



Green Solar Cities

Contract no TREN07/FP6EN/S07.70775/038573
6th Framework Programme – CONCERTO II – Integrated Project

D6.2 Report on Implementation of energy survey in Copenhagen and Salzburg D6.3 Yearly Monitoring Report

Submission date

July 2011

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Inge Straßl

Dissemination Level		
PU	Public	X
PP	Restricted to other program participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	



Green Solar Cities is a project of the CONCERTO initiative co-funded by the European Commission within the Sixth Framework Program.

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1. Methods of Data Collection / Monitoring

During the first 4 years of Green Solar Cities many innovative and interesting projects were realized. More projects will be finished until the end of the project.

In order to find out if the goals were reached and if the buildings and plants perform as planned detailed monitoring is carried out.

Different methods of Data Collection and ways of Monitoring have been introduced in the cities:

- CCDS Concerto Community Data Sheet - Calculation of the city performance
- City Performance Sheet - Comparison of the performance of plants and buildings
- Individual monitoring of the cities

The input provided by the cities and monitored data will be evaluated in detail during the next year. Some first results are shown in this report.



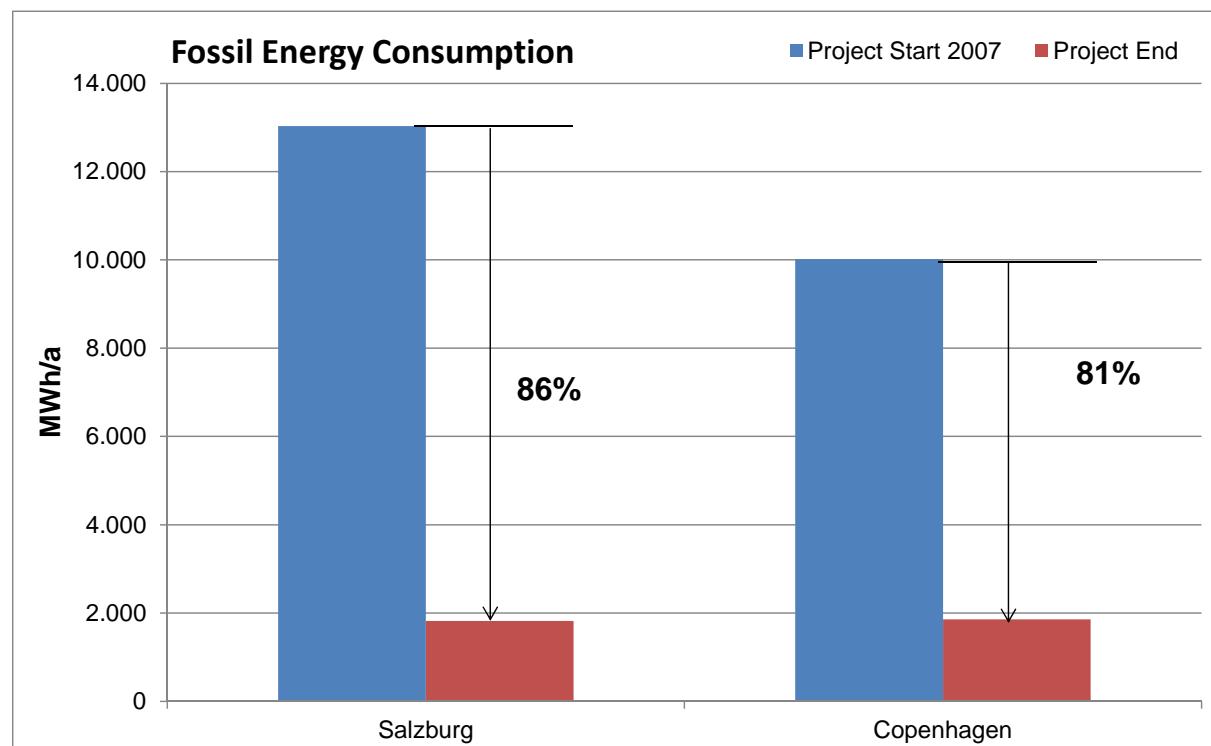
2. CCDS Concerto Community Data Sheet

Method:

The calculation of the city performance of both cities is based on the CCDS defined in Annex I.

Expected Results:

As clearly visible in the chart a large step will be taken forward in reducing the fossil energy consumption during the 5-6 year period of the project duration.



Planned Evaluation:

The actual status of the city performance of each city will be calculated in order to see the progress in reaching the set goals.

The CCDS will be updated by the partner and the numbers will be evaluated in more detail.

The actual reduction in the fossil energy consumption and the measures through which the savings are reached will be shown.

3. City Performance Sheet

Method:

An overall evaluation comparing similar projects in the two cities will be carried out.

An excel-sheet was generated which will be filled in and updated by both cities. It contains a list of all solar thermal systems, PV systems, biomass plants, new buildings, retrofits, etc. which are / will be installed until the end of the project. The template is shown in the following.

Data Buildings / Plants

Salzburg_data_buildings / Salzburg_data_plants

Data buildings (retrofits / new buildings)

Data plants (solar thermal / PV / biomass)

→ Input needed for:

- status quo planned – realized
- general information
- dimensions
- timetable
- investment costs / eligible costs / subsidy
- building characteristics
- heat / electricity demand national standard / Concerto standard
- measured / calculated savings end energy / CO₂ savings

Data Buildings

Input is needed for green cells

\Salzburg_data_buildings\ Salzburg_data_plants \



Salzburg Buildings		status quo planned - realized				general information			
		CDS							
buildings		goal	realized	planned	diff to goal	Project	Location	Investor	project partner
		m ²				Name	Address	Name	responsible
retrofit	Retrofit Apartments Core Area	3.500	0	3.500	part of area mentioned in column K				
	Retrofit Apartments Option	10.000	0	10.000					
	Retrofit Offices	9.000	0	9.000					
new	New Apartments Core Area	38.000	0	38.000					

Type of buildings as defined in the CDS

Comparison goal (CDS) - realized

Overview all projects (realized and planned)

Folie 13

Data Buildings

Input is needed for green cells

\Salzburg_data_buildings\ Salzburg_data_plants \



dimensions			timetable			costs			building characteristics				
area planned / realized	Number of dwellings	Number of buildings	start date	end date	hand-over certificate	investment costs	eligible costs	EC-funding	roof insulation	wall insulation	window U-value	others	
m ² (gross floor area)					finished/ expected	Euro	Euro	Euro	cm	cm	W/m ² K	cm	
0						0	0	0					
0						0	0	0					
0						0	0	0					

building area

timetable

costs

Information about thickness insulation

Will be compared with goal in CDS

Folie 14



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Data Buildings

Input is needed for green cells

\Salzburg_data_buildings \ Salzburg_data_plants X



heat / electricity demand				Monitoring	Monitoring	Monitoring	Monitoring
CCDS/Best	CCDS/Best	CCDS/Best	CCDS/Best	measured heat demand	measured heat demand	measured el. demand	measured el. demand
calculated heat demand retrofit: before new: standard	calculated heat demand retrofit: after new: Concerto	calculated el. demand retrofit: before new: standard	calculated el. demand retrofit: after new: Concerto	retrofit: before new: -	retrofit: after new: Concerto	retrofit: before new: -	retrofit: after new: Concerto
heating + dhw kWh _{th} /m ² a	heating + dhw kWh _{th} /m ² a	kWh _{el} /m ² a	kWh _{el} /m ² a	heating + dhw kWh _{th} /m ² a	heating + dhw kWh _{th} /m ² a	kWh _{el} /m ² a	kWh _{el} /m ² a
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Calculated heat / electricity demand

-> from CDS / BEST sheets

Measured heat / electricity demand

-> from Monitoring (when existing for 1 year)

Folie 15

Data Buildings

Input is needed for green cells

\Salzburg_data_buildings \ Salzburg_data_plants X



savings - end energy				CO2 savings						
CCDS/Best	CCDS/Best	Monitoring	Monitoring							
calculated savings	measured savings			fuel retrofit: before new: typical	fuel retrofit: after new: Concerto	CO2-factor heating retrofit: before new: typical	CO2-factor heating retrofit: after new: Concerto	CO2-factor electricity	calculated CO2 savings	measured CO2 savings
kWh _{th} /a	kWh _{el} /a	kWh _{th} /a	kWh _{el} /a			heating g CO2 / kWh _{th}	heating g CO2 / kWh _{th}	electricity g CO2 / kWh	kg CO2	
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0
0	0	0	0						0	0

Savings end energy

calculation CO₂ savings

Folie 16

-> automatically calculated



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Data Buildings

\Salzburg_data_buildings \ Salzburg_data_plants

savings - end energy			
CCDS/Best	CCDS/Best	Monitoring	Monitoring
calculated savings		measured savings	
kWh/a	kWh/a	kWh/a	kWh/a
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
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0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

Calculation savings end energy

comparison fuel (CO₂ factor):

- retrofits:**

before ⇔ after retrofit

- new buildings:**

typical fuel in city ⇔ fuel new building

Folie 17

Data Buildings

\Salzburg_data_buildings \ Salzburg_data_plants

calculated CO ₂ savings		measured CO ₂ savings
kg CO ₂		
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
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0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	

Calculation CO₂ savings

comparison energy + electricity demand / consumption:

- retrofits:**

before ⇔ after retrofit

- new buildings:**

new building according to national energy standard

↔ new building according to Concerto standard

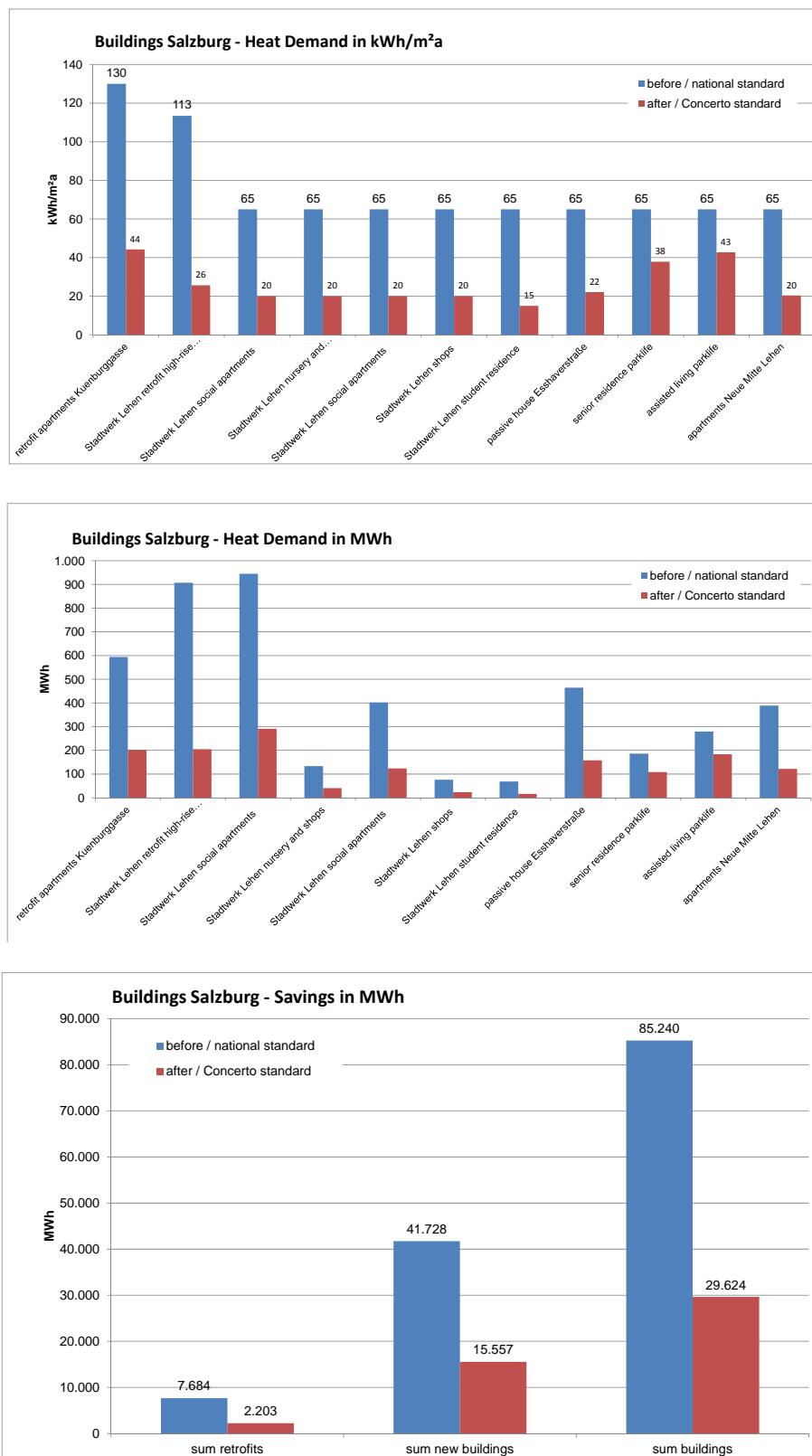
Folie 18

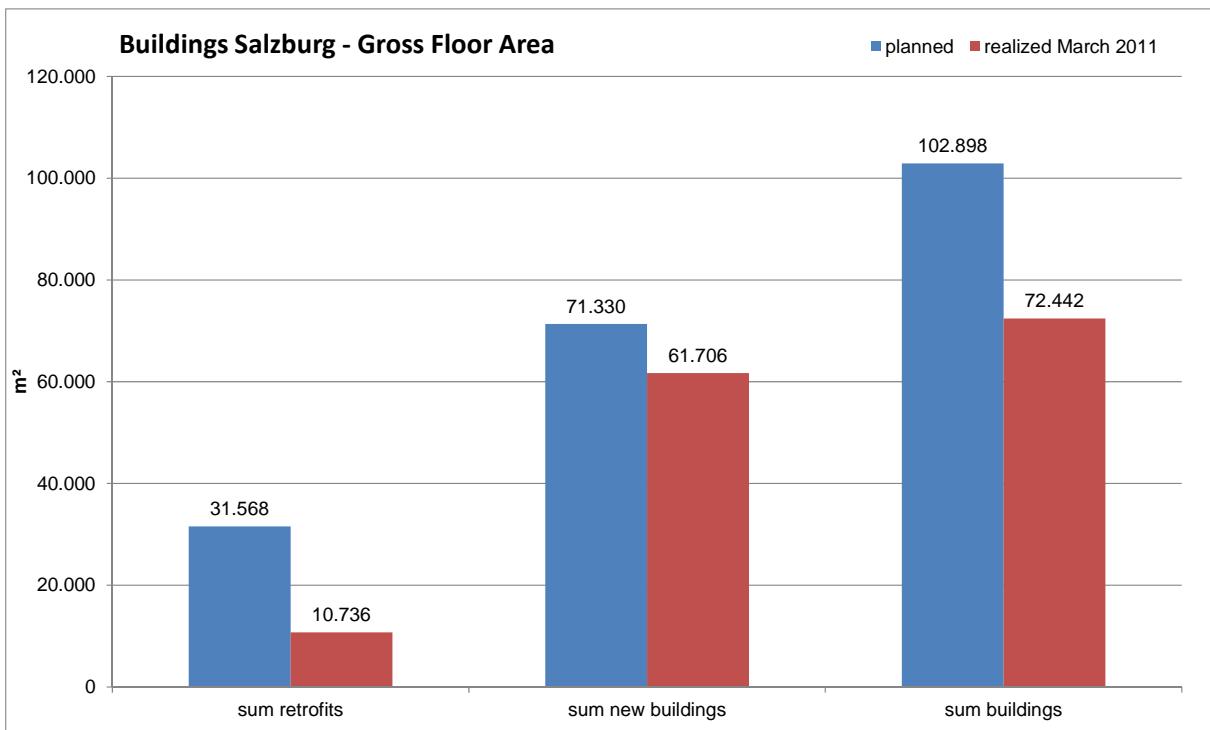
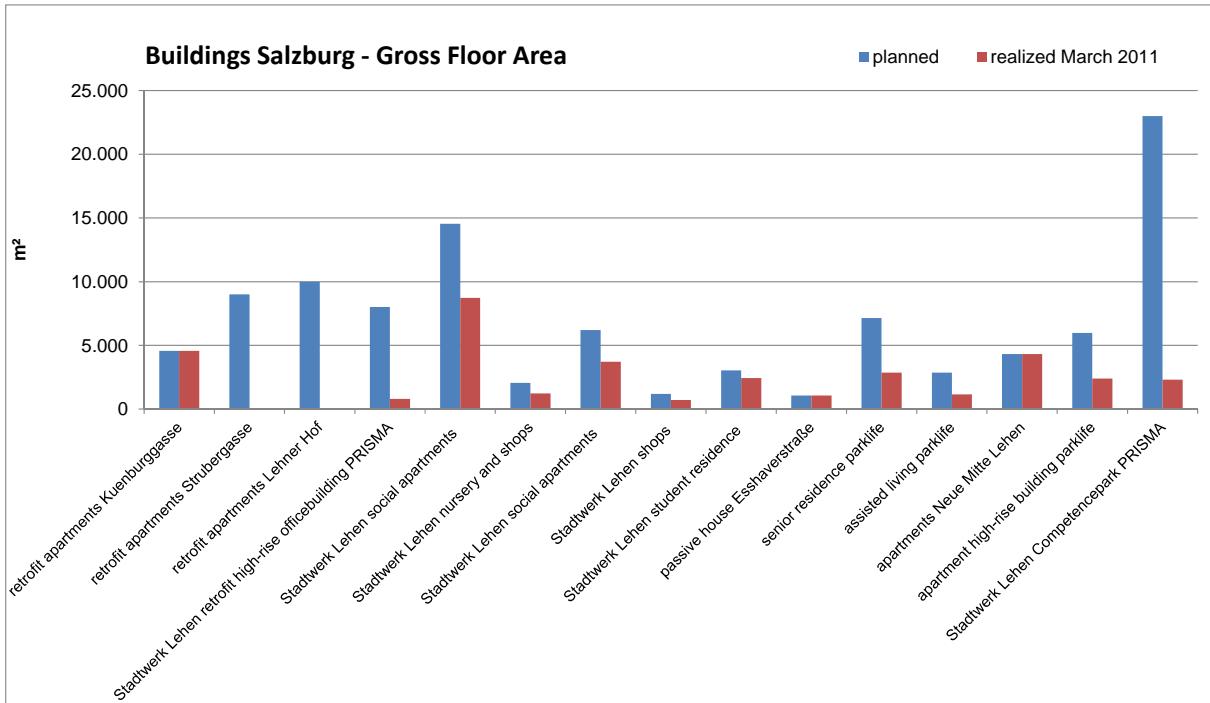


