Computer model for the energy consumption, cost, energy content and environmental loads of buildings

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SUMMARY

The computer model SIN–BIP is build as a combined model that can calculate energy consumption, price and environmental load for a building to get an energy efficient building. The program has a database with information of price, thermal conductivity, moisture conductivity, energy content and CO_2–emission for materials. On the basis of this information can the program calculate for each construction, the U–value, the moisture resistance (and if there is condensation), the price, the energy used for producing the material and the environmental load from CO_2–emission at the production. All this information is combined in tables and plots for each construction and for the whole building using the standard spreadsheet program EXCEL. The program SIN–BIP can be used for comparison of different materials and constructions based on evaluation of cost, total energy consumption and environmental load in the lifetime of the building. The most serious problem is to get information from the producers of building materials of the energy used for production and the CO_2–emission.

1. INTRODUCTION

Much effort has been spend in finding the most energy efficient building. Typically is the effort concentrated on reducing the energy consumption for heating and ventilation from a pure technical viewpoint. The problem of cost has had a secondary interest as most researchers do not know very much of the cost for different solution. The result is in many cases complicated technical installations, that is too expensive. We now have got a new area of interest – environmental load as CO_2– or SO_2–emission from the production and transport of the building materials and the load from heating and ventilating the building during the life–time. We can start with collecting information on environmental loads and build new houses with a low emission of CO_2. This is a new type of energy efficient building. But if we still do not remember to look at the cost will the influence of be minimal on the new buildings. To get engineers and architects to look at the CO_2–emission, energy consumption and cost it must be easy to find and to compare different solutions. This has been the subject of a diploma work(1) in Narvik. The result is a new easy to use computer program SIN–BIP. The letters SIN is a short name for Narvik Institute of Technology in Norwegian and the letters BIP are a shortening of Building physic Information Program.

2. THE SIN–BIP PROGRAM

The program is written in the MACRO–languages of EXCEL. The layout is therefor well–known for persons how know the WINDOWS–environment. The user will typically start with selecting a construction type – wall, roof, basement, window and door. If we look on a wall as in figure 1, can we see all the layers in the construction. Each type of layer has a code, that is pointing to the database with the technical information for each product. If we do not remember the code number we can get a window with a list, se figure 2. We must also give a thickness for each layer. After all changes in the layers in the wall construction we must update all the information that depends on the changed values. This is done by pointing and clicking on the button recalculate on the screen.

WALL: ID.NAME: Wall(ISO-150)

INSULATION LAYER.

Code	Product	Thick.
	Internal surface resistance.	
120	Spruce 15mm	15.0
191	Air gap	23.0
180	PE-foil	0.2
171	Mineral wool class39	150.0
263	Asp.imp.fiberboard 12mm	12.0
131	Wind-tight paper	1.0
190	Ventilated air gap	23.0
264	Weatherboard 19*123	19.0
	External surface resistance	

STUD LAYER

Code	Product	Thick.
	Internal surface resistance.	
120	Spruce 15mm	15.0
111	Lath 23x36	23.0
180	PE-foil	0.2
104	Timber frame_48x148	150.0
263	Asp.imp.fiberboard 12mm	12.0
131	Wind-tight paper	1.0
111	Lath 23x36	23.0
264	Weatherboard 19*123	19.0
	External surface resistance	

RECALCULATION PRODUCTCODES ?

Figure 1. SIN-BIP input data for a wall with product codes, name and thickness. Updating after change using the RECALCULATION button.

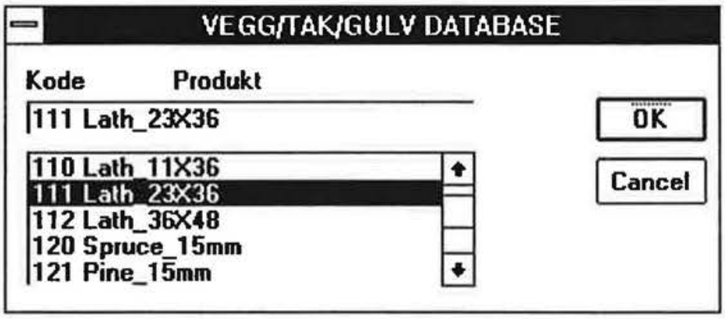

Figure 2. Window with list of products and codes.

