ADVANCED THERMAL ENVIRONMENT
ARCHTECH 419 - ASSIGNMENT 2

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PASSIVE HOUSE IN AUCKLAND & QUEENSTOWN

Contents

RESEARCH

1) Strategy
2) Brief Project Info
3) Climate data of Auckland and Queenstown
4) Water & Electricity consumption
5) Solar panels, PV dimensions
6) Solar hot water & rainwater collection

PHASE ONE – For Auckland and Queenstown

7) ALF Modeling design – Building assumptions
8) Passive House Design Features
   i) Perspective Renders
   ii) Plans
   iii) Section
   iv) Elevations
9) Structural Details from ALF
10) ALF Calculation Report

PHASE TWO

11) Phase 2: Heat load <15KWh/m²/yr

12) Conclusion
   i) Limitations of ALF
   ii) Reformation of the NZBC

13) References

Strategy

Looking at the two contrasting New Zealand climatic regions, Auckland with its warmer yet more humid climate and Queenstown with much colder, drier climate, a thermal analysis is conducted. A detached house unit will be theoretically placed in these 2 different zones to function as a passive house that complies with the NZBC. The aim here is to utilize the site factors such as orientation of the house, calculating the most efficient angle(s) for PV panels and hot solar water heaters to maximize the solar energy, capturing natural wind for ventilation, capturing rainwater through good roof design, capturing the sun for heating in winter through appropriate glazing size and storing the heat using thermal mass. The prevention of overheating in summer is resolved through good sunshades and overhangs.

The goal is to go beyond the minimum building code specification. Simple procedures such as double glazing and thicker insulation is implemented to prove that passive house can be achieved using these passive methods.

There is also implementation to reduce the energy consumption/demand through efficient energy saving methods. This will reduce the energy load the house has to meet.

Using the approximate New Zealand data for household energy consumption for electricity and water in conjunction with the program ALF (Annual Loss Factor) this assignment will calculate the heating load of less than 15KWh/m²/yr as its goal.

Brief Project Info

Location: Auckland and Queenstown
Volume: 288m³, 273m³
Floor area: 115m², 109m²
Occupants: Family of 4 (2 adults 2 children)
Functions: Living + Eating + Sleeping + Cleaning
Typology: Detached House
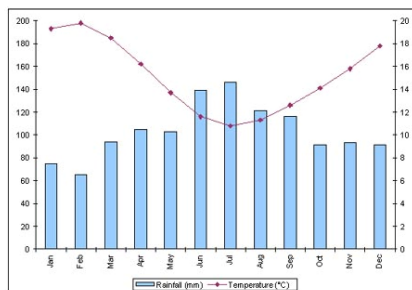Site Exposure: Medium (typical residential zones)

Climate data for Auckland and Queenstown[1]
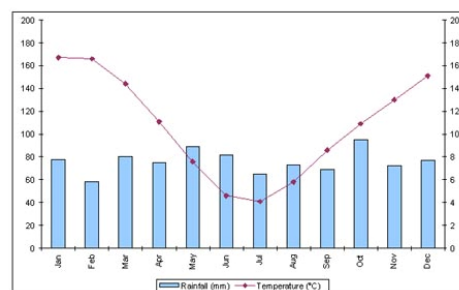

Auckland climate data – ZONE 1	Queenstown climate data – ZONE 3
CLIMATE ZONE: Sub-tropical with warm humid summers and mild wet winters.	CLIMATE ZONE: Largely dependent on the lie of the Southern Alps to the west, but many areas are also sheltered by high country to the south and

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[1] http://www.niwascience.co.nz/edu/resources/climate/overview

	east. Dry summers with low rainfall and cold winters.
TEMP RANGE: Typical summer daytime maximum air temp range from 22°C to 26°C, but seldom exceed 30°C. Winter daytime maximum air temperatures ranges from 12°C to 17°C.	TEMP RANGE: Summer afternoons are very warm, with high temperatures occurring when hot dry foehn northwesterlies blow over the Alps. Typical summer daytime max. air temp. ranges from 20°C to 26°C, occasionally rising above 30°C. Winters are very cold. Typical winter daytime max. air temp. range from 3°C to 11°C.
ANNUAL SUNSHINE HOURS: 2060hrs	ANNUAL SUNSHINE HOURS: 1921hrs
WIND: SW winds prevail for much of the year. Sea breezes often occur on warm summer days.	WIND: Wind flow is dependent on topography; however the strongest winds are often from the northwest.
RAIN: Winter usually has more rain and is the most unsettled time of year. Rainwater catchments 65mm to 150mm (approx 1260mm p.a.)	RAIN: Rainwater catchments: 40mm to 170mm (approx. 950mm p.a.)
EXTREMES/HAZARDS: In summer and autumn, storms of tropical origin may bring high winds and heavy rainfall from the east or northeast. Frosts in winter are very rare. The strength of the sun - particularly in summer is dangerous for causing skin cancer and overheating.	EXTREME/HAZARDS: Frequent, often severe frosts, and occasional snowfalls. In severe cases, snow may lie for several days or longer.
LATITUDE: 37 degrees South	LATITUDE: 45 degrees South

Auckland - Average Rainfall and Temperature

Queenstown - Average Rainfall and Temperature

Auckland average rainfall: 80,70,100,100,100,140, 150,120,120,90,100,90 (In mm)

Queenstown average rainfall: 80, 60, 80, 80, 90, 80, 70, 80, 70, 100, 80, 80 (In mm)

Electricity Consumption

Fuel use per household	Bottom 20%		Top 20%	
	Use under kWh/yr	% of energy	Use over kWh/yr	% of energy
Electricity	4,860	10%	10,380	35%
Gas	2,580	5%	9,900	34%
Solid fuel heating	450	1%	5,740	57%
LPG heating	180	3%	1,110	50%
All fuels	6,940	9%	14,450	36%

Table i : Fuel use – top and bottom 20%

Table from: http://www.branz.co.nz/branzltd/publications/pdfs/CP102.pdf

Average household of 4 consumes electricity ranges between 4,860kWh/yr to 10,380kWh/yr.[2]
Taking the average one can assume that an average household in New Zealand would approximately consumes 7620kWh/yr. Since Queenstown would use more energy on space heating especially in winter, we can assume that:

AUCKLAND	QUEENSTOWN
• would consume between 4,860 – 7,620 = Average of 6240kWh per annum	• would consume between 7,620 – 10,380 = Average of 9000kWh per annum

The electricity consumed is distributed amongst, space heating, lighting, hot water, appliances and refrigeration. It is interesting to note the relative importance of hot water heating and space heating compared to the total energy used by households which makes up 63% of the electricity usage.
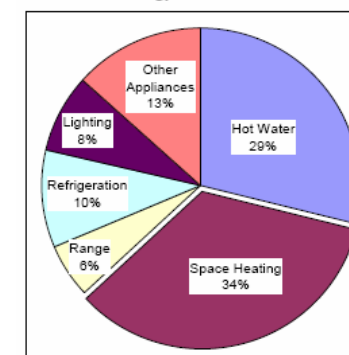

Household energy services

Table from: http://www.branz.co.nz/branzltd/publications/pdfs/CP102.pdf

[2] http://www.branz.co.nz/branzltd/publications/pdfs/CP102.pdf

Reduce energy use by 40% (To be more realistic 40% was chosen instead of sum of the indicative % below)

With an implementation to lead a more energy efficient lifestyle, the following things can be done to reduce the energy demand:

HOT WATER 29% = A standard solar thermal system can produce around 55%~75% of a household's water heating.[3]

OTHER APPLIANCES 13% = A home that is fully equipped with ENERGY STAR-qualified products will operate on about 30% less energy than a house with standard products.[4]

REFRIDGERATION 10% = ENERGY STAR qualified refrigerator models use at least 15% less energy than required by current federal standards and 40% less energy than the conventional models sold in 2001.[5]

LIGHTING 8% = Compact fluorescent lighting uses 25% the electric power as incandescent lighting to generate amount the same amount of usable light.[6] – Saving of 75%

SPACE HEATING 34% = Can be reduced by thicker insulation, thermal mass and double glazing. (See ALF calculation)

After 40% reduction an energy efficient house will…

AUCKLAND	QUEENSTOWN
• Consume average of 6240kWh per annum → 3744kWh p.a.	• Consume average of 9000kWh per annum → 5400kWh p.a.