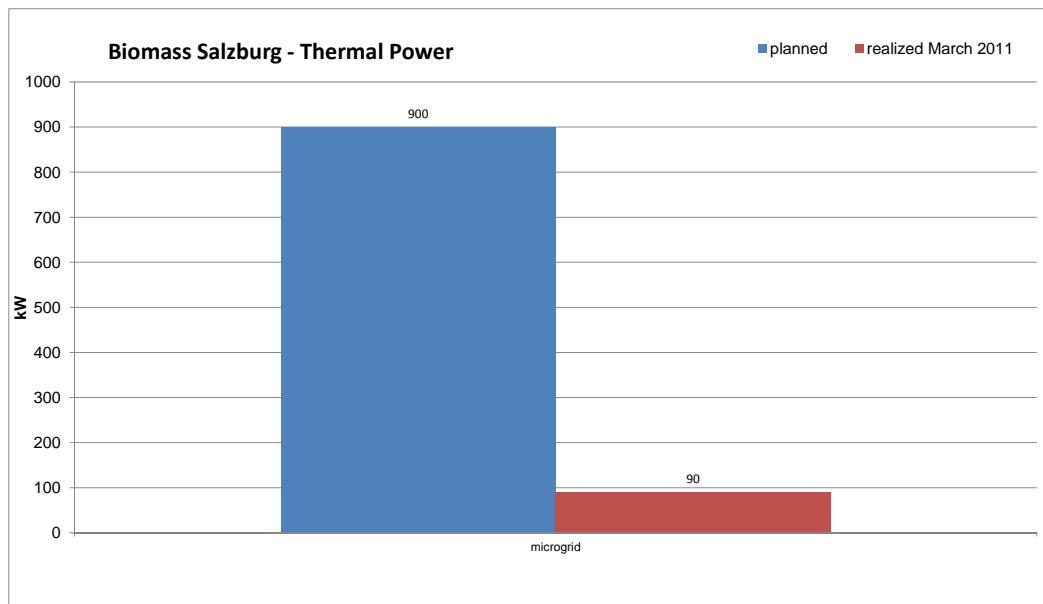
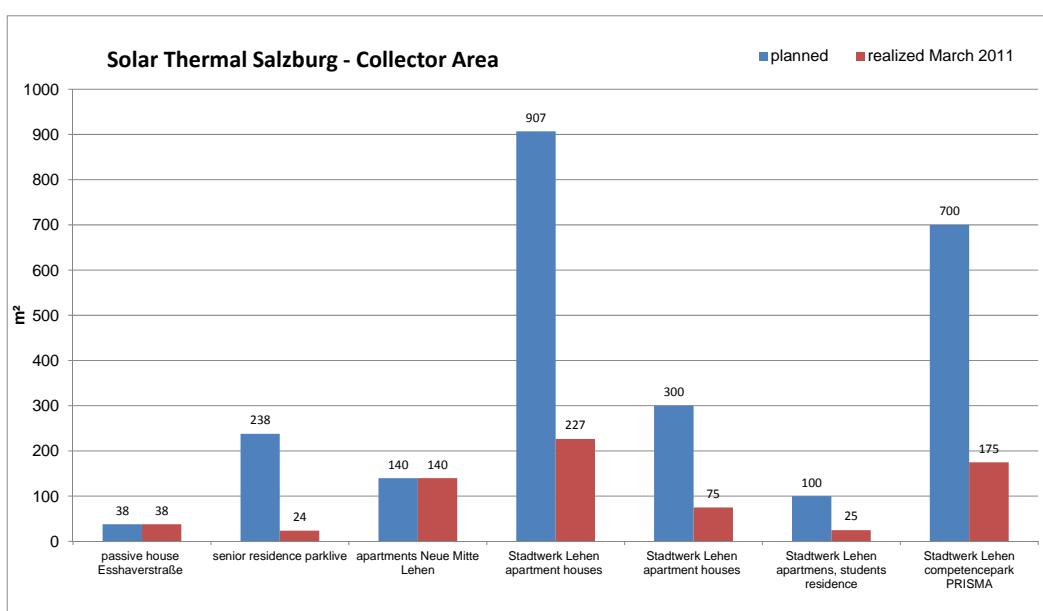
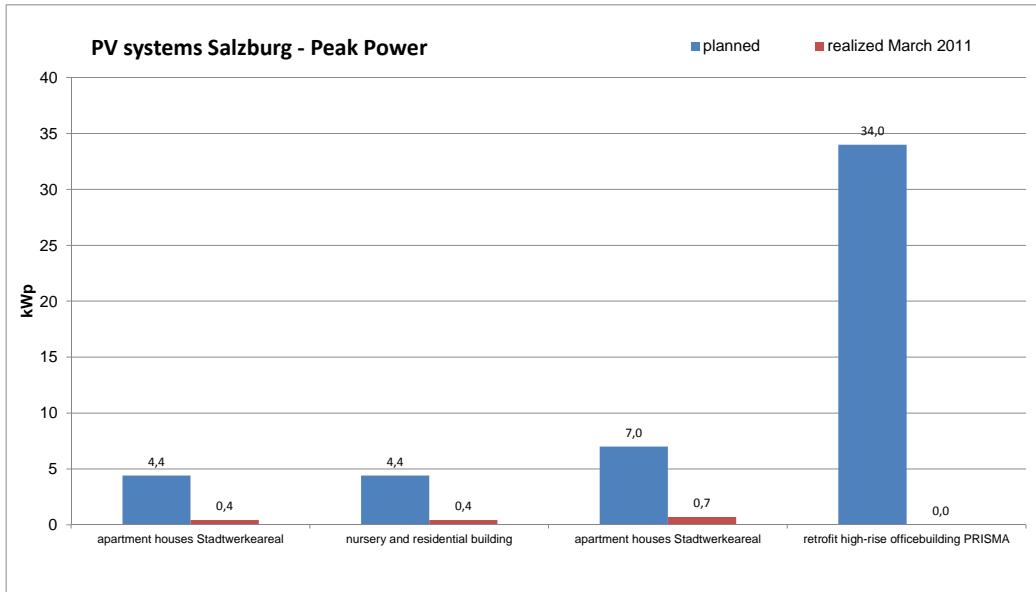
First Results:

Some first results of both cities can be seen in the following charts. Please note that the data is not complete and has to be updated later.

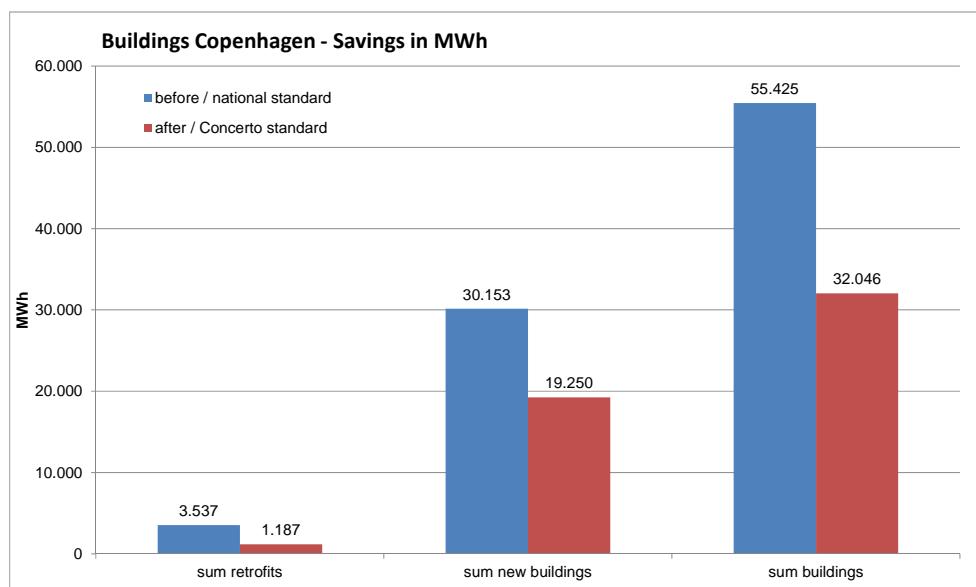
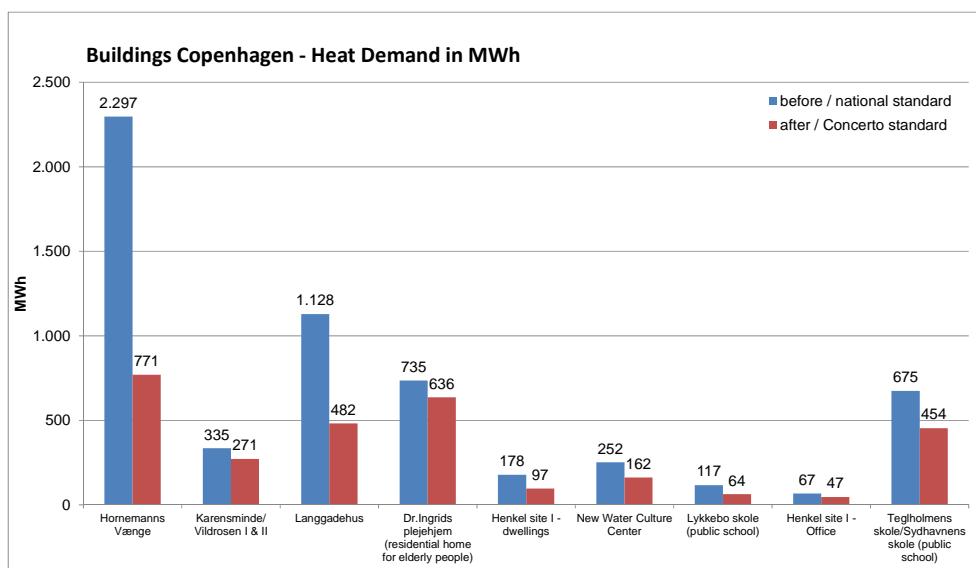
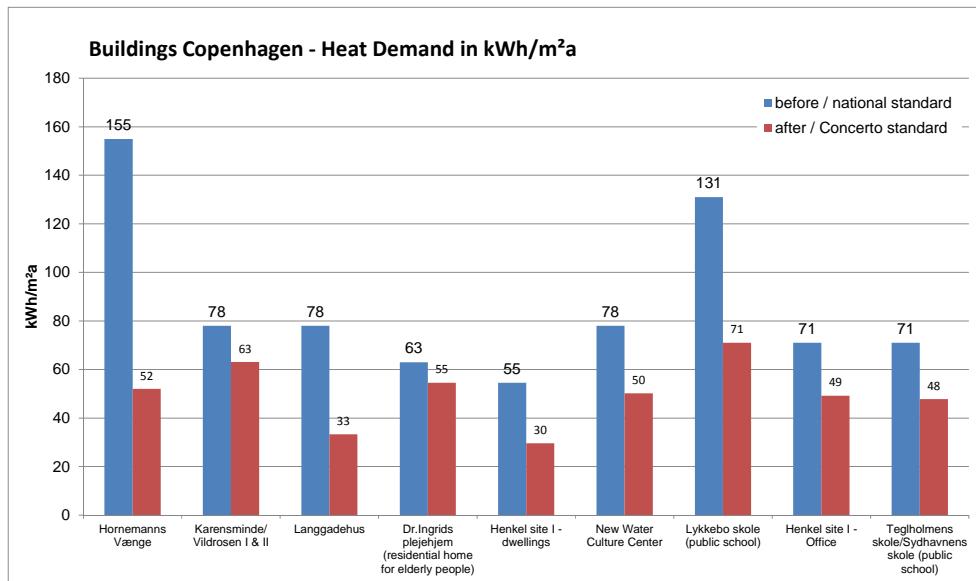
Salzburg

