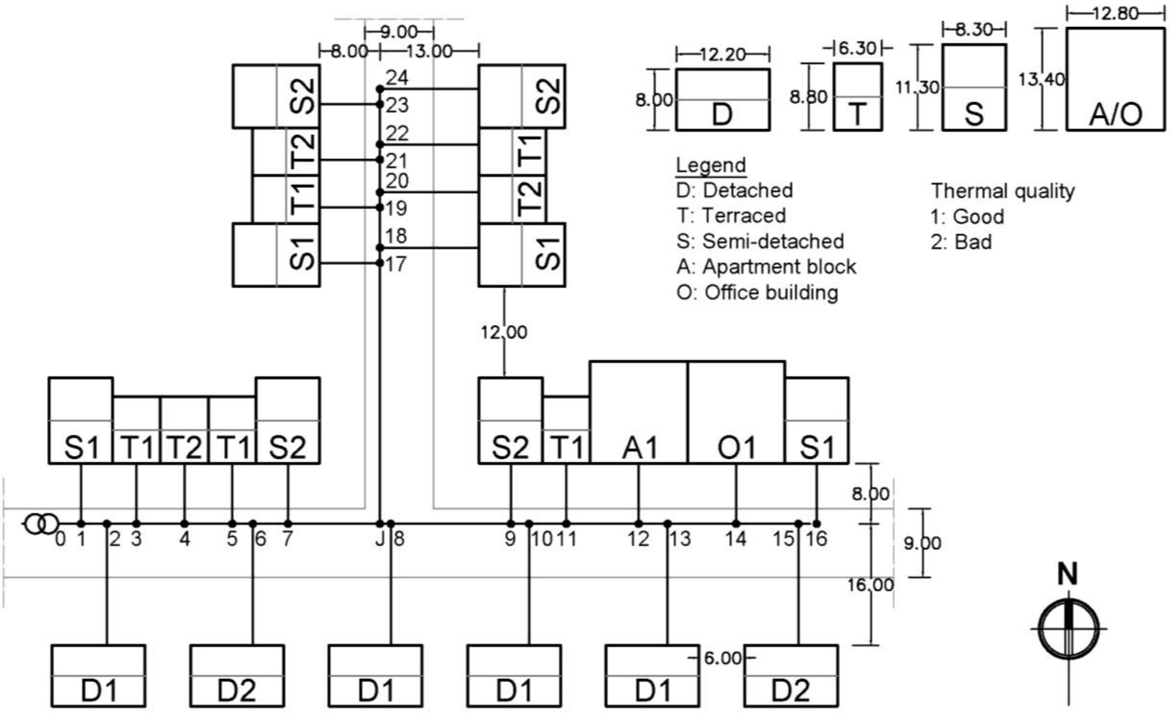

Figure 1 - Street layout of the depicted neighborhood with the depicted typologies D (detached), S (semi-detached), T (terraced), A (apartment) and O (office) for the thermal quality levels #1 (good) and #2 (bad).

The plan is given in attachment in DESTEST_NeiTyp.dwg describing all dimensions and reciprocal positions of both the buildings and the district energy system. If a district system (whether it is for heating, cooling or electricity) is included in the simulation, all piping and wiring is foreseen on a single side of the street as shown in the figure, resulting in larger differences in connection lengths.

The resulting distribution distances between the connection nodes of the dwelling and the district energy network are as follows:

Nodes n°	**0-1**	**1-2**	**2-3**	**3-4**	**4-5**	**5-6**	**6-7**	**7-J**	**J-8**	**8-9**	**9-10**	**10-11**	**11-12**
Length (m)	3.0	3.4	3.9	6.3	6.3	2.7	4.6	12.1	1.4	15.8	2.4	4.9	9.5
Nodes n°	**12-13**	**13-14**	**14-15**	**15-16**	**J-17**	**17-18**	**18-19**	**19-20**	**20-21**	**21-22**	**22-23**	**23-24**	
Length (m)	3.8	9.0	8.2	2.4	34.4	2.0	5.3	2.0	4.3	2.0	5.3	2.0	

Table 1 - Distances (in m) between the connection nodes of the dwelling with the feeder or district energy network

Building topology descriptions

The neighborhood is based on a small set of reference buildings which are combined to describe a street section: Five typologies are made for the building layouts, i.e. a detached (D), a semi-detached (S) and a terraced (T) dwelling, an apartment block (A) and an office (O) building, and two sub-topologies are made to distinct between the levels of thermal insulation, i.e. (#1) denoting a level of insulation required by the EPBD 2010 in Flanders and (#2) denoting a level of insulation similar to the one found on buildings of the period 1946-1970 in Flanders based on the IEE TABULA project.

Detailed plans of all typologies are given later in this document describing all dimensions and interior subdivisions of the buildings.

Following table gives a summary of the main building parameters of the reference buildings:

	Detached dwelling (D)	Semi-detached dwelling (S)	Terraced dwelling (T)	Apartment block (A)	Office building (O)	
Usable floor area	102.7	100.9	107.5	107.5	107.5	m²
Total floor area	185.5	187.8	161.0	161.0	161.0	m²
Heat loss area	371.1	305.1	219.1	104.6	104.6	m²
Protected volume	451.5	455.1	446.5	435.9	435.9	m³
Compactness	1.22	1.49	2.04	4.17	4.17	-

Table 2 - Summary of the main building parameters (entire building for the dwellings and typical floor for the apartment block and office building)

The given protected volumes and heat loss areas are calculated based on the dimension of the inner wall slab (at the insulation layer) and not on the exterior dimensions. This way all dimensions remain equal when changing the insulation thicknesses.

For all dwelling typologies, a fixed window-to-floor ratio is assumed for the main living areas in the dwellings, i.e. 0.25 for the living areas, 0.18 for the kitchen and bureaus, 0.12 for the sleeping rooms and 0.07 for the bathrooms.

Detached dwelling

The following table gives a summary of the main building parameters of the reference detached dwelling for each living space in the dwelling:

			Window area				
Protected volume	451.5	m³					
Livable area			**average**	**h**	**w**	**area**	
Living room	35.7	m²	11.65	1.20	2.60	3.12	m²
				0.70	0.90	0.63	m²
				2.20	3.20	7.04	m²
Kitchen	10.2	m²	3.35	1.20	3.20	3.84	m²
Bedroom 1	17.0	m²	2.62	1.20	1.20	1.44	m²
				1.20	1.40	1.68	m²
Bedroom 2	18.2	m²	2.82	1.20	2.40	2.88	m²
Bedroom 3	13.6	m²	2.10	1.20	2.25	2.70	m²
Study	8.0	m²	1.24	1.20	1.40	1.68	m²
	102.7	**m²**					
Non-livable area							
Bathroom	6.0	m²	0.55	1.20	0.80	0.96	m²
Toilet	1.7	m²		0.40	0.60	0.24	m²
Hall	21.9	m²	1.60	1.00	1.00	1.00	m²
Storage	7.7	m²					
	37.3	**m²**					

Total floor area	140.0	m^2	**North**		4.56	(%)	1.24	m^2
= livable area. x	1.363		**East**		27.34	(%)	7.44	m^2
			South		41.75	(%)	11.36	m^2
Heat loss area	371.1	m^2	**West**		26.35	(%)	7.17	m^2
Compactness	1.22		**total**				27.21	m^2
			Window-to-floor ratio				0.181	

Table 3 - General building properties for the detached dwelling

Semi-detached dwelling

The following table gives a summary of the main building parameters of the reference semi-detached dwelling for each living space in the dwelling:

