

Low cost, low energy houses

1 Introduction

Ullerød Byen in Hillerød will be used to promote low energy construction. As support for the city, Cenergia has analysed how low energy housing can be established in the most economic way.

2 Background for the calculations

New energy requirements were introduced in Denmark in April 2006. The minimum demands mean that a new building will use 25-30% less energy than a building built before April 2006. The new regulations also introduced 2 new low energy standards, which use 25% and 50% less energy, respectively. It is the idea that these low energy standards will become the standard in 5 and 10 years, respectively.

The new requirements mean that an energy frame is calculated for each building. The energy frame limits the buildings demand for energy to a specific amount of kWh/m² per year. With the new demands, not only the heating demand is taken into account, but also the demand for electricity for building operation (ventilation, cooling, pumps and lighting (only in commercial buildings)). Energy gains from passive solar heating, internal gains and renewable energy sources are also taken into account.

For houses, hotels etc., the energy frame is: $70 + 2200/A$ kWh/m² per year where A is the heated gross floor area.

The Danish Building Research Institute has issued a guideline which is part of the new requirements, which means that to comply with the requirements the guideline must be followed. Part of the guideline is the computer program Be06 which must be used to calculate the energy demand for all new buildings.

In the program you add information about the U-values and areas for the building envelope including windows and cold bridges. For windows also the orientation, the g-value and solar shading or overhang is typed in. Based on these input, the program calculates the energy balance for all windows.

Data for all electrical installations must be added, including fans, and pumps for the heating system and for the domestic hot water system. For the ventilation system you also add the airflow and the efficiency of the heat exchanger. Also the infiltration rate due to leakages or natural ventilation is added.

The heating system for the building is described by indicating if the building is heated by district heating, electricity or a boiler (on oil, gas or biomass). Any additional energy sources can be added in terms of PV, solar thermal systems, heat pumps etc.

When the total energy demand of the building is calculated, the electricity demand is multiplied by 2,5, which means that it will be very difficult to comply with the energy frame

if electrical heating is used. It is therefore also sensible to use pumps and fans with a reduced electricity consumption, as these often are in operation 24 hours a day.

The program also considers if the building may overheat by determining how much time the temperature will exceed 26°C. It is determined how much electricity would be required to cool the building to 26°C, and this energy consumption is added to the building energy demand – no matter whether the building has cooling installed or not. This is to encourage building designers to create buildings without a need for cooling and with a good indoor environment.

3 Assumptions for the calculations

Calculations have been made for a single family house, an apartment block and for dense low-rise buildings (row houses).

The calculations use a reference calculation to compare different measures which improve the energy performance of the building.

3.1 Single family houses

Amounts	
Total living area	164 m ²
Roof	164 m ²
Floor (on ground)	164 m ²
Outerwall	120 m ²
Windows and doors	36 m ²

3.1.1 Insulation

The following insulation levels in terms of U-values have been considered:

	REF	iso I	iso II	
Wall	0,23	0,20	0,15	[W/m ² K]
Floor	0,20	0,15	0,13	[W/m ² K]
Roof	0,20	0,15	0,12	[W/m ² K]

The U-values roughly correspond to these insulation thicknesses:

U-value [W/m ² K]	Thickness of insulation [mm]
0,10	450
0,15	300
0,18	250
0,20	230
0,23	200
0,30	150

Prices for extra insulation from Danish price database:

	euro/m ²						Total euro 2006	
	2000			2006			iso I - extra	iso II - extra
	REF	iso I	iso II	REF	Iso I - extra	iso II - extra		
Wall	175	179	183	209	5	10	573	1146
Floor	49	57	62	59	9	15	1436	2480
Roof	75	80	85	90	6	12	992	1984
Total							3001	5611

3.1.2 Windows

Windows: Prices from supplier SA Windows [euro/m²]

U-value	Price			Extra price		
	1,7	1,27	1,07	1,7	1,27	1,07
Price/m ²	200	237	287	0	37	87

3.1.3 Other

Improved airtightness: [euro/m²] (estimate) 2,7
 Heat recovery with heat coil, price per home, euro 1400
 Price for heating in Hillerød 2006 [euro/kWh] 0,0513

3.2 Dense low-rise

Amounts	
Total living area	115 m ²
Roof	71 m ²
Floor (on ground)	71 m ²
Outerwall	60 m ²
Windows and doors	18 m ²

3.2.1 Insulation

The following insulation levels have been considered:

U-value [W/m ² K]	Thickness of insulation [mm]
0,10	450
0,15	300
0,18	250
0,20	230
0,23	200
0,30	150

Prices for extra insulation from Danish price database:

	euro/m ²						Total euro 2006	
	2000			2006			iso I - extra	iso II - extra
	REF	iso I	iso II	REF	iso I - extra	iso II - extra		
Wall	175	179	183	209	5	10	287	573
Floor	49	57	62	59	9	15	622	1074
Roof	75	80	85	90	6	12	430	859
Total							1338	2506