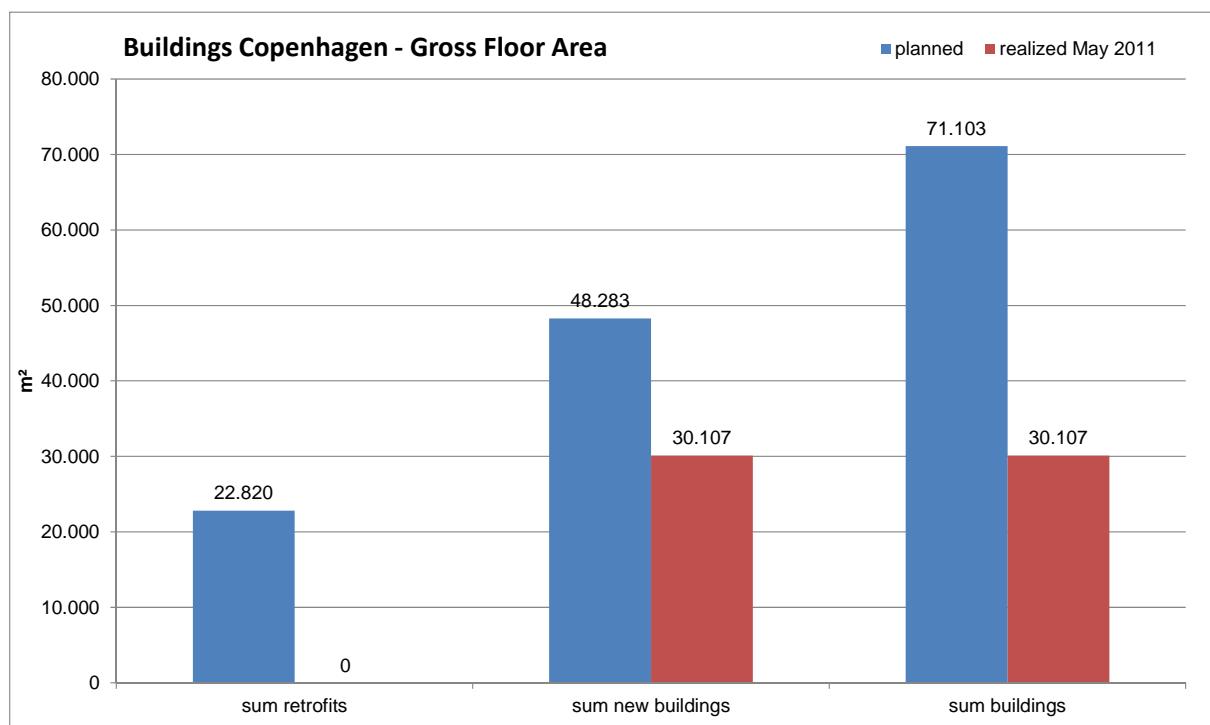
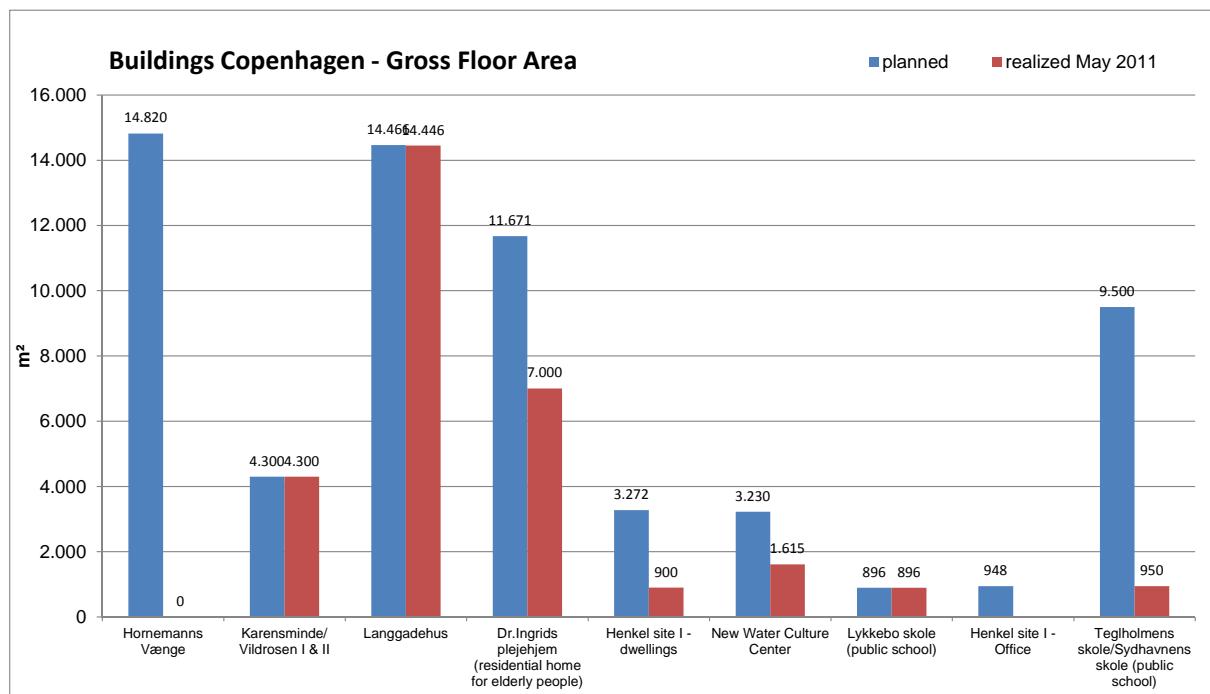


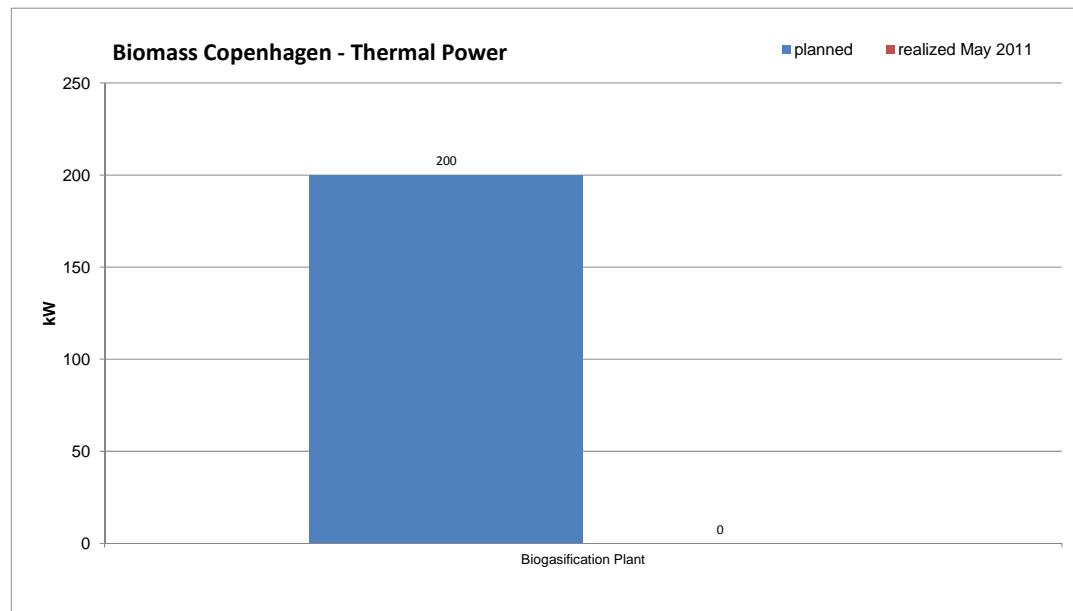
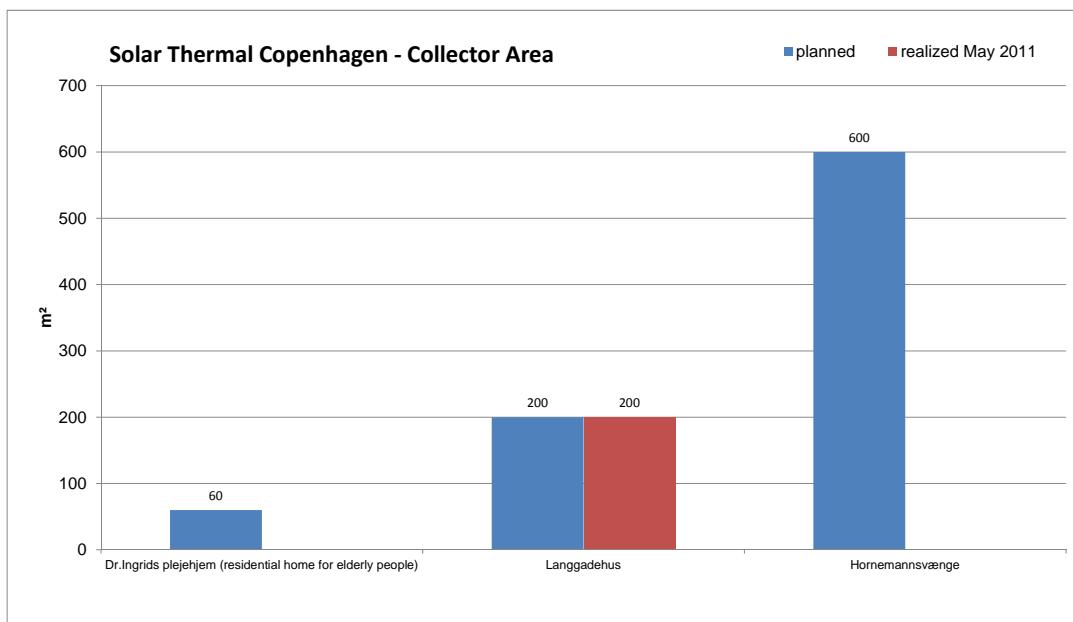
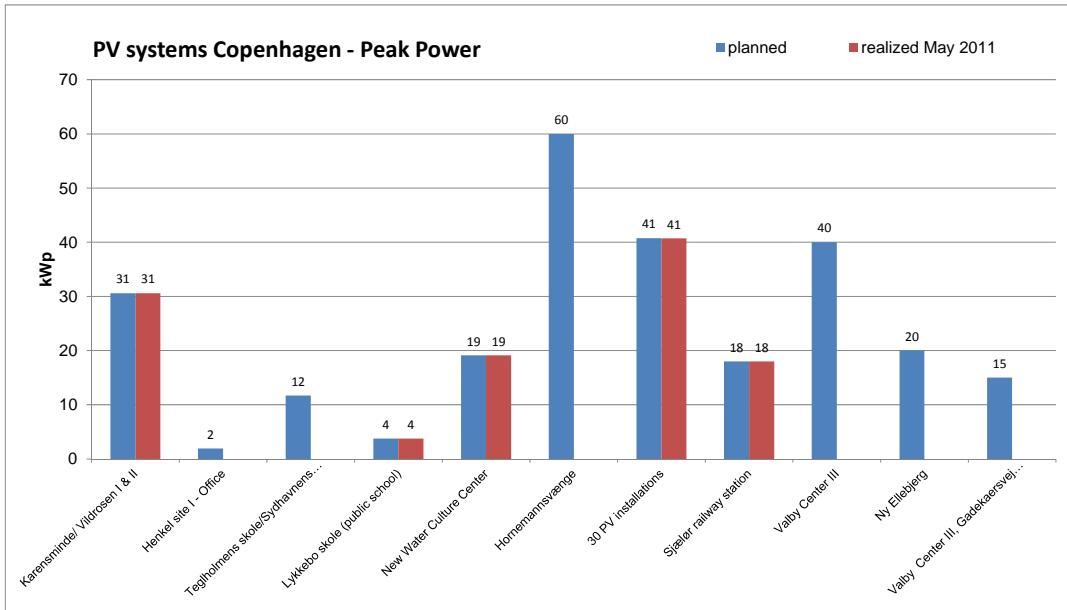




Copenhagen







Planned Evaluation:

The cities were asked to fill in the needed information in the Excel-Tool. As soon as the information is complete an overall evaluation of PV systems, solar thermal systems, retrofits, new buildings and biomass will be given comparing the systems in both cities.

For each category charts will be generated showing:

- 1) **calculated / measured savings per unit** (kWh/m², kWh/kW)
- 2) **investment costs per unit** (€/m², €/kW)
- 3) **investment costs per calculated / measured CO₂ savings** (€/kg CO₂)



4. Individual Monitoring of the Cities

Monitoring started with the first realized projects in 2008. It will be intensified until the end of the project.

Method:

An Energy controlling system for heat and electricity is being used for demo projects in the Concerto areas Salzburg and Valby/Copenhagen. In the deliverable report D6.1 some important demo projects for developing the monitoring systems in Salzburg respectively in Copenhagen were shown. During the last reporting period the partner have continued working on presenting ideas about intelligent energy monitoring systems. It will be further developed from internet systems already being used primarily with most experiences from Salzburg. The aim is to establish an overview of energy flows for both Concerto areas.

First Results:

Salzburg:

Monitoring started in Nov 2008 for project Esshaverstraße – and will continue until spring 2012. All energy use is counted and all window contacts are measured in three apartments, so that we can try to find relations between user behavior and energy consumption.

Neue Mitte Lehen: Since summer 2009 the solar plant in Neue Mitte Lehen is online. The monitoring of the solar gains can be viewed by everyone.

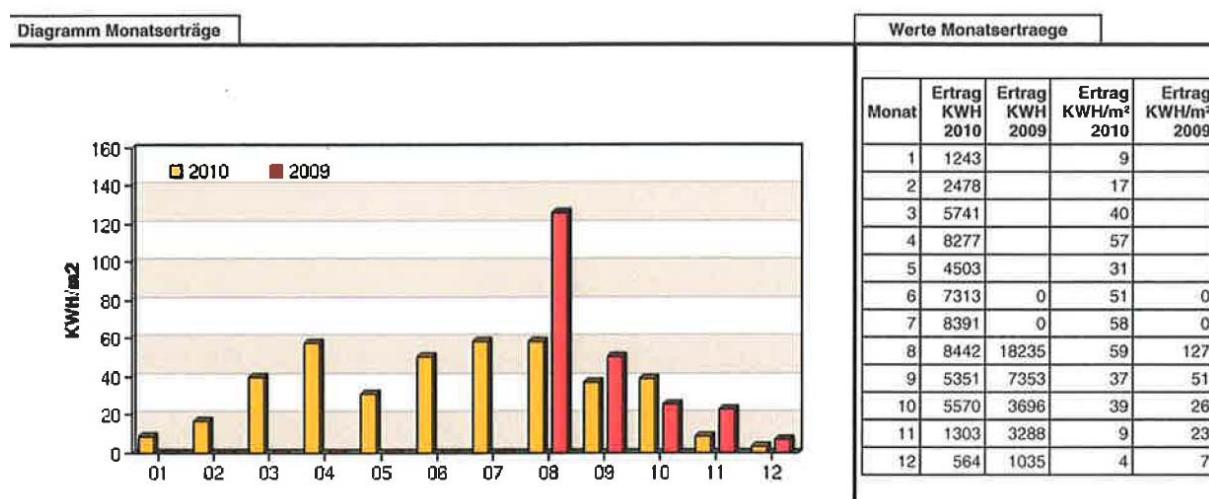
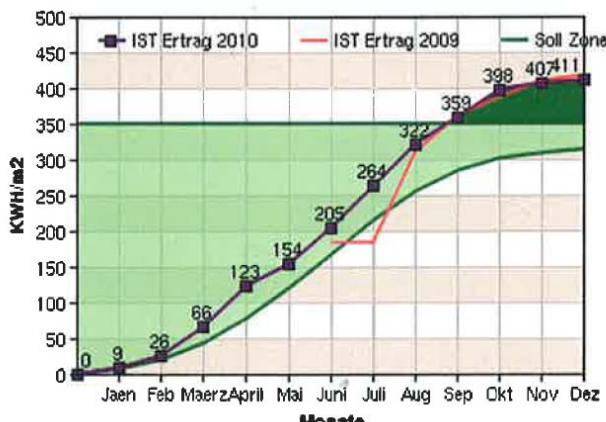


Diagramm Solarverlauf



Information

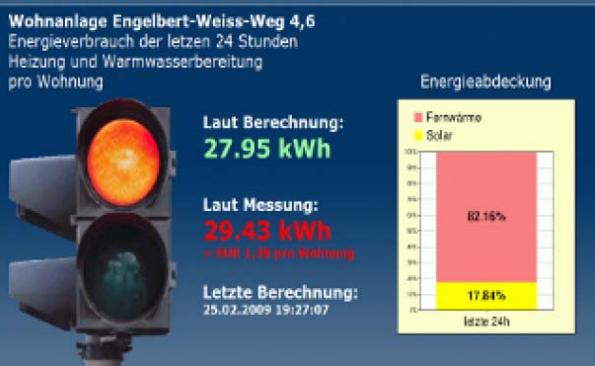
Im dargestellten Diagramm wird der Solarverlauf bis jeweils zum letzten beendeten Monat angezeigt. Der aktuelle Istwert, sollte sich im gruenen Sollbereich befinden.

For Stadtwerk Lehen a special monitoring concept is prepared. A working group has been founded to develop a monitoring system that takes special account on user information and user friendliness.

