BUILDING ENERGY AND LIGHT SIMULATIONS FOR THE DESIGN OF PASSIVE-APARTMENT BUILDINGS IN BELGIUM

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ABSTRACT

The preliminary design of a new low-energy apartment building for a demonstration project in Belgium has been simulated using DIALux evo and TRNSYS. The two main objectives of this work are to obtain affordable building designs with primary energy consumption lower than 60kWh/m^2·year (excluding appliances energy usage) and to ensure that the space heating demand for each house is below 15kWh/m^2·year. This work presents a set of design options that was obtained using GenOpt to minimize the energy demand for heating and cooling in the thermal zone with the highest demand. Photovoltaic energy generation simulations show that it is possible to reach near net zero energy buildings using these designs.

INTRODUCTION

This work presents the preliminary design of passive houses for a demonstration project of new low-energy buildings. Different energy efficient measures are taken into account. The houses will have high performance building envelopes. Air source heat pumps will be used for the domestic hot water production and the space heating demand. All the houses will use high efficiency heat recovery ventilation units. More over, LED bulbs will be employed to lower the lighting energy demand. The houses will also include photovoltaic panels to lower the primary energy demand.

The achievement of the energy targets are to be accomplished while avoiding significant changes to the architect's proposal. During the first stage, a manual optimization to diminish the space heating loads of the design was done in TRNSYS including the effects of windows U-values, efficiency of the heat recovery ventilation units and the use of earth-air heat exchanger (Canadian wells) for fresh air preheating. An estimation of the occupants' thermal comfort has been done. The roof-mounted photovoltaic power generation has been simulated using TRNSYS3D to properly place the Photovoltaic (PV) panels in the allocated roof space for each of the housing units and to diminish self-shading effects that reduce the return on the investment. The PV generation simulations also consider the effect of using higher efficiency modules. For the selection of LED luminaires, the DIALux evo software was used taking into consideration recommended illumination values for the different apartment zones (e.g. Bathrooms, kitchen, living room, dining room, etc.). The energy demand for hot water has been estimated using an expression correlating the mains water temperature to the ambient temperature, and the expected volumetric use per day based on the number of occupants. For appliances, average values for power consumption and hours of use have been employed to estimate their yearly energy consumption.

The PV simulations show that it is possible to obtain near to net zero passive energy buildings using these designs. To further expand the design options, the GenOpt program was used with the developed TRNSYS model. GenOpt has been used by several researchers for optimization design (Magnier and Haghighat 2010, Coffey et al. 2010, Carlucci and Pagliano 2013). In the near future, a validation of the simulation results will be carried out with a 2 year monitoring-campaign using energy meters and temperature and relative humidity sensors using ZigBee wireless networks (Faludi 2010).

DESIGN APPROACH

First, a complete preliminary building design with the objective of reducing space-heating loads was carried out by the project's architect. This serves as a measure to reduce the need of renewable energy sources. The building design incorporated passive strategies such as large sourth facing windows, high insulation levels and so forth. The energy performance of this design was evaluated with TRNSYS. Later on, the thermal zone with the highest heating load was optimized by changing its building envelope using GenOpt. Then, careful planning of the building illumination luminaries was done with DIALuxevo. The energy generated with photovoltaics was evaluated and shading effects were considered. The energy demands for domestic hot water were calculated as a function of the expected number of occupants and the mains water temperature. Average values for the energy use of appliances were considered in order to estimate the electrical energy demand for the whole building.

PRELIMINARY BUILDING DESIGN

Six housing units including a ground floor and a first floor form the apartment building complex. The project will be built in the town of Quaregnon, Belgium. A basic floor plant is shown in Figure 1.

Figure 1 Building Floor plants (ground and first floor)

The starting building envelope parameters are presented in Table 1.

Table 1
Basic Design Parameters

PARAMETERS	VALUE
Roof U-Value (W/m^{2}K)	0.09
Ground U-Value (W/m^{2}K)	0.09
Façade/wall (W/m^{2}K)	0.09
Glazing (W/m^{2}K)	$U \leq 0.75$
HRV_e (%)	75%≤ HRV_e
Internal Gains (W/m^2)	2.1
Ventilation rate	NBN D50-001

Figure 2 shows the thermal zones for the simulation in TRNSYS.