Water Consumption

Table from: http://www.waitakere.govt.nz/CnlSer/wtr/wtrsavetips.asp

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[3] www.smarterhomes.org.nz/energy/solar-water-heating/solar-water-heating-options/
[4] http://www.energystar.gov/index.cfm?c=refrig.pr_refrigerators
[5] http://www.energystar.gov/index.cfm?c=refrig.pr_refrigerators
[6] http://www.consumerenergycenter.com/homeandwork/homes/inside/appliances/index.html

The Waitakere council in Auckland has come up with an approximate figure of average water consumption amount per person per day.
It states a New Zealander in an average household requires 5L of drinking quality water per day for cooking, drinking and for food preparation and 170L for toilets, showering, washing, gardening and other uses.[7]

Reduce water consumption by 20%

By reducing the water usage by using dual flush toilets or composting toilets or using greywater to flush, eliminating water use for garden through implementing xeriscape, using water saving shower heads, you can minimize up to 140L per day per person (without using it for drinking/preparing food). (Approx. 20% reduction)
So assuming 140L per person per day in a household of 4 it would be 560L per day and 204,000L (3 s.f.) per year.

Solar PV Panels

The number and the type of PV system were chosen on the basis of table provided below:

Powersmart Solar System	Solar Panels	Annual Energy Production (kWh)*	Roof Area (m2)
PS-1.26kW-GTS	7 x 180W	1,902	7.44
PS-1.52kW-GTS	8 x 190W	2,295	8.97
PS-1.80kW-GTS	10 x 180W	2,718	11.22
PS-1.90kW-GTS	10 x 190W	2,869	11.22
PS-2.16kW-GTS	12 x 180W	3,262	13.46
PS-2.28kW-GTS	12 x 190W	3,443	13.46
PS-2.52kW-GTS	14 x 180W	3,805	15.71
PS-2.66kW-GTS	14 x 190W	4,017	15.71
PS-2.88kW-GTS	16 x 180W	4,349	17.95
PS-3.60kW-GTS	20 x 180W	5,436	22.43
PS-3.80kW-GTS	20 x 190W	5,738	22.43

• This table of data is based on Auckland conditions, so for Queenstown it would actually produce less energy as it as fewer sunshine hours. But considering the average sunshine hours are not significantly far apart I will use this data as an approximate value.
• Allowing more PV panels than the energy demand to cover for inconsistency and contingency.

Table from:
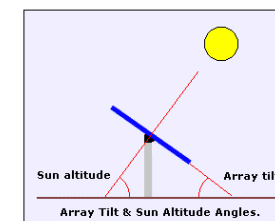http://www.powersmart.co.nz/residential/r_solarkits.html

Image from: http://www.wattsun.com/resources/calculators/photovoltaic_tilt.html

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[7] http://www.waitakere.govt.nz/abtcit/ec/bldsus/pdf/water/usingrainwtr.pdf

AUCKLAND[8] – 3744kWh/yr	QUEENSTOWN – 5000kWh/yr
• Chosen PV: 16 x 180W = 4,349kWh p.a. →Roof area required: 18m²	• Chosen PV: 20x190W = 5,738kWh p.a. →Roof area required: 22m²

PV ARRAY: SOLAR NOON TILT DATA
Sun's altitude at solar noon at different times of the year

(Auckland)
- Latitude = 37 Degrees South

(Queenstown)
- Latitude = 45 Degrees South

AUCKLAND

Month	Sun Altitude	Array Tilt
JAN	73	17
FEB	64	26
MAR	53	37
APR	41	49
MAY	33	57
* JUN	30	60
JUL	33	57
AUG	41	49
SEP	53	37
OCT	65	25
NOV	73	17
* DEC	76	14

Array Tilt = 90 degrees - Sun Altitude
Array points to NORTH

Dec: 37-15 = 22° → 68° in Summer
June: 37+15 = 52° → 38° in Winter

QUEENSTOWN

Month	Sun Altitude	Array Tilt
JAN	65	25
FEB	56	34
MAR	45	45
APR	33	57
MAY	25	65
* JUN	22	68
JUL	25	65
AUG	33	57
SEP	45	45
OCT	57	33
NOV	65	25
* DEC	68	22

Array Tilt = 90 degrees - Sun Altitude
Array points to NORTH

Dec: 45-15 = 30° → 70° in Summer
June: 45+15 = 60° → 30° in Winter

For Photovoltaic panels (and solar hot water), assuming that the panel is fixed, or has a tilt that can be adjusted seasonally, (Panels that track the movement of the sun throughout the day can receive 10% (in winter) to 40% (in summer) more energy than fixed panels) solar panels should always face true north. The tilt should be equal to the latitude, plus 15 degrees in winter, or minus 15 degrees in summer.[9]

Because heating is more desired and sunlight is scarce in winter, it is ideal to tilt the panels for winter conditions than summer. (For summer the panels can be adjusted to a higher angle)

Optimum tilting angle of PV increases the performance of the system by 10%.

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[8] Table from: http://www.wattsun.com/resources/calculators/photovoltaic_tilt.html
[9] http://www.macslab.com/optsolar.html

Rainwater Collection

A rainwater tank can provide up to 65% of your household water usage.[10]
Roof area = 100m² (10.5m x 9.5m)

Maximum[11] possible rainwater catchments

AUCKLAND	QUEENSTOWN
• = Roof area x annual rainfall x 100% efficiency = 100m² x 1260mm = 126,000L • Provides 61% of demand	• = Roof area x annual rainfall x 100% efficiency = 100m² x 950mm = 95,000L • Provides 46% of demand

Size of Rainwater tank:

MEAN MONTHLY DRY-DAYS – Not more than 1.0 mm a day of rain

Data are mean monthly values for the 1971-2000 period for locations having at least 5 complete years of data

LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
AUCKLAND	23	21	22	19	21	15	15	16	16	19	19	22	19
QUEENSTOWN	23	23	23	22	20	21	23	23	22	21	22	22	22

Mean monthly dry days calculated from: http://www.niwascience.co.nz/edu/resources/climate/wetdays

Method 1 - demand side approach[12]
A very simple method is to calculate the largest storage requirement based on the consumption rates and occupancy of the building.

Consumption per capita per day, C = 140L
Number of people per household, n = 4
Daily consumption = C x n = 560L

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[10] www.waitakere.govt.nz/CnlSer/wtr/wtrsavetips.asp
[11] Note that the amount of rain that falls on a roof that is connected to a rainwater tank is not the amount that you will collect. Evaporation and overflow lead to an overall capture of only 85% of rainfall.
http://www.questacon.edu.au/html/assets/pdf/squad_primary_term_4_07.pdf
[12] http://practicalactionpublishing.org/docs/technical_information_service/rainwater_harvesting.pdf
This simple method assumes sufficient rainfall and catchment area, and is therefore only applicable in areas where this is the situation. It is a method for acquiring rough estimate of tank size.