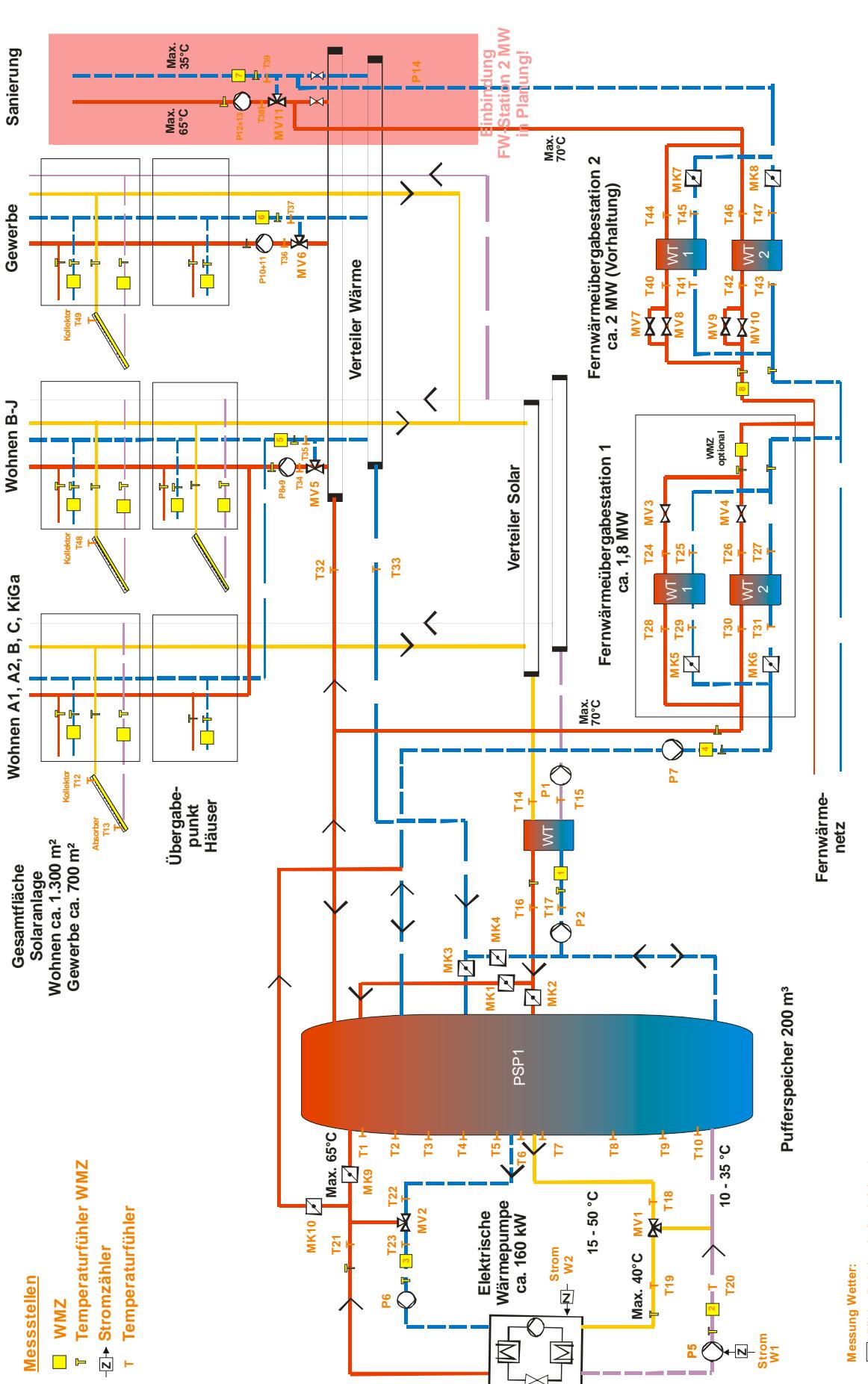
Franz Ofer Str. [Detail]	340 m²	31.12.2008	106349 KWH	312.79 [-5.93%]
Gebirgsjägerplatz [Detail]	240 m²	31.12.2008	59237 KWH	246.82 [-11.85%]
Gais Moos [Detail]	410 m²	31.12.2008	165100 KWH	378.29 [+13.77%]
Golling [Detail]	240 m²	31.12.2008	63630 KWH	265.12 [-20.26%]
Grödig [Detail]	54 m²	31.12.2008	23308 KWH	431.63 [+29.81%]
Hallein S. Hainstr. [Detail]	250 m²	31.12.2008	102503 KWH	410.33 [+67.48%]
Hallein Maratstr. [Detail]	105 m²	31.12.2008	39738 KWH	378.45 [+13.82%]
Hallein Pinglzerk. [Detail]	88 m²	31.12.2008	6748 KWH (ab 23.05.2008)	348.81 [+4.90%]
Högwaldweg [Detail]	105 m²	31.12.2008	45896 KWH	437.10 [+31.46%]
Holzmeisterstrasse [Detail]	30 m²	31.12.2008	0 KWH (ab 19.11.2008)	328.54 [-1.19%]
Innenb.Bundesstr.27 [Detail]	100 m²	31.12.2008	32504 KWH	325.04 [-2.24%]
Kleingmainergasse [Detail]	55 m²	31.12.2008	19271 KWH	350.38 [+5.38%]
Lanserwiese [Detail]	240 m²	31.12.2008	98311 KWH (ab 13.02.2008)	423.07 [+77.48%]
Lamprechtsh.Carp. [Detail]	85 m²	31.12.2008	7141 KWH (ab 20.08.2008)	252.42 [-24.06%]
Lamprechtsh.Haus [Detail]	87 m²	31.12.2008	14177 KWH (ab 20.08.2008)	331.36 [+0.34%]
Mottsee [Detail]	50 m²	31.12.2008	11154 KWH (ab 06.08.2008)	365.49 [+9.92%]
Maxgian [Detail]	136 m²	31.12.2008	62114 KWH	383.19 [+15.25%]
Neukirchen I [Detail]	56 m²	31.12.2008	27143 KWH	484.70 [+67.77%]
Naumarkt [Detail]	64 m²	31.12.2008	19782 KWH	309.09 [-7.04%]
Mittersill [Detail]	50 m²	31.12.2008	15243 KWH	304.86 [-8.31%]
Oberalm I [Detail]	45 m²	31.12.2008	14392 KWH	319.82 [-3.81%]

Online monitoring database for thermal solar plants (about 200 thermal solar plants in Salzburg are online).

Energy – traffic light in a social housing project to show the tenants if the energy need and energy use is comparable or if too much energy is used now and how much energy is coming direct from the sun.



For the district heating station Stadtwerk Lehen (heat pump, large-scale solar thermal system, district heat) a central building control system is set up. A hydraulic scheme was generated and 255 measuring points were – see the following graphs. The data will be saved every 15 minutes. A detailed evaluation will be carried out as soon as data of a few months is available.



**Hydraulikschema
Wärmeversorgung Stadt:Werk:Lehen**
.02.05.2011, STZ-EGS



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Messung Wetter:
F1 Fühler Relative Außenluftfeuchte
M1 Fühler AußenTemperatur
H1 Sensor Globalstrahlung

Copenhagen:

Monitoring started on the first demo project Karensminde in autumn 2008 for some energy parameters. A fully monitoring was carried out in 2009/2010 on four representative selected apartments. For more details see the report "Monitoring results of row houses" in the attachment.

For the next finished demo project Langgadehus elderly centre and 59 dwellings social housing the monitoring has been prepared comprising:

- individual heat and DHW remote survey meters for the 59 one family housing units
- detailed monitoring of main energy flows with remote survey for solar DHW system with 200 m² of solar collectors and the possibility to export solar energy to the elderly care center in sunny periods
- monitoring of the heating and DHW consumption for the elderly care centre including remote survey
- remote metering of the 3-5 kWp PV production for the elderly care centre (based on this a system efficiency will be calculated)
- remote monitoring of 5 selected electricity uses (ventilation, fans, etc.)
- use of Electronic Housekeeper in a few apartments
- blower door test as documentation of air tightness
- thermo photography to document possible cold bridges
- presentation of energy signatures as a quick follow up on performance figures

Planned Evaluation:

As soon as more data is available, detailed monitoring will be shown. Information will be given about the projects, measures, monitoring concept, results, problems occurred, lessons learned, energy savings, CO₂ reduction, etc.

5. Attachment – Monitoring Row Houses Karensminde (Copenhagen)

Monitoring Report



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Monitoring results of row houses:

Thomas Koppels Allé 18E, Copenhagen

Thomas Koppels Allé 22C, Copenhagen

Thomas Koppels Allé 24A, Copenhagen

Thomas Koppels Allé 26D, Copenhagen

**Monitoring results of row house
Thomas Koppels Allé 18E, Copenhagen**

Claimant Thomas Koppels Allé 18E
Copenhagen

Date 15. February 2010

Performed by Cenergia
Herlev Hovedgade 195
2730 Herlev

Caseworker Vickie Aagesen, Robert Wawerka
44660099
vaa@cenergia.dk, rw@cenergia.dk

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1. Dwelling description

The dwelling is situated in a row house on Thomas Koppels Allé 18E in Copenhagen. The living area of the two storey apartment is 121 m².

The dwelling is prefabricated and fulfills the Low Energy Class 2 standard. On the roof of the house there are PV panels installed.



Figure 1 Picture of the houses

Vildrose I, andelsbolig, type 01, 121 m²



Figure 2 Plan of the dwelling, type 01

2. Blower door test

2.1 Background and purpose

On basis of an enquiry from EU-Concerto it has been agreed that Cenergia performs an air tightness testing on a row house on Thomas Koppels Allé 18E in Copenhagen.

The assignment

Air tightness of the new build row house was made on Monday 15 February 2010 at 11:00.

The inlet and outlet of the ventilation unit were closed with tape, cooker hook wasn't closed with tape and ventilation unit was detached during the measurement.

Blower door was installed in the main entrance.

The house is a row two storey house of 121 square meters.

2.2 Measuring equipment

The measuring is performed with "Minneapolis Blower Door". Set-up and measuring equipment is in compliance with the general standard of the Canadian board, CAN/CGSB-149.10-M86 "Determination of the Air tightness of Building Envelope by the Fan Depressurization Method".

During the measuring the volume flow through leaks in the building is following formula:

$$Q = Cr \times dP^n$$

In which

Q volume electricity [l/s]

dP Difference in pressure [Pa]

Cr constant

n streaming exponent

From the size of the stream exponent the type of holes and leaks in the house can be estimated.

Type of opening	N
Large openings	0,5
Cracks	0,66
Porous materials with collections	0,75
Only porous materials	1,0

Leak area is calculated by the formula:

$$ELA = 0.001157 \times \sqrt{\rho} \times Cr \times 10^{n-0.5}$$

in which

ELA = area of leaks [m^2]

Cr = constant

ρ = the density of air

dP = diversity in pressure [Pa]

The requirements of building regulative towards leaks in new built

Airtightness through leaks in the climate shield is not allowed to exceed 1,5 l/s per m^2 heated storey area at pressure measuring at 50 Pa

2.3 Result

The readings is reported in the enclosed printed program

Infiltration at 50 Pa is measured to 183 l/s with low pressure and 179 l/s with high pressure. With a heated storey area of 121 m^2 , this corresponds to an infiltration of 1,56 l/s per m^2 and 1,57 l/s per m^2 at an air tightness of 50 Pa, and the house in this way almost comply with the air tightness demands of **1,5 l/s per m^2** .

The flow exponents have been detected to 0,74 and 0,78, corresponding to the air intake through porous materials with collections.

The following leaks were identified during the measuring:

- air entering around the connection between the walls and the doors
- air entering around the connection between the walls and the windows

Test carry out for

Name	
Adress	Thomas Koppels Alle 18E
Contactperson	tel.:

Test carry out of

Name	Cenergia Energy Consultants
Adress	Herlev Hovedgade 195
Person	RW og VAA

Building

Adress	Thomas Koppels Alle 18E
Buildingtype	Row house
Date	Test 15/2-2010 kl. 9-12 Rapport

Weatherdata

Outdoortemperatur	-1,1 °C	Airpressure, hPa	1012,3
Windspeed	2 m/s	Wind direction	NW

Buildingdata

Area to the free	
Other area	
Floor space	121 m ²
Volume	302,5 m ³

Inside measure of walls, ceiling, floor and doors and windows.

Data from the measuring

Corrected data

dPm, [Pa]	Qm, [m ³ /h]	dP, [Pa]	Q, [l/s] under	Q, [l/s] over
50	710	50	190,1	
44	630	44	168,7	
32	500	32	133,9	
37	570	37	152,6	
42	625	42	167,3	
48	680	48	182,0	
52	720	52	192,8	
50	710	50		190,1
43	620	43		166,0
36	555	36		148,6
30	475	30		127,2
35	540	35		144,6
40	600	40		160,6
45	660	45		176,7

Low pressure

$$\begin{aligned} Cr &= 10,26 & n &= 0,7439 \\ ELA &= 0,0228 \text{ m}^2 & & 228 \text{ cm}^2 \\ BR &= 1,56 \text{ l/sm}^2 & & 188 \text{ l/s} \end{aligned}$$

Overpressure

$$\begin{aligned} Cr &= 9,1356 & n &= 0,7759 \\ ELA &= 0,0219 \text{ m}^2 & & 219 \text{ cm}^2 \\ BR &= 1,57 \text{ l/sm}^2 & & 190 \text{ l/s} \end{aligned}$$

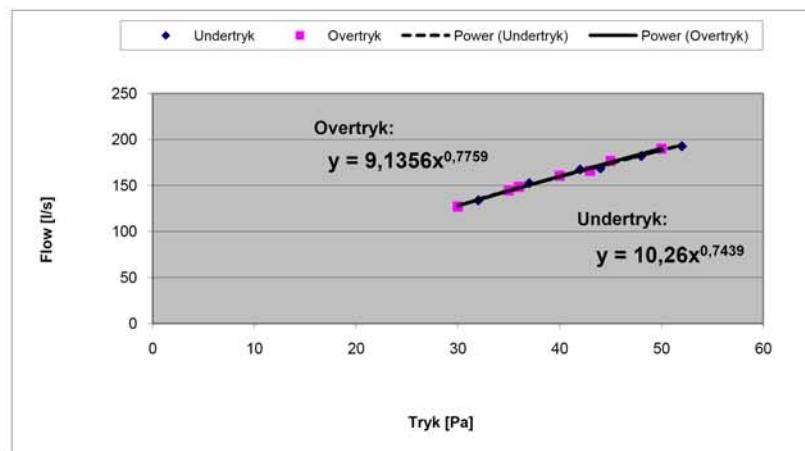


Figure 3 Readings from the blower door test

3. Air change test

An air change test for the dwelling was also made. The dwelling is equipped with ventilation with heat recovery. The air flow from the ventilation unit can be regulated by tenants (4 default speed steps).

3.1 Measuring equipment

For air change test the measurement equipment Testo 425 and Testo testovent 415 were used.

3.2 Measurement

Air flow measurement for one inlet and outlet took 30 seconds and it was done 5 times. The air flow was set on the speed step 2.

The measured and designed data for inlet and outlet are shown in the figure 4. The air change for the apartment is $214 \text{ m}^3/\text{h}$ compared to the building regulations standard which is $151 \text{ m}^3/\text{h}$. When the measurement of the outlet volume from cooker hood was made, the holes around the measuring equipment weren't taped.

no.	designed	measured	note
	air flow (m^3/h)	air flow (m^3/h)	
1	20	6	inlet
2	20	29	inlet
3	36	50	outlet
4	38	46	inlet
5	30	27	inlet
6	25	14	inlet
7	54	45	outlet
8	29	37	inlet
9	72	51	outlet
10	40	55	inlet

Σ	202	214	inlet
Σ	162	150	outlet

Figure 4 Air change measured and designed data

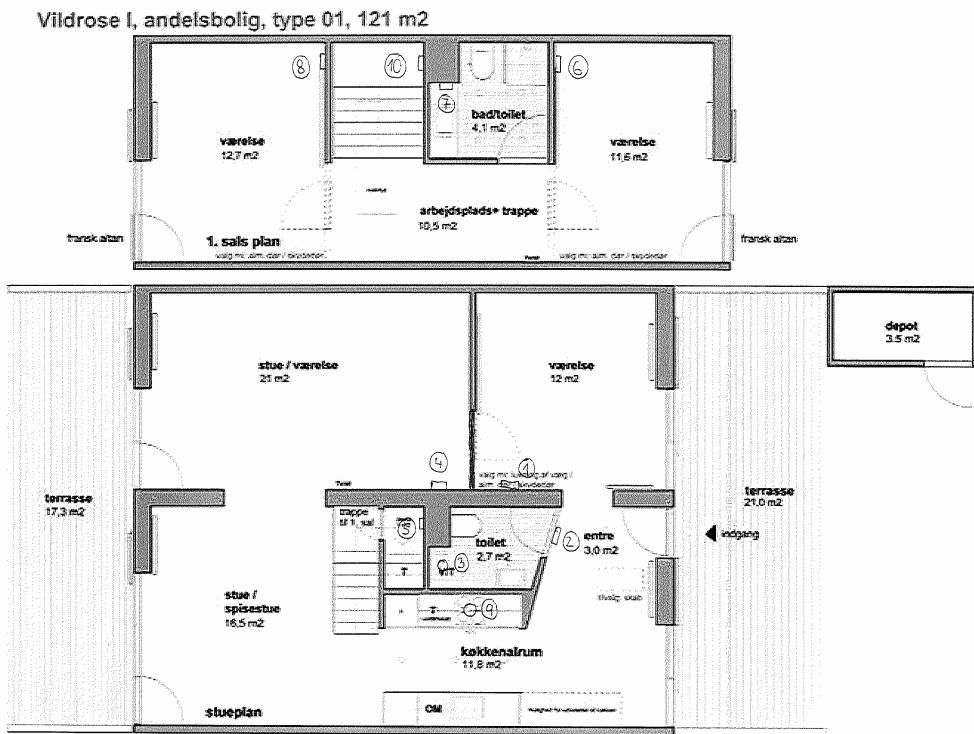


Figure 5 Placement of inlet and outlet in the apartment

3.3 Conclusion

The air change for the dwelling is $214 \text{ m}^3/\text{h}$ and the value has been higher than the required value $151 \text{ m}^3/\text{h}$. The air change is too height according to the building regulation standard. But some improvements have to be made comparing to airflow in the dwelling, because the airflows from inlet and outlet have different measured values compared to design values. The inlet air volume is too height and should be regulated to be a little less than the outlet air volume (to avoid moisture in constructions). Then the efficiency of the heat recovery is also much lower than it should be.