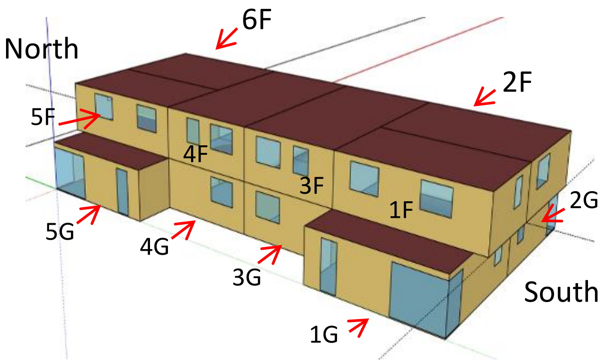

Figure 2 Thermal Zones

Modelling assumptions for the Building Design

The first assumptions for the simulation are the following:

- Heating temperature set point 20°C (no night setback)
- Ventilation rates (according to NBN D50-001) (Bureau de normalisation 1991)
- Internal gains: 2.1W/m^2
- Infiltration: 0.024 h^{-1}
- Cooling temperature set point: 25°C
- HRV_e = 85 %
- TMY2 weather data for Uccle, Belgium.

The ventilation rate used is larger than the ventilation rate required by the Passiv haus standard of 20-30 m^3/h per person (Feist et al. 2007).

Heating Loads

The heating loads (HL) for each thermal zone are presented below for windows glazings with U=0.75W/m^{2}K and G=0.613, HRV_e= 85%, windows frame's U_{fr}=3W/m^{2}K.

Table 2
Heating Loads per zone

ZONE	HL kWh/m^{2}year	ZONE	HL kWh/m^{2}year
1G	17.1	1F	16.1
2G	15.8	2F	15.3
3G	13.7	3F	14.3
4G	13.8	4F	14.3
5G	21.9	5F	19.7
6G	21.4	6F	19.9

As can be seen in the previous table, the zone with maximum heating load demand is 5G. This is not surprising since the zone is in the north west side of the building and has lower solar gains (see Figure 2).

In order to optimize the design for the building envelope in zone 5G, GenOpt (Wetter 2011) was used in conjunction with TRNSYS. In total 11 parameters were studied and are explained below.

The north facing and west facing walls were studied in detail. The insulation thickness for both of them was varied (LI-Nth and LI-Wst). The insulation type was polystyrene with an assumed k value of 0.031W/(mK). The width of three different windows was varied too. For four windows (See Figure 1), different window specifications were studied (see Table 4). For the optimization, the following parameters were also taken into account (Table 3):

Table 3
Optimization parameters and ranges

	MIN	INI	MAX	STEP
HRV_e	0.70	0.70	0.95	0.05
W-w2	0.40m	0.80m	1.2m	0.10m
W-w3	0.71m	1.42m	2.14m	0.10m
W-w4	1.4m	2.80m	4.2m	0.10m
LI-Nth	0.20m	0.39m	0.60m	0.01m
LI-Wst	0.20m	0.39m	0.60m	0.01m

Table 4
Windows Glazing's U and G Values

WINDOW TYPE (Typ)	*U* (W/m²K)	*G* (%)
1	0.68	0.407
2	0.40	0.408
3	0.70	0.501
4	0.59	0.451
5	0.61	0.402
6	0.59	0.584
7	0.63	0.418
8	0.75	0.613

The window frames tested have four *U* values: 3.03, 2.4, 1.7 and 0.8 W/m^2K.

Thermal Comfort

TRNSYS uses standard EN ISO 7730 for the thermal comfort calculation, and the dermination of the predicted mean vote (PMV). For the simulations, the simple model was selected, and it is based on the area weighted mean surface temperatures. As input parameters, a constant metabolic rate of 1 met, a constant velocity of 0.1m/s and a clothing factor equal to 1 in winter, 0.5 in summer and 0.8 during the rest of the year was used.

The winter time for the simulation was defined as the time between October 22^{nd} to May 19^{th}, and summer between June 15^{th} until August 16^{th}.

