ABODO Cabin Initial High-Performance Design

Date: 28 May 2020

Purpose

We have prepared an initial design review for ABODO Cabin, analysing the building's performance as currently specified/built and options that could have been used to increase thermal performance up to Low Energy Building and Passive House standards. This report is intended to show *what* needs to be done for this specific design and site to meet various performance goals.

Summary

The building is very small and well oriented with heavily shaded glazing. The design has quite a high form factor of 3.9 (form factor is surface area divided by the useful floor area) - primarily due to the size as it is a simple form. Typically a design with a form factor higher than 3 indicates a challenging design from a heat loss perspective. This kind of design will require significantly higher insulation levels than are typical in New Zealand to meet Passive House standards and possibly new approaches to construction to accommodate these. The spec design performs significantly better than code in terms of heating requirements (approximately one third the heating load), but there are opportunities to optimise the performance.

We have modelled design variants of four different solutions with increasing levels of performance. To reach Passive House standards this building would require the following:

- Double the size of the building to reduce the form factor,
- a high efficiency Mechanical Ventilation Heat Recovery unit (MVHR),
- Triple glazing with high performance frames,
- The ability to remove the window shades in winter on the north side
- 300mm PIR Insulation and 190mm of batts under the floor.

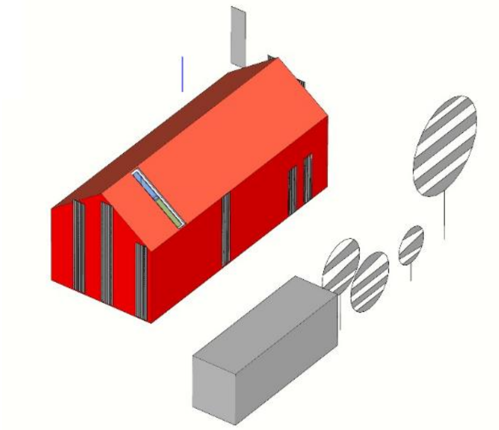


Figure 1: North East view of the House on site.

Variations Explored

- **Variant 3** is a combination of simple upgrades to the spec design. These are what we would recommend are incorporated for any future iterations on this design. These upgrades will reduce the building's heating demand down from 98 to 43 kWh/m2/a. This Is nearly Low Energy Building Certification level.
    - High performance triple glazing with the same timber frames
    - A more efficient MVHR unit (Zehender Comfoair 350)
    - 120mm PIR insulation to walls and roof
    - An additional layer of batts under the floor joists and two layers of batts between the joists.
    - The ability to remove the window shades (rainscreen battens) in winter
    - Airtightness testing to meet 0.6 ACHn50.
- **Variant 4** looks at the impact of having a larger building as might be needed for a family home, we doubled the floor area. This reduces the heating demand slightly more to 37 kWh/m2/a but of course increases the total heating requirements.
- **Variant 5** gets the building to Low Energy Building standards at it's current size. This requires:
    - 200mm PIR insulation
    - 340mm of batts in the sub floor
    - plus the upgrades in variant 3
- **Variant 6** is described in the summary and takes the building all the way to Passive House standards. This would require re-considering the building envelope design to fit the amount of insulation required (3x the spec thickness) as well as doubling the size of the building.

Heat pump sizing table:

Variant	Name	Heating Load W/m²	Cooling Load W/m²	Frequency of overheating (> 25 °C)	HP Heating Capacity kW	HP Cooling capacity kW
1	NZ Code	97.7	2.5	3%	17	0
2	Spec	37.0	2.6	0%	7	0
3	Common high perf spec	19.1	4.4	1%	3	1
4	Double scale building	15.6	0.0	0%	3	0
5	LEB & movable exterior shading on north	14.9	4.7	1%	3	1
6	PH scale double size & movable exterior shading on north	8.8	0.0	3%	2	0

Variants

For the initial review process, we have modelled the building thermal envelope (the external shell) along with the site shading provided (see Figure 1). We then model several variants (using Passive House Planning Package or PHPP) to determine the building's overall heating/cooling energy usage (Figure 2). We start with the NZ Building Code legal minimum as a reference point, then assess the performance of the specified design and finally move up in performance in economic steps.

1. NZ Code
    a. Building code minimum performance
2. Spec
    a. Specified performance, as per the drawings provided
3. Common high perfomance spec
    a. High performance triple glazing with timber frames
    b. A more efficient MVHR unit (Zehender Comfoair 350)
    c. 120mm PIR insulation to walls and roof
    d. An additional layer of PIR under the floor joists and two layers of batts between the joists.
    e. The ability to remove the window shades (rainscreen battens) in winter
    f. Airtightness testing to meet 0.6 ACHn50.
4. Double scale building
    a. Double the floor area, keeping the window area the same
5. LEB & movable exterior shading on north
    a. 200mm PIR insulation
    b. 150mm of PIR under the joists (plus 2 layers of batts)
    c. plus the upgrades in variant 3
6. PH - double scale
    a. As specified in the summary.