4. Indoor climate test

Indoor climate test for the dwelling was made. It was decided to measure indoor climate in the living room and bedroom for 5 days.

4.1 Measuring equipment

For measurements were used data loggers Gemini Tinytag Ultra.

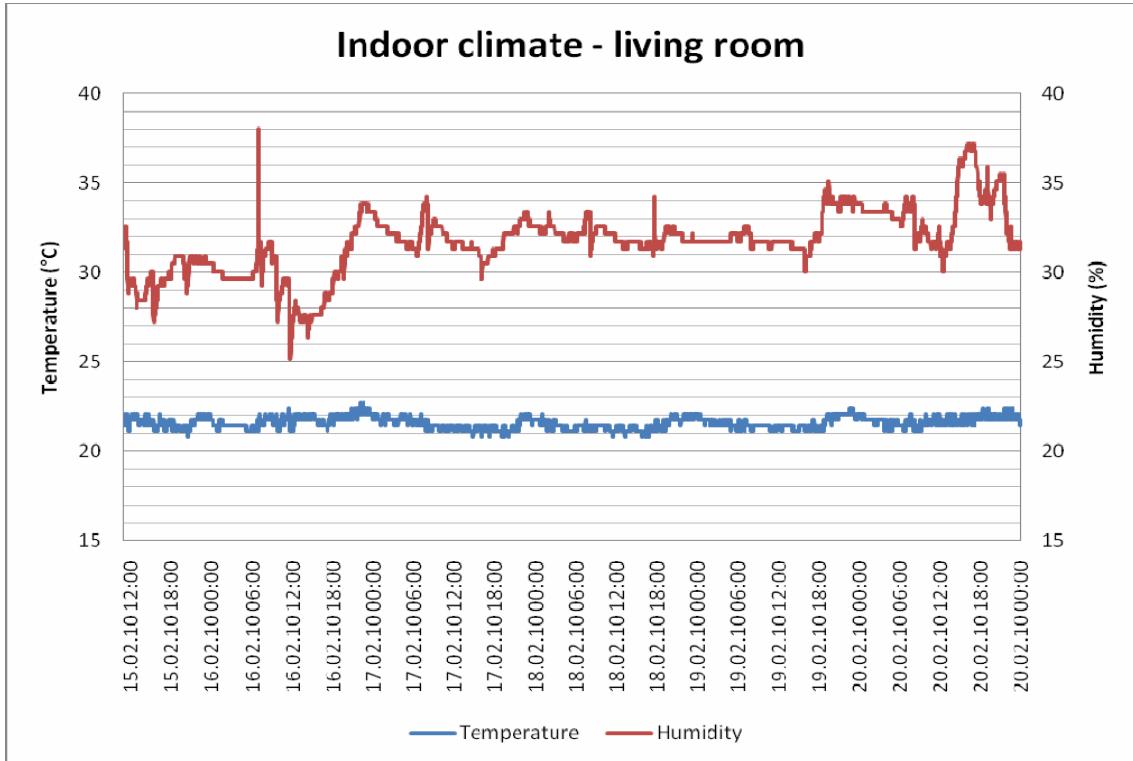
4.2 Measurement

For indoor climate test were used two data loggers. One data logger was placed in the living room and the second one in the bedroom. The measurements in the apartment were made for 5 days (from Monday 15.02.2010 until Saturday 20.02.2010). The results are shown in the graph 1 and 2.

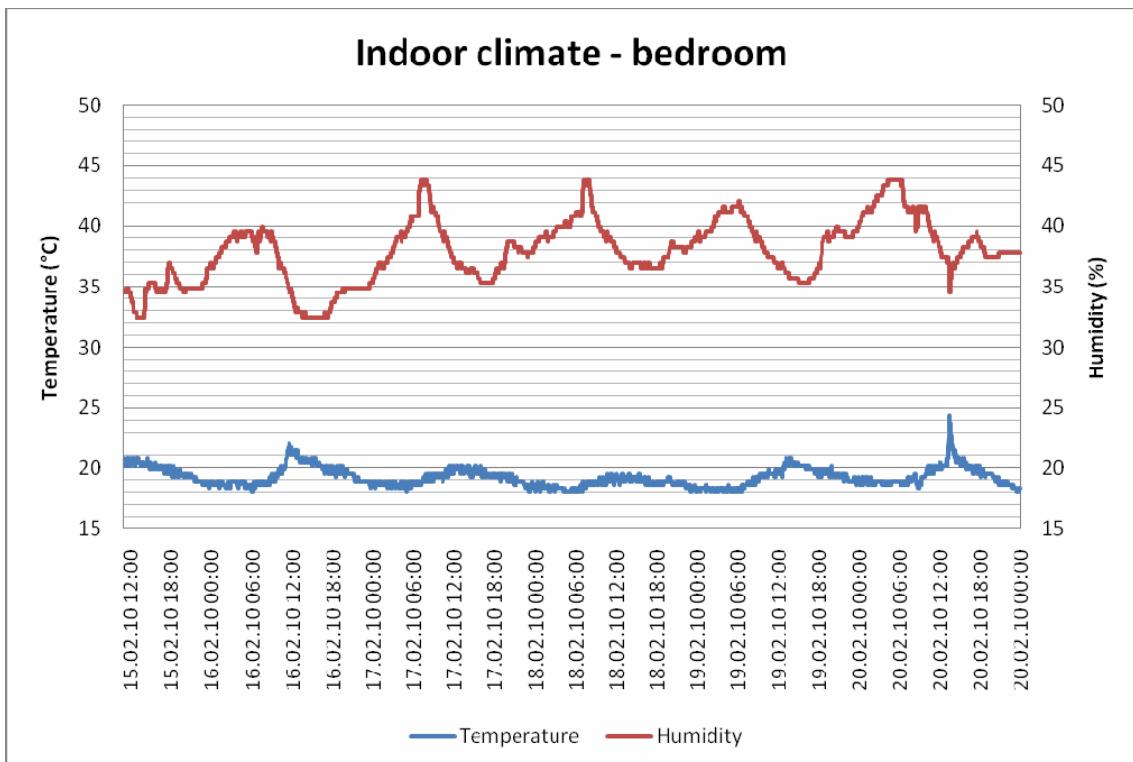
As you can see from the graph 1, the indoor temperature in the living room is around $21,6^\circ\text{C}$ compare to 20°C which is the common design temperature.

The average temperature in the bedroom is around 19,3°C. The optimal temperature during the day should be 20°C and around 18°C during the sleeping time.

The average humidity in living room is 31,7% and in the bedroom 37,9%.



Graph 1 Temperature and humidity in the living room



Graph 2 Temperature and humidity in the bedroom

4.3 Conclusion

The temperature in the apartment is a bit high. The optimal temperature should be around 20°C in living areas and around 18°C for sleeping.

The humidity in the apartment should be around 40%. The measured mean humidity was around 31,7% in living room and 37,9% in the bedroom.

5. Energy consumption

The energy consumptions for the dwelling, where 3 people are living, are shown in the tables (water, district heating and EL consumption).

Water consumption

Period	m ³
15.02.08 - 01.12.09	66
02.12.08 - 24.02.10	111

Source: Copenhagen Energy

District heating consumption

Period	kWh
29.02.08 – 21.09.08	2803
22.09.08 – 29.04.09	6425
30.04.09 – 29.09.09	1098
30.09.09 – 30.09.10*	8000

* expected consumption

Source: Copenhagen Energy

EL consumption

Period	kWh
29.02.08 – 23.04.08	363
24.04.08 – 31.12.08	2196
01.01.09 – 31.01.09	350
01.02.09 – 25.02.09	168
26.02.09 – 28.02.09	33
01.03.09 – 31.12.09	2407

Source: Dong Energy

Key numbers, kWh/m ² year			
Energy frame			
BR: 97,3	Class 2: 63,2	Class 1: 44,1	
Total energy requirement		64,8	
Contribution to energy requirement	Net requirement		
Heat	49,7	Room heating	29,7
El. for operation of building	4,6 *2,5	Domestic hot water	16,5
Excessive in rooms	3,6	Cooling	0,0
Selected electricity requirements		Heat loss from installations	
Lighting	0,0	Room heating	0,9
Heating of rooms	0,0	Domestic hot water	3,4
Heating of DHW	0,0	Output from special sources	
Heat pump	0,0	Solar heat	0,0
Ventilators	3,9	Heat pump	0,0
Pumps	0,7	Solar cells	0,0
Cooling	0,0		
Total el. consumption	35,3		

Figure 6 Calculations of energy requirement in Be06 without solar cells

(Class 2 is 65% of the Building Regulation consumption)

Source: Viggo Madesn A/S

5.1 Conclusion

The water consumption for all apartment (3 person) is 239,5 litres per day. That means 79,8 litres per person per day. The water consumption according to building regulations standard is expected to be 120 litres per person per day.

The district heating consumption is 61,0 kWh/m² per year (during the period: 22.09.08 – 29.09.09). The calculated demand from Be06 is 53,3 kWh/m² per year. So the consumption is 14,4% higher than the calculated.

Electricity consumption in the apartment is 3005,5 kWh per year, that means 1001,8 kWh per person per year. The average electricity consumption in Denmark is 1423 kWh per person per year.

6. Final conclusion

Some parts of house construction weren't made in the required quality. When the windows and doors were placed some mistakes were made.

There are still some possibilities how to save energy. As the indoor climate test showed, the temperature in the apartment is too height and due to the heating consumption can be reduced.

**Monitoring results of row house
Thomas Koppels Allé 22C, Copenhagen**

Claimant Thomas Koppels Allé 22C
Copenhagen

Date 17. February 2010

Performed by Cenergia
Herlev Hovedgade 195
2730 Herlev

Caseworker Vickie Aagesen, Robert Wawerka
44660099
vaa@cenergia.dk, rw@cenergia.dk

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4.1	Measuring equipment.....	8
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1. Dwelling description

The dwelling is situated in a row house on Thomas Koppels Allé 22C in Copenhagen. The living area of the two storey apartment is 127 m².

The dwelling is prefabricated and fulfils the Low Energy Class 2 standard. On the roof of the house there are PV panels installed.



Figure 1 Picture of the houses

Vildrose I, andelsbolig, type 02, 127 m²



Figure 2 Plan of the dwelling, type 02

2. Blower door test

2.1 Background and purpose

On basis of an enquiry from EU-Concerto it has been agreed that Cenergia performs an air tightness testing on a row house on Thomas Koppels Allé 22C in Copenhagen.

The assignment

Air tightness of new build row house was made on Monday 17 February 2010 at 11:00.

The in and out valves of the ventilation unit and kitchen hook were closed with tape and ventilation unit was detached during the measurement.

Blower door was installed in the main entrance.

The house is a terraced two storey house of 127 square meters.

2.2 Measuring equipment

The measuring is performed with "Minneapolis Blower Door". Set-up and measuring equipment is in compliance with the general standard of the Canadian board, CAN/CGSB-149.10-M86 "Determination of the Air tightness of Building Envelope by the Fan Depressurization Method".

During the measuring the volume flow through leaks in the building is following formula:

$$Q = Cr \times dP^n$$

In which

Q volume electricity [l/s]

dP Difference in pressure [Pa]

Cr constant

n streaming exponent

From the size of the stream exponent the type of holes and leaks in the house can be estimated.

Type of opening	N
Large openings	0,5
Cracks	0,66
Porous materials with collections	0,75
Only porous materials	1,0

Leak area is calculated by the formula:

$$ELA = 0.001157 \times \sqrt{\rho} \times Cr \times 10^{n-0.5}$$

in which

ELA = area of leaks [m^2]

Cr = constant

ρ = the density of air

dP = diversity in pressure [Pa]

The requirements of building regulative towards leaks in new built

Air tightness through leaks in the climate shield is not allowed to exceed 1,5 l/s per m^2 heated storey area at pressure measuring at 50 Pa.

2.3 Conclusion

The readings is reported in the enclosed printed program

Infiltration at 50 Pa is measured to 183 l/s with low pressure and 179 l/s with high pressure. With a heated storey area of 127 m^2 , this corresponds to an infiltration of 1,44 l/s per m^2 and 1,41 l/s per m^2 at an air tightness of 50 Pa, and the house in this way comply with the air tightness demands of **1,5 l/s per m^2** .

The flow exponents have been detected to 0,72 and 0,68, corresponding to the air intake through cracks and porous materials with collections.

The following leaks were identified during the measuring:

- air entering around the connection between the walls and the doors
- air entering around the connection between the walls and the windows

Test carry out for:

Name	
Adress	Thomas Koppels Alle 22C
Contactperson	tel.:

Test carry out of

Name	Cenergia Energy Consultants
Adress	Herlev Hovedgade 195
Person	RW og VAA

Building

Adress	Thomas Koppels Alle 22C
Buildingtype	Row house
Date	Test 17/2-2010 kl. 9-12 Rapport

Weather data

Outdoortemperatur	-0,4 °C	Airpressure, hPa	1004,8
Windspeed	7 m/s	Wind direction	NW

Building data

Area to the free	
Other area	
Floor space	127 m ²
Volume	317,5 m ³

Inside measure of walls, ceiling, floor and doors and windows.

Data from the measuring

Corrected data

dPm, [Pa]	Qm, [m ³ /h]	dP, [Pa]	Q, [l/s] under	Q, [l/s] over
50	690	50	185,7	
51	700	51	188,3	
42	600	42	161,4	
35	525	35	141,3	
30,5	490	30,5	131,8	
39	540	39	145,3	
45	630	45	169,5	
51	680	51		183,0
46	640	46		172,2
40	570	40		153,4
36	520	36		139,9
29,5	450	29,5		121,1
32	480	32		129,2
25	435	25		117,0

Low pressure

$$\begin{aligned} Cr &= 10,835 & n &= 0,7228 \\ ELA &= 0,0230 \text{ m}^2 & & 230 \text{ cm}^2 \\ BR &= 1,44 \text{ l/sm}^2 & & 183 \text{ l/s} \end{aligned}$$

Overpressure

$$\begin{aligned} Cr &= 12,597 & n &= 0,6779 \\ ELA &= 0,0241 \text{ m}^2 & & 241 \text{ cm}^2 \\ BR &= 1,41 \text{ l/sm}^2 & & 179 \text{ l/s} \end{aligned}$$

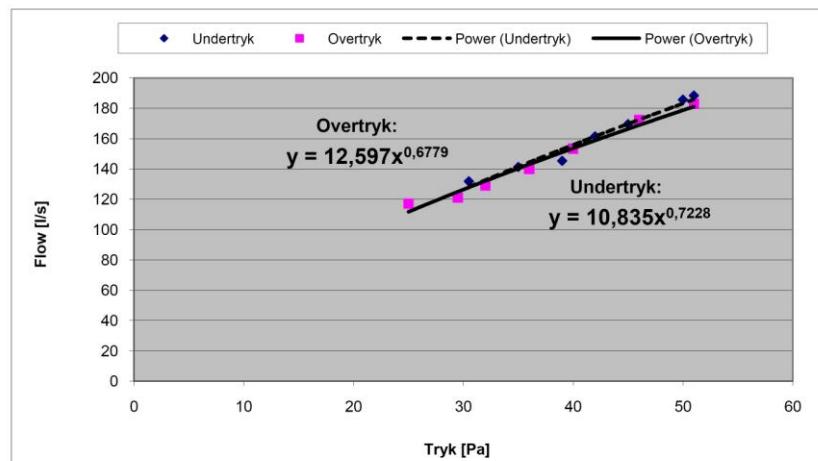


Figure 3 Readings from the blower door test

3. Air change test

An air change test for the dwelling was also made. The dwelling is equipped with ventilation with heat recovery. The air flow from the ventilation unit can be regulated by tenants (4 default speed steps).