The predicted percentage dissatisfied (PPD) can be calculated directly with the equation proposed by Fanger (1970):

$$PPD = 100 - 95e^{-0.03353PMV^4 - 0.2179PMV^2} \quad (1)$$

With the previous equation, for a PMV of 0.5, the PPD is 10.2%.Typically a PMV below or equal to 0.5 is considered as acceptable values for thermal comfort. The average yearly absolute PMV value for the simulation has been calculated.

Cost Estimation

The cost estimation includes the price for insulation and its installation, the price of glazing and window frames. Average prices have been considered using data from (Detroz and Croufer 2013) that were obtained by a market study.

Optimization

Due to the large amount of possible different design configurations, an optimization tool can search for the optimized design solutions without having to evaluate all the different design options.

GenOpt Optimization results

The GenOpt optimization tool allows for the optimization of one cost function. In this study, the selected function was the minimization of the heating and cooling loads. The used optimization algorithm is the GPSPSOCCHJ that uses a generalized pattern search algorithm (GPS) that is initialized using a particle swarm optimization algorithm (Wetter 2011).

The optimization took 3.876 hr to perform 417 simulations on a genuine intel processor with 6 cores.

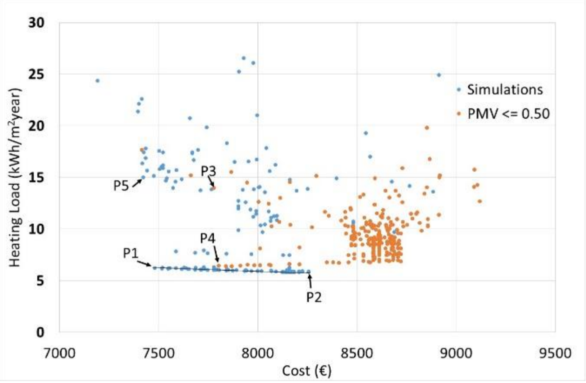

Figure 3 Optimization results for zone 5G

Figure 3 shows the optimization results with GenOpt. The objective funcion is plotted in the *y* axis in Figure 3. As displayed in the figure, there are numerous results that will ensure that the heating loads are below the limit of $15kWhr/m^2$. The results that also include a PMV lower or equal to 0.5 are displayed in orange color. It is important to remark that the results are not for a multi-objetive optimization, since the minimization of the cost was not part of the search algorithm. In a multiobjective optimization, the objective is to find the set of optimal solutions that are pareto-optimal. The solutions are pareto-optimal if they are not dominated by another solution that is better at least in one objective function value (Van Veldhuizen and Lamont 1998).

In Figure 3 five points of interest have been selected:

- 2 pts (P1 and P2) at the edges of a pseudo pareto front (since not obtained with a multi-objective optimization),
- 2 pts in orange for the lowest price and below 15 kWh/m^2·year and another point for lowest energy demand when the PMV is lower-equal than 0.5 (P3 and P4).
- 1 pt below 15 kWh/m^2·year and lowest cost (P5).

The results for the 5 points and their parameter values for are summarized in Table 5 and 6.

Table 5
Cost, HL, CL and PMV for optimal solutions

POINT	COST €	HL kWh/m²yr	CL kWh/m²yr	PMV
1	7482	6.18	0.28	0.52
2	8258	5.89	0.31	0.51
3	7780	13.97	2.04	0.47
4	7805	6.41	0.48	0.49
5	7425	14.98	0.73	0.55

Table 6
Parameters values for the optimal points

POINT	1	2	3	4	5
HRV_e	0.95	0.95	0.85	0.95	0.90
W-w2	0.40	0.40	0.70	0.40	0.6
W-w3	0.725	0.825	1.025	0.925	1.225
W-w4	1.4	1.4	2.1	1.7	2.1
LI-Nth	0.57	0.6	0.52	0.54	0.52
LI-Wst	0.42	0.6	0.36	0.39	0.36
W2	Typ-2	Typ-2	Typ-3	Typ-2	Typ-1
W3	Typ-2	Typ-2	Typ-4	Typ-2	Typ-2
W4	Typ-2	Typ-2	Typ-6	Typ-2	Typ-2
W5	Typ-2	Typ-2	Typ-8	Typ-2	Typ-6
U_{fr}	0.8	0.8	1.7	0.8	3.03