AUCKLAND	QUEENSTOWN
• Mean monthly dry period = 19 days • Storage requirement, T = 560 x 19 = 10,640L • x4, 3000L SlimlineTank or, • x3, 5000L Polymer Tank	• Mean monthly dry period = 22 days • Storage requirement, T = 560 x 22 = 12,320L • x5, 3000L SlimlineTank or, • x3, 5000L Polymer Tank

3000L Slimline Tank

This slimline design provides maximum capacity in a minimum space. Available in an impressive array of attractive colours to complement your home.

	Litres	Gallons
Size	3000	660

	Metric (mm)
Width	805
Length	2400
Wall Height	1865
Inlet Height	2000

Image from: http://www.urbantanks.com.au/slimline-rainwater-tanks-3000litre.html

5000L Polymer Tank

This large traditional tank is ideal for connection to existing plumbing for a wide range of household uses, from drinking water to garden irrigation to water for the laundry and bathroom. Available in an impressive array of attractive colours to complement your home.

	Litres
Size	5000

	Metric (mm)
Diameter	1840
Inlet Height	2040
Apex Roof Height	2170

*Image from: http://www.urbantanks.com.au/slimline-rainwater-tanks-5000litre.html*

Solar Hot water

A standard solar thermal system can produce around 55%~75% of a household's water heating.[13]

Evacuated Tube Solar Hot Water Systems
From: http://www.enviro-friendly.com/evacuated-tube-solar-hot-water.shtml
http://www.enviro-friendly.com/Endless-Solar-Advantage.pdf

- Can be mounted on roofs or against walls. (horizontal placement)
- Tubes are more advantageous than flat plate.

Images from: http://www.enviro-friendly.com/evacuated-tube-solar-hot-water.shtml

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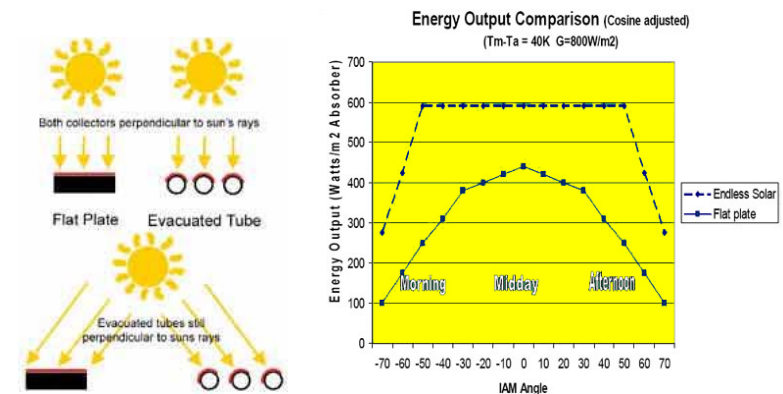
[13] www.smarterhomes.org.nz/energy/solar-water-heating/solar-water-heating-options/

Size of Hot water cylinder: Approx 300L capacity needed for family of 4[14]

Electric Boosted Systems

Model	Litres	Aux. Mode	Load	No. People	Price *	RECs +
10-tube	170	Off-Peak	Small	Up to 3	$3302.00	11
22-tube	264	Off-Peak	Medium	Up to 5	$3929.00	24

Endless Solar™ Collectors

Measurement	10 tube collector	22 tube collector	30 tube collector
Weight(incframe/tubes/manifold)	40kg	82kg	108kg
Height (including manifold)	2000mm	2000mm	2000mm
Width	885mm	1845mm	2485mm
Distance between inlet and outlet ports*	805mm	1765mm	2405mm
Surface Area	1.77m2	3.69m2	4.97m2

Endless Solar™ Electric Boosted Tanks

Tank Size	Height of Tank	Tank Diameter	Hot Water Outlet**	Return Flow** (to Tank)	Cold Water Inlet**
250L	1606mm	566mm	1195mm	370mm	168mm
315L	1961mm	580mm	1495mm	425mm	168mm

*Distances given are from the base of the tank

Tables from: http://www.enviro-friendly.com/Endless-Solar-Roughing-In.pdf

22 tubes model can accommodate for approx 5 people according to the tables above. The approx dimensions are given with the appropriate hot water tank size that should be of a reasonably close distance from the solar tubes.

* In the design more solar tubes are provided than the recommended size to make sure it delivers more than it is needed in case of days when solar energy is scarce (especially in Queenstown).

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[14] http://www.solarindustries.org.nz/documents/solarWatersystems.pdf

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ALF Building design – Modeling assumptions

Due to the dependency on the climatic conditions, the house in Auckland and Queenstown will vary slightly in terms of…

a) Wall, Roof, Floor thickness – This will determine the total floor area and volume.
b) Different R value for insulation
c) Desired Heating level. (i.e. Auckland can easily achieve higher heating level temperature and schedule due to warmer conditions.)
d) Heating season – Queenstown will have longer heating periods.

AUCKLAND HOUSE - DESIGN	QUEENSTOWN HOUSE - DESIGN
PROJECT SETUP • Total Floor area= 115m² • Room Height = 2.5m • Number of occupants = 4 **CLIMATE & HEATING** • Heating Schedule= Morning & evening 7:00-9:00 and 17:00-23:00 • Heating Level = 18°C[15] • Location: Auckland in the Upper North Island • Heating Season: June to August • Annual Loss Factor: 5.2 • Annual Gain Factors: N 176, NE 99, E 66, SE 50, S 48 SW 50, W 116, NW 184, H 122 • Internal Gain Multiplier: 0.73 • Wind Zone Factor: 0.8 • H1 Climate Location: warm , BPI Target: 0.13 • NZS 4218:1996 Climate Zone: 1 **SLAB FLOOR** • Slab on ground floor area = 60m2 • Perimeter length = 10m	**PROJECT SETUP** • Total Floor area= 109m² • Room Height = 2.5m • Number of occupants = 4 **CLIMATE & HEATING** • Heating Schedule= Morning & evening 7:00-9:00 and 17:00-23:00 • Heating Level = 18°C • Location: Queenstown in the Lower South Island • Heating Season: April to October • Annual Loss Factor: 18.1 • Annual Gain Factors: N 324, NE 204, E 158, SE 137, S 128 SW 163, W 287, NW 382, H 304 • Internal Gain Multiplier: 1.71 • Wind Zone Factor: 0.8 • H1 Climate Location: warm , BPI Target: 0.12 • NZS 4218:1996 Climate Zone: 3 **SLAB FLOOR** • Slab on ground floor area = 60m2

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[15] The World Health Organisation recommends that all living and sleeping areas for health and comfort, inside temperatures should be between 18ºC and 24ºC. From: http://www.level.org.nz/energy/space-heating-and-cooling/
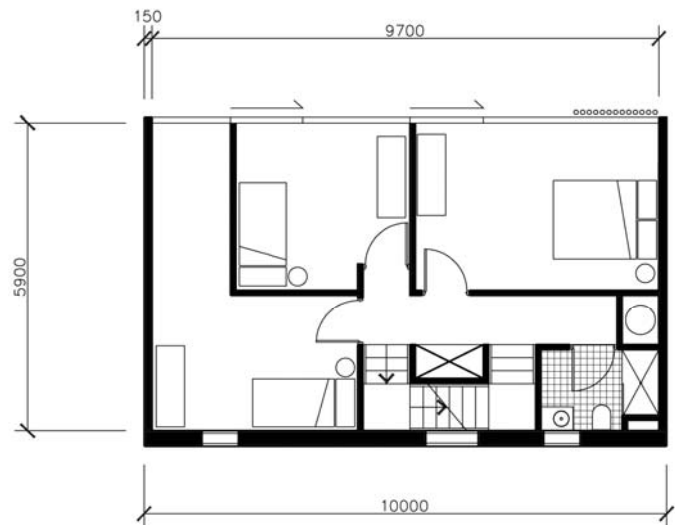
- External wall thickness= 0.15m
- Edge insulation width= 0.1m
- Exposed concrete floor/tiles
- Soil Conductivity: 1.2 W/m°C
- Under Floor R-value: 0 m²°C/W
- Slab and Ground R-value: 3.029532 m²°C/W
- Floor Covering R-value: 0 m²°C/W
- Total Slab Floor R-value: 3.03 m²°C/W