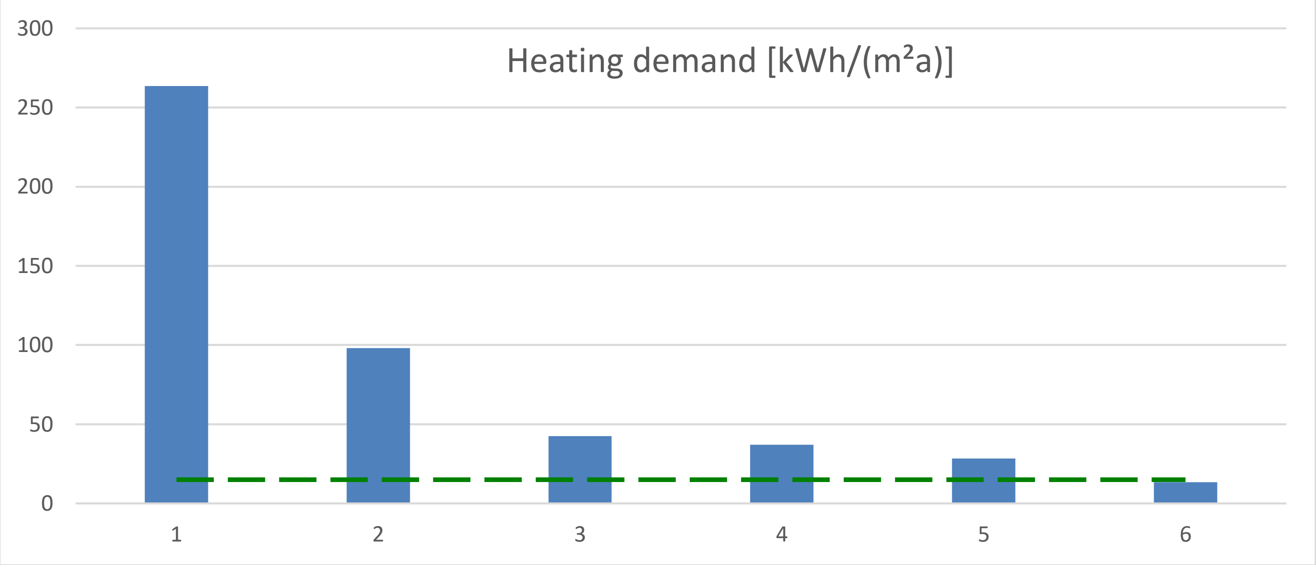


Figure 2: Variants according to heating demand.

Thermal Comfort

Reduced heating demand is not necessarily indicative of winter thermal comfort, the house will require an adequately sized heat source and a means of distributing the heat throughout the house. The windows in particular are likely to fail thermal comfort criteria, you are likely to get cold if you sit right up against the windows.

When designing a high performance house it is also important to consider summer thermal comfort, even in New Zealand's climates. Very well insulated houses will often overheat significantly in summer unless special attention is paid to glass selection, shading for the windows or a cooling system supplied. Passive House certification permits up to 10% overheating, which experience tells us occupants find unpleasantly hot. Additionally, the modelling assumes occupants leave windows open at night in summer for cooling and use any shading devices provided. But, if the occupants keep all the windows closed because they like it nice and quiet, or don't close the blinds because they like the view, the building will overheat even more than expected.

Frequency of overheating (>25°C)

One of the ways we work to understand overheating in this building is to run what we call a stress-test. To perform the stress-test, we remove any window/night ventilation, set the operable shading to minimum and set the MVHR to standard rate on summer bypass (or leave on the continuous extract fan). Then if the building is below 5% overheating, we've got a building that's *easy to keep cool*. If it's over 5% overheating, and almost all buildings are, then it is *likely to overheat*. Put in a heat pump for cooling or at the absolute least put in the wiring/ducting to add one easily later. This stress-test gives us a consistent measure to compare between buildings so you know how this building might work if you wanted to keep it closed for noise or security reasons.

When we run the stress test on this building the as-built overheating ranges from Is less than 236 hours of overheating a year (3%). The spec building is not likely to overheat with the fixed window shades.

Table 1: Stress test with no operable shading or windows opened.