After the update can we select other windows that will show calculation of U-value, temperature distribution, moisture distribution, cost, energy content and CO_2-emission. Figure 3 is an example of calculated cost, energy content and CO_2-emission for a wall construction. Figure 4 is a plot of the energy content for each layer in the wall. We can also get the yearly energy consumption, the total cost and the total energy content and CO_2-emission for the whole building. All tables and plots can be printed.

WALL:					
Layer	Thickness	Energy content		Unit price	CO2-Emission
From inside:	mm	kWh/m3	kWh	NOK	kg
Spruce 15mm	15.0	956	2470	23939	815
Air gap	23.0	0	0	0	0
PE-foil	0.2	21340	551	1894	171
Mineral wool class39	100.0	111	1629	6587	489
Asp.Imp.fiberboard 12mm	12.0	4300	8887	7922	2666
Wind-tight paper	1.0	2800	482	1206	130
Ventilated air gap	23.0	0	0	0	0
Weatherboard 19*123	19.0	760	2487	26694	821
	0.0	0	0	0	0
From stud wall:	146.0		3379	43451	1115
Total for wall			19886	111693	6207

Figure 3. Calculated energy content, cost and CO_2–emission from the wall in figure 1.

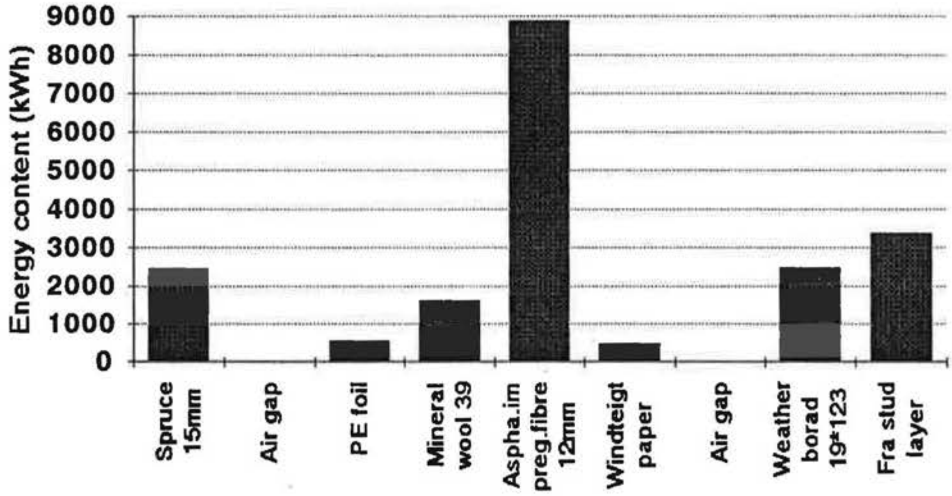

Figure 4. Plot from SIN–BIP of energy content for the wall in figure 3.

3. THE PRODUCT–DATABASE

The product database is the basis of all the calculations in the program. The product database contains information on thermal conductivity, moisture conductivity, density, unit price, energy content and CO_2–emission. The first three are physical parameters that are well known in calculation of heat and moisture transfer. These parameters can always be measured on a sample of the material.
The last three parameters are not physical parameters, so information must come from the producer. The unit price in NOK/m3 is a sum of materials cost, working cost and related cost

for placing the product in the final place in the building. The energy content is the amount of energy in kWh/m3 used for producing the material. The CO_2–emission is the emission in kg/kWh from the production of the material. The values for the two last parameters have been taken from (2) with the production processes from 1970 and the CO_2–emission from the production based on fossil fuel.
To get the real data for cost is very difficult, but they can be found in different cost calculation books. The real costs will always be influenced of time and place of the building and the building market. It is better to get some cost value and later make an easy recalculation with a more correct value.
Data for energy content and CO_2–emission from materials is not easy to get, and we must expect, that there is a large scatter in the values from different producers. This is caused by the difficulty in finding the values. The first problem is that most producers have more than one product. What is value for a single product? The second problem is that the result will depend of the type of fuel used. Example: Electricity can be made from coal fired power plant with CO_2–emission or water turbines without CO_2–emission.