Protected volume	455.1	m^3	**Window area**					
Livable area			**average**	**h**	**w**		**area**	
Living room	45.6	m^2	14.91	1.20	4.30		5.16	m^2
				2.20	2.65		5.83	m^2
				1.20	2.40		2.88	m^2
Kitchen	12.7	m^2	4.15	1.20	1.85		2.22	m^2
				1.20	1.20		1.44	m^2
Bedroom 1	12.5	m^2	1.93	1.20	2.40		2.88	m^2
Bedroom 2	18.0	m^2	2.78	1.20	2.40		2.88	m^2
Bedroom 3	12.1	m^2	1.88	1.00	2.00		2.00	m^2
	100.9	**m^2**						
Non-livable area								
Bathroom	6.9	m^2	0.64	1.00	1.00		1.00	m^2
Toilet	1.8	m^2		0.80	0.80		0.64	m^2
Hall	19.7	m^2						
Storage	4.5	m^2						
	33.0	**m^2**						
Floor area	133.9	m^2	**North**		0	(%)	0.00	m^2
= livable area. x	1.327		**East**		14.33	(%)	3.86	m^2
			South		45.9	(%)	12.36	m^2
Heat loss area	305.1	m^2	**West**		39.77	(%)	10.71	m^2
Compactness	1.49		**Total**				26.93	m^2
			Window-to-floor ratio				0.178	

Table 4 - General building properties for the semi-detached dwelling

Terraced dwelling

The following table gives a summary of the main building parameters of the reference terraced dwelling for each living space in the dwelling:

Protected volume	446.5	m^3	**Window area**					
Livable area			**average**	**h**	**w**		**area**	
Living room	32.4	m^2	10.57	2.20	2.40		5.28	m^2

				1.20	2.40		2.88	m^2
Kitchen	11.2	m^2	3.05	1.20	1.90		2.28	m^2
				0.90	0.70		0.63	m^2
Bedroom 1	17.4	m^2	2.68	1.20	2.40		2.88	m^2
Bedroom 2	14.6	m^2	2.26	1.20	2.40		2.88	m^2
Bedroom 3	16.0	m^2	2.46	1.00	2.00		2.00	m^2
Study	9.0		1.38	1.00	2.00		2.00	m^2
	100.4	**m^2**						
Non-livable area								
Bathroom	6.3	m^2	0.58	1.20	0.80		0.96	m^2
Toilet	1.7	m^2						
Hall	20.8	m^2	1.60	1.20	0.90		1.08	m^2
				1.00	1.00		1.00	m^2
Storage	2.2	m^2		1.00	1.00		1.00	m^2
	23.0	**m^2**						
Total floor area	123.4	m^2	**North**		39.57	(%)	9.84	m^2
= livable area. x	1.229		**East**		0	(%)	0.00	m^2
			South		51.27	(%)	12.75	m^2
Heat loss area	219.1	m^2	**West**		9.17	(%)	2.28	m^2
Compactness	2.04		**Total**				24.87	m^2
			Window-to-floor ratio				0.167	

Table 5 - General building properties for the terraced dwelling

Apartment block (and office building)

The following table gives a summary of the main building parameters of the reference apartment for each living space in the dwelling, representing a single floor of a five-storey building with equal floors:

Protected volume	435.9	m^3	**Window area**					
Livable area			**Average**	**h**	**w**		**area**	
Living room	45.7	m^2	14.93	1.20	3.40		4.08	m^2
				2.20	3.80		8.36	m^2
Kitchen	14.7	m^2	4.79	1.20	2.40		2.88	m^2
				0.90	0.70		0.63	m^2
Bedroom 1	17.2	m^2	2.66	1.20	2.20		2.64	m^2
Bedroom 2	13.3	m^2	2.06	1.20	1.80		2.16	m^2
Bedroom 3	16.6	m^2	2.56	1.20	2.20		2.64	m^2
	107.5	**m^2**						
Non-livable area								
Bathroom	8.7	m^2	0.80	1.20	0.90		1.08	m^2
Toilet	1.4	m^2						
Hall	16.2	m^2	1.60	2.20	0.80		0.00	m^2
Storage	6.2	m^2						
	32.5	**m^2**						
Floor area	140.0	m^2	**North**		34.82	(%)	8.52	m^2
= livable area. x	1.302		**East**		0	(%)	0.00	m^2
			South		62.61	(%)	15.32	m^2
Heat loss area	104.6	m^2	**West**		2.58	(%)	0.63	m^2

Compactness	4.17	**Total**	24.47	m^2
		Window-to-floor ratio	0.168	

Table 6 - General building properties for a single floor of the apartment (and office) building

Building thermal sub-topology descriptions

Construction elements

Two sub-topologies are made to distinguish between the levels of thermal insulation, i.e. (#1) denoting a level of insulation required for the EPB 2010 in Flanders and (#2) denoting a level of insulation similar to the one found on buildings of the period 1946-1970 in Flanders, based on the IEE TABULA project.

A summary of the levels of thermal insulation for the different construction elements of the building envelope is given in the following table:

State	Construction	Elements	U-value / infiltration rate
#1	Façade	Cavity wall with 6 cm mineral wool wall insulation	0.40 W/(m^2K)
	Roof	10 cm mineral wool roof insulation between rafters	0.3 W/(m^2K)
		or 8 cm XPS on concrete flat roof	
	Floor	5 cm XPS floor insulation below screed	0.4 W/(m^2K)
	Windows	Insulated profiles Uf 1.8 - high performance glazing U_g 1.1	1.7 W/(m^2K)
	Doors	Insulated door leafs	2.9 W/(m^2K)
	In-/exfiltration	- (at 50 Pa)	10 m^3/(h.m^2)

Table 7 - Sub-typology of the construction elements for state #1

State	Construction	Elements	U-value / infiltration rate
#2	Façade	Outer brick leaf, air cavity 5cm, inner brick leaf	1.7 W/(m^2K)
	Roof	Wooden roof construction with tiles, interior finishing	2.85 W/(m^2K)
	Floor	Concrete structural floor, floor screed and floor finishing	3.0 W/(m^2K)
	Windows	Wooden window profiles - single glazing	5.0 W/(m^2K)
	Doors	Un-insulated door leafs	4.0 W/(m^2K)
	In-/exfiltration	- (at 50 Pa)	6 m^3/(h.m^2)

Table 8 - Sub-typology of the construction elements for state #2

The detailed composition of the construction elements of the envelope was defined based on the IEE TABULA project descriptions with the aim to reach the desired U-values (in most cases). Additional information is given for the composition of typical internal walls and floors. The data given in the next tables is valid for all types of buildings, depending only on the state (#1 or #2).

