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Correlations of Heating Demand Energy for Buildings of Increasing Heated Floor Space.

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The aim of this paper was to research the effects of varying treated floor area (TFA) sizes on energy use of a given building. This was done by using excel based software. To reach the aim, five simple buildings with varying floorspace were designed, each with proportionately similar geometry, shape and components.

The result was a clear indication of decreasing space heating energy use over the span of the five buildings with the thermal envelope being the greatest contributor to the decrease in energy use.

The results would suggest that there is not a need to design the thermal envelope of buildings of smaller TFA’s the same way the thermal envelope of buildings with larger TFA’s are designed. There is also a lot of stress put on the U values (and their low values) when designing buildings. The results might beg the question, as designing programs advance, could U-value regulations be laxed and final energy use be pressured in the designing phase. This would mean that there could be savings on material consumption as there would not be a need for such intense thermal envelopes and then also energy savings in the summer as cooling demands would be lower.

Keywords	energy calculation, treated floor area, PHPP, thermal envelope.

Contents

1 Introduction

The purpose of this paper is to research the effect of rising heated floor space on the space heating demand of a residential building using excel based software. In following the regulations of the National Building Code of Finland’s section D3 (2012) Energy efficiency of buildings it is stated that the energy efficiency of building regulations and guidelines is based on the practical use of the building and whether it is a separate small house, office building, commercial building, commercial accommodation, large gym, hospital or other building [1].

In as much as researching the effects of higher floor space on space heating demand it is hoped to see a correlation between higher floor spaces and a lower space heating demand and also to achieve tangible values for this phenomenon. These values could then be valuable in the understanding of how buildings might be designed more conservatively which would hopefully result in the furthering of sustainable measures in construction and design. It is important to remember that due to the aims of the paper there is no specific effort to try to create or design a fully functioning building or residence.

This paper will first explain the methodology of this research starting with the guidelines used, then move onto the tools which were used to gain numerical values, and then explain the limitations or boundaries in which the work was undertaken. The next section of the paper will introduce the building components used for the design for the buildings with their own technical specifications used in space heating calculations. There will then be visual representations of the constructions, mainly to help understand the ventilation calculations. The paper will then be concluded with results and discussion.

2 Methodology

As this research was undertaken in Helsinki, Finland, the parameters for the situation of the building are based in Helsinki and the parameters for the design of building components and connected energy regulations are done following the Finnish National Building Code. As this project does not research an existent situation it is possible for these parameters and their results to be shifted into different environments anywhere in the world.

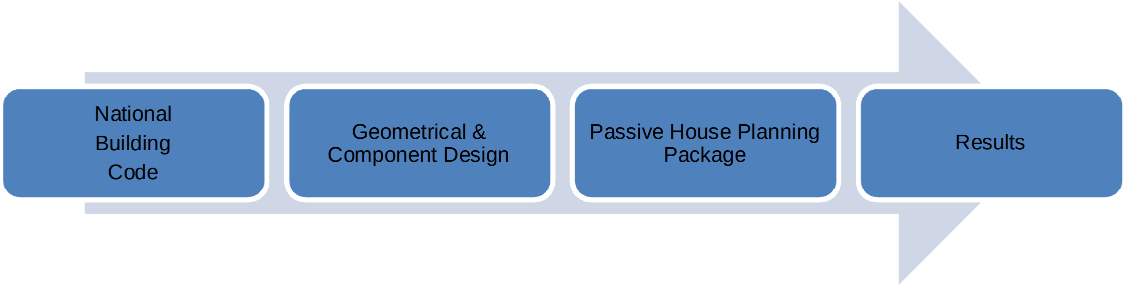


Figure 1 Flow of practical research and tools for paper.

The practical workings for this research will roughly follow the flow shown in figure 1. The design of the computational buildings is based off the Finnish national building code which creates the parameters of our geometrical & component design which are then added into the PHPP files to create results.

2.1 The National Building Code of Finland

The parameters of the energy calculations in this project follow the National Building Code of Finland’s section D3 (2012) Energy efficiency of buildings, regulations and guidelines [1]. By the time this paper is finished there will have been slight changes to the regulations on ventilation unit heat recovery and electrical efficiency (specific fan power). It is important to state that this paper has used the older levels of heat recovery and electrical efficiency. This does not in any way take away from or change the goal of the findings in this paper.

Table 1 below holds the information used for the building components and their U-values, it is found in section 2.5.4 of the D3. The U value of a given component is the rate of transfer of heat through a structure which can be a single material or a composite, divided by the difference in temperature across that structure. [2.]

Table 1. Thermal transmittance coefficients of building components, D3 [1].

Wall	0.17 W/(m²K)
log wall (the minimum thickness of the log structure 180 mm)	0.40 W/(m²K)
upper floor and base floor bordering on outside air	0.09 W/(m²K)
base floor bordering on crawl space (total area of ventilation openings not exceeding 8 thousandths of the base floor area)	0.17 W/(m²K)
building component against the ground	0.16 W/(m²K)
window, roof window, door	1.0 W/(m²K)

Table 1 below holds the information used for the building components and their U-values, it is found in section 2.5.4 of the D3. The U value of a given component is the rate of transfer of heat through a structure which can be a single material or a composite, divided by the difference in temperature across that structure [2].

The code on energy efficiency was not used in its entirety in the study. The largest parts of the code which were used were the sections 2.5 Thermal loss of the building and 2.6 2.6 Energy efficiency of the ventilation system and their subsequent sections 2.5.4, 2.5.11, 2.6.1 and 2.6.2.

2.2 Passive House Planning Package

To achieve accurate results for energy calculations, the Passive House Planning Package (PHPP) was used. The PHPP is an excel based ‘’workbook’’ which systematically goes through the various parameters needed for energy calculations [3]. Beginning with the location of the building, i.e. Helsinki, Finland, the excel file works systematically through stages of the design of a chosen building. The calculations start with the components of the thermal envelope, then work through the components of glazing, window frames and ventilation systems, then the shading (for this research not relevant). Finally, the limitations and parameters of the ventilation unit are set. Each section has its own sheet within the PHPP excel file.

For the purposes of this paper the PHPP file used is a simplified or smaller version to the full version of the PHPP, a mini PHPP. Thus, the sections of additional ventilation, summer ventilation, cooling, district heating, solar district heating, PV panels and electricity use are not included. These sections are not relevant for the research parameters of this paper as the aim is to see correlations within the space heating of certain structures.

2.3 Geometrical Make up

As the point of this project was to research the relationship between the sizes of buildings, or floor space, and the energy use of the buildings, the geometrical consistency of the structures across the changing sizes is important. As well as the geometry and/or shape of the building, the amount of window area must stay consistent from one building to another. The consistency of location, shape, size, window area and building components throughout the calculations will assure that the results hold true to the aim of this paper, which is to find out what correlations exist between floor space and space heating energy demand, and to gain tangible data of those numbers.