Results

As can be seen in the results, the pseudo pareto front is rather flat for the varied paremeters. An investment increase of 10.4% results only in a 4.9% reduction of the expected heating load. Regarding the PMV being just above 0.5 for point 1, this can be improved by slighty increasing the room temperature set point. For three of the five optimal points, the type of windows found is type 2, which corresponds to the one with the lowest *U* value. The results clearly point out that it is better to resize the windows rather than increase the insulation thickness.

For Point 1, the number of hours when the temperature is above 25°C is 86 hours which represents less than 1% of overheating events throughout the year.

Lighting study

In order to diminish the electrical loads, the LED technology has been chosen due to its high luminous efficacy (lm/W) and longer life expectancy. To select the equipment, we have used the recommended lighting levels as provided by Deneyer (2011) (Table 7) as criteria. The DIALux evo software has been used to simulate the lighting distribution in the building (DIAL GmbH 2012) (See Figure 4). The ground floor will need a combination of luminaires totaling about 646 W, for the first floor the required total power is about 1086W.

Table 7
Average Recommended Illumination Levels (after (Deneyer 2011))

ROOM	AVER ILLUMINATION
Entrance room and corridors	
Entrance hall/room	100 lx
Corridors	50-100 lx
Stairs	100 lx
Bathrooms and WC	
Ambient Lighting	200 lx
Illumination of the mirror and sink	300-500 lx
Toilets	100 lx
Kitchen	
Ambient lighting	200-300 lx
Work Plane	200-500 lx
Living Room	
Resting zone (couch, etc.)	50-200 lx
Reading	300 lx
Dining Room	
Ambient Lighting	100 lx
Table illumination	100-300 lx
Bedrooms	
Ambient Lighting	100-200 lx
Reading Zone	300 lx
Laundry room, cellar, garage etc.	
Ambient Lighting	50-100 lx
Working zone (crafts, ironing, etc.)	300 lx

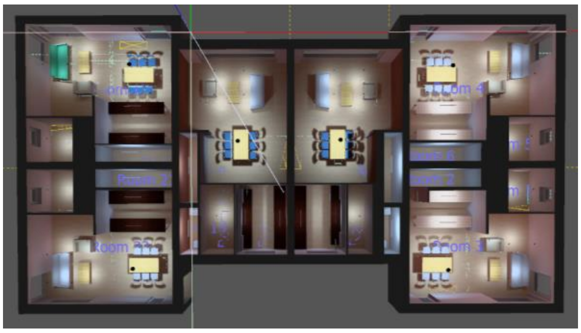

Figure 4 Illumination rendering for the ground floor carried out with DIALux evo.

In order to estimate the energy consumption by lighting for the residential buildings, we will base our assumptions in monitored data for residential houses (Vine and Fielding 2006). The article summarizes research from a set of different references. The monitored average usage hours per day (HPD) ranged from 2.0 to 4.6. However, more recent monitored data (2004-2005) states that the usage is in the range of 2.2 to 3.1 HPD (Vine and Fielding 2006).

Using the previous figures, we have a lower estimation, based at 2.2HPD, of 2.4 kWh/(m^2·year) and a higher energy estimation, based at 3.1HPD, of 3.4kWh/(m^2·year).

Appliances Energy consumption

Typical appliances for housing have been considered for the estimation of the energy consumption. The values of the estimation are presented in Table 8.

Therefore the power consumption due to appliances is estimated to range between 27.3 to 36.3 kWh/(m^2·year). Energy savings can be obtained by selecting appliances with higher efficiency levels. The values in Table 8 are indicative only.

Table 8
Energy Consumption Estimation for Appliances (Convention UMONS-Laborelec 2013, Energuide 2012, ARENE (Ile de France) 2009).