State #1							
Wall external					U=	0.4	W/m²K
	layers	d [m]	λ[W/mK]	ρ[kg/m³]	c [J/kgK]	R[m²K/W]	C[J/m²K]
	High dens. brick	0.10	1.1	1850	840	0.091	155400
	Air cavity	0.03		1.204	287	0.180	10
	MW	0.06	0.036	1850	840	1.667	93240
	Low dens. brick	0.14	0.41	850	840	0.341	99960
	Plaster	0.02	0.6	975	840	0.033	16380
Roof					U=	0.3	W/m²K
	layers	d [m]	λ[W/mK]	ρ[kg/m³]	c [J/kgK]	R[m²K/W]	C[J/m²K]
	Tiled roof	0.025	1	1700	840	0.025	35700
	Air cavity	0.03		1.204	287	0.160	10
	MW	0.10	0.036	2100	840	2.778	176400
	Wood	0.02	0.11	550	1880	0.182	20680
	Plaster	0.02	0.6	975	840	0.033	16380

Flat Roof					U=	0.3	W/m²K
	layers	d [m]	λ[W/mK]	ρ[kg/m³]	c [J/kgK]	R[m²K/W]	C[J/m²K]
	Lightweight con.	0.03	1.2	1600	840	0.025	40320
	XPS	0.08	0.024	40	1470	3.333	4704
	Concrete	0.13	1.7	2400	840	0.076	262080

Floor					U=	0.4	W/m²K
	layers	d [m]	λ[W/mK]	ρ[kg/m³]	c [J/kgK]	R[m²K/W]	C[J/m²K]
	Tiles	0.02	1.4	2100	840	0.014	35280
	Screed	0.06	0.6	1100	860	0.100	56760
	XPS	0.05	0.024	40	1470	2.083	2940
	Concrete	0.20	1.7	2400	840	0.143	352800

Wall internal					U=	2.0	W/m²K
	layers	d [m]	λ[W/mK]	ρ[kg/m³]	c [J/kgK]	R[m²K/W]	C[J/m²K]
	Plaster	0.02	0.6	975	840	0.033	16380
	High dens. brick	0.10	0.54	1400	840	0.185	117600
	Plaster	0.02	0.6	975	840	0.033	16380

Floor internal					U=	1.9	W/m²K
	layers	d [m]	λ[W/mK]	ρ[kg/m³]	c [J/kgK]	R[m²K/W]	C[J/m²K]
	Tiles	0.02	1.4	2100	840	0.014	35280
	Screed	0.06	0.6	1100	860	0.100	56760
	Concrete	0.20	1.7	2400	840	0.143	352800
	Plaster	0.02	0.6	975	840	0.033	16380

Table 9 - Detailed composition of the construction elements for state #1

State #2							
Wall external					U=	1.7	W/m²K
	layers	d [m]	λ [W/mK]	ρ [kg/m³]	c [J/kgK]	R[m²K/W]	C[J/m²K]
	High dens. brick	0.08	1.1	1850	840	0.073	124320
	Air cavity	0.05		1.204	287	0.160	17
	High dens. brick	0.14	0.9	1850	840	0.156	217560
	Plaster	0.02	0.6	975	840	0.033	16380

Roof					U=	2.85	W/m²K
	layers	d [m]	λ [W/mK]	ρ [kg/m³]	c [J/kgK]	R[m²K/W]	C[J/m²K]
	Tiled roof	0.02	1.3	1700	840	0.015	28560
	Air cavity	0.03		1.204	287	0.160	10
	Gypsum board	0.02	0.6	975	840	0.033	16380

Floor					U=	3.0	W/m²K
	layers	d [m]	λ [W/mK]	ρ [kg/m³]	c [J/kgK]	R[m²K/W]	C[J/m²K]
	Tiles	0.02	1.4	2100	840	0.014	35280
	Screed	0.05	0.6	1100	860	0.083	47300
	Concrete	0.12	1.7	2400	840	0.086	211680

Wall internal					U=	1.75	W/m²K
	layers	d [m]	λ [W/mK]	ρ [kg/m³]	c [J/kgK]	R[m²K/W]	C[J/m²K]
	Plaster	0.02	0.6	975	840	0.033	16380
	High dens. brick	0.14	0.54	1400	840	0.259	164640
	Plaster	0.02	0.6	975	840	0.033	16380

Floor internal					U=	1.5	W/m²K
	layers	d [m]	λ [W/mK]	ρ [kg/m³]	c [J/kgK]	R[m²K/W]	C[J/m²K]
	Wooden floor	0.02	0.18	700	1880	0.111	26320
	Screed	0.08	0.6	1100	860	0.133	75680
	Concrete	0.2	1.7	2400	840	0.143	352800
	Plaster	0.02	0.6	975	840	0.033	16380

Table 10 - Detailed composition of the construction elements for state #2

More details are necessary for the windows, and their angle dependent properties. Both states 1 and 2, and the office will have a 4/15/4 double pane window, with an argon-filled cavity and a low-e coating with a long-wave emissivity of .04 on the inner pane. The resulting U-value is 1.1 W/m²K and the g-value of 0.589 is derived from following incident-angle dependent transmittances τ_{sw} and absorptances α_{sw} for the outer (o) and inner (i) pane :

	0	10	20	30	40	50	60	70	80	90
τ_{sw}	.521	.524	.517	.508	.495	.472	.418	.312	.153	.000

Table 11 - Shortwave transmittance of the window depending on the incident angle.

	0	10	20	30	40	50	60	70	80	90

$\alpha_{sw,o}$	.102	.104	.112	.117	.119	.123	.135	.142	.105	.000
$\alpha_{sw,i}$	.022	.022	.023	.023	.025	.026	.027	.029	.031	.000

Table 12 - Shortwave absorptances of the window outer (o) and inner (i) pane depending on the incident angle

The properties for diffuse light may be taken equal to the values found for an incident angle of 60 degrees.

Heating, hot water and ventilation systems

State #1 residential buildings are heated by an air-to-water heat pump, while state #2 buildings are heating by a condensing gas boiler. There are no cooling systems installed in residential buildings.

In office buildings, the cooling load is covered by an air-cooled chiller and the heating load by a condensing gas boiler. The same simulation model of the condensing boiler is used for both residential and office buildings.

In a first step, the distribution and emission systems are not simulated. The condensing boiler, the heat pumps and the chiller are assumed to provide water at respectively 50°C, 40°C and 7°C.

Heat pump

The heat pump is an air-to-water heat pump presenting the following performances:

The heat pump can be modeled by the following set of equations (i.e. the “Consoclim” model):

[illegible]

Where
- the ‘fl’ and ‘pl’ indexes stand respectively for full and part load;
- the ‘nom’ index is used for quantities evaluated in the nominal working conditions.

In nominal conditions are:

$T_{air;out} = 7$ [°C]

$T_{w;ex;cd} = 35$ [°C]

$COP_{nom} = 3.9$ [-]

[illegible] is the nominal capacity of the heat pump and should be adjusted to cover the peak heating load of the building.

The validity range of the model is:

- $T_{air;out}$ = -20°C to 20°C
- $T_{w;ex;cd}$ = 30 to 55°C

A manufacturer data sheet gives 9 working points that were used to determine the following model parameters:

C_0	C_1	C_2	D_0	D_1	D_2	K_1	K_2
0.949	-8.05	111.09	0.968	0.0226	-0.0063	0	0.67

<u>Boiler</u>

The model of the boiler, based on manufacturer data, consists in an efficiency varying with operating conditions: return water temperature, water flow rate and firing rate (modulation of the capacity at part load).

The boiler efficiency is given for different part load conditions, with a flow rate fraction varying from 0.05 to 1 and with supply water temperature varying from 20°C to 80°C.

The boiler efficiency is calculated by interpolating values in **Table 13 to Table** 17, where

$$partial_{load} = \frac{\dot{Q}_{boiler}}{\dot{Q}_{boiler,n}}$$

$$Flowratefraction = \frac{\dot{M}_{w,boiler}}{\dot{M}_{w,boiler,n}}$$

$T_{w,boiler,su}$ = return water temperature to the boiler

At this stage, it is assumed that the boiler is operated at maximal water flow rate (flow rate fraction of 1) and delivers water at a temperature of 50°C. The capacity of the boiler is modulated to cover the heating load. The nominal capacity of the boiler must be adjusted to cover the peak heating load.