	NZ Code	Spec	Common High Perf	Double Scale	LEB	PH
	1	2	3	4	5	6
Stress Test – no natural ventilation or operable shading						
Frequency of overheating (> 25 °C)	4%	3%	8%	0%	12%	2%
Annual hours of overheating (> 25 °C)	386	236	718	9	1094	164
'Normal' – 0.3ACH window and night ventilation						
Frequency of overheating (> 25 °C)	3%	0%	1%	0%	1%	0%
Annual hours of overheating (> 25 °C)	291	32	45	0	49	0

Airtightness

The building durability and performance is dependent on the air/vapour control layer being continuous, & without leaks, for the life of the building. The key to this airtightness performance is to specify the control layer installation (i.e. design it properly) and then test it (air leakage testing) to make certain it was built properly. We would expect that the only air leaks In this building would be through the joinery Installation and the floor junctions. Warm roof (and In this building that means the walls as well) do not tend to have any air leaks.

Constructions

Wall Constructions

Figure 3: Exterior wall: 1. Rainscreen on 2. cross battens over 3. two layers of waterproof membrane 3. rigid PIR insulation, 4. vapour barrier, 5. ply 6. timber panelling as the wall lining

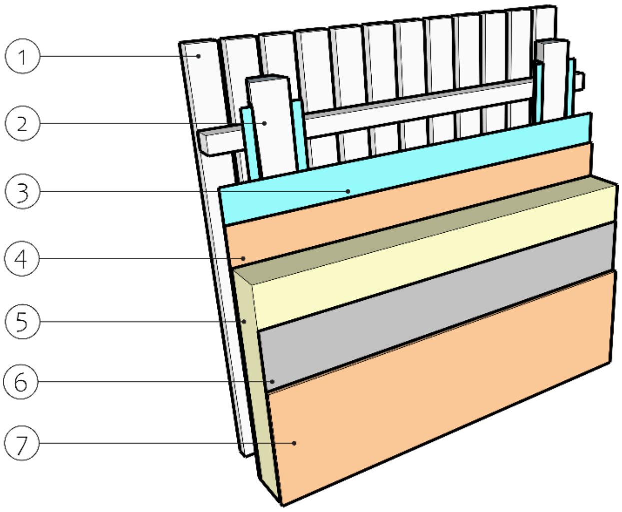


Table 2: Wall Constructions Table

Variant	Name	Wall Construction Description
1	NZ Code	Rainscreen on cross-battens / 2 layers waterproof membrane **/ 65mm** rigid PIR insulation/ vapour barrier / 12mm ply/ 10mm timber panelling
2	Spec	Rainscreen on cross-battens / 2 layers waterproof membrane / **100mm** rigid PIR insulation/ vapour barrier / 12mm ply/ 10mm timber panelling
3	Common High Perf	Rainscreen on cross-battens / 2 layers waterproof membrane / **120mm** rigid PIR insulation/ vapour barrier / 12mm ply/ 10mm timber panelling
4	Double Scale	Same as variant 3
5	LEB	Rainscreen on cross-battens / 2 layers waterproof membrane / **200mm** rigid PIR insulation/ vapour barrier / 12mm ply/ 10mm timber panelling
6	PH	Rainscreen on cross-battens / 2 layers waterproof membrane / **300mm** rigid PIR insulation/ vapour barrier / 12mm ply/ 10mm timber panelling

Roof Constructions

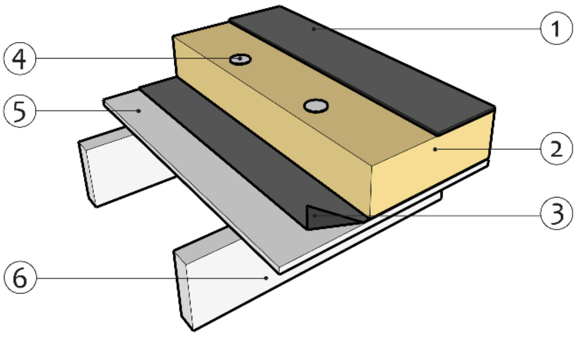


Figure 4: 1. Rainscreen on cross battens (not shown) over two layers of waterproof membrane 2. rigid PIR insulation, 3. vapour barrier, 5. ply then timber sarking 6. rafters

Table 3: Roof table.