The methodologies of how each individual building component was used within the frame of the calculations will be explained in section three of this paper. In the next section 2.3.1, it is explained how the original building got its shape and positioning.

2.3.1 Building Sizes

Five separate building sizes were chosen at the beginning of the final year project. The sizes were not based on any real-life examples but were chosen to show five separate styles of residential buildings which naturally grow in size. These five styles are, from smallest floor area to largest, a detached single home at 100 m², a semi-detached home at 400 m², a row house at 1000 m², a loft apartment building at 2500 m² and finally an apartment building at 5000 m².

For the 2500 m² and the 5000 m² buildings there has been a causeway façade added to the north side of the building, again to keep consistency throughout the project’s buildings as changing the indoor areas (e.g. adding corridors) and parameters would create outliers in the data between the separate buildings.

For this research the building shape was kept very simple to make the reproduction of different buildings easier to follow while also keeping the results within a framework of minimal change. In doing this it will again assure that final results are accurate across the scope of the five buildings and removes any doubt of outliers being lost in the complicated shapes of other buildings.

The geometrical shape of the computational buildings is not based on any regulations, as there are none. However, all the buildings have in common that the Southern façade should make up a larger percentage of the buildings than the east and west facing façades to increase energy efficiency of space heating, as the sun rises in the east and sets in the west [4]. Thus, the shape of the building became a rectangle with the northern/southern façades at a percentage of 60% of the total perimeter and the Eastern/Western facades at 40% of the total perimeter, as can be seen in figure 2.

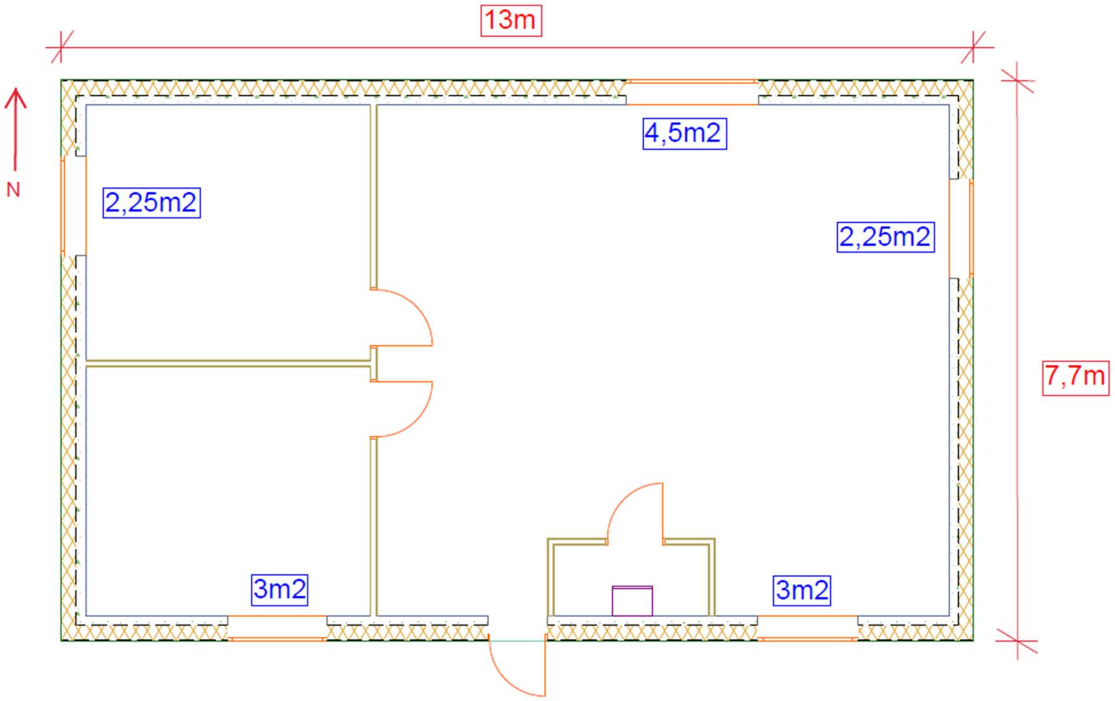


Figure 2. 100 m² layout showing perimeter lengths and window amounts.

The southern façade of the building faces true south, 180 degrees from north. This percentile breakdown of the various components and areas of each building is essential in finding clear correlations between floor space and space heating energy values.

3 Geometry of Building

As stated above, the geometry of the building is important for consistency. Simple math is used to ensure the consistency of the geometry of the buildings from the detached single home at 100 m², semi-detached home at 400 m², the row house at 1000 m², the loft apartment building at 2500 m² and finally to an apartment building at 5000 m².

As the perimeter of a 100 m² building as a square would be 40 meters (10mx10m) the next step in designing the perimeter is establishing the equivalent perimeter values for a building with Northern and Southern perimeter values at about 60% and Eastern and Western perimeter values at about 40%. The result becomes 12 meters for the N/S façades and 8 meters for the E/W façades.

Through trial and error, the lengths of the perimeter were set at 13 meters for the North-South façades and 7.7 meters for the East-West Facades of the 100 m² building. The values correspond closely to a need of 60% for the North-South façades and 40% East-West facades. As a percentage the facades work out to 62.8% for the North-South Façade and 27.2% for the East-West Façade.

With the multiplication of the numbers there is created a treated floor space of 100.1m². To this perimeter is then added the thermal envelope for outer wall calculations. It is important to note here that throughout the buildings, even though their individual titles are represented as whole numbers, they are not exact. The 100 m² building is actually 100.1 m², 400 m² building is 400.20 m², 1000 m² building is 1001 m², 2500 m² building is 2522.4 m² and the 5000 m² apartment is 5004.12 m². These differences in size will not create meaningful differences to the results at the end of this research as they are minuscule and a clear correlation will be seen if there is one.

To achieve succession between the varying floor sizes of the buildings, a simple mathematic equation was utilized. The following example is the equation used to find the multipliable values for the floor area of the building:

$$\sqrt{\frac{(400m2/2)}{100m2}} = 1.41(\text{co-efficient of buildings perimeters})$$

Here the dividing factor of two after the floor space (400 m²) represents the number of floors in the building.

Southern/Northern Facade $13\ meters * 1.41 = 18.33\ meters$

Eastern/Western Facade $7.7\ meters * 1.41 = 10.86\ meters$

In the above example the perimeter measurements for the 400 m² building are established. After the co-efficient for each individual building has been calculated it is then used to multiply the original perimeter measurements of the 100 m² building. In this sense the design of all buildings is based off of the 100 m² buildings geometry and this then keeps the buildings consistent between each other as the floor space grows.

Table 2. Co-efficient of individual building sizes.