Table 13 : Boiler efficiency at 30% firing rate

		Flowratefraction									
		0.05	0.06667	0.1	0.1667	0.25	0.35	0.5	0.6667	0.8333	1
$T_{w,boiler,su}$	20	0.9751	0.9768	0.9810	0.9847	0.9882	0.9920	0.9920	0.9920	0.9920	0.9920
	30	0.9620	0.9636	0.9680	0.9735	0.9776	0.9820	0.9820	0.9820	0.9820	0.9820
	40	0.9380	0.9380	0.9380	0.9420	0.9420	0.9530	0.9530	0.9530	0.9530	0.9530
	50	0.9020	0.9020	0.9035	0.9050	0.9050	0.9100	0.9100	0.9100	0.9100	0.9100
	55	0.8700	0.8700	0.8700	0.8700	0.8700	0.8700	0.8700	0.8700	0.8700	0.8700
	60	0.8700	0.8700	0.8700	0.8700	0.8700	0.8700	0.8700	0.8700	0.8700	0.8700
	70	0.8630	0.8630	0.8630	0.8630	0.8630	0.8630	0.8630	0.8630	0.8630	0.8630
	80	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520

Table 14 : Boiler efficiency at 45% firing rate

		Flowratefraction									
		0.05	0.06667	0.1	0.1667	0.25	0.35	0.5	0.6667	0.8333	1
$T_{w,boiler,su}$	20	0.9707	0.9707	0.9725	0.9775	0.9804	0.9832	0.9873	0.9877	0.9877	0.9877
	30	0.9551	0.9551	0.9568	0.9619	0.9667	0.9700	0.9746	0.9751	0.9751	0.9751
	40	0.9303	0.9303	0.9303	0.9303	0.9343	0.9343	0.9343	0.9453	0.9453	0.9453
	50	0.8945	0.8945	0.8945	0.8971	0.8975	0.8975	0.8975	0.9025	0.9025	0.9025
	55	0.8683	0.8683	0.8683	0.8683	0.8683	0.8683	0.8683	0.8683	0.8683	0.8683
	60	0.8683	0.8683	0.8683	0.8683	0.8683	0.8683	0.8683	0.8683	0.8683	0.8683
	70	0.8617	0.8617	0.8617	0.8617	0.8617	0.8617	0.8617	0.8617	0.8617	0.8617
	80	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520

Table 15 : Boiler efficiency at 60% firing rate

		Flowratefraction									
		0.05	0.06667	0.1	0.1667	0.25	0.35	0.5	0.6667	0.8333	1
$T_{w,boiler,su}$	20	0.9664	0.9664	0.9665	0.9710	0.9740	0.9766	0.9796	0.9830	0.9834	0.9834
	30	0.9483	0.9483	0.9483	0.9528	0.9562	0.9604	0.9639	0.9678	0.9683	0.9683
	40	0.9226	0.9226	0.9226	0.9226	0.9266	0.9266	0.9266	0.9266	0.9376	0.9376
	50	0.8870	0.8870	0.8870	0.8870	0.8900	0.8900	0.8900	0.8900	0.8950	0.8950
	55	0.8666	0.8666	0.8666	0.8666	0.8666	0.8666	0.8666	0.8666	0.8666	0.8666
	60	0.8666	0.8666	0.8666	0.8666	0.8666	0.8666	0.8666	0.8666	0.8666	0.8666
	70	0.8604	0.8604	0.8604	0.8604	0.8604	0.8604	0.8604	0.8604	0.8604	0.8604
	80	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520

Table 16 : Boiler efficiency at 80% firing rate

		Flowratefraction									
		0.05	0.06667	0.1	0.1667	0.25	0.35	0.5	0.6667	0.8333	1
$T_{w,boiler,su}$	20	0.9607	0.9607	0.9607	0.9622	0.9663	0.9686	0.9713	0.9739	0.9764	0.9777
	30	0.9391	0.9391	0.9391	0.9400	0.9447	0.9476	0.9519	0.9548	0.9577	0.9591
	40	0.9123	0.9123	0.9123	0.9123	0.9123	0.9163	0.9163	0.9163	0.9163	0.9273
	50	0.8870	0.8770	0.8770	0.8770	0.8778	0.8800	0.8800	0.8800	0.8800	0.8850
	55	0.8643	0.8643	0.8643	0.8643	0.8643	0.8643	0.8643	0.8643	0.8643	0.8643
	60	0.8643	0.8643	0.8643	0.8643	0.8643	0.8643	0.8643	0.8643	0.8643	0.8643
	70	0.8587	0.8587	0.8587	0.8587	0.8587	0.8587	0.8587	0.8587	0.8587	0.8587
	80	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520

Table 17 : Boiler efficiency at 100% firing rate

		Flowratefraction									
		0.05	0.06667	0.1	0.1667	0.25	0.35	0.5	0.6667	0.8333	1
$T_{w,boiler,su}$	20	0.9550	0.9550	0.9550	0.9551	0.9581	0.9613	0.9638	0.9661	0.9682	0.9702
	30	0.9300	0.9300	0.9300	0.9300	0.9331	0.9363	0.9401	0.9433	0.9456	0.9480
	40	0.9020	0.9020	0.9020	0.9020	0.9020	0.9020	0.9060	0.9060	0.9060	0.9060
	50	0.8670	0.8670	0.8670	0.8670	0.8670	0.8690	0.8700	0.8700	0.8700	0.8700
	55	0.8620	0.8620	0.8620	0.8620	0.8620	0.8620	0.8620	0.8620	0.8620	0.8620
	60	0.8620	0.8620	0.8620	0.8620	0.8620	0.8620	0.8620	0.8620	0.8620	0.8620
	70	0.8570	0.8570	0.8570	0.8570	0.8570	0.8570	0.8570	0.8570	0.8570	0.8570
	80	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520	0.8520

Chiller

The chiller model relies on three relationships enabling to predict the performance of the machine in off-design conditions and part load operation:

- Chiller capacity as a function of the operating conditions (secondary fluids temperatures) at full load :

$$\dot{Q}_{ev,fl} = \dot{Q}_{ev,fl,ref}\left(1 + D_1\left(T_{sf,su,cd} - T_{sf,su,cd,ref}\right) + D_2\left(T_{sf,ex,ev} - T_{sf,ex,ev,ref}\right)\right)$$

- Electric power demand as a function of the operating conditions (secondary fluids temperatures) at full load (« fl ») :

$$\frac{\dot{W}_{ch,fl}}{\dot{Q}_{ev,fl}} = \left(\frac{\dot{W}_{ch,fl}}{\dot{Q}_{ev,fl}}\right)_{ref}\left(1 + C_1\Delta T + C_2\Delta T^2\right) \text{ s.t. } \Delta T = \left(\frac{T_{sf,su,cd}}{T_{sf,ex,ev}}\right) - \left(\frac{T_{sf,su,cd}}{T_{sf,ex,ev}}\right)_{ref}$$

- Electric power ratio in part load (« pl ») conditions :

$$\frac{\dot{W}_{ch,pl}}{\dot{W}_{ch,pl,ref}} = K_1 + (K_2 - K_1)\frac{\dot{Q}_{ev,pl}}{\dot{Q}_{ev,fl}} + (1 - K_2)\left(\frac{\dot{Q}_{ev,pl}}{\dot{Q}_{ev,fl}}\right)^2$$

Parameters of the model are:

C_1	C_2	D_1	D_2	K_1	K_2
8.15	24.15	-0.01	0.033	0	0.82

The nominal (“ref”) conditions of the chiller are:
- $T_{sf,su,cd,ref}$ = 35°C (temperature of the secondary fluid (air) at the condenser supply)
- $T_{sf,ex,ev,ref}$ = 7°C (temperature of the secondary fluid at the evaporator exhaust)
- EER=3.4 (EER of the machine in nominal conditions)
- $Q_{ev,fl,ref}$ (cooling capacity at full load) has to be determined to cover the peak cooling load of the building.