3.2.2 Windows

Windows: Prices from supplier SA Windows [euro/m²]

	Price			Extra price		
U-value	1,7	1,27	1,07	1,7	1,27	1,07
Price/m ²	200	237	287	0	37	87

3.2.3 Other

Improved airtightness: [euro/m ²] (estimate)	2,7
Heat recovery with heat coil, price per home, euro	1400
Price for heating in Hillerød 2006 [euro/kWh]	0,0513

3.3 Apartment blocks

Assumptions

Amounts			
Total living area	1081 m ²	6 small apartments	66 m ²
Roof	360 m ²	6 large apartments	91 m ²
Floor (on ground)	313 m ²		
Outerwall	568 m ²		
Windows and doors	162 m ²		

3.3.1 Insulation

U-value [W/m ² K]	Thickness of insulation [mm]
0,10	450
0,15	300
0,18	250
0,20	230
0,23	200
0,30	150



Prices for extra insulation from Danish price database:

	euro/m ²								Total euro		
	2000				2006				2006		
	REF	iso I	iso II	iso III	REF	iso I - extra	iso II - extra	iso III -	iso I - extra	iso II - extra	iso III -
Wall	175	179	183	191	209	5	10	19	2712	5424	10848
Floor	49	57	62	73	59	9	15	28	2744	4740	8682
Roof	75	80	85	95	90	6	12	24	2180	4361	8664
Total									7637	14525	28194

3.3.2 Windows

Windows: Prices from supplier SA Windows [euro/m²]

	Price				Extra price			
U-value	1,7	1,27	1,07	0,8	1,7	1,27	1,07	0,8
Price/m ²	200	237	287	400	0	37	87	200

3.3.3 Other

Improved airtightness: [euro/m ²] (estimate)	2,7
Heat recovery with heat coil, price per home, euro	1400
Price for heating in Hillerød 2006 [euro/kWh]	0,0513
Solar thermal system: based on 2,5 m ² per apartment, 30 m ² in total, total price:	24000
Price for PV: 12 m ² (1 m ² pr apartment) :	6400



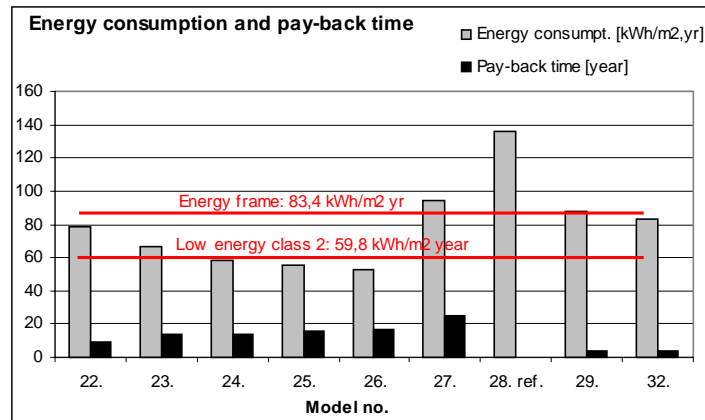
4 Results

4.1 Single family house

No.	DHW [l/m ² ,yr]		Solar thermal	Insulation [W/m ² K]			Infiltration [l/h]		Heat recovery	Windows, U-value [W/m ² K]			Energy consumpt. [kWh/m ² ar]	Extra costs, total [euro]	Energy saving [kWh/m ² yr]	Saving comp. to ref. [euro/yr]	Pay back time [yr]
	250	200		REF	Iso I	Iso II	0,1	0,05		1,70	1,27	1,07					
*			2667	0	3001	5611	0	437	1400	0	1320	3120					
22.	1				1		1		1	1			78,9	4401	57,2	482	9
23.		1				1	1		1		1		66,7	8331	69,4	584	14
24.		1				1		1	1				58,5	8768	77,6	653	13
25.		1				1		1	1			1	55,2	10568	80,9	681	16
26.	1		1			1		1	1		1		52,9	11435	83,2	700	16
27.	1					1	1					1	94,1	8731	42	354	25
28. ref.	1			1			1			1			136,1	0	0	0	0
29.	1			1			1		1	1			87,8	1400	48,3	407	3
32.	1			1				1	1	1			83,3	1837	52,8	445	4

* The costs in the yellow row are the total costs for the individual items. For windows, infiltration (air tightness) and insulation the unit price per m² is multiplied by the number of m² as found in the table under assumptions, where also the unit prices are found.

15 kWh/m² has been added to the reference model, corresponding to the average quality of new buildings.