Using the database and the program makes it easy to compare 2 types of constructions. An example is the outer part of a wooden stud wall.
Here can we use either 1) an asphalt impregnated wood fibre board or 2) wood fibre board and a 2 mm asphalt felt.
Construction 1 – an asphalt impregnated wood fibre board
Price 46 NOK
Energy content 51.6 kWh (12 mm of 4300 kWh/m3(energy content))
CO_2–emission 15.5 kg (0.3 kg CO_2/kWh times 51.6 kWh)

Construction 2 – an 12 mm wood fibre board (wfb) and a 2 mm asphalt felt (af)
Price 49 NOK (wfb 42 NOK plus af 7 NOK)
Energy content 25.3 kWh (wfb 12 mm of 1640 kWh/m3 plus af 2 mm of 2800 kWh/m3)
CO_2–emission 8.0 kg (wfb 0.33 kg/kWh times 19.7 kWh plus af 0.27 kg/kWh times 5.6 kWh)

A selection based on price will make number 1 the best, but based on CO_2–emission will number 2 be best. The price difference is so small that a CO_2–based tax or a more environmental conscious builder will take construction 2. We have found in other examples, that it can cost very much to reduce the CO_2–emission because we must change the construction type. The layers have different functions as air tightness, thermal insulation, moisture resistance or is needed for the stability of the wall. So changing to a material with a lower CO_2–emission can give problems with some of the functions. All the function has to be remembered when we change a material in our construction to get an energy efficient solution.

4. ECONOMIC INSULATION THICKNESS

The program has been use on a typical Norwegian single family house of 120 m2 placed in Narvik. The roof is insulated with mineral wool. The building code demands 200 mm thickness. We have changed the insulation thickness in the roof from 50 mm to 700 mm to find the economic insulation thickness based on the present value of the construction costs and running energy costs. The result is that the highest present value is found for 300 mm, if the life time is 50 years. These results can not be used in other countries as the price of energy, climate and the building cost will be different.

Figure 5 presents the result based on simple pay back time for the investment. The vertical axis is the cost in NOK or pay back time in years. The horizontal axis is the insulation thickness in mm. An example: We want information of an insulation thickness of 300 mm. We find 300 mm on the horizontal axis and move up until we come the first curve. This is the energy savings in NOK/year. On the left vertical axis we get the value 2000 NOK/year. If we use the second curve, we will get the extra investment for the 300 mm insulation. On the left vertical axis we get the value 14000 NOK. If we use third curve, we can get the simple pay back time. On the right vertical axis we get 7 years. It is easy to get values for other insulation thicknesses.
The result is that the simple pay back time is short for thermal insulation in roofs. This is all well known.

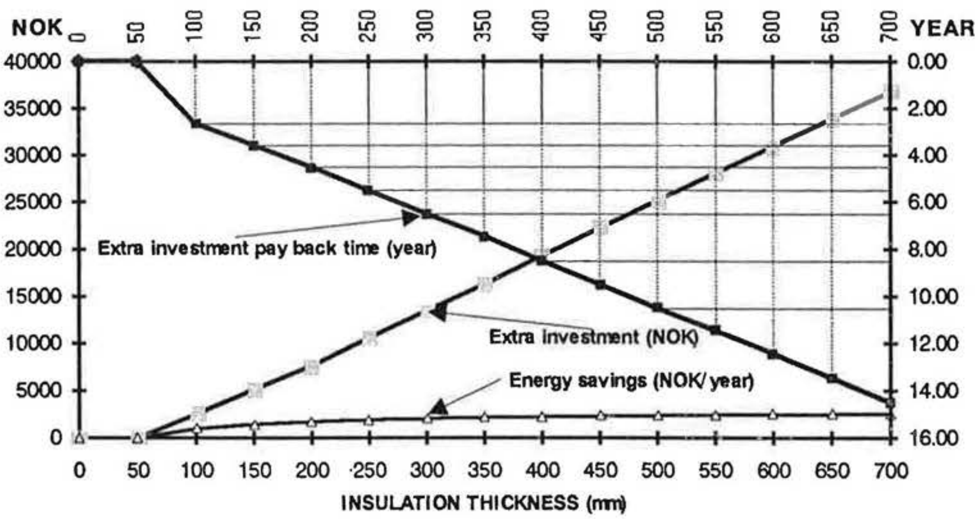

Figure 5 Energy savings in NOK, extra investment and simple pay back time as function of insulation thickness.