Occupancy description

In order to exclude or to simplify the handling of discontinuities and events in the modeling at neighborhood level at focus on the implemented physics, a constant set-point temperature T_{sh} of 21°C for heating will be assumed in the very first versions of this modeling exercise, and no cooling and cooling set-point will be applied.
This assumption will be refined in the following version of this modeling exercise.

Reference plans

Detached house

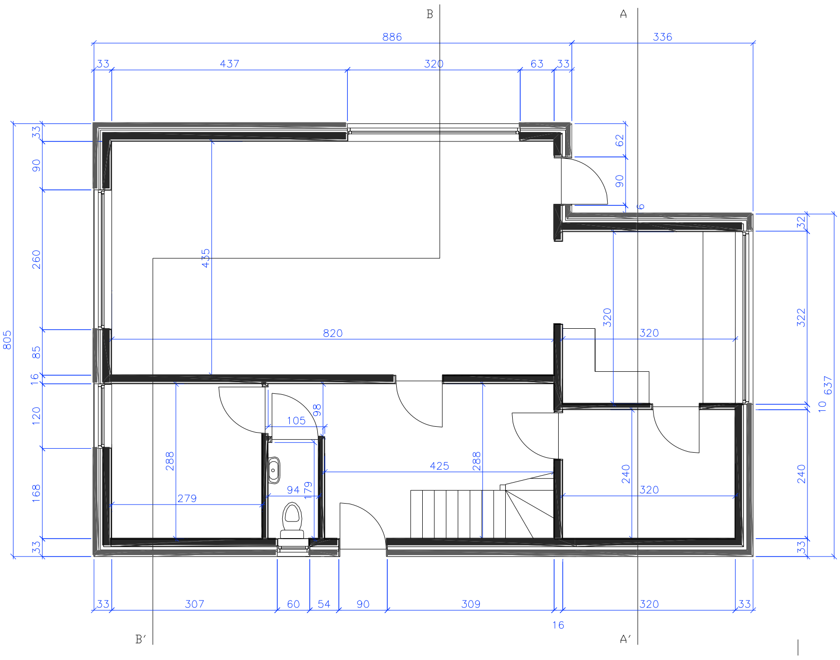

Figure 2 - Detached house: Ground floor plan

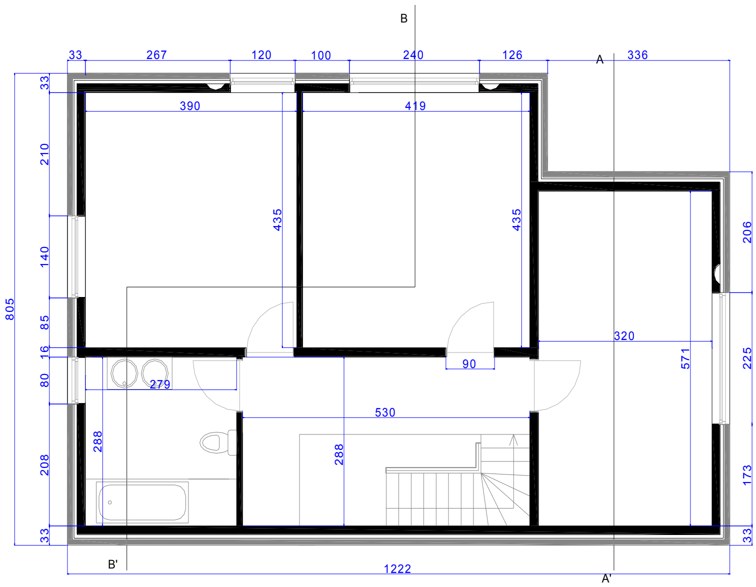

Figure 3 - Detached house: 1st floor plan

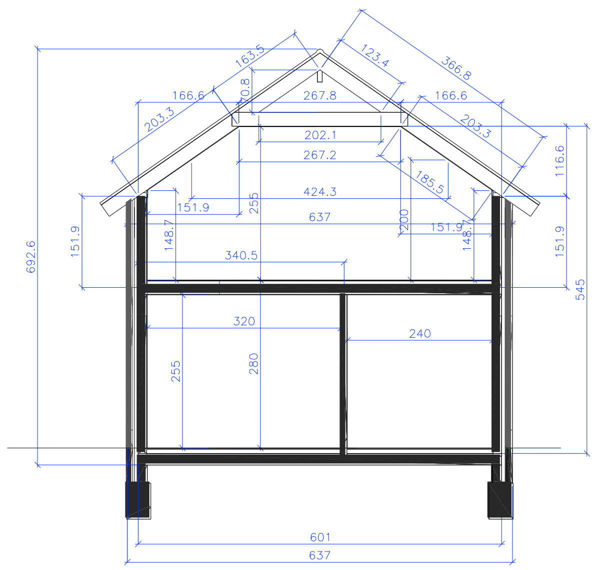

Figure 4 - Detached house: Section AA'

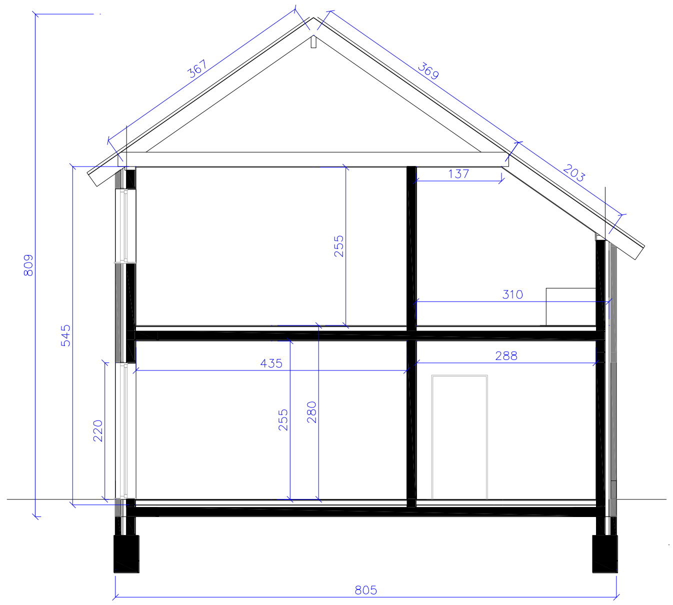

Figure 5 - Detached house: Section BB'

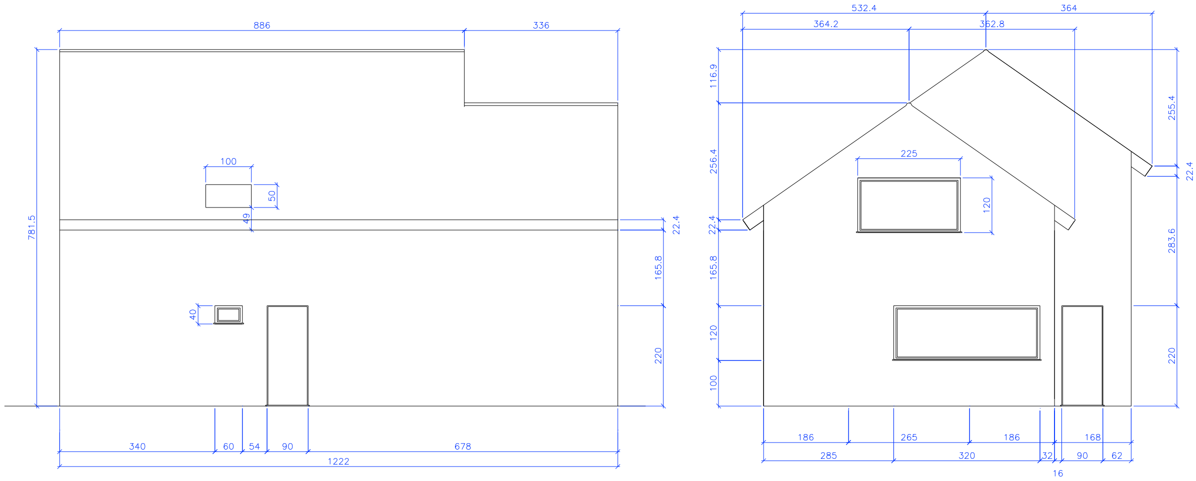

Figure 6 - Detached house: North elevation (left) and West elevation (right)