Variant	Name	Roof Construction Description
1	NZ Code	Rainscreen on cross-battens / 2 layers waterproof membrane **/ 65mm** rigid PIR insulation/ 18mm ply/ 10mm timber sarking
2	Spec	Rainscreen on cross-battens / 2 layers waterproof membrane / **100mm** rigid PIR insulation/ 18mm ply/ 10mm timber sarking
3	Common High Perf	Rainscreen on cross-battens / 2 layers waterproof membrane / **120mm** rigid PIR insulation/ 18mm ply/ 10mm timber sarking
4	Double Scale	Same as variant 3
5	LEB	Rainscreen on cross-battens / 2 layers waterproof membrane / **200mm** rigid PIR insulation/ 18mm ply/ 10mm timber sarking
6	PH	Rainscreen on cross-battens / 2 layers waterproof membrane / **300mm** rigid PIR insulation/ 18mm ply/ 10mm timber sarking

Floor Constructions

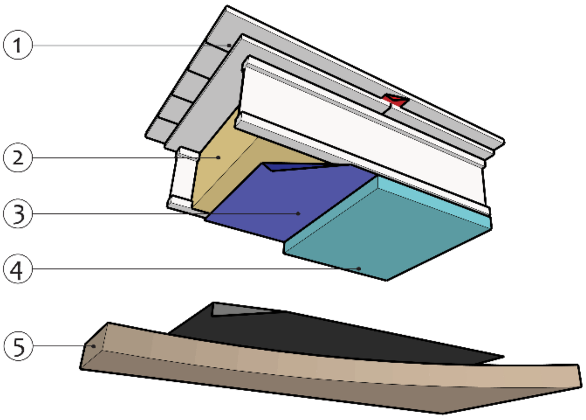


Figure 5: 1. Timber flooring over particleboard 2. batt insulation between joists 3. airtightness layer 4. optional additional PIR insulation 5. vented subfloor cavity with vapour barrier over earth.

Table 4: Foundation table.

Variant	Name	Construction Description
1	NZ Code	18mm timber flooring / 20mm particleboard / 120mm air gap with joists / 70mm pink batt insulation between joists / vented sub floor
2	Spec	18mm timber flooring / 20mm particleboard / 80mm air gap with joists / 110mm pink batts insulation between joists / vented sub floor
3	Common High Perf	18mm timber flooring / 20mm particleboard / two layers of pink batts insulation, R3.2 140mm wall batt then 70mm R1.6 snug floor batt between joists / 120mm PIR foam under joists / vented sub floor
4	Double Scale	Same as variant 3
5	LEB	Same as variant 3
6	PH	18mm timber flooring / 20mm particleboard / two layers of pink batts insulation, R3.2 140mm wall batt then 70mm R1.6 snug floor batt between joists / **150mm** PIR foam under joists / vented sub floor

Next step

This completes the **Initial Review Phase** of our process. The next step would typically be to discuss what you want to build and move into the Detail Design Phase so that we can work out how it is to be built. As the building Is already constructed and Is not able to target Low Energy or Passive House Certification this completes this work.

We are assembling an Introduction to Passive House for the Abodo seminar In Australia. With your permission we'd like to use this cabin to show how buildings perform across climate zones. For example this building as-built has sufficient insulation to potentially be a Low Energy Building In Melbourne and In Perth or Sydney would potentially be a Passive House.

Appendices

Window Analysis

In our process we have generated a graphic showing the window heat gains per square meter from high to low (or losses) from red to blue. This is to illustrate how each window contributes to the building heating or heat losses in the winter and overheating and cooling in the summer. You may wish to rationalise windows that don't contribute to heat gain in winter and/or contribute to overheating In summer.