5. ENERGY ECONOMIC INSULATION THICKNESS

The program can calculate another type of economic insulation type, that is not so well known – the energy economic insulation thickness. Instead of being interested in the cost we are interested in the energy use during the life time of the building. In the same example as above we found an optimal value of the energy economic insulation thickness of above 700 mm. This is well above the economic insulation thickness, so we will have no risk in using more energy for producing the insulation material that we save in the life time of the building.
Figure 6 presents the simple energy pay back time. The horizontal axis is the insulation thickness in mm. The vertical axis is the energy in kWh of the pay back time. The use of the figure is the same as described for figure 5. The result is that for 300 mm insulation is savings in energy per year higher than the energy used to produce the mineral wool. The pay back time is 0.8 year.
A building based on total energy used for the materials and for the heating and ventilation in the life time would have very high insulation thicknesses. This would be very expensive as we can find in figure 5. This is a good example that an optimisation based on only one parameter can be impossible because of other practical aspects. We could also have use the program to find the house with the lowest CO_2–emission, but that would without doubt be very expensive.

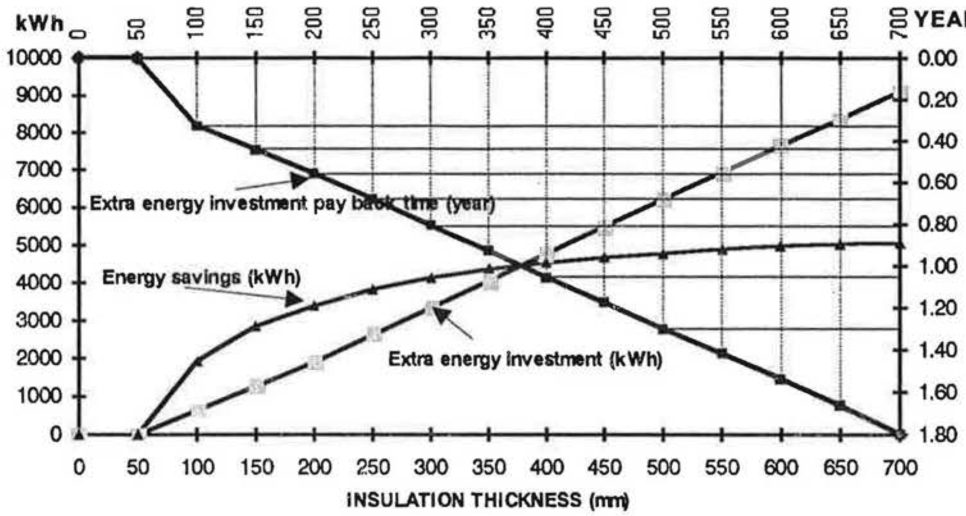

Figure 6. Energy savings in kWh, extra investment in energy and simple pay back time as function of insulation thickness.

6. CONCLUSION

To build an energy efficient building we must look at the total energy use during the life time of the building, but we must never forget practical aspects and the investment and running cost. The program SIN–BIP can be used for selecting materials and constructions in an energy efficient building based on either energy economy or environmental load as energy content and CO_2–emission. We expect later to include technical installations in the program, as we know that they have high costs and use much energy to produce. The program is easy to use, if we have the parameters for the materials. To get the physical parameters for the materials is in most cases easy. The difficult problem is to get the non physical parameters as cost, energy content and CO_2–emission. The results from the program will never be better that the supplied basic information. To build energy efficient buildings we must work together to find the information. For the non physical parameters we must make definitions of how to calculate them.

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