	100 m²	400 m²	1000 m²	2500 m²	5000 m²
Floors	1	2	2	3	4
Apartments	1	2	5	12	32
Co-Efficient	1	1,41	2,24	2,89	3,54
*13 meters	13m	18.33m	29.07m	37.53m	45.96m
*7.7 meters	7.7m	10.86m	1722m	22.23m	27.22m

For each building, using the same equation, the results of the perimeter length in relationship to the number of floors is shown in table 2. These results were used in the design of the geometry of the calculated buildings

3.1 Geometrical relationship to Windows

Second to the geometrical consistency between the buildings in importance is the consistency of the window areas between each separately sized building. These areas can and should be thought of as a percentage of the building's floor area according to the D3 building regulations, in this section we will look at the percentage of window per building and the percentage of window space per façade.

The section 2.5.4 of the D3 defines:

> The reference value of the total window area in the building is 15% of the floor area of the floors that are wholly or partly on the ground, but may not exceed 50% of the total area of outside walls. The window area is calculated in accordance with the external frame dimensions. [1]

Table 3. Total window areas for each building.

100 m²	15m² of Window space
400 m²	60m² of Window space
1000 m²	150m² of Window space
2500 m²	375m² of Window space
5000 m²	750m² of Window space

Using this section of the building code the window areas for each separate building can be established based on their floor space. As shown above in section 2.5.4, this section of the code leaves some room for change as to how many square meters of window is desired [1]. For this paper we used the lowest percentage of 15% of the total floor space for each building.

3.2 Design of Buildings

Creating aesthetic and functional designs was not the aim of this research and so as each design is taken into consideration, it is critical to remember that within the PHPP calculations this paper is only looking at relationships between larger heated floor spaces and energy use. The buildings are not such that living in them would be functionally or aesthetically pleasurable, but this is another section of design which this paper is not going to delve into.

3.2.1 100 m²

The 100 m² structure got its shape first. Therefore, it could be said that all other buildings gained their final shape/build based on the structure of this building.

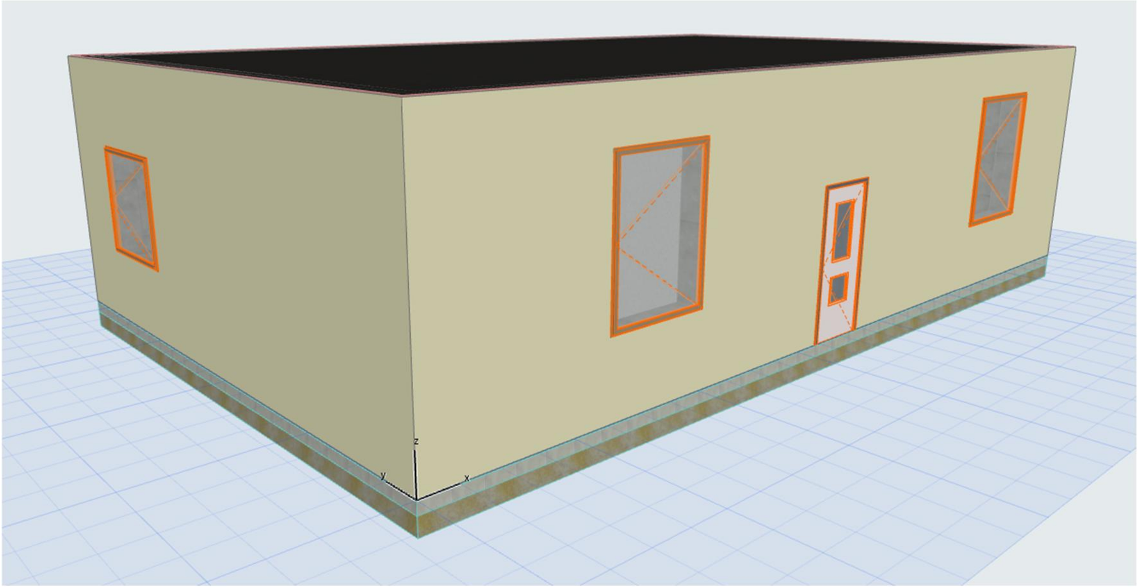


Figure 3. 100m² single family house.

A three-dimensional view of 100 m² building is shown in figure 3. This view is showing the southern wall of the building.

3.2.2 400 m²

Figure 4. 400m² semi-detached dwelling

The 400 m² is a semi-detached dwelling, and it is the first of the structures which was created having two floors. It is neatly divided down the middle and both dwellings are identical. A three-dimensional view of 400 m² buildings front shown in figure 4.

3.2.3 1000 m²

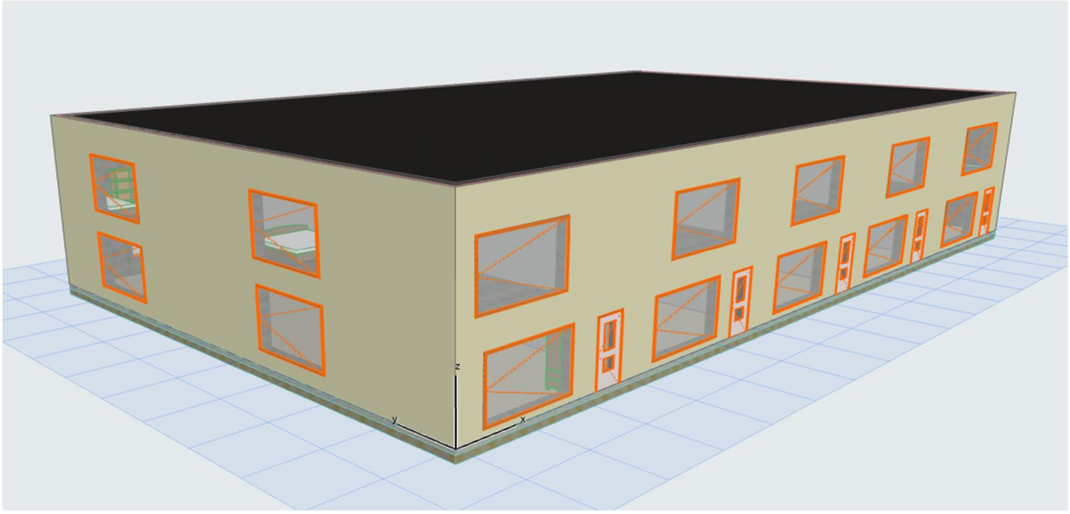


Figure 5. 1000m² row house design.

The 1000 m² row house construction is based on a typical row house design with each of the five-dwellings consisting of two floors. A dimensional view of 1000 m² building is shown in figure 5.

3.2.4 2500 m²

The 2500 m² apartment building is made up of 12 apartments, two of which on the top floor are lofts. On the outside of this design an outdoor causeway was added. It is non-heated but serves as an entry point to all apartments so that there is not a need to have corridor or basement areas which would be treated as semi-heated areas. This helped keep consistency between the treated floor area of the designed buildings.