WALLS
- Type 1
- Timber Framed Wall, Rusticated or Shiplap Weatherboards, Insulation Within Framing - 150 mm Framing.
- 2 Dwangs, Studs 600 mm ctr., Blanket and Segment Insulants
- Insulation R-value: 1.9 m²°C/W
- Construction R-value: 1.875 m²°C/W

Name	Orientation	Length(m)	Height(m)
Wall A	East	6	5.6
Wall B	West	6	5.6

Net Area(m²)	Window Area (m²)
Wall A: 33.6	0
Wall B: 33.6	0

- Type 2
- Concrete Block Wall, Externally Insulated 47x22 strap, Straps 400 mm ctr.
- Rigid and Semi-Rigid Insulants on external side of wall
- Insulation R-value: 1.9 m²°C/W
- Construction R-value: 2.4 m²°C/W

Name	Orientation	Length(m)	Height(m)
Wall C	South	10	2.8
Wall F	South	10	2.8

Net Area(m²)	Window Area (m²)
Wall C: 26.0	1.98
Wall F: 26.0	1.98

- Perimeter length = 10m
- External wall thickness= 0.4m
- Edge insulation width= 0m
- Exposed concrete floor/tiles
- Soil Conductivity: 1.2 W/m°C
- Under Floor R-value: 1.3 m²°C/W
- Slab and Ground R-value: 4.855701 m²°C/W
- Floor Covering R-value: 1m²°C/W
- Total Slab Floor R-value: = 5.86 m²°C/W

WALLS
- Type 1
- Timber Framed Wall, Rusticated or Shiplap Weatherboards, Insulation Within Framing - 150 mm Framing.
- 3 Dwangs, Studs 600 mm ctr., Blanket and Segment Insulants
- Insulation R-value: 4.3 m²°C/W
- Construction R-value: 3.25 m²°C/W

Name	Orientation	Length(m)	Height(m)
Wall A	East	6	5.6
Wall B	West	6	5.6

Net Area(m²)	Window Area (m²)
Wall A: 33.6	0
Wall B: 33.6	0

- Type 2
- Cavity Brick or Block Wall, Cavity width depends on the thickness required by the insulant
- Insulation R-value: 30 m²°C/W
- Construction R-value: 30.30001 m²°C/W

Name	Orientation	Length(m)	Height(m)
Wall C	South	10	2.8
Wall F	South	10	2.8

Net Area(m²)	Window Area (m²)
Wall C: 26.0	1.98
Wall D: 26.0	1.98

- Type 3
- Timber Framed Wall, Sheet Cladding, Insulation Within Framing - 150 mm Framing
- 2 Dwangs, Studs 600 mm ctr., Blanket and Segment Insulants
- Insulation R-value: 1.9 m²°C/W
- Construction R-value: 1.775 m²°C/W

Name	Orientation	Length(m)	Height(m)
Wall D	North	10	2.8
Wall E	North	10	2.8

Net Area(m²)	Window Area (m²)
Wall D: 11.0	17
Wall E: 3.8	24.25

WINDOWS

- Type 1
- Glass: Double, argon filled, outside:clear / inside:low emissivity coating
- Frame: Wood or uPVC frame
- R-value: 0.53 m²°C/W
- Solar Heat Gain Coefficient: 54 %

Number	Wall/	Orientation	Width	Height	Net Shading
Wind. 1	Wall C	South	0.7	0.7	0.49
Wind. 2	Wall C	South	1	1	1
Wind. 3	Wall C	South	0.7	0.7	0.49
Wind. 1	Wall D	North	6.8	2.5	17
Wind. 1	Wall E	North	9.7	2.5	24.25
Wind. 1	Wall F	South	0.7	0.7	0.49
Wind. 2	Wall F	South	1	1	1
Wind. 3	Wall F	South	0.7	0.7	0.49

ROOFS
- Flat Metal Deck Roof, Ceiling Dwangs Ceiling Joist 194x47 600ctr., Dwang 69x47 900ctr., Rigid and Semi-Rigid Insulants
- Insulation R-value: 2.9 m²°C/W
- Construction R-value: 2.25 m²°C/W

- Type 3
- Timber Framed Wall, Sheet Cladding, Insulation Within Framing - 150 mm Framing
- 3 Dwangs, Studs 600 mm ctr., Blanket and Segment Insulants
- Insulation R-value: 4.3 m²°C/W
- Construction R-value: 3.15 m²°C/W

Name	Orientation	Length(m)	Height(m)
Wall D	North	10	2.8
Wall E	North	10	2.8

Net Area(m²)	Window Area (m²)
Wall D: 5.0	23
Wall E: 5.0	23

WINDOWS

- Type 1
- Glass: Double, argon filled, outside:clear / inside:low emissivity coating
- Frame: Wood or uPVC frame
- R-value: 0.53 m²°C/W
- Solar Heat Gain Coefficient: 54 %

Number	Wall/	Orientation	Width	Height	Net Shading
Wind. 1	Wall C	South	0.7	0.7	0.49
Wind. 2	Wall C	South	1	1	1
Wind. 3	Wall C	South	0.7	0.7	0.49
Wind. 1	Wall D	North	9.2	2.5	23
Wind. 1	Wall E	North	9.2	2.5	23
Wind. 1	Wall F	South	0.7	0.7	0.49
Wind. 2	Wall F	South	1	1	1
Wind. 3	Wall F	South	0.7	0.7	0.49

ROOFS
- Flat Metal Deck Roof, Ceiling Battens Ceiling Joist 194x47 600ctr., Dwang 35x69 <600ctr., Blanket and Segment Insulants*
- Insulation R-value: 4.3 m²°C/W
- Construction R-value: 4.2 m²°C/W

Name	Length	Width	Net Area	Window Area
Roof A	10.5	9.5	99.8	0

AIR LEAKAGE
- Basic Airtightness: Airtight
- No. of Open Fires without Flue
- Restrictors: 0
- No. of Open Fires with Flue Restrictors: 0
- Area of Large Gaps: 0 mm²
- The house has passive vents.
- The location-independent Air Leakage Rate is 0.25 ac/h.
- Site Exposure: medium exposed
- Wind Zone Factor: 0.8
- Local Air Leakage Rate: 0.50 ac/h
- House Volume: 288 m³

THERMAL MASS
- Concrete Floor: 120 m², 150mm slab with full insulation (83 Wh/m²°C)
- Thermal Mass: 9960 kWh/°C
- External Walls: 187.7 m², Solid timber wall (44mm) (7 Wh/m²°C)
- Thermal Mass: 1314 kWh/°C
- Internal Walls: 57.8 m², Solid timber wall (44mm) (20 Wh/m²°C)
- Thermal Mass: 405 kWh/°C
- Total Floor Area (used for Furniture and Ceiling): 115.0 m² (4.5 Wh/m²°C + 2.5 Wh/m²°C)
- Thermal Mass: 805 kWh/°C
- Total Thermal Mass: 12484 kWh/°C
- Effective Thermal Mass: 348.9 W/°C