APPLIANCE	AVER. POWER (W)	HOURS PER DAY (H/DAY)	YEARLY DEMAND (kWh)
Refrigerator	40	24	350.4
Stove	1400	1	511
Oven	2300	0.67	486.7
Microwave	710	0.14	51.1
Dishwasher	1200	0.8	350.4
Coffee maker	700	0.167	42.6
Washing machine	1250	0.57	260.1
Dryer	1150	1	419.7
TV(Bertoldi and Atanasiu 2007)	300	3.87	423.8
Total Energy consumption per apartment per year			3054

Energy Consumption Estimation for Domestic Hot Water

To estimate the energy consumption for Domestic Hot Water (DHW), it is necessary to know the water mains temperature, the number of persons and their water usage, and the supply temperature.

SATO et al. (2011) employed the following equation to calculate the mains water temperature (T_w) from the average ambient air temperature:

$$T_W = 0.8516 * T_a + 2.473 \qquad (2)$$

where T_a is the average ambient air temperature.
The energy demand for hot water supply (DHW in kJ/day) can be the calculated using the following expression:

$$DHW = \dot{m} c_p (T_H - T_W) = V \rho c_p (T_H - T_W) \qquad (3)$$

where: c_p is the specific heat of water assumed constant at 4.184 kJ/(kg°C), ρ the water density assumed constant at 1000 kg/m^3, V the volumetric flow rate in m^3/day, T_H is the supply water temperature, typically between 55 to 60°C. For our analysis, we will assume 60°C for T_H.
The ambient weather data for Brussels national airport was obtained from RETScreen (Natural Resources Canada 2013) and is shown in Table 9.

Table 9
Weather data for Brussels National Airport RETScreen (Natural Resources Canada 2013)

MONTH	AVERAGE AMBIENT AIR TEMPERATURE (°C)
January	3.4
February	3.6
March	6.5
April	9.3
May	13.2
June	15.9
July	18.2
August	18
September	14.9
October	11.3
November	6.8
December	4.4

Figure 4 shows the expected monthly energy demand for hot water for the two different scenarios.

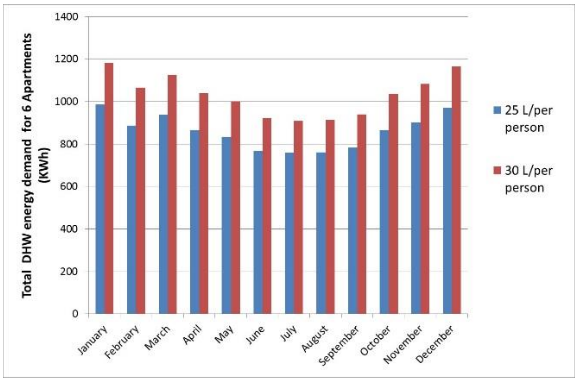

Figure 4 DHW demand through the year under different usage rates scenarios.

Table 10
DHW demand for the six Apartment Building

	SCENARIO	
	25 L/PERSON	30 L/PERSON
Total Yearly DHW demand (kWh/year)	10313	12375
Total Yearly DHW demand (kWh/m^{2}year)	17.8	21.3
Electrical demand (kWh/m^{2}year) with ASHP COP 3.1	5.7	6.9
Electrical demand (kWh/m^{2}year) with ASHP COP 2.5	7.1	8.5

For the number of liters used per day, the following assumptions have been used: a) 25 L/per person and b) 30 L/per person. Apartments 1, 2, 5 and 6 are assumed to have 3 occupants each, and apartment 3 and 4, have 4 occupants each.

Table 10 summarizes the yearly total energy consumption assuming different values for the effective COP of an ASHP. The DHW demand was also calculated using the method proposed by the Energy performance of buildings (AGW 2008). The method takes into account the number of bathrooms and kitchen sinks, together with the unit's volume as inputs. With this method, the obtained demand is 16.3 kWh/m$^{2}\cdot$year. This value is very close to the demand of 25 L/person.

Renewable energy generation

The installation of photovoltaic panels has been studied for the roofs of the buildings using TRNSYS (Klein, Duffie and Beckman 2006, TRANSSOLAR Energietechnik GmbH 2012). Shading analysis has been done for a specific panel (Sanyo HIT-N240SE10). The PV panel main characteristics are summarized in Table 11. This panel has a module efficiency of 19%. It is important to note that the renewable energy generation was not included in the previous optimization with GenOpt.