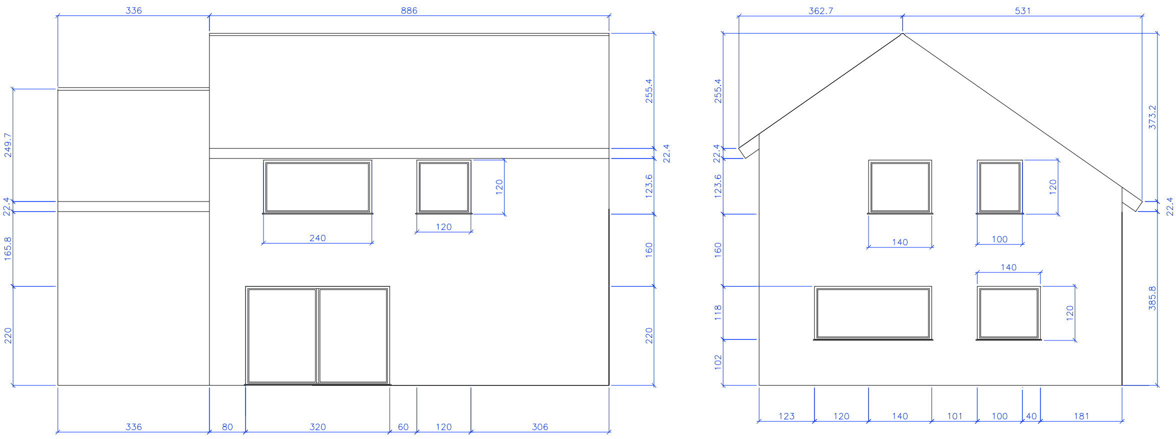

Figure 7 - Detached house: South elevation (left) and East elevation (right)

Semi-detached house

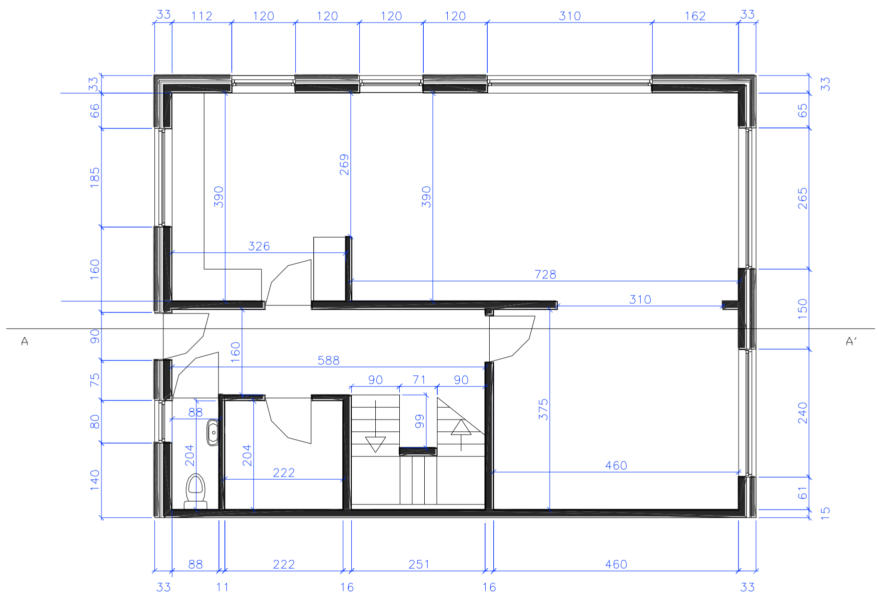

Figure 8 - Semi-detached house: Ground floor plan

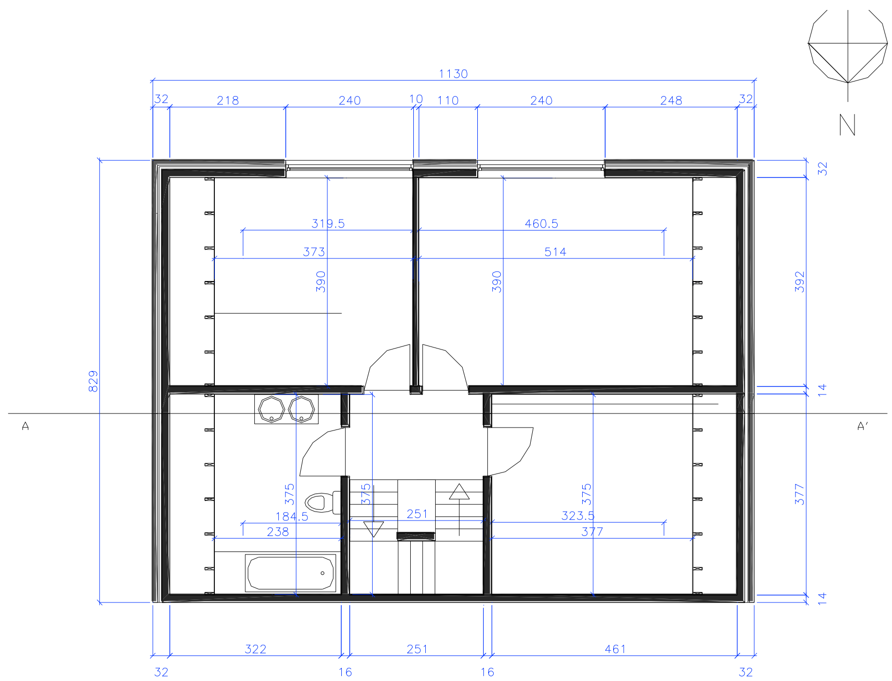

Figure 9 - Semi-detached house: 1st floor plan

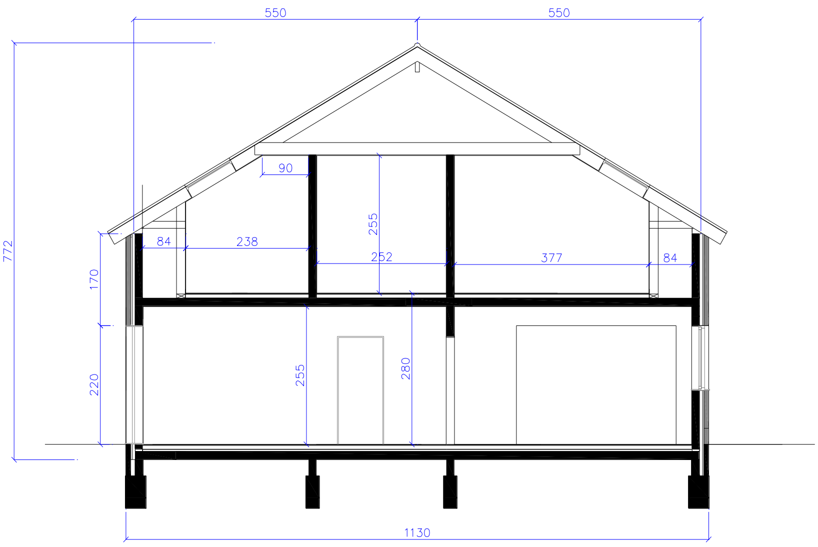

Figure 10 - Semi-detached house: Section AA'