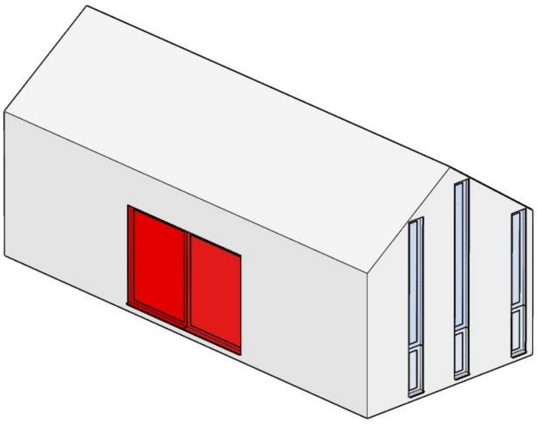


Figure 7: Summer Heat Losses and Gains per square meter – North East

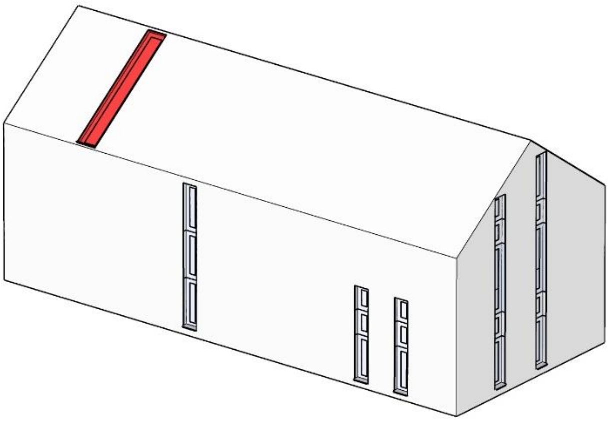


Figure 8: Summer Heat Losses and Gains per square meter – South West

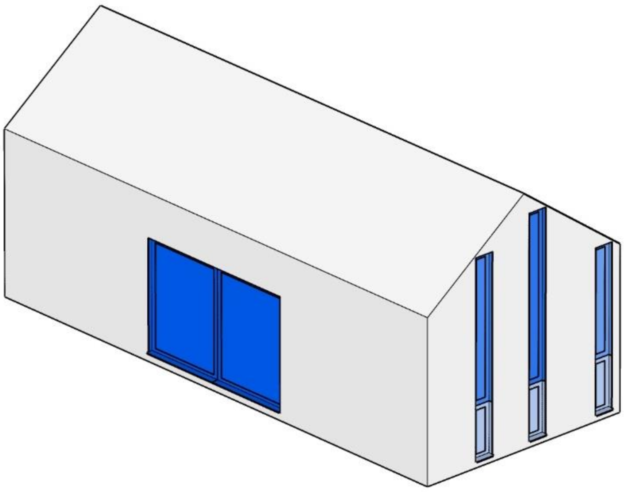