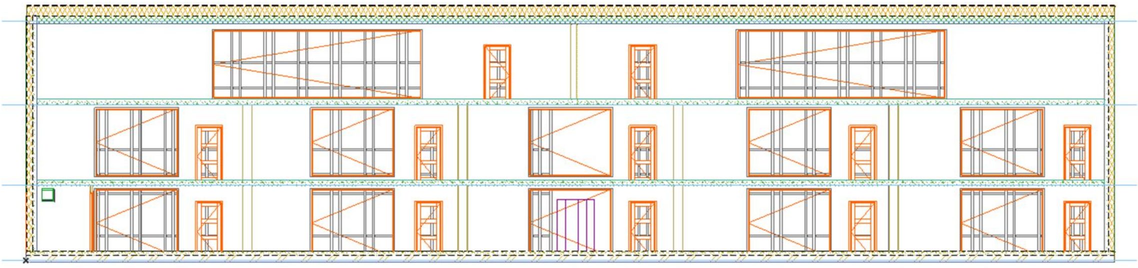


Figure 6. A West to East section of the 2500m² building.

In figure 6 we can see the location and layout of the living spaces from an east-west Section of 2500 m² building.

3.2.5 5000m²

The design for the 5000 m² apartment building consists of 32 apartments. The shape of the apartments or their functionality is not important for this research, as the effects of space heating are being researched.

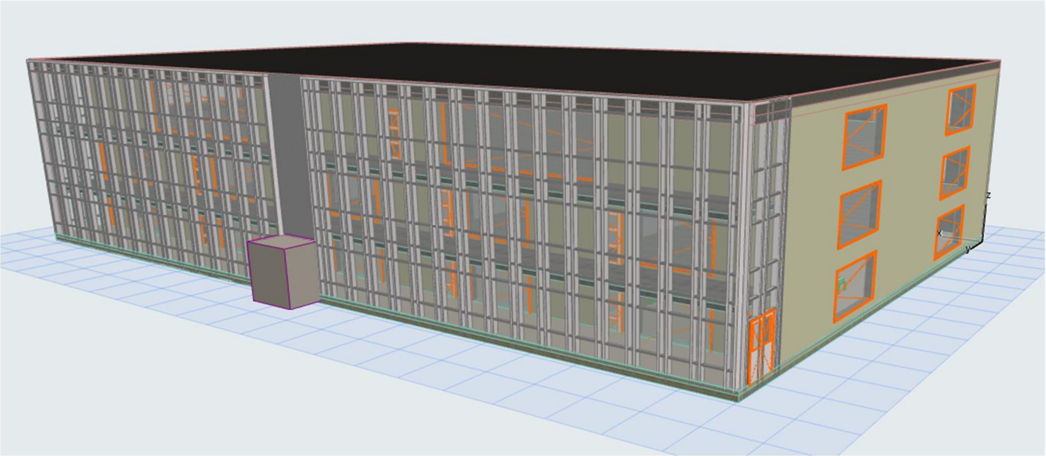


Figure 7. The 5000m² apartment building.

In figure 7 there is shown a three-dimensional view of 5000m² apartment (causeway and lift).

4 Building Components of Thermal Envelope.

The building components create the thermal envelope of the structure. The thermal envelope is one of the most crucial elements for energy savings in residential buildings [5]. The thermal envelope is made up of the walls, ground floor, roof, windows and doors. In the PHPP files for this project, internal walls and floors of multi-story buildings are not added in the calculations as they are irrelevant and made redundant for the needs of this research.

It is also important to note that the elements chosen would be able to be utilised in structures of varying sizes (100 m² to 5000 m²). This then fulfils the aims of consistency which is needed to achieve an accurate result between the separate buildings.

4.1 Thermal Bridge

As it is understood within the Finnish Building Code section C4 the thermal bridges of a given structure are calculated from the inside of the structure. Conversely, the Passive House Planning Package excel file measures the thermal bridge's energy losses from the outside of the buildings envelope. The difference between the point in which thermal bridges are calculated makes the calculation of thermal bridges within the scope of the C4 redundant as the outer measurements of the PHPP file are more extreme than the inner measurements of the C4. [6.]

However, on section 18.2.8 of the PHPP workbook it is explained that because PHPP requires the outer measurements of the thermal envelope the geometrical thermal bridges are already accounted for in the calculated transmission losses of the elements themselves [11, p.118]. This then gives the opportunity to assume that the constructions are built in a way that thermal bridges are non-existent, and thus achieve a thermal bridge free structure.

4.2 Wall Element

By following the National Building Code of Finland, it is found that for residential buildings, the required U-Value for walls of a residential building is 0.17 W/m²K. In the PHPP file the designed U-value for this construction's wall is 0.174 W/m²K. When rounded down, is equal to the required U-value in the D3. [1.]

Case: D3 Wall

The wall construction is based on a product description of Paroc, a Finnish producer of mineral wool insulation.

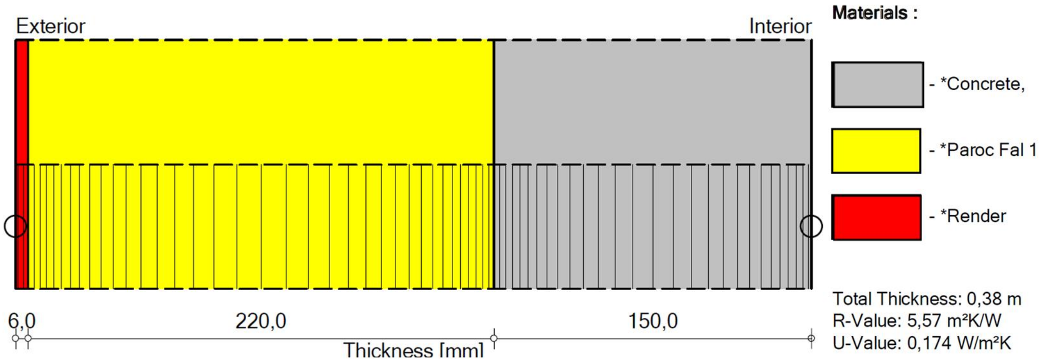


Figure 8. Wall construction in accordance with the D3 building regulations.

The given solution for the façade structure is based on a lamella construction (figure 8) and was chosen because it can be applied to all the different sized buildings from a single-family house to an apartment building [7].

4.3 Roof Element

The roof element in the PHPP file fulfils the National Building Code’s U-value parameters with a value of 0.09 W/m²K. The design for the roof is based on a model from the Paroc website under than name Ontelolaatta which translates from Finnish to English as hollow core slab [8].