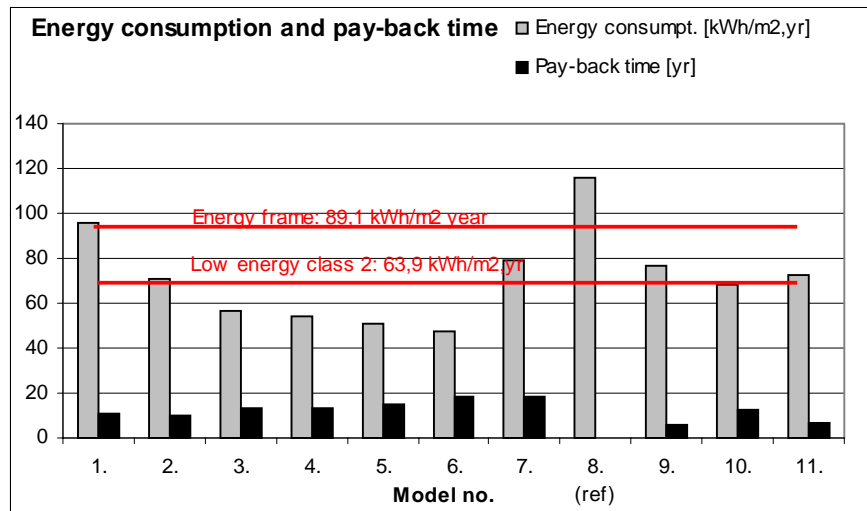


4.2 Dense low-rise

No.	DHW [l/m ² ,yr]		Solar thermal	Insulation [W/m ² K]			Infiltration [l/h]		Heat recovery	Windows, U-value [W/m ² K]			Energy consumpt. [kWh/m ² ,yr]	Extra costs, total [euro]	Energy saving [kWh/m ² ,yr]	Saving comp. to ref. [euro/yr]	Pay back time [yr]
	250	200		REF	Iso I	Iso II	0,1	0,05		1,70	1,27	1,07					
*			2667	0	1338	2506	0	307	1400	0	660	1560					
1.	1				1		1			1			95,5	1338	20,7	122	11
2.	1				1		1			1			71,1	2738	45,1	266	10
3.		1				1	1				1		56,4	4566	59,8	353	13
4.		1				1		1			1		54,1	4873	62,1	367	13
5.		1				1		1				1	51,0	5773	65,2	385	15
6.	1		1			1		1			1		47,5	7539	68,7	406	19
7.	1					1	1					1	79,4	4066	36,8	217	19
8. (ref)	1			1			1						116,2	0	0	0	0
9.	1			1			1			1			76,5	1400	39,7	234	6
10.	1				Walls	Roof+floor	1			1			68,7	3620	47,5	280	13
11.	1			1				1		1			72,7	1707	43,5	257	7
12.																	

The costs in the yellow row are the total costs for the individual items. For windows, infiltration (air tightness) and insulation the unit price pr m² is multiplied by the number of m² as found in the table under assumptions, where also the unit prices are found.

15 kWh/m² has been added to the reference model, corresponding to the average quality of new buildings.





4.2.1 Apartment blocks

No.	DHW [l/m ² ,yr]		Solar thermal	Insulation [W/m ² K]				Infiltration [l/h]		Heat recovery	Windows, U-value [W/m ² K]				Energy consumpt. [kWh/m ² år]	Extra costs, total [euro]	Energy saving [kWh/m ² yr]	Saving comp. to ref. [euro/yr]	Pay back time [yr]
	250	200		REF	Iso I	Iso II	Iso III	0,1	0,05		1,70	1,27	1,07	0,8					
*			24000	0	7637	14525	28194	0	2883	16800	0	5940	14040	32400					
40 ref.	1			1				1			1			103,2	0	0	0	0	
41	1					1		1					1	72,2	28565	31	1720	17	
42	1				1			1				1		78,5	13577	24,7	1371	10	
46	1						1	1					1	66,4	60594	36,8	2042	30	
43	1			1					1	1	1			55,1	19683	48,1	2669	7	
44	1			1					1	1		1		50,8	25623	52,4	2908	9	
45	1			1				1		1	1			58,2	16800	45	2497	7	
47	1						1	1	1				1	38,4	80276	64,8	3596	22	
48 ph	1		1				1	1	1				1	33,2	104276	70	3884	27	
49 ph+PV	1		1				1	1	1				1	30,6	110676	72,6	4029	27	

Model 48 also includes the following "passiv haus" measures: Reduced cold bridges around doors and walls and an internal heat gain of 2,1 W/m² instead of 5 W/m² which is standard in the Danish guidelines
 Model 49 is based on the measures of model 48, but with 1 m² af PV per home, equal to 12 m² in total

* The costs in the yellow row are the total costs for the individual items. For windows, infiltration (air tightness) and insulation the unit price pr m² is multiplied by the number of m² as found in the table under assumptions, where also the unit prices are found.

15 kWh/m² has been added to the reference model, corresponding to the average quality of new buildings. This means that the actual energy consumption is often higher than the calculated energy consumption. In this case and in the future it is expected that there will be an increased focus on energy quality control in the building industry.