Figure 9: Winter Heat Losses and Gains per square meter – North East

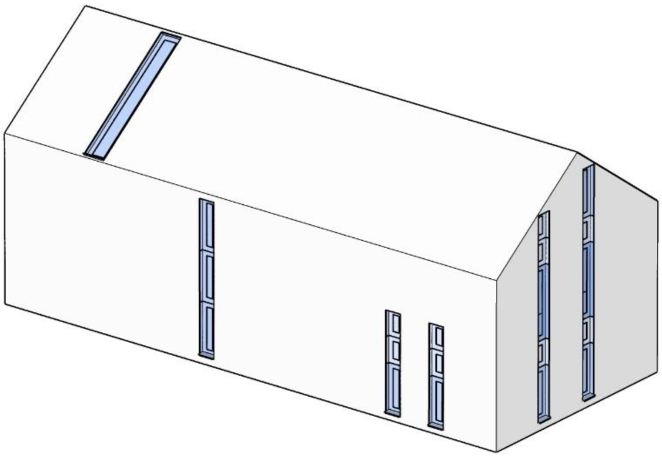


Figure 10: Winter Heat Losses and Gains per square meter – South West

Energy Balance Graphs

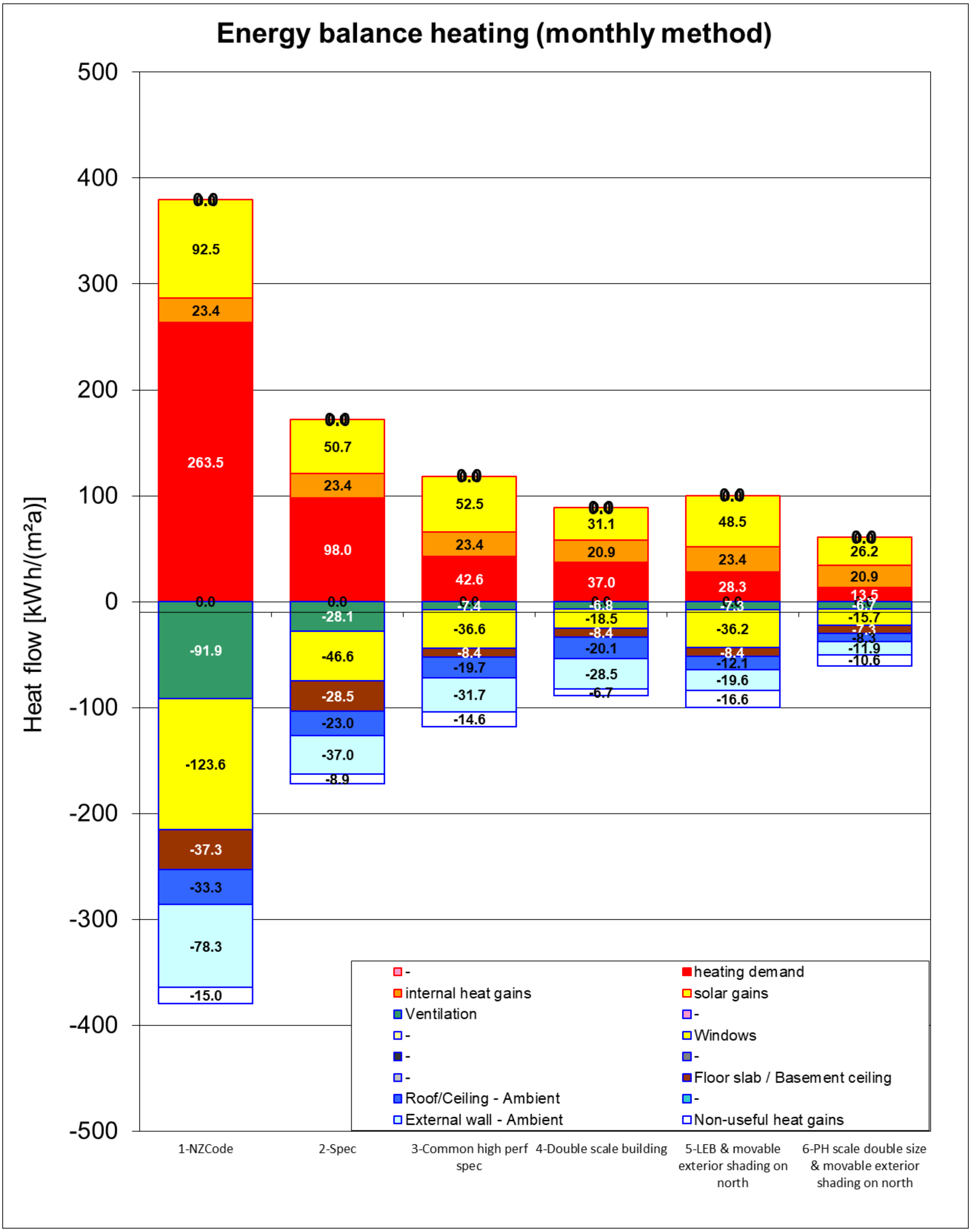


Figure 11: All variants heating demand energy balance.