Case: D3 Roof

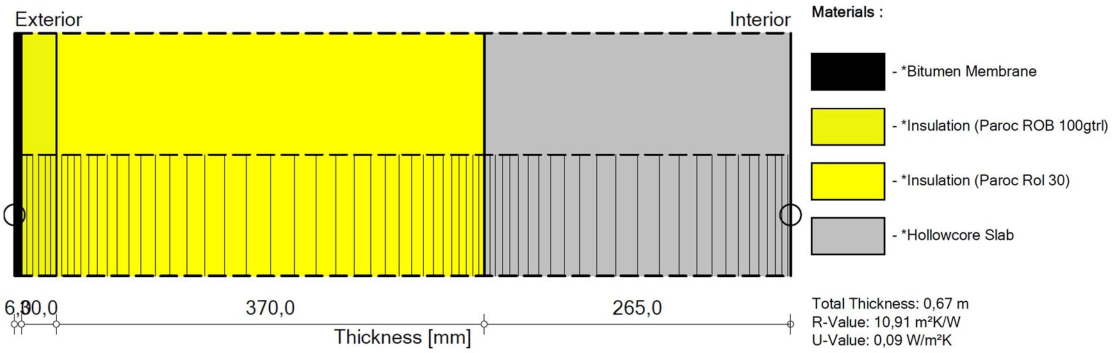


Figure 9. Roof structure fulfilling the D3 regulations.

The roof design uses a§ 265mm thick hollow core slab for the structural section, a water vapour barrier not shown in figure 9. The insulation layer consists of lamella mineral wool at a thickness of 370mm and wind protection hard mineral wool of 30mm on top of the lamella insulation. The structure is finished with waterproofing bitumen membrane.

This roof structure is a construction type that could be easily found in the region of Helsinki, Finland, as is input into the PHPP file’s section on location. The roof style is a flat roof construction in all the constructions.

4.4 Ground Element

The ground element for the buildings is not based on any existing construction and was made up purely for calculation purposes for this project. However, it is within the bounds of a real-life situation.

Case D3: Floor

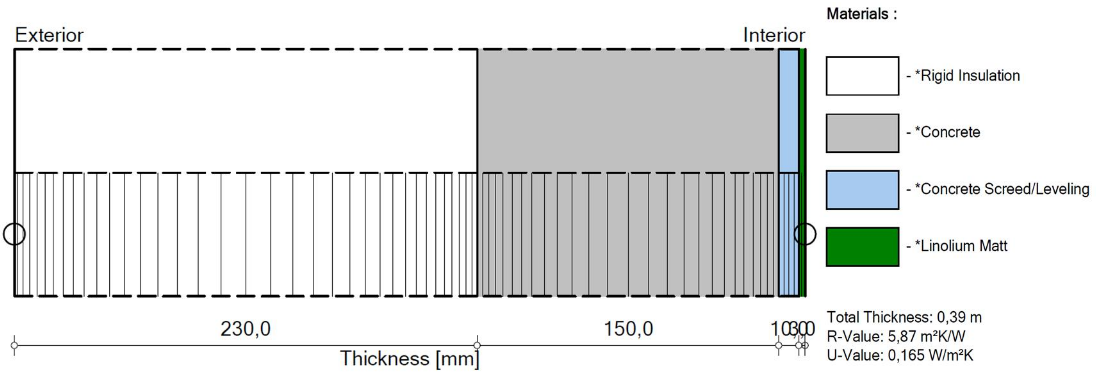


Figure 10. Ground floor structure.

In accordance to the U-value represented in the National Building Code, the U-value for a building component against the ground is 0.16 W/m²K [1]. The component in figure 10 was chosen to be against the ground to create simplicity and consistency between the buildings for the energy calculations of each building. The U-values for the floor in the PHPP file ended up being 0.161 W/m²K which meets the D3’s regulations.

Within the PHPP files there is a section devoted to heating losses through the ground, the “ground” tab. It is important to mention that in conjunction with this floor structure there is also insulation added to the whole perimeter of the building which comes 1.2 meters from the buildings edge and is 100mm thick with a U-Value of 0.34 W/m²K.

The perimeter insulation is based on the help file, RT 81-10590RT [9, p. 5] section P/RS 204. Here it is advised that from anywhere between 60mm to 150mm of insulation should be used around the perimeter of the building [9]. These papers are guides for design and are based upon the National Building Codes Thermal Insulation Guidelines 2003.

4.5 Windows

Following the National Building Code, the windows had to meet the regulation of a U-value of 1.0 W/m²K for the inputs into the PHPP file [1]. A window by "KUHMON ikkuna" was chosen as the window for all the buildings, the MSEAL 170 ENERGY [Appendix 1].

In the PHPP file the parameters which affect the energy calculations are split into two sections, Glazing and Window Frames. For this paper it is not important to have precise details of the windows which will be used as there is not a real case of energy use being calculated. In the PHPP file the glazing section holds the valuable information which coincides with KUHMON Ikkuna's window, this is the U-value of the window. The MSEAL 170 Energy's U value is .99 W/(m²K), a g value of 0.4 was assumed for this section.

The second section of the window component in the PHPP is the frames. In this section, the values needed are the U value for the frames, frame width, glazing edge thermal bridge heat loss co-efficient, and the installation thermal bridge heat loss co-efficient. The information given by KUHMON ikkuna does not reveal the U-value of the window frames, so a U-value of .99 was assumed for the frame. The frame width was entered as 156mm which coincides with the detail pictures of the MSEAL 170 ENERGY. The "Glazing Edge Thermal Bridge" heat loss co-efficient is .040 W/mK. and is assumed as such according to other windows in the PHPP data base. Finally, the "Installation thermal bridge" heat loss co-efficient has an input of .04 W/mK, according to section 13.3 Window Frames of the PHPP planning package (instructional booklet) the Installation Thermal Bridge can be assumed as .04 W/mK for input certified windows [11].

4.6 Ventilation

As the PHPP is a file made for the calculation of energy use in passive buildings, there were some parts of the files which had to be changed in order to fit the needs of a building that is being built in accordance to the D3, Energy Efficiency of Buildings. The only ventilation units found within the PHPP files have a much too high heat recovery efficiency. Fortunately for the parameters of this paper there was no need to find an existing unit to emulate, and this allows the creation of a ventilation unit which fulfilled the minimum requirements for section 2.5.11 and 2.6.1.1 of the D3 Energy Efficiency [1].

4.6.1 Efficiency of Ventilation Units

Sections 2.5.11 and 2.6.1.1 of the building code detail, the minimum efficiency requirements of the heat recovery, in percentages, and the minimum efficiency requirements of the electrical power of the ventilation unit, respectively in kW/m3s [1]. The unit kW/m3s is converted to Wh/m3 to fulfil the required unit for use in the PHPP file.

The minimum efficiency ratio of the heat recovery of the ventilation unit has to have a minimum of 45%. This is the value which must be used for the ventilation unit of the PHPP file. This could be seen as a low value for heat recovery, but for the goal of this project it is not crucial.

The minimum specific fan power, as referred to in the D3 National Building Code, is 2.0 kW/(m3/s). This value must be converted to Wh/m3 so that it is compatible with PHPP [1].

((2.0 kW(m3/s) / (3600 seconds)) * 1000 watts = .55 Wh/m3.

It is important to note that the value is for a mechanical supply and extract air system, which is what is used in the PHPP file, as opposed to an extract ventilation system which is not used in this research. The supply and extraction flows are 100% balanced.