3.1 Measuring equipment

For air change test the measurement equipment Testo 425 and Testo testovent 415 were used.

3.2 Measurement

Air flow measurement for one inlet and outlet took 30 seconds and it was done 5 times. The air flow was set on the speed step 2.

The measured and designed data for inlet and outlet are shown in the figure 4. The air change for the apartment is $166 \text{ m}^3/\text{h}$ compared to the building regulations standard which is $159 \text{ m}^3/\text{h}$.

no.	designed	measured	note
	air flow (m^3/h)	air flow (m^3/h)	
1	38	37	inlet
2	36	31	outlet
3	42	17	Inlet
4	54	41	outlet
5	25	40	inlet
6	29	38	inlet
7	54	34	inlet
8	72	80	outlet

Σ	188	166	inlet
Σ	162	152	outlet

Figure 4 Air change measured and designed data

Vildrose 1, andeisbolig, type 02, 127 m²

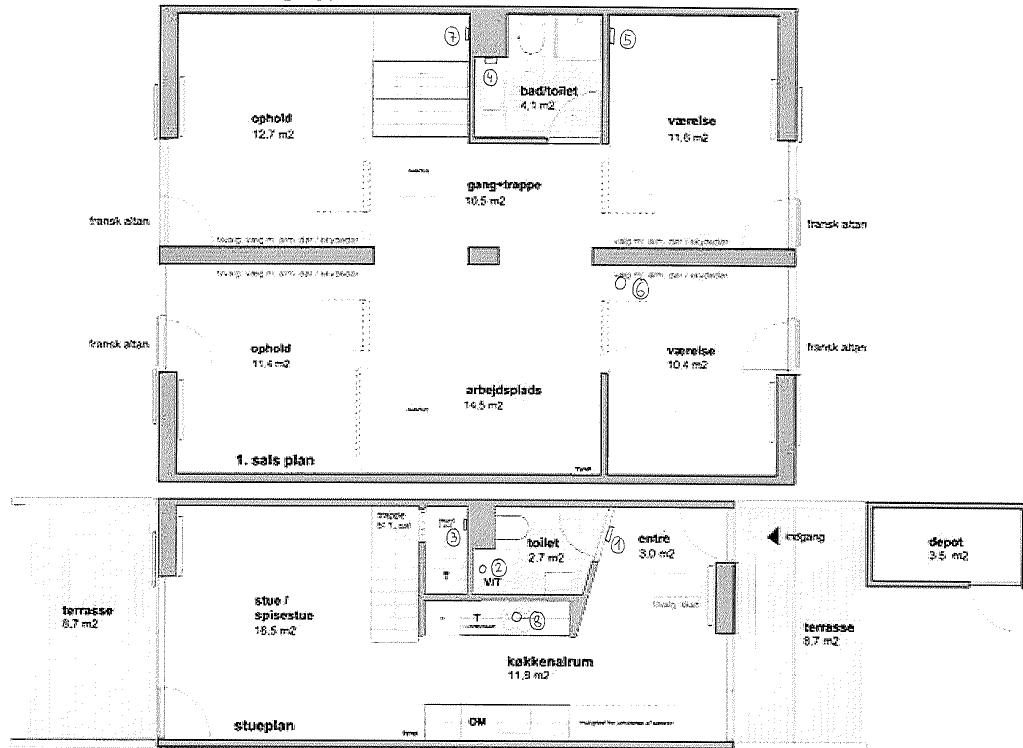


Figure 5 Placement of inlet and outlet in the apartment

3.1 Conclusion

The air change for the dwelling is 166 m³/h and the value is just a little bit higher than the required value 159 m³/h. But some improvements have to be made comparing to airflow in the dwelling, because the airflows from inlet and outlet have different measured values compared to design values.

4. Indoor climate test

Indoor climate test for the dwelling was made. It was decided to measure indoor climate in the living room and bedroom for 7 days.

4.1 Measuring equipment

For measurements were used data loggers Gemini Tinytag Ultra 2.

4.2 Measurement

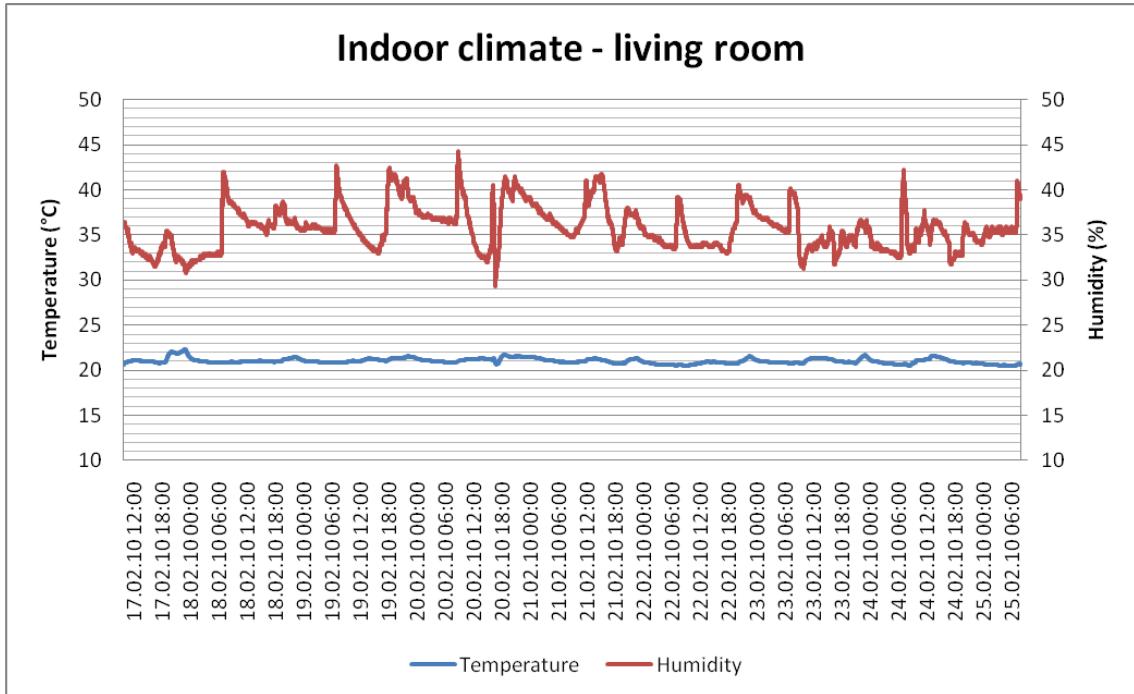
For indoor climate test were used two data loggers. One data logger was placed in the living room and the second one in the bedroom. The measurements in the apartment were made for 7 days (from Wednesday 17.02.2010 until Thursday 25.02.2010). The results are shown in the graph 1 and 2.

As you can see from the graph 1, the indoor temperature in the living room is around 21,0°C compare to 20°C which is the common design temperature.

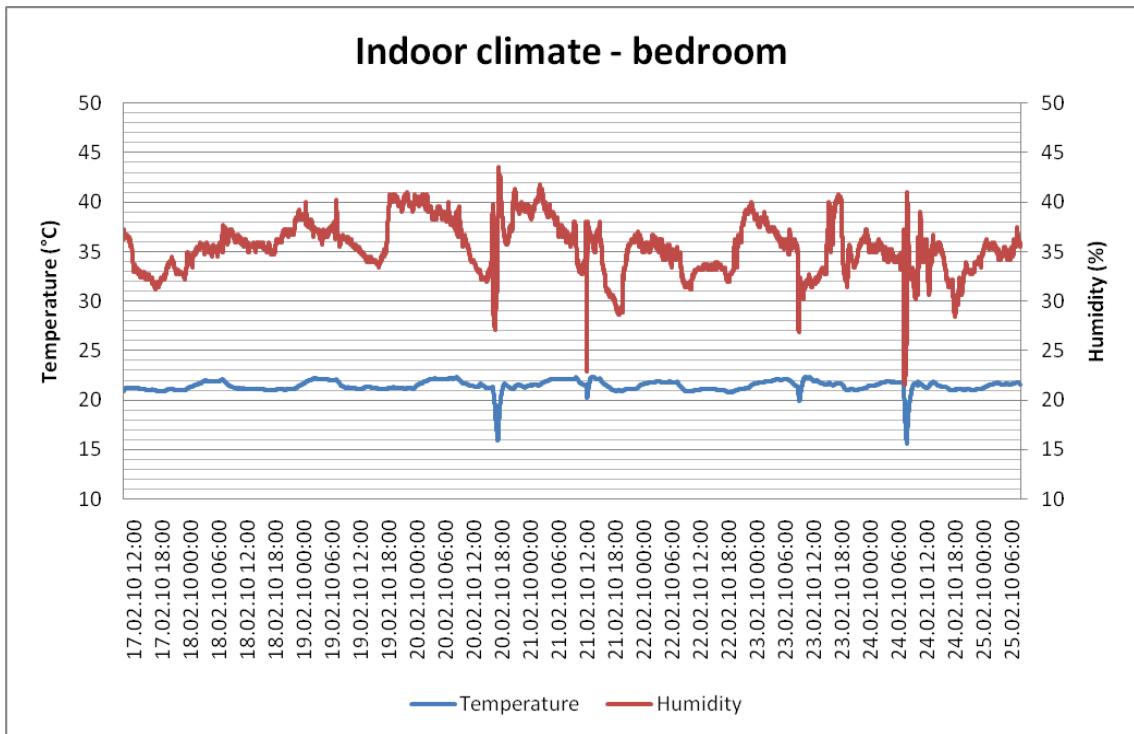
The average temperature in the bedroom is around 21,4°C. The optimal temperature during the day should be 20°C and around 18°C during the sleeping time. In the graph

2 you can see two temperature drops which maybe mean that window was opened for some period.

The average humidity in living room is 35,8% and in the bedroom 35,4%.



Graph 1 Temperature and humidity in the living room



Graph 2 Temperature and humidity in the bedroom

4.3 Conclusion

The temperature in the apartment is a bit higher compared to the designed temperature for the winter period. In the graph 2 you can see the temperature drops which maybe were caused by opened window. The optimal temperature should be around 20°C in living areas and around 18°C for sleeping.

The humidity in the apartment should be around 40%. The measured mean humidity was around 35,8% in living room and 35,4% in the bedroom.

5. Energy consumption

The energy consumptions for the dwelling, where 3 people are living, are shown in the tables (water, district heating and EL consumption).

Water consumption

Period	m ³
30.04.08 - 09.01.09	63
10.01.09 - 14.02.10	93

Source: Copenhagen Energy

District heating consumption

Period	kWh
30.04.08 - 19.09.08	2088
20.09.08 - 15.09.09	8411
16.09.09 - 30.09.10*	9000

* expected consumption

Source: Copenhagen Energy

EL consumption

Period	kWh
01.05.08 - 26.12.08	1982
27.12.08 - 22.12.09	3068

Source: Dong Energy

Key numbers, kWh/m ² year			
Energy frame			
BR: 95,1	Class 2: 62,6	Class 1: 43,7	
Total energy requirement	63,1		
Contribution to energy requirement		Net requirement	
Heat	47,5	Room heating	31,2
El. for operation of building	4,8 *2,5	Domestic hot water	15,9
Excessive in rooms	3,6	Cooling	0,0
Selected electricity requirements		Heat loss from installations	
Lighting	0,0	Room heating	0,0
Heating of rooms	0,0	Domestic hot water	2,8
Heating of DHW	0,0		
Heat pump	0,0	Output from special sources	
Ventilators	3,8	Solar heat	0,0
Pumps	0,7	Heat pump	0,0
Cooling	0,0	Solar cells	0,0
Total el. consumption	35,5		

*Figure 5 Calculations of energy requirement in Be06 without solar cells
(Class 2 is 66% of the Building Regulation consumption)*

Source: Viggo Madesn A/S

5.1 Conclusion

The water consumption for all apartment (3 persons) is 238,2 litres per day. That means 79,4 litres per person per day. The water consumption is expected to be 120 litres per person per day according to Elsparefonden.

The district heating consumption is 67,0 kWh/m² per year (during the period: 20.09.08 – 15.09.09). The calculated demand from Be06 is 51,1 kWh/m² per year. So the consumption is 31% higher than the calculated.

Electricity consumption in the apartment is 3067 kWh per year, that means 1022,3 kWh per person per year. The average electricity consumption in Denmark is 1423 kWh per person per year.

6. Final conclusion

Some parts of house construction weren't made in the required quality. When the windows and doors were placed some mistakes were made. But the air tightness for the dwelling is fulfilled.

**Monitoring result of row house
Thomas Koppels Allé 24A, Copenhagen**

Claimant Thomas Koppels Allé 24A
Copenhagen

Date 19. February 2010

Performed by Cenergia
Herlev Hovedgade 195
2730 Herlev

Caseworker Vickie Aagesen, Robert Wawerka
44660099
vaa@cenergia.dk, rw@cenergia.dk

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1. Dwelling description

The dwelling is situated in a row house on Thomas Koppels Allé 24A in Copenhagen. The living area of the two storey apartment is 85 m².

The dwelling is prefabricated and fulfils the Low Energy Class 2 standard. On the roof of the house there are PV panels installed.



Figure 1 Picture of the houses

Vildrose II, billig bolig, type 00, 85 m²



Figure 2 Plan of the dwelling, type 00

2. Blower door test

2.1 Background and purpose

On basis of an enquiry from EU-Concerto it has been agreed that Cenergia performs an air tightness testing on a row house on Thomas Koppels Allé 24A in Copenhagen.

The assignment

Air tightness of the new build row house was made on Monday 19 February 2010 at 16:00.

The inlet and outlet of the ventilation unit and cooker hook were closed with tape and ventilation unit was detached during the measurement.

Blower door was installed in the main entrance.

The house is a terraced two storey house of 85 square meters.

2.2 Measuring equipment and measurement

The measuring was performed with "Minneapolis Blower Door". Set-up and measuring equipment is in compliance with the general standard of the Canadian board, CAN/CGSB-149.10-M86 "Determination of the Air tightness of Building Envelope by the Fan Depressurization Method".

During the measuring the volume flow through leaks in the building is following formula:

$$Q = Cr \times dP^n$$

In which

Q volume electricity [l/s]

dP Difference in pressure [Pa]

Cr constant

n streaming exponent

From the size of the stream exponent the type of holes and leaks in the house can be estimated.

Type of opening	N
Large openings	0,5
Cracks	0,66
Porous materials with collections	0,75
Only porous materials	1,0

Leak area is calculated by the formula:

$$ELA = 0.001157 \times \sqrt{\rho} \times Cr \times 10^{n-0.5}$$

in which

ELA = area of leaks [m^2]

Cr = constant

ρ = the density of air

dP = diversity in pressure [Pa]

The requirements of building regulative towards leaks in new built

Airtightness through leaks in the climate shield is not allowed to exceed 1,5 l/s per m^2 heated storey area at pressure measuring at 50 Pa

2.3 Conclusion

The readings is reported in the enclosed printed program

Infiltration at 50 Pa is measured to 164 l/s with low pressure and 164 l/s with high pressure. With a heated storey area of $85 m^2$, this corresponds to an infiltration of 1,93 l/s per m^2 and 1,93 l/s per m^2 at an air tightness of 50 Pa, and the house in this way don't comply with the air tightness demands of **1,5 l/s per m^2** .

The flow exponents have been detected to 0,84 and 0,70, corresponding to the air intake through porous materials with collections.

The following leaks were identified during the measuring:

- air entering around the connection between the walls and the doors
- air entering around the connection between the walls and the windows
- leakages around the ventilation pipes and installation shaft in the bathroom (figure 3)



Figure 3 Leakage place in the bathroom

Test carry out for:

Name	
Adress	Thomas Koppels Alle 24A
Contactperson	tel.:

Test carry out of

Name	Cenergia Energy Consultants
Adress	Herlev Hovedgade 195
Person	RW og VAA

Building

Adress	Thomas Koppels Alle 24A
Buildingtype	Row house
Date	Test 19/2-2010 kl.14:30 Rapport

Weatherdata

Outdoortemperatur	1,1 °C	Airpressure, hPa	991,9
Windspeed	7 m/s	Wind direction	NW

Buildingdata

Area to the free	
Other area	
Floor space	85 m ²
Volume	212,5 m ³

Inside measure of walls, ceiling, floor and doors and windows.

