ENVIRONMENTAL ASSESSMENT OF ENERGY CONSERVATION TECHNOLOGIES FOR HEATING AND VENTILATION – A CASE STUDY

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ABSTRACT

More than three quarters of all consumed energy in buildings are used for heating, ventilation and sanitary hot water preparation. Energy conservation on these areas has a great potential for reduction of fossil fuels consumption and could greatly contribute to environmental assessment. In striving for reduction of energy use in buildings new criteria are enforced as a measure for energy use in buildings. Material and devices manufacturing for energy conservation by heating and ventilation and their installation and operation have the influence on the environment in the whole building's lifetime. By energy analyses only energy flows are considered whereas by environmental assessment also influences on people's health, ecosystem quality and resources depletion are considered. This method is known as LCA method. In the article different technologies for reduction of energy use in buildings are presented and their influence on the environment in the building's lifetime are shown. For each analysed technology embodied energy is determined and their inventories with carried out evaluation using Eco-indicator 99 method have been made.

KEYWORDS

Energy conservation, embodied energy, eco-points, eco-indicator 99

SELECTED METHODS FOR ENERGY AND ENVIRONMENTAL ASSESSMENT

For energy and environmental assessment of technologies for rational use of energy three different methods have been used in our work:

Energy use for heating and sanitary hot water preparation; several simple engineering methods are available for energy use for heating based on average monthly values – M5000, ISO 9234, EN 832,… In this work method described in EN 832 standard has been used. The results are presented as a heating load in kWh/m^2 of living area.

Embodied energy; embodied energy defines energy use for material production, equipment and system manufacturing. The same effect on rational use of energy in the building could be achieved with different systems but energy use for their manufacturing could be very different. Based on known embodied energy and calculated energy savings an energy pay back period could be determined. Energy pay back period is defined as a time in which embodied energy returns trough energy savings. As we only intend to compare different technologies we assumed that energy used for transport and installation into the building are the same for all cases and it has not been included into calculated embodied energy.

Environmental assessment; for environmental assessment of different technologies an Eco-indicator 99 method has been used. With this method different building components or systems could be evaluated in the whole estimated life cycle (LCA) based on used unrenewable sources and space, emissions into air, water and ground and consequences on ecosystems and people's health.

A CASE OF BUILDING PLANNING BASED ON ENERGY AND ENVIRONMENTAL ASSESSMENT

Building planning based on energy and environmental assessment of selected technologies for rational use of energy is shown on a selected building. Following technologies have been analysed:

- Different type and thickness of thermal insulation on wall, ceiling and floor
- Different systems for sanitary hot water preparation
- Natural and mechanical ventilation with heat recovery
- Sunspace with frame of different material

Building will be built in the town with latitude of 46^o, and degree-days DD=3200 Kday/year, yearly solar irradiation is 1200 kWh/m^2year and number of solar hours is 1100 h/year. Building's living area is 205 m^2, $f_o=A/V=0{,}713\ m^{-1}$. Building is heated with oil and sanitary hot water with electric heater.

Figure 1: South-west and north façade of analysed building

COMPARISON OF DIFFERENT TECHNOLOGIES BASED ON BUILDING'S ENERGY VALUE

Building's specific energy use for heating is shown on Figure 2. Base building represents a building with thermal insulation that corresponds to national thermal regulation (U_{wall}=0,6 W/m^{2}K, U_{roof}=0,25 W/m^{2}K, U_{floor}=0,45 W/m^{2}K, U_{window}=1,3 W/m^{2}K). Building is naturally ventilated and sanitary water is heated with electric heater. Besides base building also other analysed measures for rational energy use are shown:

- Thicker thermal insulation (1) mineral wool and (2) polystyrene; the thickness has been selected so that insulation could be built in by usual procedure;
- System for mechanical ventilation with heat recovery (3) with average yearly heat recovery efficiency of 50%;
- Solar system (4) with 8 m2 of solar collector area with 70% of solar fraction;
- Sunspace with wooden (5) or Al (6) framing and the same glassing as windows – sunspace area has been added to the total living area for E-value calculation;
- Different combinations of these technologies are presented at the end.

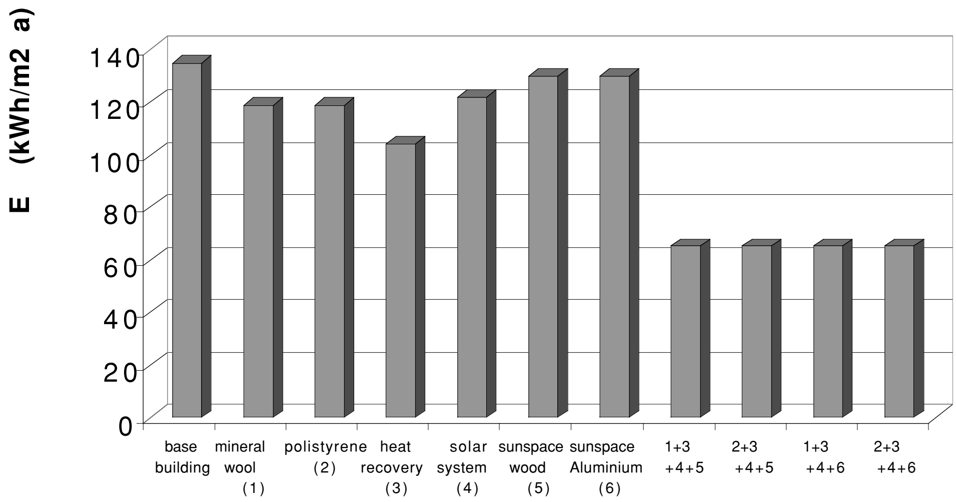

Figure 2: Building's E values with different energy conservation technologies installed