4.6.2 Air Tightness

In the Ventilation section of the PHPP files, there is a section on the infiltration air rate. This simply means that values are added into the PHPP files to represent the amount of air which leaks from the thermal envelope. This is an important measurement and building regulation in new buildings as it affects directly on the space heating energy usage.

There are three important numbers to understand the ventilation section of the PHPP file, the n50 which is the airtightness as flow rate of infiltration, divided by m3 or building volume when the pressure difference is 50 Pa. The next important figure is the 1/h, infiltration air change rate which cannot been used without the n50 value. 1/h represents, the amount of times the air inside the building is changed over in an hour.

Finally, the value q50 (m3/h m^2) represents another indicator of air loss in the PHPP file. It is the amount of metre cubed air (m3) divided by the total m^2 of the thermal envelope in an hour. The section 2.5.7 of the D3 Energy efficiency of buildings National Building Code states that 2.0 (m3/h m^2) is used in the calculation of the reference thermal loss of the building which is what is needed for the calculations [1, p. 14].

As a theoretical and abstract buildings ventilation is being calculated, the n50 for the pressure test is set so that the air permeability (q50) of the buildings is at a constant 2.0 m3/(h m^2).

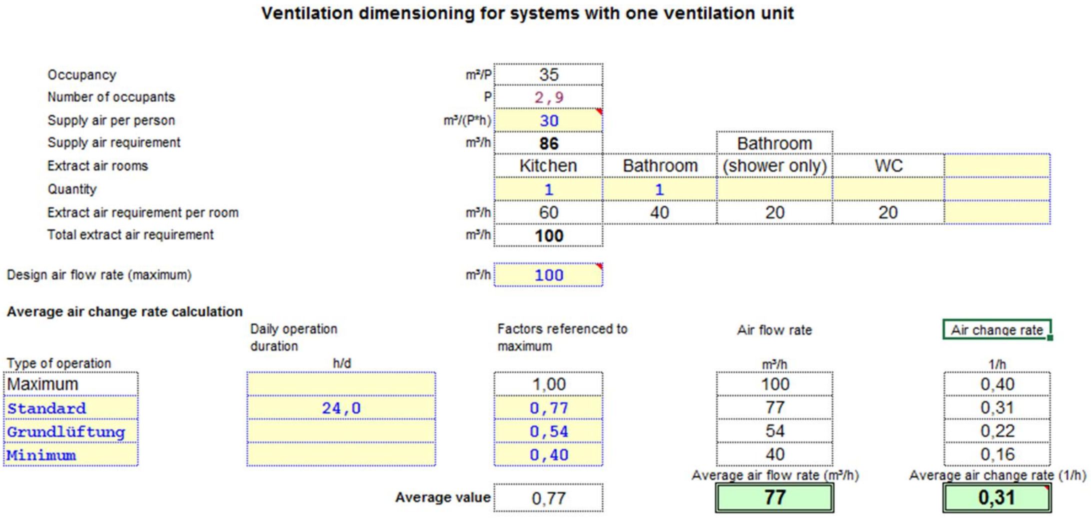
Section 2.3.1 of the C3 National Building code states that the air tightness of the building should be so that the ventilation systems “works as it is designed to”, this is the regulation. It is also stated, as a guideline, that it would be good for the air change rate of the thermal envelope to be as close to 1 exchange per hour (1/h) as possible. Here the regulation of the n50 and then the guideline of the n50 is found. [10, p. 4.]

4.6.3 Air Flow Rates

Another important part of ventilation calculations is the air flows. The air flows for a given building consist of supply and extract air, in the buildings there is a balanced ventilation system which means the supply of air is equal to the extraction of air. Adequate airflows for buildings are created for comfort and health reasons.

Within the PHPP there is a system of calculating air flow values for a given building. The PHPP file does not calculate supply air volumes based on the amount of apartments or residents. There is a fixed calculation which is based solely on the Treated Floor Area (TFA). So, after the TFA is known, the PHPP automatically calculates the needed amount of air based on a fixed factor of 35m² per person. In the PHPP file there is a fixed air supply rate of 30m3/h per person. This amount, 30m3/h per person, is based on DIN standards (Deutsches Institut für Normung or the German Institute for Standardization) and is applicable for this research as it fulfils the Finnish standard of 6(dm3/s)/person.

Another crucial factor for air flow rates is the extraction. The extraction of a ventilation system is essential for the health of building occupants and the buildings structures. Again, this research works within the confines of the PHPP Excel file, which is provides a section in which it is required to add the total amounts of kitchens, bathrooms, bathrooms with only a shower and finally toilets within the building. These amounts are then multiplied by fixed PHPP file extraction rates, 60m3/h for kitchens, 40m3/h for bathrooms and 20m3/h for toilets. The amounts of kitchens, bathroom and toilets have been kept quite consistent as to keep consistency between buildings [11, p. 106].



Ventilation dimensioning for systems with one ventilation unit

Occupancy	m^3/P	35				
Number of occupants	P	2,9				
Supply air per person	m^3/(P*h)	30				
Supply air requirement	m^3/h	**86**				
Extract air rooms		Kitchen	Bathroom	Bathroom (shower only)	WC	
Quantity		1	1			
Extract air requirement per room	m^3/h	60	40	20	20	
Total extract air requirement	m^3/h	**100**				
Design air flow rate (maximum)	m^3/h	100				

Average air change rate calculation

Type of operation	Daily operation duration h/d	Factors referenced to maximum	Air flow rate m^3/h	Air change rate 1/h
Maximum		1,00	100	0,40
Standard	24,0	0,77	77	0,31
Grundlüftung		0,54	54	0,22
Minimum		0,40	40	0,16
	Average value	0,77	Average air flow rate (m^3/h) **77**	Average air change rate (1/h) **0,31**

Figure 11. A screenshot from the PHPP excel file of ventilation dimensioning [11, p. 106].

Once the supply and extraction flow rates are calculated based on the factors previously noted, the average flow rate for a given building can then calculated. The average flow is actually equal to the total extraction air requirement multiplied by a standard operation reference of .77. This refers to the fact that the ventilation is not working on maximum level for 24 hours a day. Figure 11. shows the standard inputs for balanced ventilation based on 100m² building taken from the PHPP file.

4.6.4 Ducts

The PHPP file section for Ventilation, piping dimensions must be filled out to achieve accurate space heating energy results. The section on piping covers the length of exterior air ducts, length of exhaust air ducts, diameter of pipes (nominal), insulation thickness, reflectivity (yes-no) and finally thermal conductivity of the insulation.

Both the supply and extract air pipes were set at 160mm diameter and given 60mm thick insulation. The thermal conductivity of the insulation is based on values given in the PHPP planning package booklet [11; p, 46] and was input as 0.04 W/(mK).