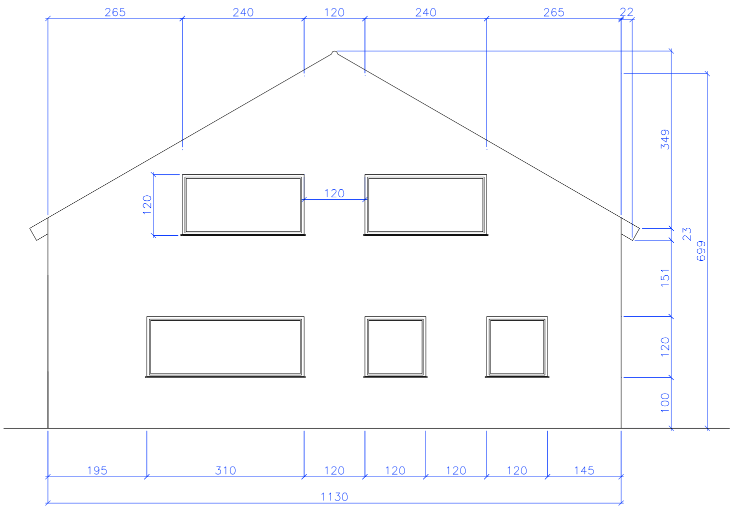

Figure 11 - Semi-detached house: South elevation

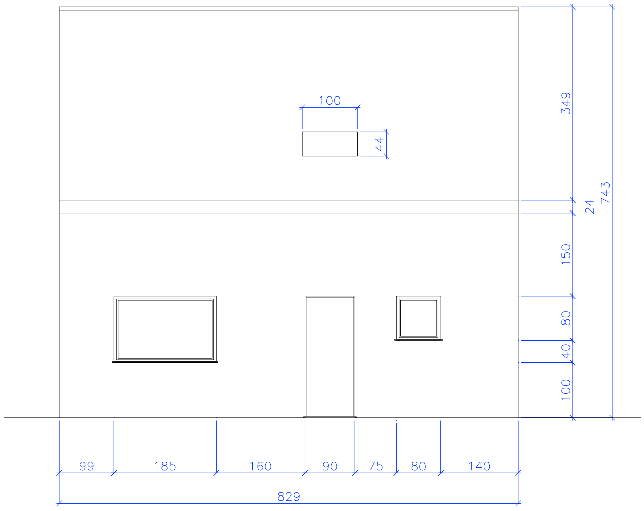

Figure 12 - Semi-detached house: East elevation

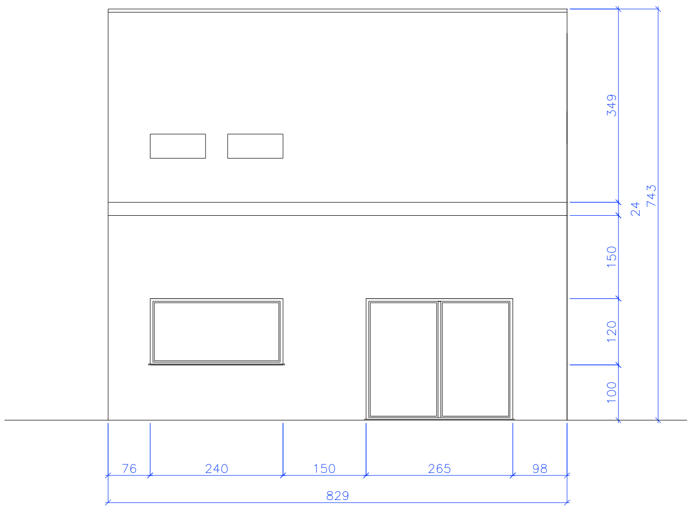

Figure 13 - Semi-detached house: West elevation

Terraced house

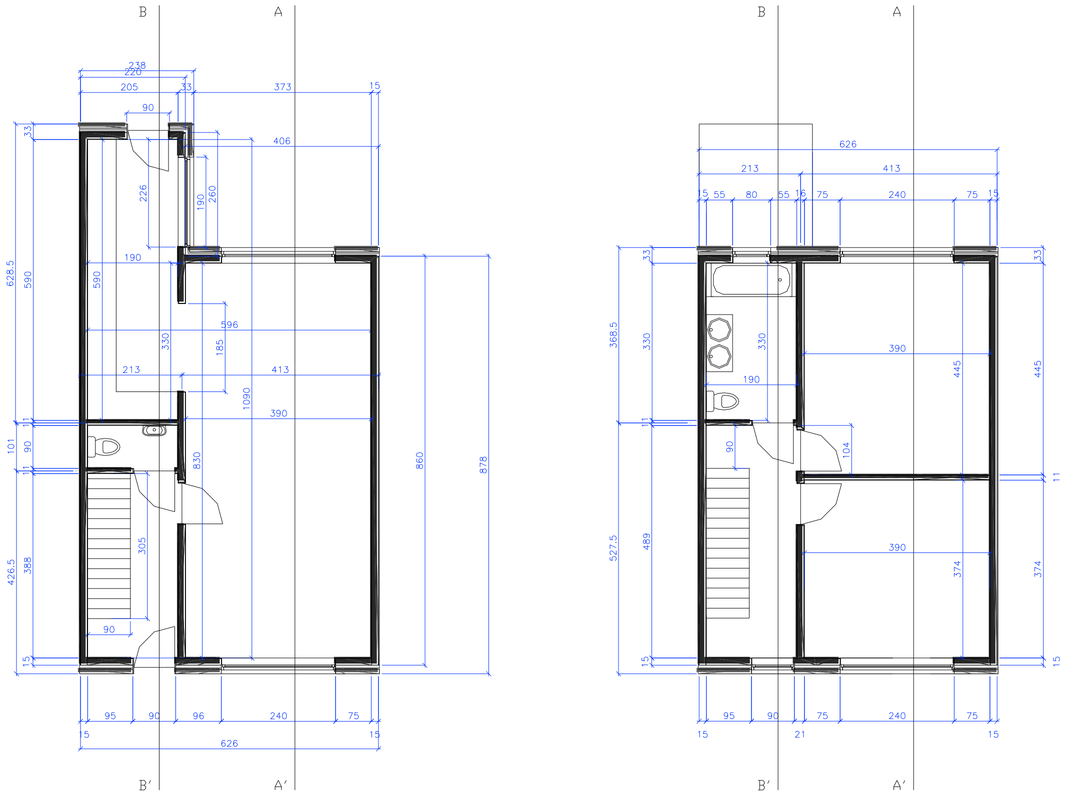

Figure 14 - Terraced house: Ground floor plan (left) and 1st floor plan (right)