Comparison shows that a base building has relatively large E-value, which could be most efficiently reduced with mechanical ventilation with heat recovery. Almost equivalently follows a better thermal insulation and solar system. The smallest reduction in energy consumption is achieved with sunspace, especially because direct solar gains trough the windows are reduced. E-value is reduced almost on half of the base building with combination of all four analysed technologies. From the Figure 2 it could also be seen that technologies with the same effect on energy use could not be ranked. This deficiency will be suppressed with comparison of embodied energy.

COMPARISON OF DIFFERENT TECHNOLOGIES BASED ON EMBODIED ENERGY

The amount of with material and system embodied energy has been determined using inventories and data of energy use for their manufacturing. As we have focused only on technologies comparison, energy use for installation has not been considered. Example of inventories for embodied energy for solar system is shown on Table 1. Values for all considered technologies are shown on Figure 3, where only the difference in embodied energy ΔEE and difference in energy use ΔE compared to the base building is shown. Energy pay back period could be defined as a ratio of ΔEE/ΔE. It is shown on Figure 4.

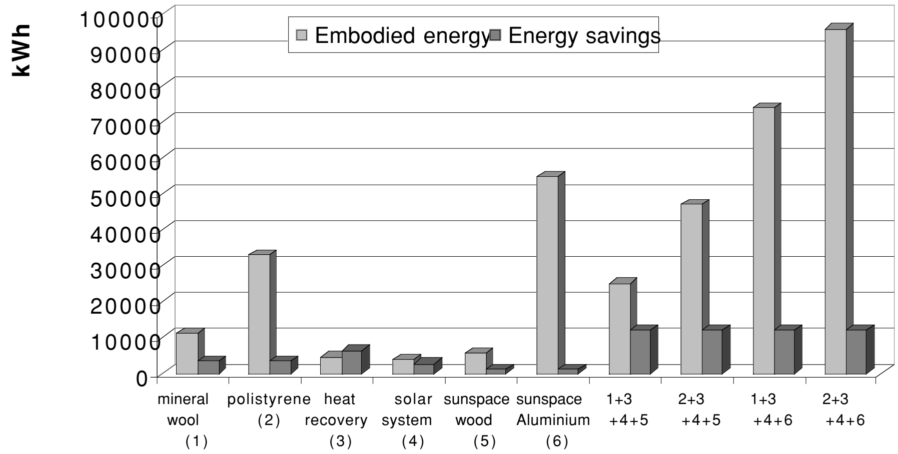

Figure 3: The difference in embodied energy and yearly energy savings compared to the base building

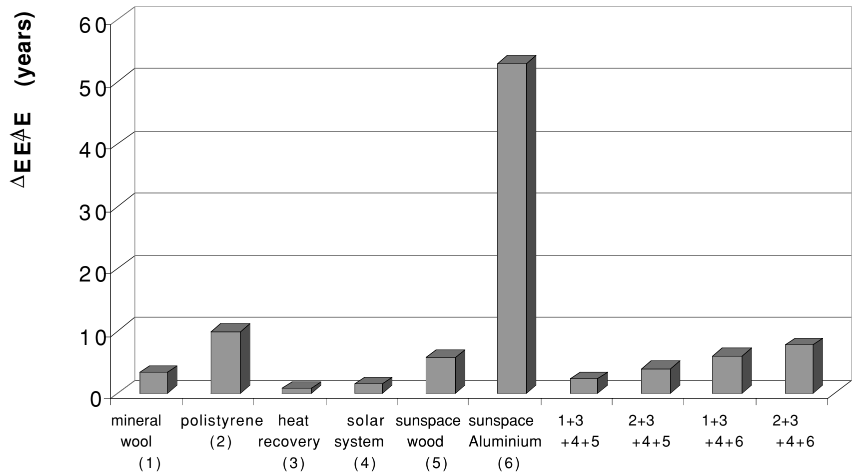

Figure 4: Energy pay back period for embodied energy

COMPARISON OF DIFFERENT TECHNOLOGIES BASED ON INFLUENCE ON THE ENVIRONMENT

Comparison of embodied energy for different technologies does not show their influence on the environment in the whole lifetime. This deficiency could be overcome by using one of the LCA methods – in our case we used method Eco-indicator 99. Inventories have been made to determine total number of eco-points. Example of such inventories is shown in Table 2. Building lifetime of 30 years has been selected. In inventories for some systems components a shorter lifetime has been considered and their replacement and maintenance anticipated. Figure 5 shows sum of embodied eco-points for each technology and eco-points, which are the result of energy use for heating, sanitary hot water and systems operation. It could be concluded that different technologies could be sorted according to their influence on the environment.