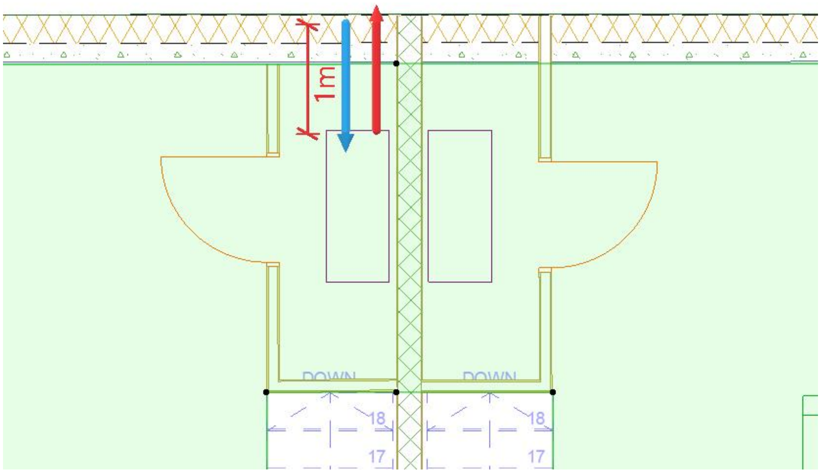


Figure 12. Piping lengths for individual apartments

The lengths of the ventilation ducts were entered as a cumulative amount for each building, as each apartment had its own ventilation unit and ducts. For example, in the 100 m² building there is a supply ventilation pipe length of 1 meter and an exhaust ventilation pipe of the length of 1 m as shown in figure 12. From here the piping length for supply and exhaust is simply multiplied by the number of apartments in each individual building as shown in table 4.

Table 4. Calculated length of ducts for individual computational buildings.

Building	Num. of Apartments	Supply Pipe	Exhaust Pipe
100 m²	1	1 meter	1 meter
400 m²	2	2 meters	2 meters
1000 m²	5	5 meters	5 meters
2500 m²	12	12 meters	12 meters
5000 m²	32	32 meters	32 meters

This method of dimensioning was chosen due to the layout of the PHPP mini file which does not allow for the design of complicated ventilation systems, and because of the constraints of this research which is not venturing into the energy use of any given technical system of a building. This would be work for further research. Thus, the significant differences in piping length do not affect heavily on the heating demand or the heating load bur are needed to gain outputs for the Heating Demand and Heating load of the designed buildings.

5 Results

After having filled out all five Passive House Planning Package Excel files for each individual building, the appropriate results were collected and put into an individual Excel file to create visual representations of the data. the data has been represented in two graphs, the first graph represents each computational building's individual component's heat gains and losses. The second graph shows the heating demand and heating load of each designed building.

5.1 Gains and Losses

The heat gains and losses are represented visually in figure 13 with a graph. The numerical values for the gains and losses on the y axis are divided among the five computational buildings on the x-axis. The gains represented are internal heat gains and solar gains and the losses are represented as ventilation losses, external wall ambient losses, window losses, floor slab losses and finally roof losses.

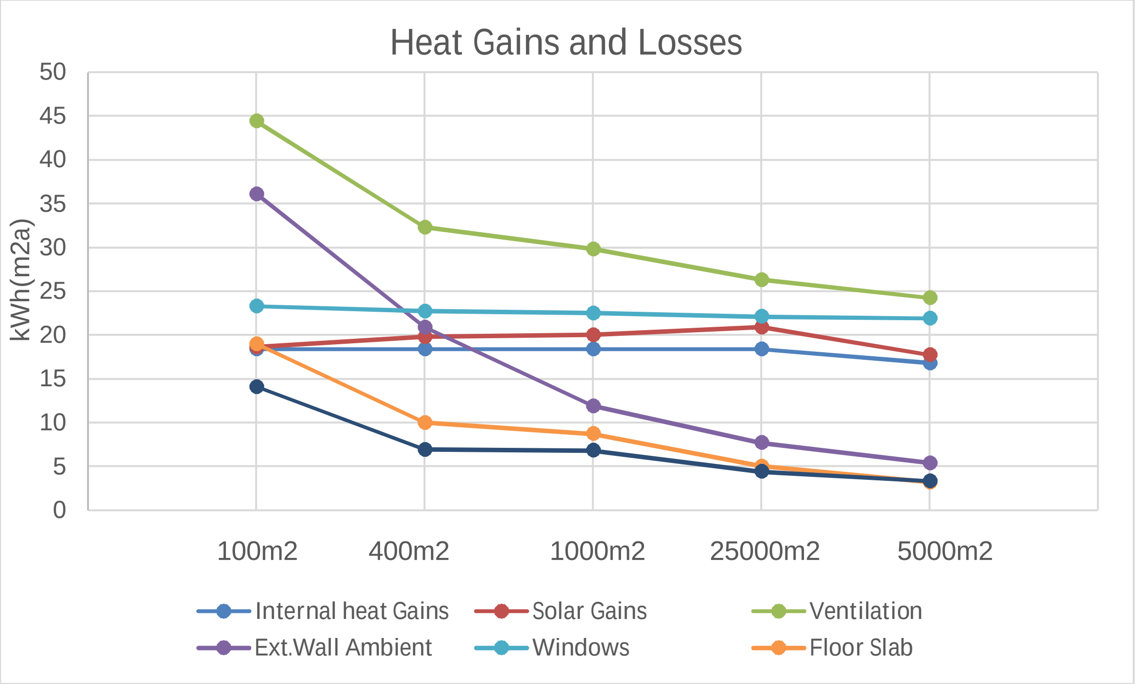


Figure 13. Heating gains and losses of buildings different components

Energy gains means the amount of heat energy a particular building receives without any specific energy input. A good example of this is the heating energy gains received from the sun, electrical appliances and people. Within the PHPP internal gains and solar gains are calculated separately.

In this research the internal heat gains consist of heat which is created by people and electrical appliances. The heat generated by electrical appliance, however, is very low and may only include heat gains from the ventilation system as the PHPP mini file does not include spreadsheets (excel) for the electrical design of the building.

Solar gains are measured after the location of our structure (Helsinki, Finland) has been chosen and then using global radiation data in conjunction with window size and their orientation to the sun (north, south, east or west).

Losses of energy within the construction are more varied than gains. The ventilation losses are mostly due to the piping of the ventilation system and the distance the air travels in the ducts. Since there is a heat recovery system in place the losses are within the unit too. The heat losses through the thermal envelope (windows, walls, roof and slab) are easily understood as heat energy lost through the envelope of a construction and are due to colder conditions outside of a building.

5.2 Space Heating Values

The main point of this paper was to find correlations, if any, between rising floor space and energy use. The following graph figure 14 shows the final outcomes from each PHPP file for each individual building.

There are two values, heating demand and heating load. The heating demand could be understood as the demand of energy a building needs annually to heat its space, the heating load is then the energy needed in a space to keep it at a comfortable temperature.