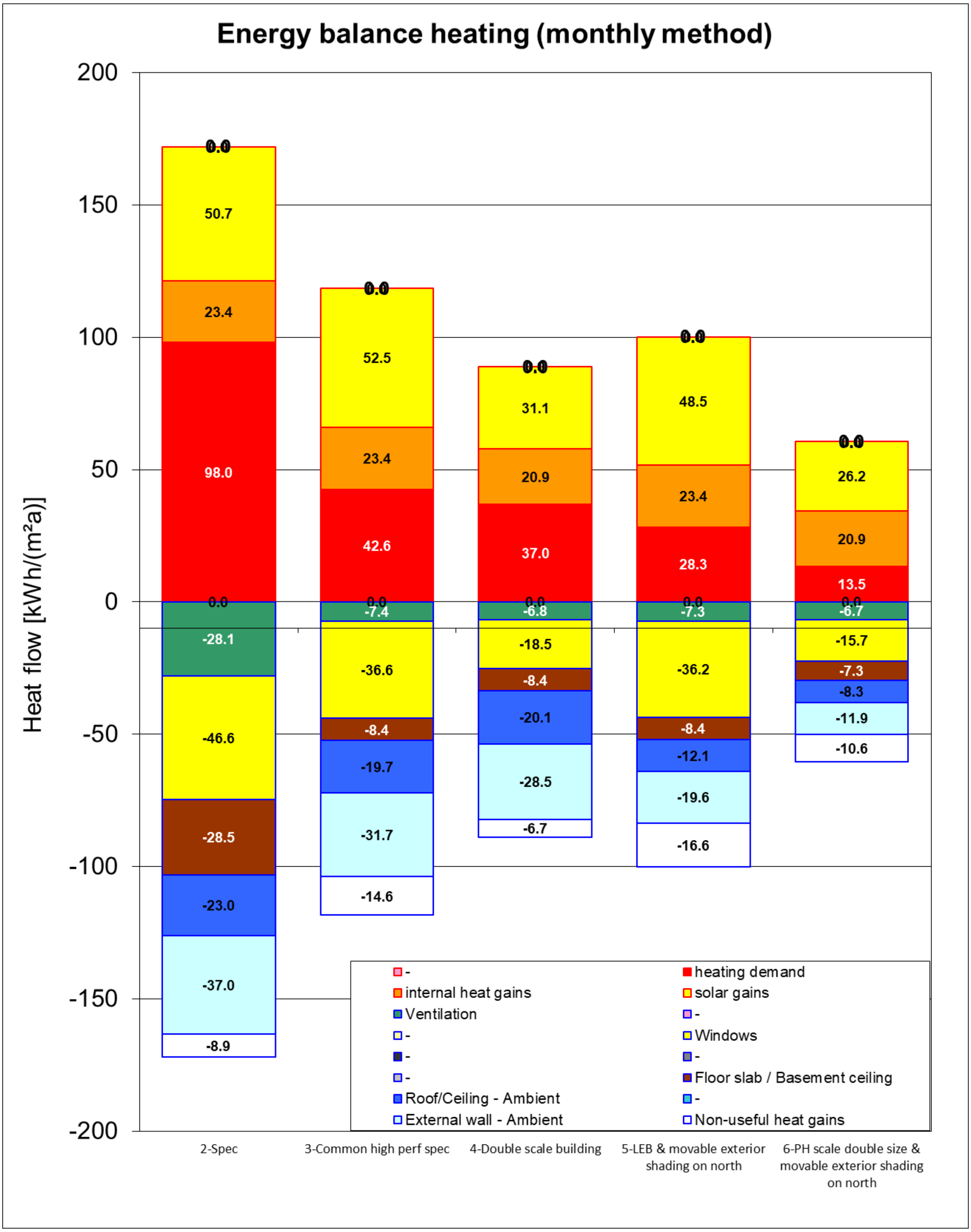
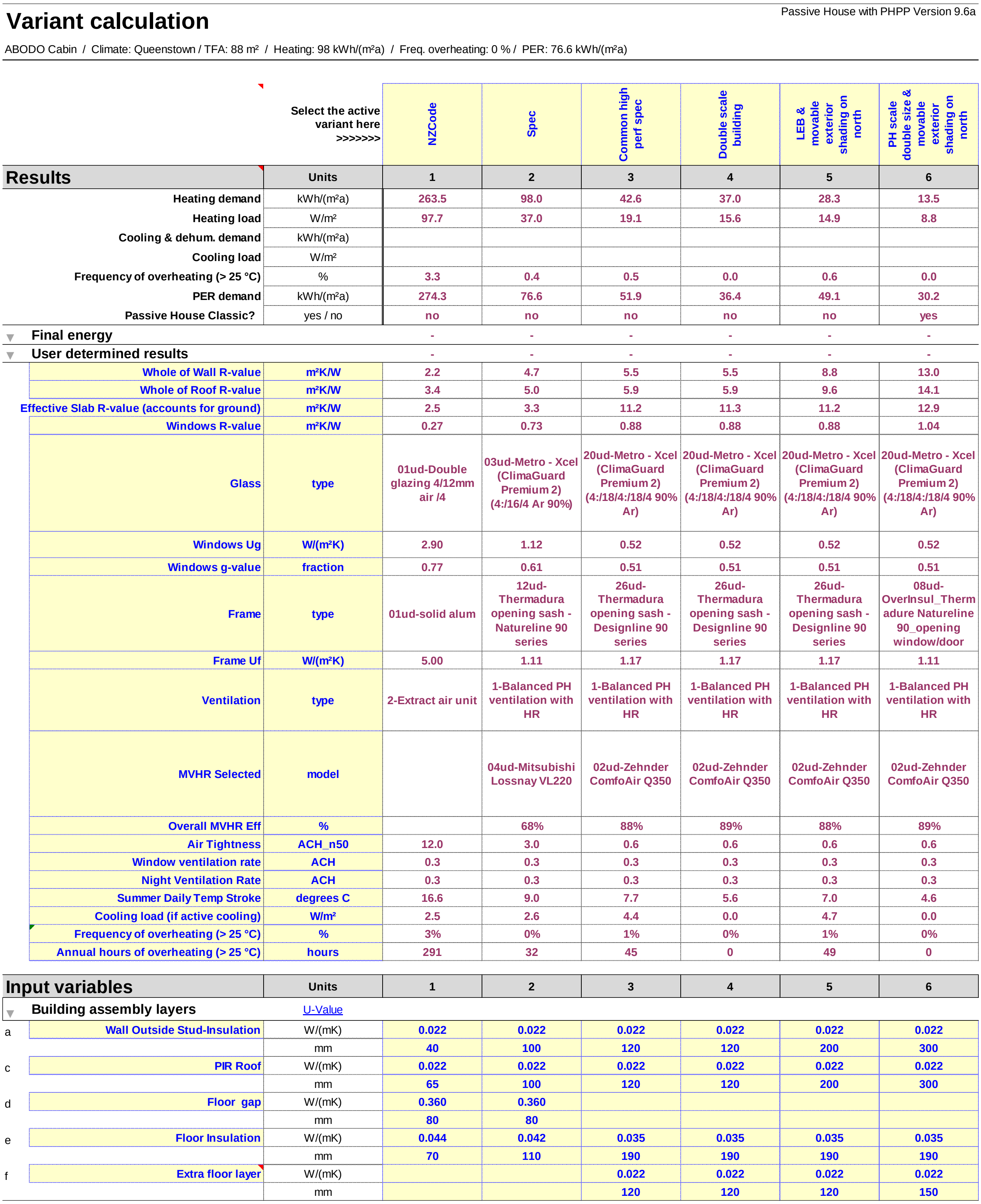


Figure 12: Variants 2-6 – Specified constructions heating demand energy balance.