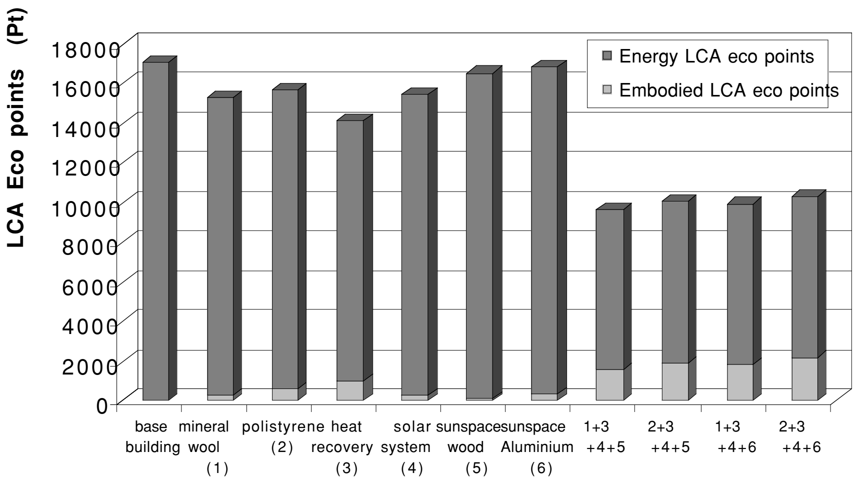

Figure 5: Sum of embodied eco–points and energy eco-points for heating, sanitary water heating and system operation

CONCLUSIONS

Presented results of energy use in building show, that analysed technologies in this case study are comparable concerning energy savings. Only when different technologies are combined greater savings could be achieved, that is why it is important to analyse all planed technologies. Embodied energy could serve as an indicator by selection of individual technology. All analysed technologies in this article, with exception of sunspace, have short energy pay back period of les than 10 years.

Calculated eco-points in the building's lifetime clearly show that all technologies are manufactured with relatively small influence on the environment. The most important remains rational energy use in building's lifetime. When several technologies are applied, which leads to a greater reduction of energy use, it becomes evident that the influence of embodied eco-points becomes more important. Modern trends in building construction are coupled with measures that enable minimal energy use, so it could be expected that environmental assessment will become the most important method in integral building planning.

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TABLE 1
Inventory for building's solar system

System or component: **Solar system**		Project: **Case 4**	
Date:			
Notes and conclusion: 8m^2 of SC, 300 l HS, 30m Cu pipes - insulated. In life time one replacement of HS. Electricity consumption is calculated for building lifetime (30 years).			
Manufacturing Materials			
Materials or processes	Quantity	kWh/kg	Result
Cooper	36 kg	15,5	558
Mineral wool	32 kg	2,5	80
Aluminium	24 kg	70,4	1690
Glass	80 kg	1	80
Rubber	4 kg	6	24
Stainless steel*	140 kg	7,3	1022
Polystyrene*	18 kg	6	108
Aluminium*	10 kg	70,4	704
Cu pipes	21 kg	15,5	326
Mineral wool	3 kg	2,5	7
Sum (kWh)			**4599**

* One replacement of heat storage in buildings life time

TABLE 2
LCA inventory for solar system

System or component: **Solar system**		Project: **Case 4**	
Date:			
Notes and conclusion: 8m^2 of SC, 300 l HS, 30m Cu pipes - insulated. In life time one replacement of HS. Electricity consumption is calculated for building life time (30 years).			
Manufacturing Materials, processes, transport, supplementary energy			
Materials or processes	Quantity	Indicator	Result
Cooper	36 kg	1400	50.400
Mineral wool	32 kg	61	1.952
Aluminium	24 kg	780	18.720
Al extrusion	24 kg	72	1.728
Glass	80 kg	49	3.920
Rubber	4 kg	360	1.440
Stainless steel*	140 kg	910	127.400
Polystyrene*	18 kg	480	8.640
Aluminium*	10 kg	780	7.800
Al extrusion*	10 kg	72	720
Cu pipes	21 kg	1400	29.400
Mineral wool	3 kg	61	183
Sum (mPt)			252.303
Usage Transport, energy and auxiliary material			
Process	Quantity	Indicator	Result
Transport	50 tkm	34	1.700
El. energy (supplementary)	39.990 kWh	47	1.879.530
Sum (mPt)			1.881.230
Depositing Depositing process by material type			
Materials or processes	Quantity	Indicator	Result
Cooper	36 kg	-1290	-46.440
Recycled Al	24 kg	-720	-17.280
Glass	80 kg	-15	-1.200
Rubber	4 kg	4.3	17
Metal sheet	140 kg	-70	-9.800
Al recycling	10 kg	-720	-7.200
Cu pipes	21 kg	-1290	-27.090
Mineral wool	0.4 m^3	140	56
Polystyrene	0.6 m^3	140	84
Mineral wool-pipes	0.04 m^3	140	6
Sum (mPt)			-108.847
SUM (all phases) (mPt)			**2.024.686**