Name	Length	Width	Net Area	Window Area
Roof A	10.5	9.5	99.8	0

AIR LEAKAGE
- Basic Airtightness: Airtight
- No. of Open Fires without Flue
- Restrictors: 0
- No. of Open Fires with Flue Restrictors: 0
- Area of Large Gaps: 0 mm²
- The house has passive vents.
- The location-independent Air Leakage Rate is 0.25 ac/h.
- Site Exposure: medium exposed
- Wind Zone Factor: 0.8
- Local Air Leakage Rate: 0.50 ac/h
- House Volume: 273 m³

THERMAL MASS
- Concrete Floor: 120 m², 150mm slab with full insulation (83 Wh/m²°C)
- Thermal Mass: 9960 kWh/°C
- External Walls: 187.7 m², Solid timber wall (62mm) (10 Wh/m²°C)
- Thermal Mass: 1877 kWh/°C
- Internal Walls: 55.0 m², Solid timber wall (62mm) (10 Wh/m²°C)
- Thermal Mass: 550 kWh/°C
- Total Floor Area (used for Furniture and Ceiling): 109 m² (4.5 Wh/m²°C + 2.5 Wh/m²°C)
- Thermal Mass: 763 kWh/°C
- Total Thermal Mass: 13150 kWh/°C
- Effective Thermal Mass: 330.7 W/°C

Passive House for Auckland

Perspectives renders of the house facing North

First Floor

150
9700
5900
10000

First Floor

1000
5950
6000
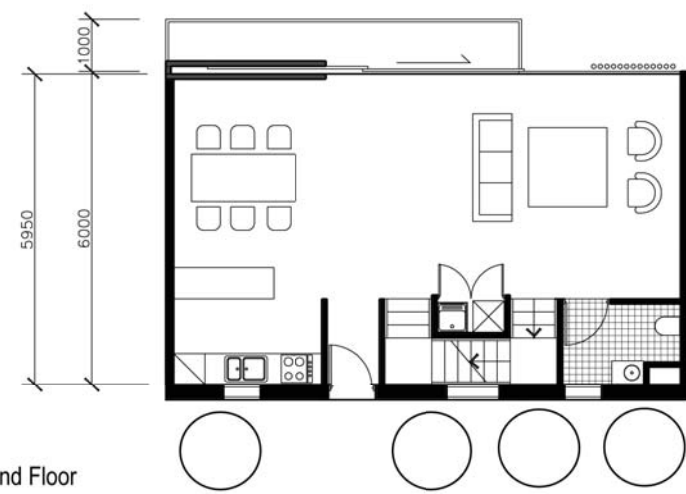
Ground Floor

North Elevation
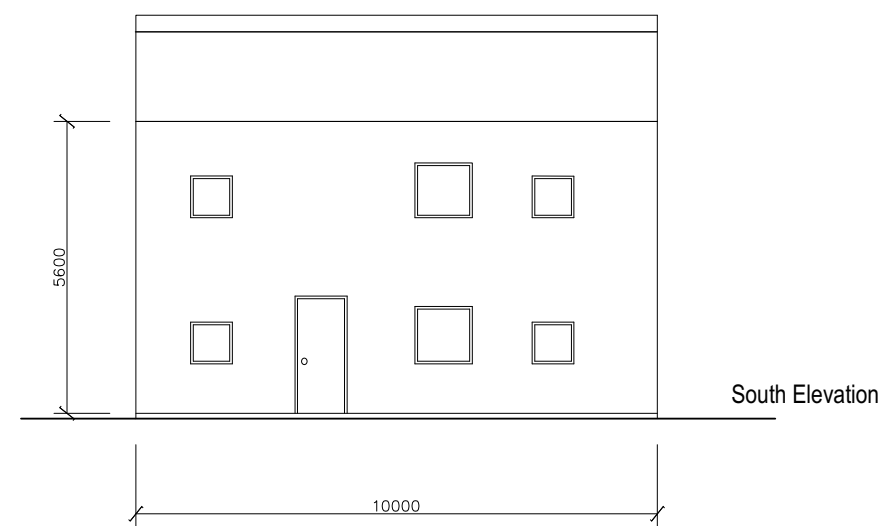
2800
2800
10000

North Elevation

South Elevation

5600
10000

South Elevation

West Elevation

7230

2500

1000

38°

East Elevation

SUMMER

SPRING /
AUTUMN

WINTER

76°

53°

30°

68°

SUMMER TILT
ANGLE FOR PV

HOT
WATER
CYLINDER

2800

2800

RAIN
WATER
TANK
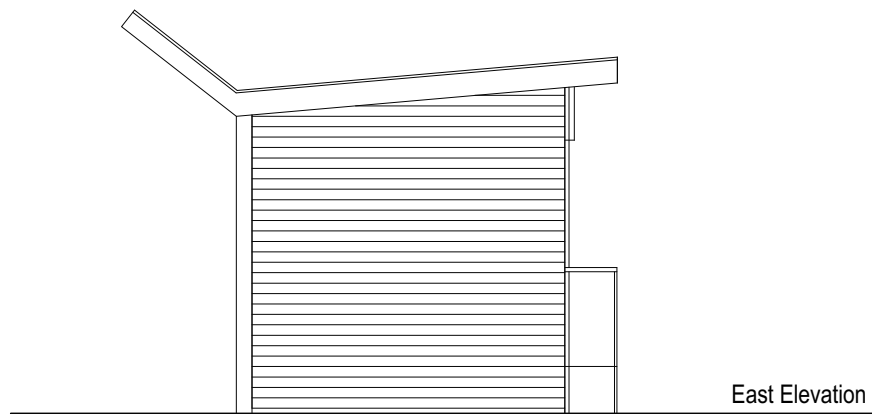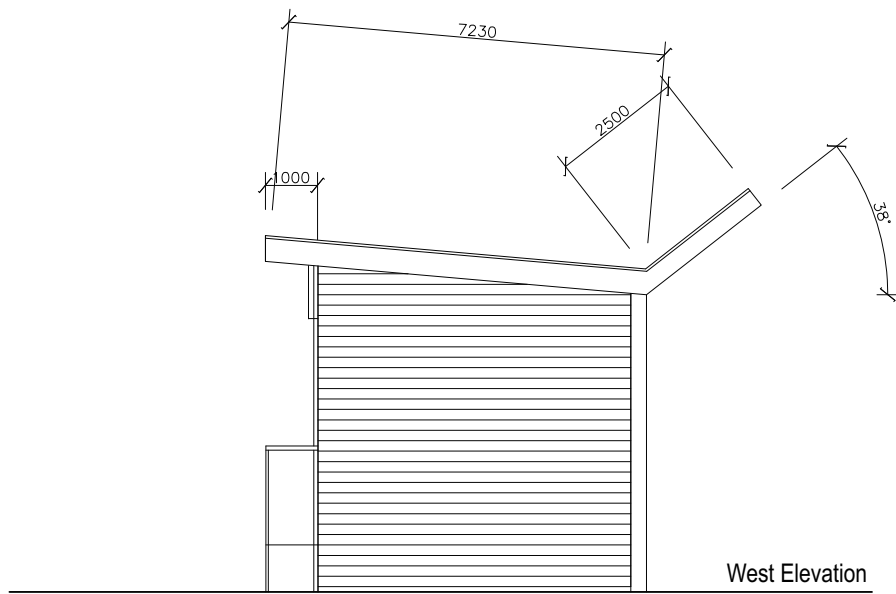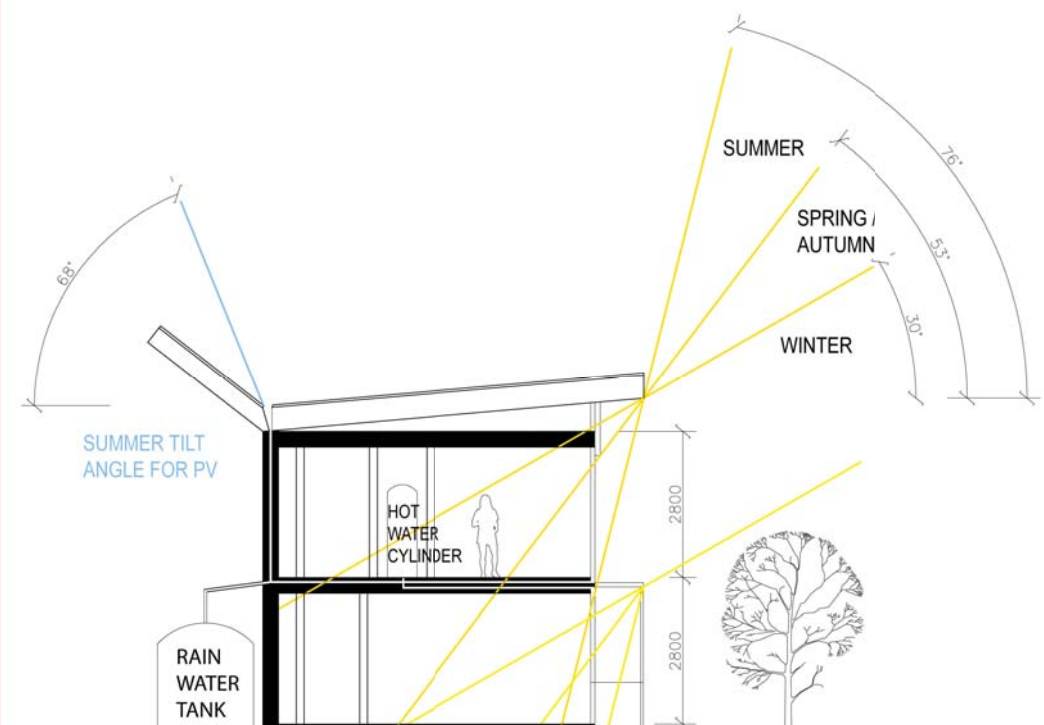
Design features include: (also applies to Queenstown House)