Table 11
PV module specifications for Sanyo HIT- N240SE10

Nominal Power (W)	240
Max power tolerance (%)	+10/-5
Max system voltage (V)	1000
Max Voltage (V)	43.7
Maximum Power current (A)	5.51
Open circuit voltage (V)	52.4
Short circuit current (A)	5.85
Cell efficiency (%)	21.6
Module efficiency (%)	19
Length (mm)	1580
Width (mm)	798

Energy Analysis for 35 PV Panels for Apartments 3 and 4

For the apartments in the middle of the building (3 and 4), each tilted roof has the dimensions of 9.32 X 6.12 m^{2}. For comparison purposes, the same amounts of panels were placed in apartments 1-2 and 3 to evaluate the effect of shading. In practice, apartments 1 and 2, 5 and 6 will have their roof separated in two sections (9.32m/2 = 4.66m), since the apartments will be sold with their respective PV arrays to the customers.

Figure 5 shows the PV installations for roofs of apartment 1(reference) and 3. Apartment 4 will produce the same amount of energy as apartment 3. Table 12 presents the expected energy output for the shaded and the unshaded PV surfaces.

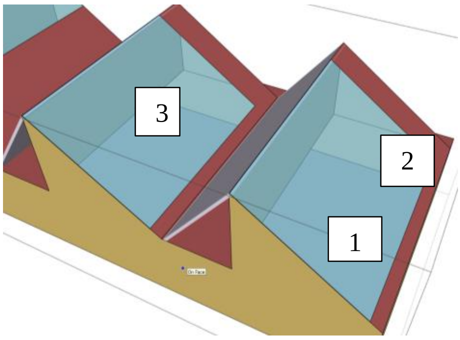

Figure 5 Area occupied by 35 Sanyo HIT-N240SE10 panels. The first roof surface (1&2) does not suffer from shading while the second area does (Apt 3, 44.13m^{2}).

Table 12
Energy output

	FOR APARMENTS 3 & 4 (SHADED)	**REFERENCE SURFACE (UNSHADED)**
Estimated yearly energy production (before inverter)	7.408 MWh	8.206 MWh
% Decrease from the higher value	9.72%	0

Energy generation analysis were carried out in a similar fashion taking into consideration the available tilted surface area in the roofs with the results summarized in Table 13. Figure 6 shows the different energy outputs per array including shading effects.

Table 13 Predicted energy output for a combination of PV installations considering shading effects

LAB	**PV CONFIGURATIONS**	**ENERGY kWh/m²y**
1	17 Panels (Apt:1,2 unshaded)	51.91
2	35 Panels (Apt:3,4 shaded)	
3	17 Panels (Apt: 5,6 shaded)	
4	15 Panels(Apt:1,2 unshaded)	46.21
5	30 Panels (Apt:3,4 shaded)	
6	15 Panels (Apt:5,6 shaded)	
7	10 Panels(Apt:1,2 unshaded)	35.34
8	25 Panels (Apt:3,4 shaded)	
9	10 Panels (Apt:5,6 shaded)	
10	10 Panels (Apt:1,2 unshaded)	31.72
11	20 Panels (Apt:3,4 shaded)	
12	10 Panels (Apt:5,6 shaded)	
13	10 Panels(Apt:1,2 unshaded)	27.93
14	15 Panels (Apt:3,4 shaded)	
15	10 Panels (Apt:5,6 shaded)	

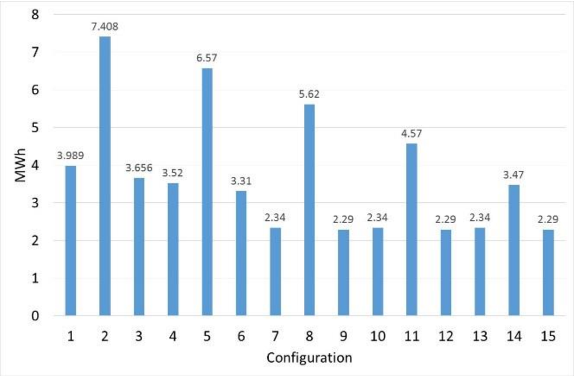

Figure 6 Energy output for different configurations per PV array per apartment.