Data from the measuring

Corrected data

dPm, [Pa]	Qm, [m ³ /h]	dP, [Pa]	Q, [l/s] under	Q, [l/s] over
50	600	50	162,9	
45	555	45	150,7	
40	510	40	138,5	
35	445	35	120,8	
31,5	410	31,5	111,3	
42	510	42	138,5	
48	590	48	160,2	
53,5	640	53,5		173,8
51	615	51		167,0
45,5	565	45,5		153,4
39	500	39		135,8
34	460	34		124,9
30	430	30		116,8
41	530	41		143,9

Low pressure

$$\begin{aligned} Cr &= 6,0642 & n &= 0,843 \\ ELA &= 0,0170 \text{ m}^2 & & 170 \text{ cm}^2 \\ BR &= 1,93 \text{ l/sm}^2 & & 164 \text{ l/s} \end{aligned}$$

Overpressure

$$\begin{aligned} Cr &= 10,769 & n &= 0,6968 \\ ELA &= 0,0215 \text{ m}^2 & & 215 \text{ cm}^2 \\ BR &= 1,93 \text{ l/sm}^2 & & 164 \text{ l/s} \end{aligned}$$

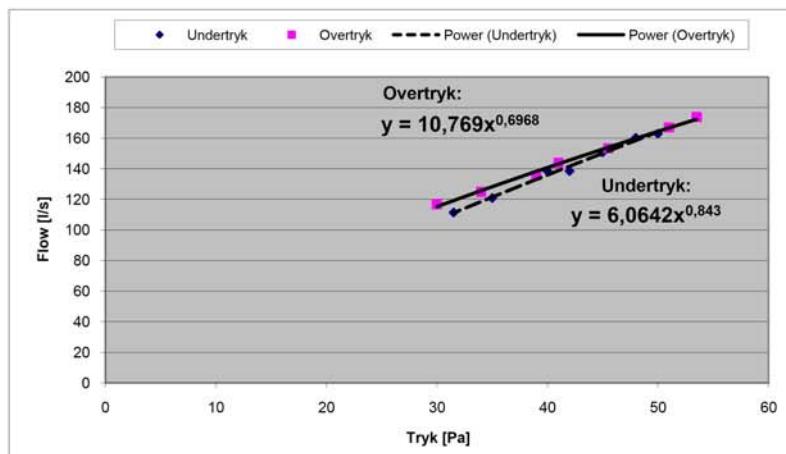


Figure 4 Readings from the blower door test

3. Air change test

An air change test for the dwelling was also made. The dwelling is equipped with ventilation with heat recovery. The air flow from the ventilation unit can be regulated by tenants (4 default speed steps).

3.1 Measuring equipment

For air change test the measurement equipment Testo 425 and Testo testovent 415 were used.

3.2 Measurement

Air flow measurement for one inlet and outlet took 30 seconds and it was done 5 times. The air flow was set on the speed step 2.

The measured and designed data for inlet and outlet are shown in the figure 5. The air change for the apartment is $144 \text{ m}^3/\text{h}$ compared to the building regulations standard which is $106 \text{ m}^3/\text{h}$. When the measurement was made the outlet volume from cooker hood wasn't measured.

no.	designed	measured	note
	air flow (m^3/h)	air flow (m^3/h)	
1	38	54	inlet
2	54	44	outlet
3	42	23	inlet
4	20	18	outlet
5	26	18	inlet
6	40	49	inlet
7	72	72*	outlet

* not measured

Σ	146	144	inlet
Σ	146	134	outlet

Figure 5 Air change measured and designed data

Vildrose II, billig bolig, type 00, 85 m²



Figure 6 Placement inlet and outlet in the apartment

3.3 Conclusion

The air change for the dwelling is 144 m³/h and the value has been higher than the required value 106 m³/h. The air change is too height according to the building regulation standard. But some improvements have to be made comparing to airflow in the dwelling, because the airflows from inlet and outlet have different measured values compared to design values. By reducing the air change to required value the energy consumption of the dwelling will be reduced too.

4. Indoor climate test

Indoor climate test for the dwelling was made. It was decided to measure indoor climate in the kitchen/dining room and workroom for 6 days.

4.1 Measuring equipment

For measurements were used data loggers Gemini Tinytag Ultra.

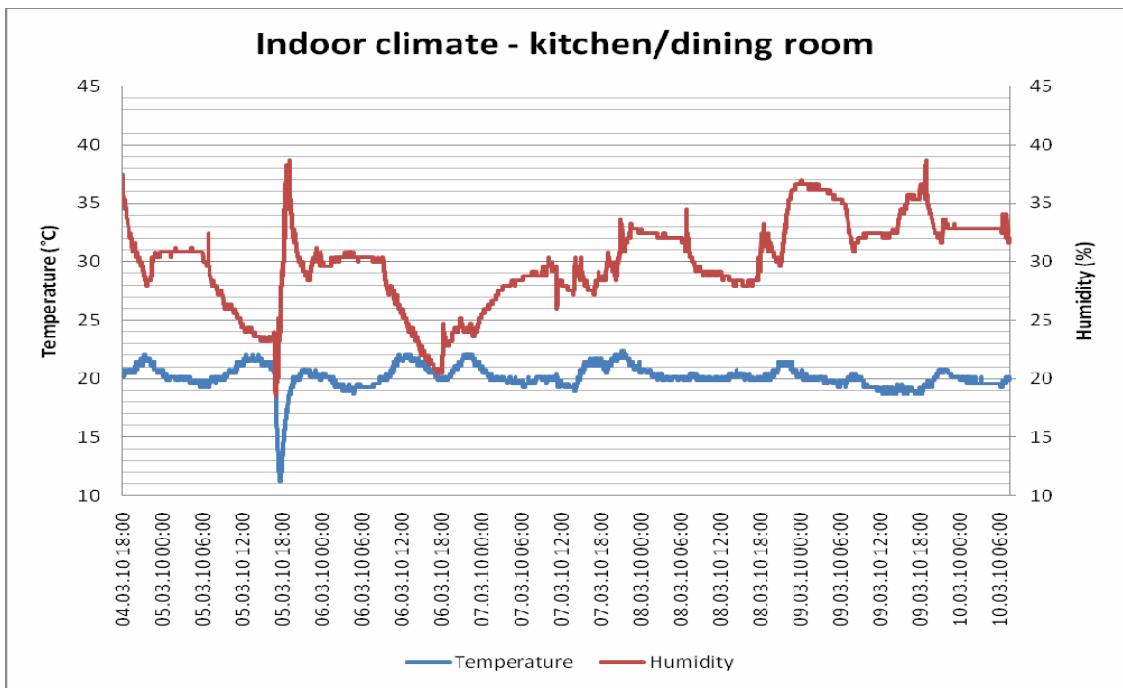
4.2 Measurement

For indoor climate test were used two data loggers. One data logger was placed in the kitchen/dining room and the second one in the workroom. The measurements in the apartment were made for 6 days (from Thursday 04.03.2010 until Wednesday 10.03.2010). The results are shown in graph 1 and 2.

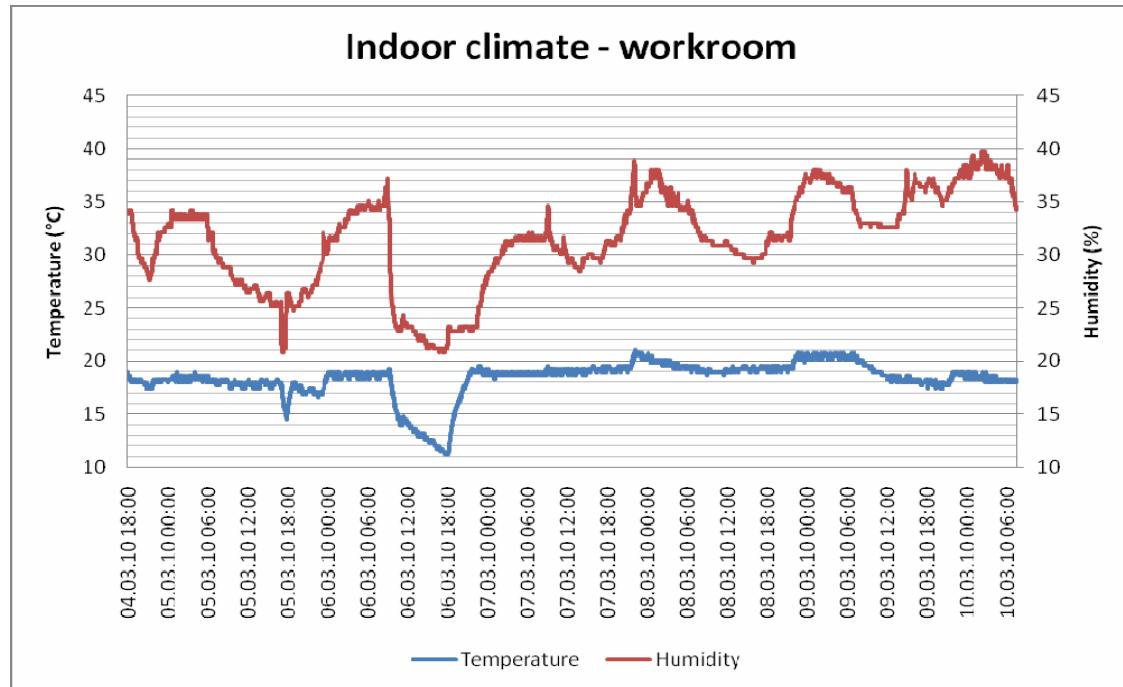
As you can see from the graph 1, the indoor temperature in the kitchen/dining room is around 20,3°C (the temperature drop isn't included in calculation) compared to 20°C which is the common design temperature. There was one temperature drop during the measurement which perhaps means that window was opened for short time (graph 1).

The average temperature in the workroom is around 18,8°C (the temperature drop is not included in calculation). The optimal temperature during the day should be 20°C. There was one temperature drop during the measurement which perhaps means that window was opened for longer period (graph 2).

The average humidity in kitchen/dining room is 35,8% and in the workroom 29,9%.



Graph 1 Temperature and humidity in the kitchen/dining room



Graph 2 Temperature and humidity in the workroom

4.3 Conclusion

The temperature in the apartment is almost fulfilling the building regulation standard. The optimal temperature should be around 20°C in living areas.

The humidity in the apartment should be around 40%. The measured mean humidity was around 35,8% in the kitchen/dining room and around 29,9% in the workroom.

5. Energy consumption

The energy consumptions for the dwelling, where 2 people are living, are shown in the tables (water, district heating and EL consumption).

Water consumption

Period	m ³
30.04.08 - 09.01.09	53
28.11.09 – 12.02.10	120

Source: Copenhagen Energy

District heating consumption

Period	kWh
30.04.08 - 15.09.08	991
16.09.08 - 14.09.09	5750
15.09.09 - 30.09.10*	6000

* expected consumption

Source: Copenhagen Energy

EL consumption

Period	kWh
01.05.08 - 20.07.08	612
21.07.08 – 31.07.08	98
01.08.08 – 22.12.08	1190
23.12.08 – 31.01.09	384
01.02.09 – 26.08.09	1524
27.08.09 – 10.12.09	897

Source: Dong Energy

Key numbers, kWh/m ² year			
Energy frame			
BR: 110,2	Class 2: 68,8	Class 1: 47,9	
Total energy requirement		71,4	
Contribution to energy requirement			Net requirement
Heat	52,2	Room heating 29,2	
El. for operation of building	5,9 *2,5	Domestic hot water 17,6	
Excessive in rooms	4,4	Cooling 0,0	
Selected electricity requirements			Heat loss from installations
Lighting	0,0	Room heating 1,2	
Heating of rooms	0,0	Domestic hot water 4,5	
Heating of DHW	0,0		
Heat pump	0,0	Output from special sources	
Ventilators	4,3	Solar heat 0,0	
Pumps	1,1	Heat pump 0,0	
Cooling	0,0	Solar cells 0,0	
Total el. consumption	36,5		

*Figure 7 Calculations of energy requirement in Be06 without solar cells
(Class 2 is 62% of the Building Regulation consumption)*

Source: Viggo Madesn A/S

5.1 Conclusion

The water consumption for the apartment (2 person) is 252,9 litres per day. That means 126,5 litres per person per day. The water consumption according to building regulations standard is expected to be 120 litres per person per day.

The district heating consumption is 67,6 kWh/m² per year (during the period: 16.09.08 – 14.09.09). The calculated demand from Be06 is 56,7 kWh/m² per year. So the consumption is 19,2% higher than the calculated.

Electricity consumption in the apartment is 2915,7 kWh per year, that means 1457,9 kWh per person per year. The average electricity consumption in Denmark is 1423 kWh per person per year.

6. Final conclusion

Some parts of house construction weren't made in the required quality. When the windows, doors and ventilation pipes to service shaft were placed some mistakes were made with respect to air leakage.

There are still some possibilities how to save energy. As the air flow test showed, the air flow volume in the apartment is too height and due to the electricity consumption can be reduced.

**Monitoring results of row house
Thomas Koppels Allé 26D, Copenhagen**

Claimant Thomas Koppels Allé 26D
Copenhagen

Date 25. February 2010

Performed by Cenergia
Herlev Hovedgade 195
2730 Herlev

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1. Dwelling description

The dwelling is situated in a row house on Thomas Koppels Allé 26D in Copenhagen. The living area of the two storey apartment is 127 m².

The dwelling is prefabricated and fulfils the Low Energy Class 2 standard. On the roof of the house there are PV panels installed.



Figure 1 Picture of the houses

Vildrose I, andelsbolig, type 02, 127 m²



Figure 2 Plan of the dwelling, type 02

2. Blower door test

2.1 Background and purpose

On basis of an enquiry from EU-Concerto it has been agreed that Cenergia performs an air tightness testing on a row house on Thomas Koppels Allé 26D in Copenhagen.

The assignment

Air tightness of the new build row house was made on Monday 25 February 2010 at 11:00.

The inlet and outlet of the ventilation unit and cooker hook were closed with tape and ventilation unit was detached during the measurement.

Blower door was installed in the main entrance.

The house is a row two storey house of 127 square meters.

2.2 Measuring equipment

The measuring is performed with "Minneapolis Blower Door". Set-up and measuring equipment is in compliance with the general standard of the Canadian board, CAN/CGSB-149.10-M86 "Determination of the Air tightness of Building Envelope by the Fan Depressurization Method".

During the measuring the volume flow through leaks in the building is following formula:

$$Q = Cr \times dP^n$$

In which

Q volume electricity [l/s]

dP Difference in pressure [Pa]

Cr constant

n streaming exponent

From the size of the stream exponent the type of holes and leaks in the house can be estimated.

Type of opening	N
Large openings	0,5
Cracks	0,66
Porous materials with collections	0,75
Only porous materials	1,0

Leak area is calculated by the formula:

$$ELA = 0.001157 \times \sqrt{\rho} \times Cr \times 10^{n-0.5}$$

in which

ELA = area of leaks [m^2]

Cr = constant

ρ = the density of air

dP = diversity in pressure [Pa]

The requirements of building regulative towards leaks in new built

Air tightness through leaks in the climate shield is not allowed to exceed 1,5 l/s per m^2 heated storey area at pressure measuring at 50 Pa

2.3 Conclusion

The readings is reported in the enclosed printed program

Infiltration at 50 Pa is measured to 153 l/s with low pressure and 163 l/s with high pressure. With a heated storey area of 127 m^2 , this corresponds to an infiltration of 1,20 l/s per m^2 and 1,29 l/s per m^2 at an air tightness of 50 Pa, and the house in this way comply with the air tightness demands of **1,5 l/s per m^2** .

The flow exponents have been detected to 0,64 and 0,72, corresponding to the air intake through cracks and porous materials with collections.