- Movable shades on the 1st level (bedrooms)
- Horizontal screens to block sun's ray in summer in first floor
- Pergola and deciduous trees to help shade from the sun in summer for ground level (living space)
- 'Butterfly roof' to maximize collection of rainwater and angled to capture maximum solar energy.
- No windows present on the East and West façade to allow future extensions and also minimize solar glare which is present during sunrise and sunset
- Very minimal and necessary windows on South façade
- Thermal mass (concrete) for floors
- Heavy solid construction in south wall to maximize structural strength (to support roof) and increase insulation (minimize heat loss through critical south façade)
- Vertically places solar hot water tubes that provides occupants with hot water and also provides shading to the bedroom behind (but allows light to pass through).
- 6m depth allows daylighting
- Windows present on the southern façade allows cross ventilation
- The hot water cylinder is placed close to the solar tubes to minimize heat loss through transfer.
- Repetition of services to ground and first floor (i.e. toilets) and placing of the "served" spaces (such as kitchen, laundry, bathroom – requires water) in southern end of the house for easy pipeworks.
- The presence of a pergola can be later converted to a conservatory.
- The large amount of glazing present on the northern end captures maximum sunlight which is desirable in winter.
- Metal roofing reflects the sun's ray to reduce overheating.
- Effective gutter system in order to maximize the capture of rainwater.

Structural Detail selected from options available in ALF

Ceiling
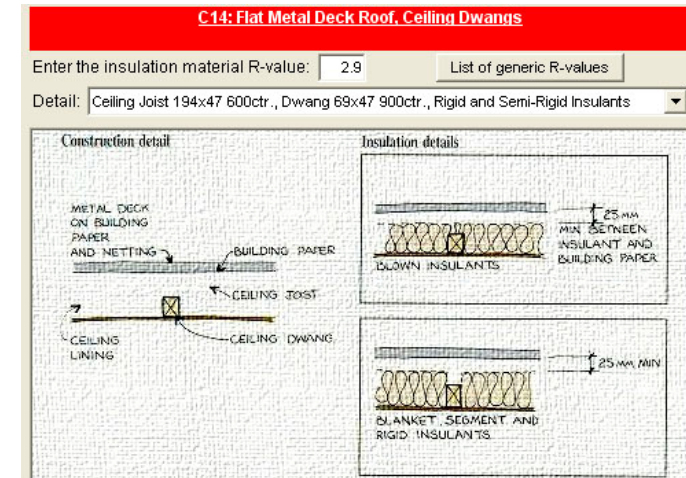
East and West Wall
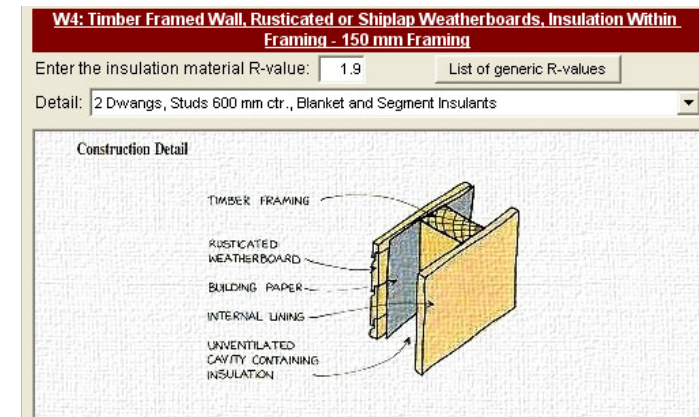
South Wall
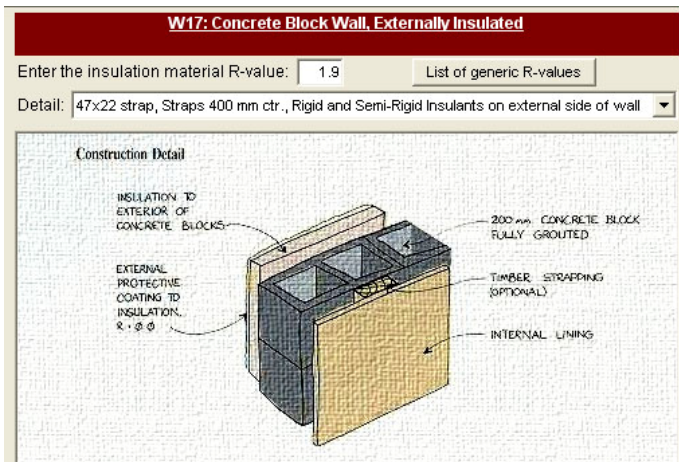
* Extra attention has been made to ensure that the insulation value does not exceed the specified dimensions of the detail.
In this case polystyrene/foam has been chosen as the insulation material for it has relatively higher R value compared to the other insulation materials.