Variant Calculations



Variant calculation

Passive House with PHPP Version 9.6a

ABODO Cabin / Climate: Queenstown / TFA: 88 m² / Heating: 98 kWh/(m²a) / Freq. overheating: 0 % / PER: 76.6 kWh/(m²a)

	Select the active variant here >>>>>>>	NZCode	Spec	Common high perf spec	Double scale building	LEB & movable exterior shading on north	PH scale double size & movable exterior shading on north
Results	Units	1	2	3	4	5	6
Heating demand	kWh/(m²a)	263.5	98.0	42.6	37.0	28.3	13.5
Heating load	W/m²	97.7	37.0	19.1	15.6	14.9	8.8
Cooling & dehum. demand	kWh/(m²a)						
Cooling load	W/m²						
Frequency of overheating (> 25 °C)	%	3.3	0.4	0.5	0.0	0.6	0.0
PER demand	kWh/(m²a)	274.3	76.6	51.9	36.4	49.1	30.2
Passive House Classic?	yes / no	no	no	no	no	no	yes
Final energy		-	-	-	-	-	-
User determined results		-	-	-	-	-	-
Whole of Wall R-value	m²K/W	2.2	4.7	5.5	5.5	8.8	13.0
Whole of Roof R-value	m²K/W	3.4	5.0	5.9	5.9	9.6	14.1
Effective Slab R-value (accounts for ground)	m²K/W	2.5	3.3	11.2	11.3	11.2	12.9
Windows R-value	m²K/W	0.27	0.73	0.88	0.88	0.88	1.04
Glass	type	01ud-Double glazing 4/12mm air /4	03ud-Metro - Xcel (ClimaGuard Premium 2) (4:/16/4 Ar 90%)	20ud-Metro - Xcel (ClimaGuard Premium 2) (4:/18/4:/18/4 90% Ar)	20ud-Metro - Xcel (ClimaGuard Premium 2) (4:/18/4:/18/4 90% Ar)	20ud-Metro - Xcel (ClimaGuard Premium 2) (4:/18/4:/18/4 90% Ar)	20ud-Metro - Xcel (ClimaGuard Premium 2) (4:/18/4:/18/4 90% Ar)
Windows Ug	W/(m²K)	2.90	1.12	0.52	0.52	0.52	0.52
Windows g-value	fraction	0.77	0.61	0.51	0.51	0.51	0.51
Frame	type	01ud-solid alum	12ud-Thermadura opening sash - Natureline 90 series	26ud-Thermadura opening sash - Designline 90 series	26ud-Thermadura opening sash - Designline 90 series	26ud-Thermadura opening sash - Designline 90 series	08ud-OverInsul_Thermadure Natureline 90_opening window/door
Frame Uf	W/(m²K)	5.00	1.11	1.17	1.17	1.17	1.11
Ventilation	type	2-Extract air unit	1-Balanced PH ventilation with HR	1-Balanced PH ventilation with HR	1-Balanced PH ventilation with HR	1-Balanced PH ventilation with HR	1-Balanced PH ventilation with HR
MVHR Selected	model		04ud-Mitsubishi Lossnay VL220	02ud-Zehnder ComfoAir Q350	02ud-Zehnder ComfoAir Q350	02ud-Zehnder ComfoAir Q350	02ud-Zehnder ComfoAir Q350
Overall MVHR Eff	%		68%	88%	89%	88%	89%
Air Tightness	ACH_n50	12.0	3.0	0.6	0.6	0.6	0.6
Window ventilation rate	ACH	0.3	0.3	0.3	0.3	0.3	0.3
Night Ventilation Rate	ACH	0.3	0.3	0.3	0.3	0.3	0.3
Summer Daily Temp Stroke	degrees C	16.6	9.0	7.7	5.6	7.0	4.6
Cooling load (if active cooling)	W/m²	2.5	2.6	4.4	0.0	4.7	0.0
Frequency of overheating (> 25 °C)	%	3%	0%	1%	0%	1%	0%
Annual hours of overheating (> 25 °C)	hours	291	32	45	0	49	0

	Input variables	Units	1	2	3	4	5	6
	Building assembly layers	U-Value						
a	Wall Outside Stud-Insulation	W/(mK)	0.022	0.022	0.022	0.022	0.022	0.022
		mm	40	100	120	120	200	300
c	PIR Roof	W/(mK)	0.022	0.022	0.022	0.022	0.022	0.022
		mm	65	100	120	120	200	300
d	Floor gap	W/(mK)	0.360	0.360				
		mm	80	80				
e	Floor Insulation	W/(mK)	0.044	0.042	0.035	0.035	0.035	0.035
		mm	70	110	190	190	190	190
f	Extra floor layer	W/(mK)			0.022	0.022	0.022	0.022
		mm			120	120	120	150

Figure 13: Variants results.