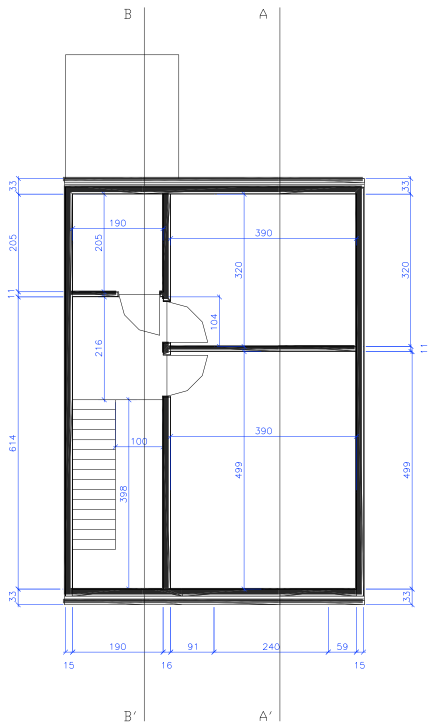

Figure 15 - Terraced house: 2nd floor plan

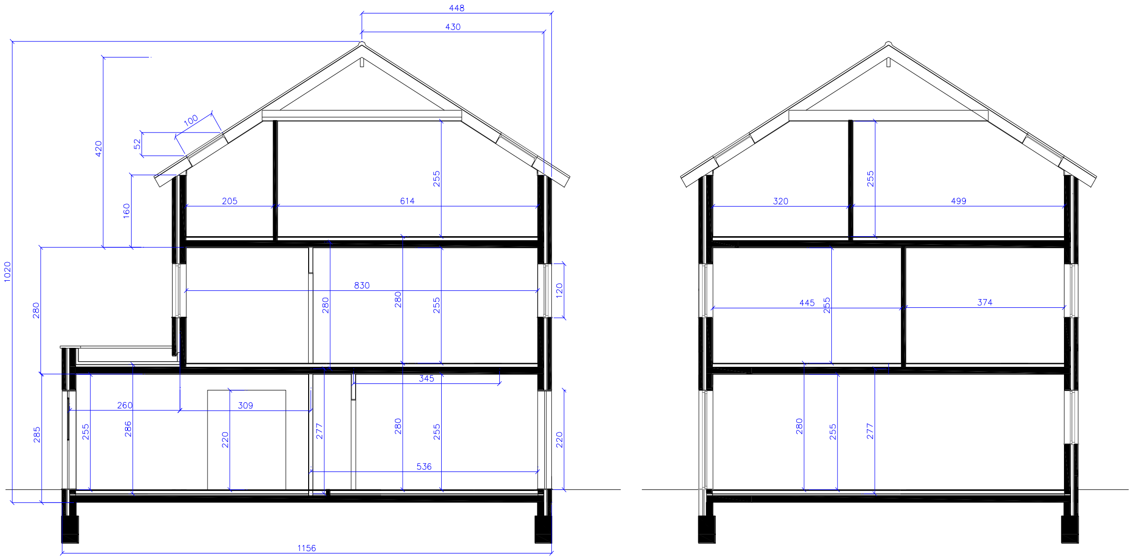

Figure 16 - [illegible]d [illegible]BB' [illegible]d AA' [illegible]

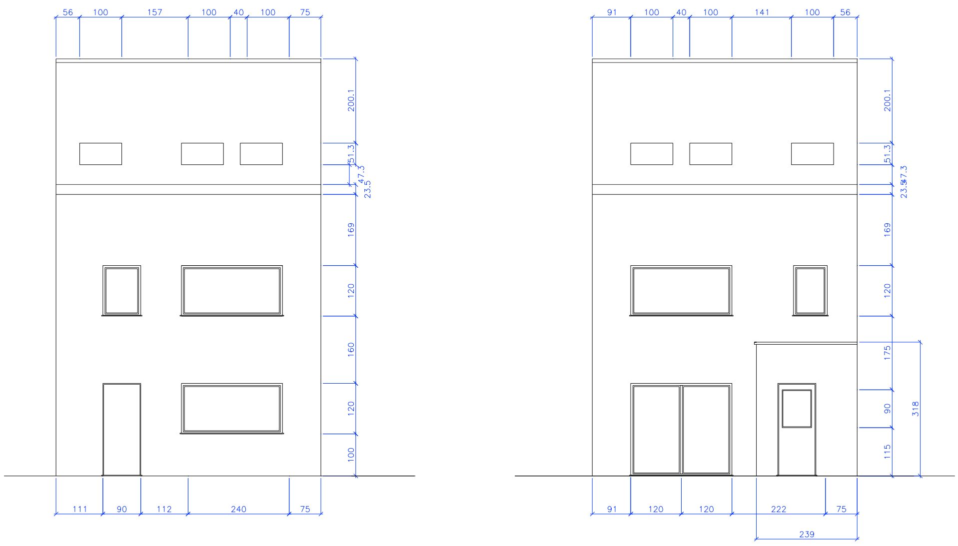

Figure 17 - Terraced house: North elevation (left) and South elevation (right)

Apartment/office typical floor

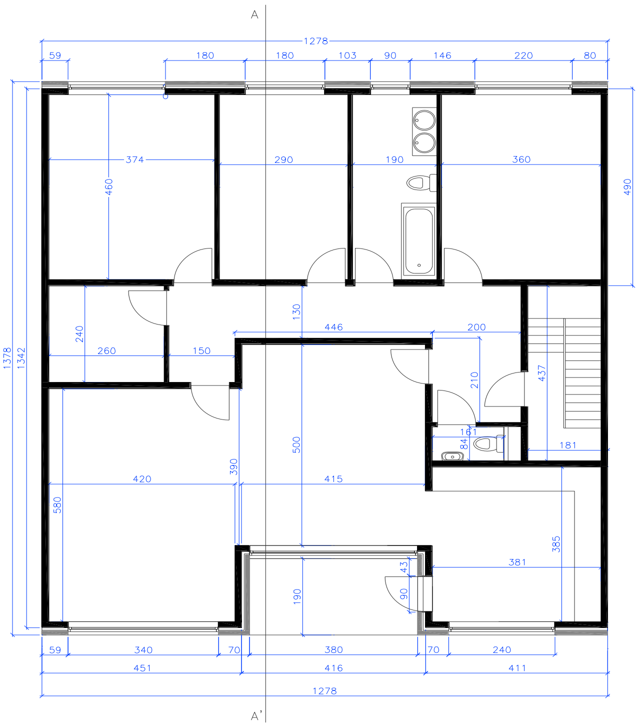

Figure 18 - Apartment block / Office building: Typical floor plan

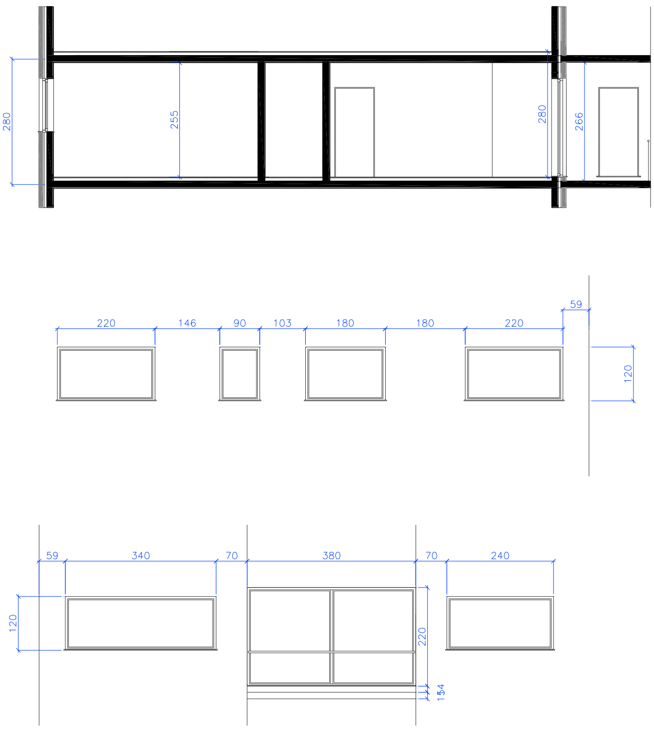

Figure 19 - Apartment block / Office building: Section AA' (top), North elevation (middle) and South elevation (bottom) of a typical floor