Passive House for Queenstown

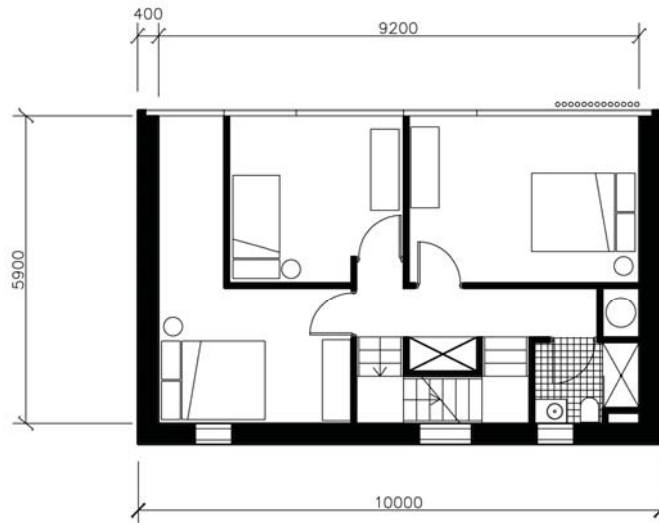## Differences from the Auckland House model/design:

- Thicker walls (Wall thickness are 400mm – Auckland is 150mm)
- Although misleading in the render shown above but Queenstown would need more PV panels than Auckland. (See solar panel research) and also the angle of butterfly roof is lower than Auckland.
- No presence of movable screens. (Queenstown is dependent on capturing solar energy for its heating. It is critical to maximize the sunshine intake)
- Thicker insulation – Bigger R value
- V.I.P (R=30) used on the southern side to minimize heat loss in order to retain reasonable wall thickness.

Vacuum Insulated Panels

A Vacuum Insulated Panel (VIP) uses the insulative effects of a vacuum to produce much higher insulative values than conventional insulation. Conventional insulation produces an R-value of 8 or less per inch (25.4mm) (fiberglass being towards the lower end and foam panels towards the higher end). VIPs are commonly as high as R-30 per inch, and have achieved commercially viable levels of R-50 per inch.[16]

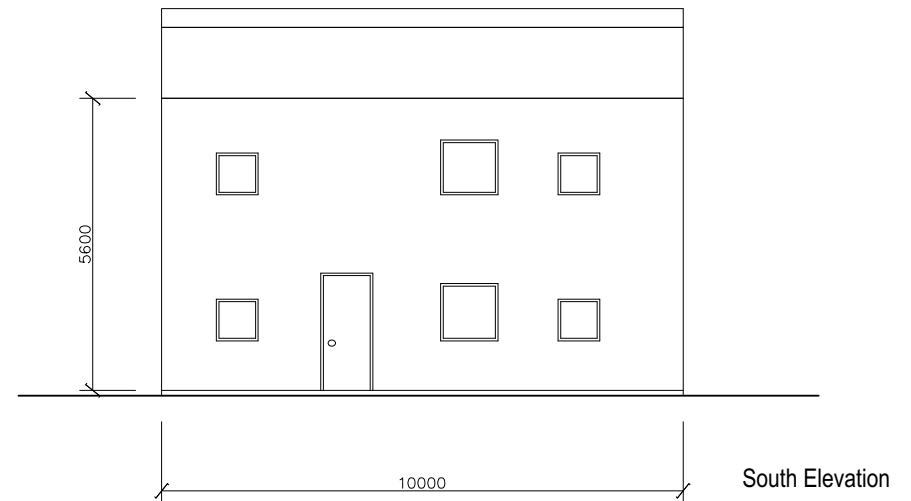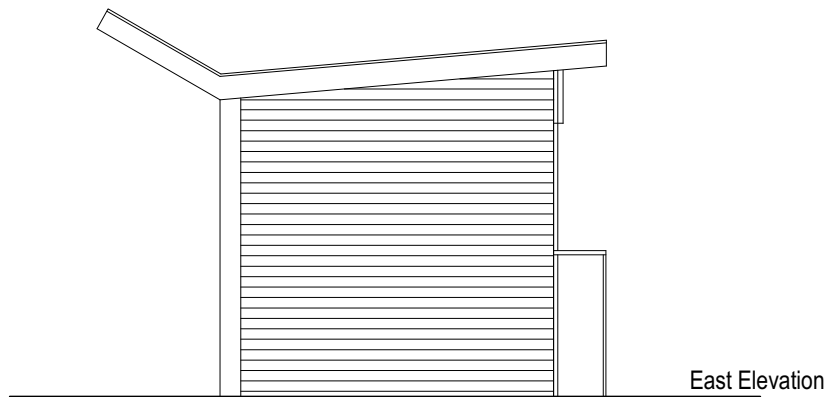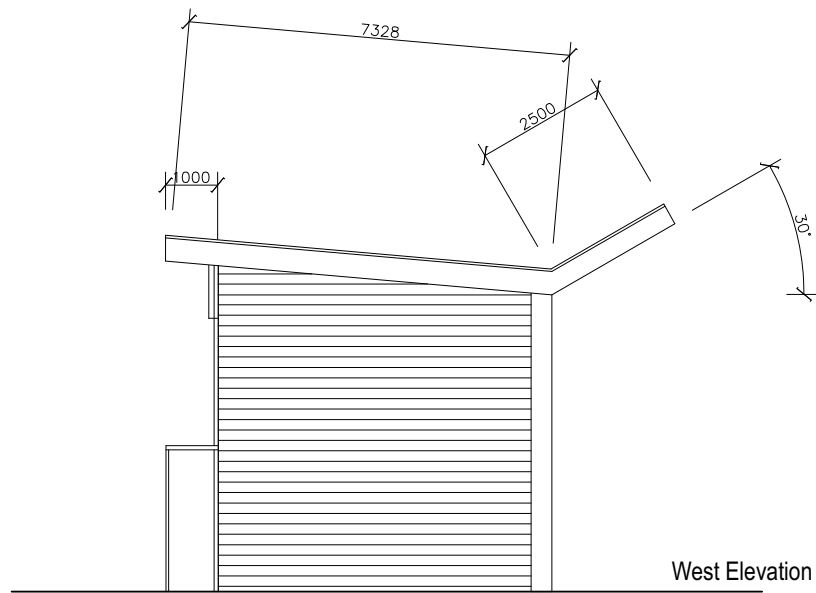[16] http://en.wikipedia.org/wiki/Vacuum_insulated_panel

First Floor

400
9200
5900
10000

Ground Floor

1000
5950
6000

North Elevation

2800
2800
10000

South Elevation

5600
10000

7328

2500

1000

30°
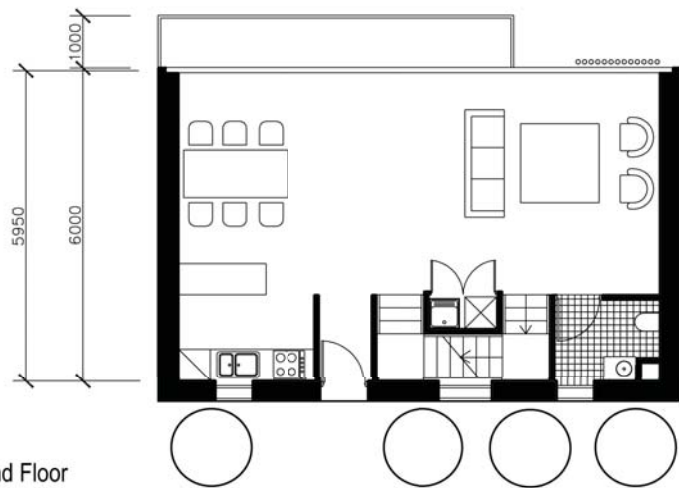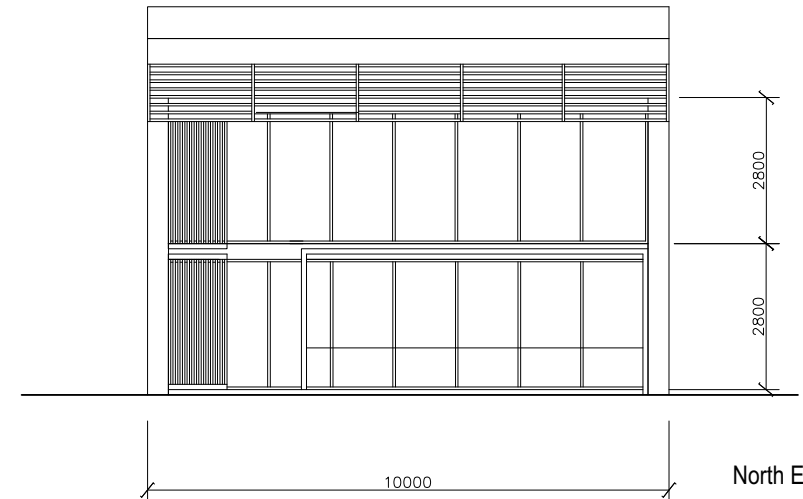
West Elevation