The following leaks were identified during the measuring:

- air entering around the connection between the walls and the doors
- air entering around the connection between the walls and the windows
- air entering around the connection between the walls and the ceilings

Test carry out for:

Name	
Adress	Thomas Koppels Alle 26D
Contactperson	tel.:

Test carry out of

Name	Cenergia Energy Consultants
Adress	Herlev Hovedgade 195
Person	RW og VAA

Building

Adress	Thomas Koppels Alle 26D
Buildingtype	Row house
Date	Test 25/2-2010 kl. 9-12 Rapport

Weatherdata

Outdoortemperatur	1 °C	Airpressure, hPa	999,9
Windspeed	7 m/s	Wind direction	NW

Buildingdata

Area to the free	
Other area	
Floor space	127 m ²
Volume	317,5 m ³

Inside measure of walls, ceiling, floor and doors and windows.

Data from the measuring

Corrected data

dPm, [Pa]	Qm, [m ³ /h]	dP, [Pa]	Q, [l/s] under	Q, [l/s] over
52	585	52	158,2	
45,5	525	45,5	142,0	
40,5	490	40,5	132,5	
36	460	36	124,4	
32	420	32	113,6	
29	400	29	108,2	
48	550	48	148,7	
51,5	610	51,5		165,0
47	585	47		158,2
44	550	44		148,7
40,5	520	40,5		140,6
35,5	470	35,5		127,1
29	400	29		108,2
32	450	32		121,7

Low pressure

$$\begin{aligned} Cr &= 12,245 & n &= 0,6449 \\ ELA &= 0,0217 \text{ m}^2 & & 217 \text{ cm}^2 \\ BR &= 1,20 \text{ l/sm}^2 & & 153 \text{ l/s} \end{aligned}$$

Overpressure

$$\begin{aligned} Cr &= 9,775 & n &= 0,72 \\ ELA &= 0,0206 \text{ m}^2 & & 206 \text{ cm}^2 \\ BR &= 1,29 \text{ l/sm}^2 & & 163 \text{ l/s} \end{aligned}$$

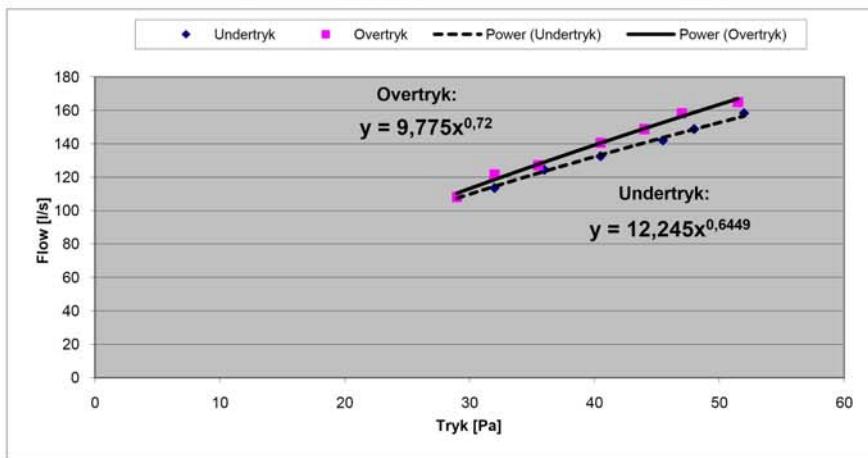


Figure 3 Readings from the blower door test

3. Air change test

An air change test for the dwelling was also made. The dwelling is equipped with ventilation with heat recovery. The air flow from the ventilation unit can be regulated by tenants (4 default speed steps).

3.1 Measuring equipment

For air change test the measurement equipment Testo 425 and Testo testovent 415 were used.

3.2 Measurement

Air flow measurement for one inlet and outlet took 30 seconds and it was done 5 times. The air flow was set on the speed step 2.

The measured and designed data for inlet and outlet are shown in the figure 4. The air change for the apartment is $191 \text{ m}^3/\text{h}$ compared to the building regulations standard which is $159 \text{ m}^3/\text{h}$.

no.	designed	measured	note
	air flow (m^3/h)	air flow (m^3/h)	
1	38	25	inlet
2	36	23	outlet
3	42	44	Inlet
4	29	33	inlet
5	25	22	inlet
6	54	45	outlet
7	25	23	inlet
8	29	11	inlet
9	*	22	inlet
10	72	123	outlet

*no designed

Σ	188	180	inlet
Σ	162	191	outlet

Figure 4 Air change measured and designed data

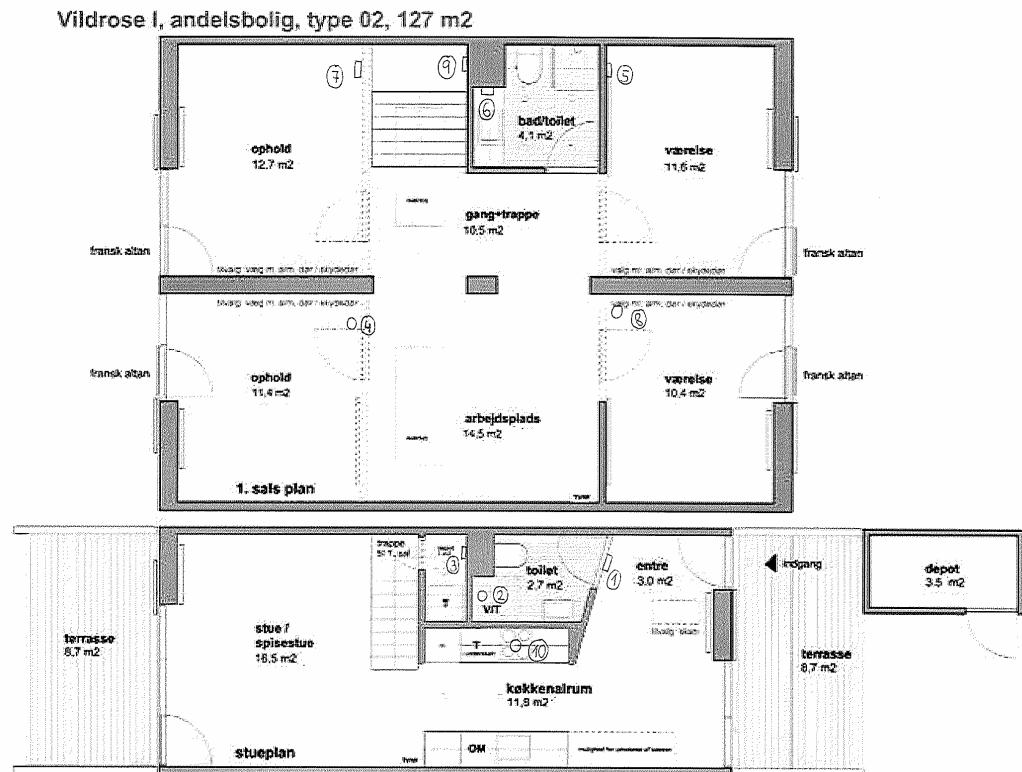


Figure 5 Placement of inlet and outlet in the apartment

3.3 Conclusion

The air change for the dwelling is $191 \text{ m}^3/\text{h}$ and the value has been higher than the required value $159 \text{ m}^3/\text{h}$. The air change is higher according to the building regulation standard. But some improvements have to be made comparing to airflow in the dwelling, because the airflows from inlet and outlet have different measured values compared to design values.

4. Indoor climate test

Indoor climate test for the dwelling was made. It was decided to measure indoor climate in the living room and bedroom for 11 days.

4.1 Measuring equipment

For measurements were used data loggers Gemini Tinytag Ultra 2.

4.2 Measurement

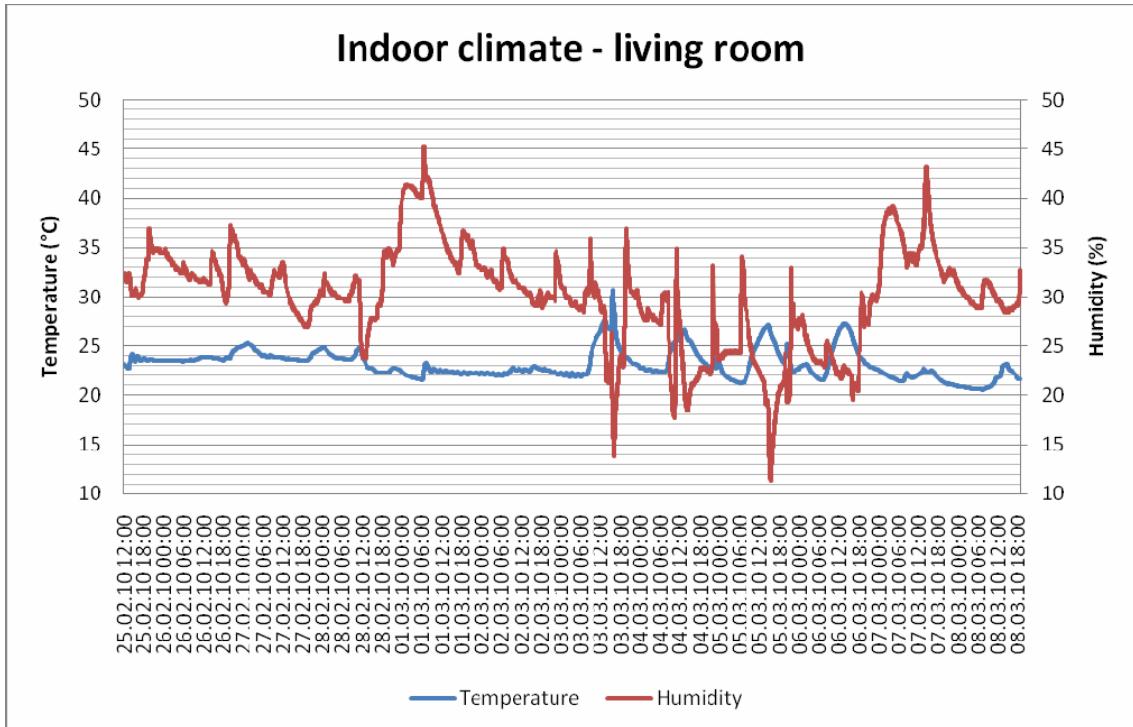
For indoor climate test were used two data loggers. One data logger was placed in the living room and the second one in the bedroom. The measurements in the apartment were made for 11 days (from Thursday 25.02.2010 until Monday 08.03.2010). The results are shown in the graph 1 and 2.

As you can see from the graph 1, the indoor temperature in the living room is around 23.2°C compare to 20°C which is the common design temperature.

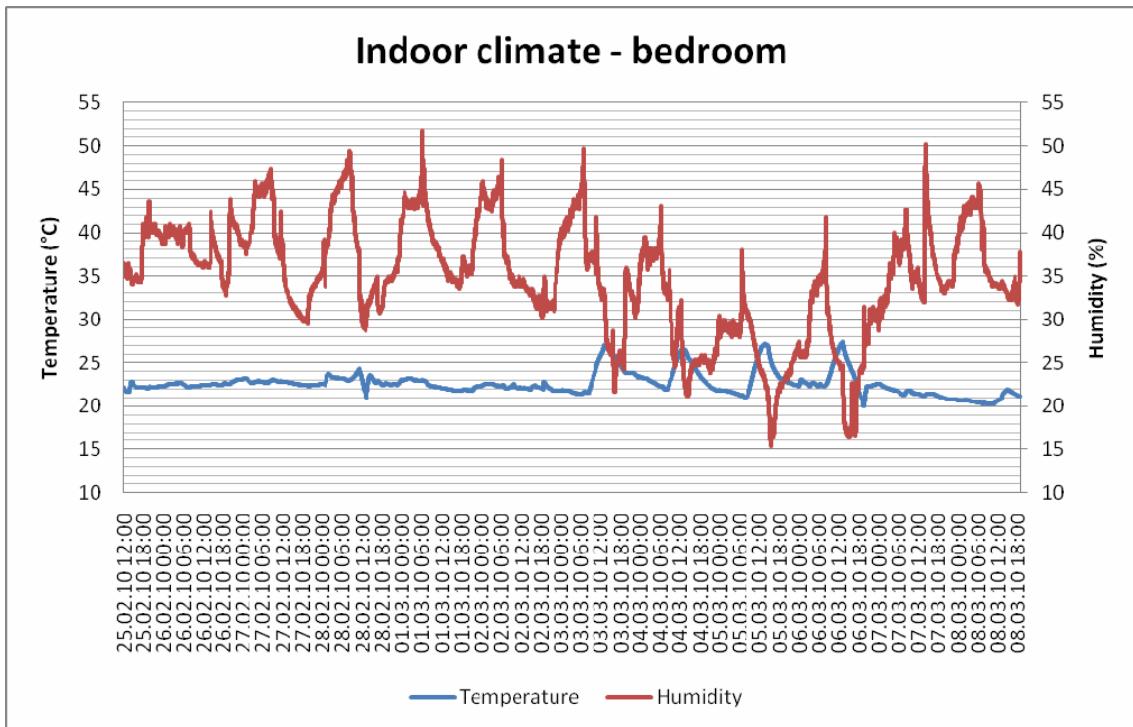
The average temperature in the bedroom is around 22.6°C . The optimal temperature during the day should be 20°C and around 18°C during the sleeping time.

In the graph 1 and 2 you can see temperature drops during the days 03.03.2010 – 06.03.2010 which maybe means that the temperature rises because of solar radiation into the rooms.

The average humidity in living room is 30,0% and in the bedroom 34,7%.



Graph 1 Temperature and humidity in the living room



Graph 2 Temperature and humidity in the bedroom

4.3 Conclusion

The temperature in the apartment is a too height compared to the designed temperature for the winter period. In the graph 1 and 2 you can see the temperature drops around midday which maybe were caused by solar radiation. The optimal temperature should be around 20°C in living areas and around 18°C for sleeping.

The humidity in the apartment should be around 40%. The measured mean humidity was around 30,0% in living room and 34,7% in the bedroom.

5. Energy consumption

The energy consumptions for the dwelling, where 3 people are living, are shown in the tables (water, district heating and EL consumption).

Water consumption

Period	m ³
01.05.08 – 06.12.08	66
07.12.08 – 23.02.10	144

Source: Copenhagen Energy

District heating consumption

Period	kWh
30.04.08 – 15.09.08	1601
16.09.08 – 18.09.08	8320
19.09.09 – 30.09.10*	9000

* expected consumption

Source: Copenhagen Energy

EL consumption

Period	kWh
01.05.08 – 01.07.08	656
02.07.08 – 30.12.08	2090
31.12.08 – 01.07.09	2194
02.07.09 – 01.01.10	2246

Source: Dong Energy

Key numbers, kWh/m ² year			
Energy frame			
BR: 95,1	Class 2: 62,6	Class 1: 43,7	
Total energy requirement		63,1	
Contribution to energy requirement		Net requirement	
Heat	47,5	Room heating	31,2
El. for operation of building	4,8 *2,5	Domestic hot water	15,9
Excessive in rooms	3,6	Cooling	0,0
Selected electricity requirements		Heat loss from installations	
Lighting	0,0	Room heating	0,0
Heating of rooms	0,0	Domestic hot water	2,8
Heating of DHW	0,0		
Heat pump	0,0	Output from special sources	
Ventilators	3,8	Solar heat	0,0
Pumps	0,7	Heat pump	0,0
Cooling	0,0	Solar cells	0,0
Total el. consumption	35,5		

*Figure 5 Calculations of energy requirement in Be06 without solar cells
(Class 2 is 66% of the Building Regulation consumption)*

Source: Viggo Madesn A/S

5.1 Conclusion

The water consumption for all apartment (3 person) is 316,3 litres per day. That means 105,4 litres per person per day. The water consumption according to building regulations standard is expected to be 120 litres per person per day.

The district heating consumption is 65,2 kWh/m² per year (during the period: 15.09.08 – 18.09.09). The calculated demand from Be06 is 51,1 kWh/m² per year. So the consumption is 27,6% higher than the calculated.

Electricity consumption in the apartment is 4299,8 kWh per year, that means 1433,3 kWh per person per year. The average electricity consumption in Denmark is 1423 kWh per person per year.

6. Final conclusion

Some parts of house construction weren't made in the required quality. When the windows and doors were placed some mistakes were made. But the air tightness for the dwelling is fulfilled.

There are still some possibilities how to save energy. As the indoor climate test showed, the temperature in the apartment is too height and due to the heating consumption can be reduced.