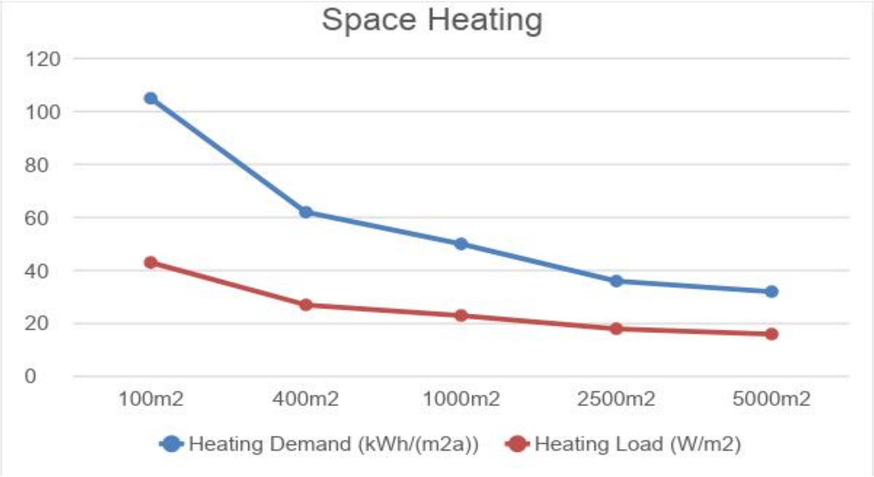


Figure 14. Difference in heating demand and load across span of buildings.

The results would suggest that when the floor space is increased there are naturally created savings in heating energy. Furthermore, a larger building can hold onto or use its internal energy gains to a higher efficiency than a smaller building.

6 Discussion

From the results it can be see that there is a clear correlation between floor sizing in houses and heating energy demand. However, the aim of this research was to establish what the numbers would look like. After now getting the results for the research, it is important to discuss how these results could be used.

The findings in this research might be used to help create a more conservative design for buildings. In figure 13 it is shown that the thermal envelope holds the largest savings of energy as the size of the computational buildings grow, this should be focussed on foremost. If the design of the thermal envelope could be based on treated floor area amounts, it might be realised that such massive thermal envelope structures are not needed. For example, for the building of 5000 m², the heating energy demand is reaching low levels, 32 kWh/ (m²a). With that information it could be reasoned that the same thermal envelope designed for a 400 m² building would be too “heavy” for a 5000 m² building create problems of overheating in the summer months. Could it be that some larger scale buildings use unnecessary resources, time and money creating unnecessary thick façade structures?

It has been discussed earlier in this paper in section 4 that the Finnish Buildings Regulations for energy demand and its minimal U-values for a building’s walls, windows, doors etc. are required to meet a certain level. Why is this? Maybe the total treated floor area and geometry of a building could be established first and upon this adapt the thermal envelope structure to achieve mandated energy demands.

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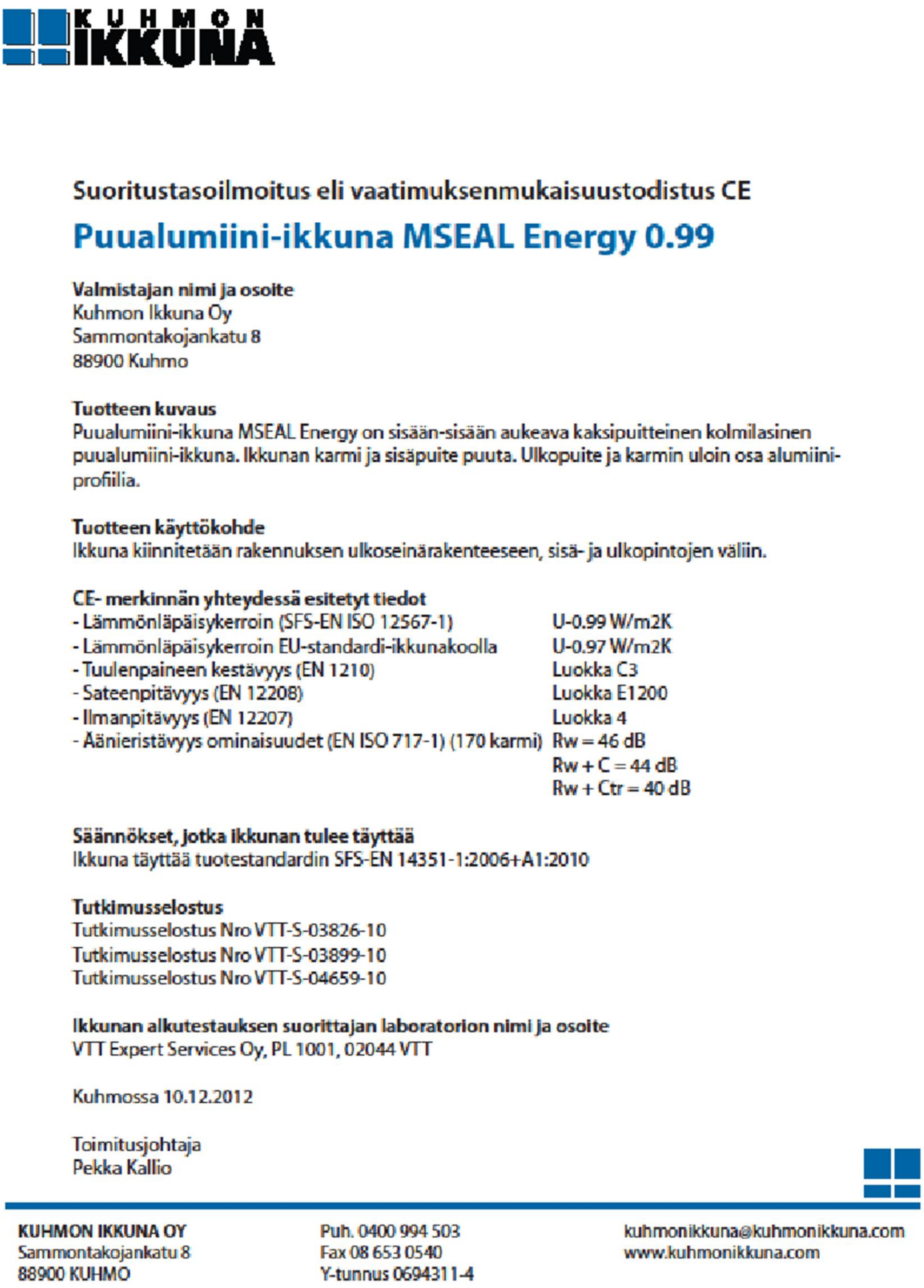

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- Lämmönläpäisykerroin EU-standardi-ikkunakoolla	U-0.97 W/m2K
- Tuulenpaineen kestävyys (EN 1210)	Luokka C3
- Sateenpitävyys (EN 12208)	Luokka E1200
- Ilmanpitävyys (EN 12207)	Luokka 4
- Äänieristävyys ominaisuudet (EN ISO 717-1) (170 karmi)	Rw = 46 dB Rw + C = 44 dB Rw + Ctr = 40 dB

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