As can be seen in Table 13, different combinations of PV modules have been studied including the shading effects for the Belgian building demonstration site. The simulations show that it is possible to reach 51.9 kWh/(m^2·year) of renewable energy production for the whole building.

A summary of the electrical loads for apartment 5 is shown in Table 14. It is assumed an ASHP with a COP of 2.7 is used to provide the space heating.

Table 14
Summary of Electrical loads for Apartment 5

LOADS	kWh/(m²·year) (electrical)	PRIMARY ENERGY DEMAND kWh/(m²·year)
Space Heating (ASHP COP 2.7)	5.4	13.5
Cooling	NA	0
Ventilation	2.8	7
Domestic Hot Water (ASHP COP 2.5	8.8	22
Lighting	3.26	8.15
Total	**20.26**	**50.65**
Renewable energy	**-23.75**	**-59.37**

In Table 14, a primary energy factor for electricity of 2.5 has been used.

Monitoring Plan

An energy commissioning for the building is planned to ensure that the systems are in order and for the verification of the initial energy targets. It has been previously reported that typical deviations can be 300-400% on the energy consumption (Larsen and Jensen 2011, Gram-Hanssen 2005). In the report, the deviation is due to different user's behaviour patterns and the performance of the construction and equipment.

At least one housing unit will be monitored for a period of 2 years. During this time, the room temperature and relative humidity will be measured with digital sensors read by microcontrollers and the data will be transmitted to an Ethernet connected base station using ZigBee certified radios (Faludi 2010).

Energy consumption by the air source heat pump will be measured as well as the thermal energy produced by the heat pump to produce the space heating. The energy consumed for the domestic hot water production will be measured. The energy consumed by the HRV unit will be measured continuously. Discrete measurements to determine the efficiency of the HRV unit are planned. Exterior environmental parameters such as temperature, wind speed and solar radiation will be monitored. We will also measure the solar energy transmitted through the windows. For energy generation, the incident solar radiation on the PV panels and the energy produced before and after the inverter will be monitored as well.

CONCLUSION

The present work has shown that there are multiple solutions that will ensure the heating load will be below the 15 kWh/(m^2·year). The optimization also yields some light on the overall investment cost. DIALux evo was used to find the right amount of fixtures needed while respecting minimum recommended illumination values. The simulations also show that it is possible to reach a near zero energy building with the PV generation contribution. Further work will include a multi-objective optimization to minimize the cost and space heating load.

NOMENCLATURE

T_H,	Supply water temperature,
T_a,	Ambient air temperature,
T_w,	Mains water temperature,
$\dot{m}$,	Mass flow rate,
V,	Volumetric flow rate,
c_p,	Specific heat of water,
U,	Heat transfer coefficient,
HRV,	Heat recovery ventilator
HRV_e,	Heat recovery ventilator efficiency
LI-Nth	Insulation thickness for north wall (5G)
LI-Wst	Insulation thickness for west wall (5G)
COP,	Coefficient of performance
W-w#	Window width number
W#,	Window number
HL,	Heating Load
CL,	Cooling Load
PV,	Photovoltaics
PMV,	Predicted mean vote
PPD,	Predicted percentage dissatisfied

ACKNOWLEDGEMENTS

This work is part of the NEED4B consortium activities and it is co-financed by the European Commission through the Seventh Framework Programme.

REFERENCES

AGW. 2008. Arrêté du Gouvernement wallon déterminant la méthode de calcul et les exigences, les agréments et les sanctions applicables en matière de performance énergétique et de climat intérieur des bâtiments. Annexe 1 - Méthode de détermination du niveau de consommation d'énergie primaire des bâtiments résidentiels., 107.

ARENE (Ile de France). 2009. Efficient use of Electricity.

Bertoldi, P. & B. Atanasiu (2007) Electricity consumption and efficiency trends in the enlarged European Union. IES–JRC. European Union.

Bureau de normalisation. 1991. NBN D 50-001 Dispositifs de ventilation dans les bâtiments d'habitation. Bruxelles.

Carlucci, S. & L. Pagliano. 2013. An optimization procedure based on thermal discomfort minimization to support the design of comfortable net zero energy buildings. In 13th Conference of the International Building Performance Simulation Association, BS, 3690-3697.

Coffey, B., F. Haghighat, E. Morofsky & E. Kutrowski (2010) A software framework for model predictive control with GenOpt. Energy and Buildings, 42, 1084-1092.

Convention UMONS-Laborelec. 2013. Etude de la flexibilité de la consommation électrique des pompes à chaleur utilisées pour le chauffage de l'habitat (Flexipac). In Rapport Final. UMONS.

Deneyer, A. H., P.D.; Deroisy, B.; Roisin, B.; Bodart, M.; Deltour, J. 2011. Guide Pratique et Technique de l'Éclairage Résidentiel. 57 Centre Scientifique et Technique de la Construction, CSTC.

Detroz, J. & M. Croufer. 2013. CO-ZEB. Rapport final du project (4) Couts d'investissements initiaux. ed. Département de l'Energie et du Bâtiment durable, 53. SPW-DG04.

DIAL GmbH. 2012. DIALux evo 1. The software standard for calculating lighting layouts, User Manual.

Energuide (2012) How much energy do my household appliances use. http://www.energuide.be/en/questions-answers/how-much-energy-do-my-household-appliances-use/71

Faludi, R. 2010. Building wireless sensor networks: with ZigBee, XBee, arduino, and processing. O'reilly.

Fanger, P. O. 1970. Thermal comfort: Analysis and applications in environmental engineering. Danish Technical Pres.

Feist, W., R. Pfluger, B. Kaufmann, J. Schnieders & O. Kah. 2007. Logiciel de conception de maison passive 2007. Exigences relatives à la certification de maison passives.

Gram-Hanssen, K. (2005) Husholdningers elforbrug - hvem bruger hvor meget, til hvad og hvorfor?, SBI 2005:12,Danish Building Research Ins.

Klein, S., J. Duffie & W. Beckman (2006) Trnsys 17. A transient simulation program. Solar Energy Laboratory, Univeristy of Wisconsin, Madison.

Larsen, T. S. & R. L. Jensen. 2011. Comparison of Measured and Calculated Values for the Indoor Environment in One of the First Danish Passive Houses. In Proceedings of Building Simulation, 1414-1421.

Magnier, L. & F. Haghighat (2010) Multiobjective optimization of building design using TRNSYS simulations, genetic algorithm, and Artificial Neural Network. Building and Environment, 45, 739-746.

Natural Resources Canada. 2013. RETScreen Software Suite. In Empowering Cleaner Energy Decisions, ed. R. International.

Sato, R., T. Asawa & A. Hoyano. 2011. Numerical Analysis of Thermal Environment and Energy Consumption for an Actual Residential Area Based on Various Inhabitants' Behavior Schedules. In PLEA 2011: Architecture & Sustainable Development: Conference Proceedings of the 27th International Conference on Passive and Low Energy Architecture, Louvain-la-Neuve, Belgium, 13-15 July, 2011, 29. Presses univ. de Louvain.

TRANSSOLAR Energietechnik GmbH. 2012. TTRNSYS 17, a TRaNsient SYstem Simulation Program, Volume 5, Multizone Building Modeling with Type56 and TRNBUILD.

Van Veldhuizen, D. A. & G. B. Lamont. 1998. Evolutionary computation and convergence to a pareto front. In Late Breaking Papers at the Genetic Programming 1998 Conference, 221-228. Citeseer.

Vine, E. & D. Fielding (2006) An evaluation of residential CFL hours-of-use methodologies and estimates: Recommendations for evaluators and program managers. Energy and Buildings, 38, 1388-1394.

Wetter, M. (2011) GenOpt Generic Optimization Program User Manual Version 3.1. 0. Simulation Research Group, Building Technologies Department, Lawrence Berkeley National Laboratory, Berkeley, CA, USA.