East Elevation

Queenstown House Elevations
1:100

70°

SUMMER

68°

SPRING / AUTUMN

45°

WINTER

22°

SUMMER TILT
ANGLE FOR PV

HOT
WATER
CYLINDER

2800

RAIN
WATER
TANK

2800
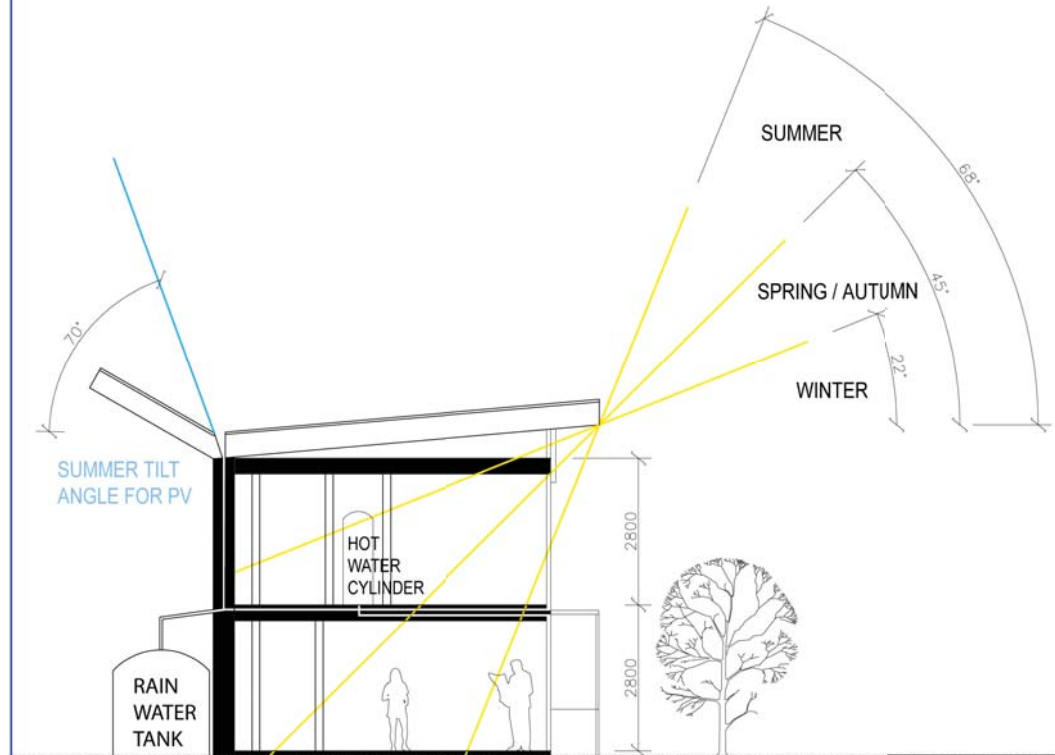
Queenstown House Section
1:100

Structural Detail selected from options available in ALF

Southern Wall (West and East are the same construction as Auckland House)

W18: Cavity Brick or Block Wall

Enter the insulation material R-value: 30   List of generic R-values

Detail: Cavity width depends on the thickness required by the insulant

Construction Detail

BRICK OR BLOCK
BLOCK
CEMENT PLASTER
CAVITY CONTAINING INSULATION
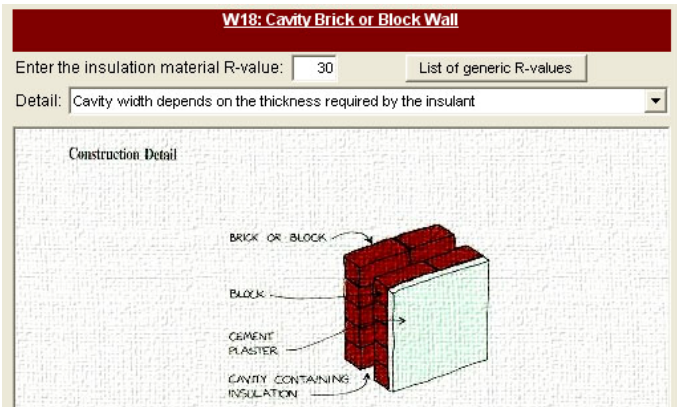
* Cavity containing insulation would be vacuum insulated panels (VIP) with R value of 30.
Also between the gaps there will be space for drainage that has captured the rainwater from the roof to the rainwater tank.

Roof

C13: Flat Metal Deck Roof, Ceiling Battens

Enter the insulation material R-value: 4.3   List of generic R-values

Detail: Ceiling Joist 194x47 600ctr., Batten 35x69 <600ctr., Blanket and Segment Insulants*

Construction detail

METAL DECK ON BUILDING PAPER AND NETTING
BUILDING PAPER
CEILING JOIST
CEILING LINING
CEILING BATTENS

Insulation details

25 MM MIN BETWEEN INSULANT AND BUILDING PAPER
BLOWN INSULANTS

25 MM MIN
BLANKET SEGMENT AND RIGID INSULANTS
•POSITIONED ON TOP OF CEILING BATTENS

* R value of 4.3 is the maximum allowed thickness for the allocated construction detail.

ALF Calculation Report – Auckland

NZ Building Code Compliance

In order to comply with the Energy Efficiency Clause H1 (2000) of the New Zealand Building Code a building has to have a BPI of less than 0.13 kWh/m²/Degree Days if it is in a warm location and less than 0.12 kWh/m²/Degree Days if it is in a cool location. Warm locations are locations with an average number of winter (May to August) degree days of less than 920. Cool locations are locations with 920 degree days or more. The currenly selected location (Auckland) is a warm location. The target BPI is therefore 0.13.

Alternatively, the building complies if it is built to NZS 4218:1996. This standard has three different methods to show compliance: the Schedule Method, the Calculation Method and the Modelling Method.

ALF checks the designed building for a BPI and for the NZS 4218:1996 Schedule and Calculation Methods.

The currently selected NZS 4218 target R-values are for a "non-solid construction".

The current design rates are:

BPI = 0.034	H1 pass
NZS 4218 (Schedule)	H1 pass
NZS 4218 (Calculation)	H1 pass

The current building design complies with Clause H1 of the NZBC because it complies with at least one of the H1 compliance methods. However, in order to comply with the NZBC it also has to comply with Clause E3 (Moisture) of the NZBC.

The acceptable solution of Clause E3 of the NZBC requires that R-values for walls, roofs and ceilings shall be no less than:

a) For light timber frame wall or other framed wall constructions with cavities, 1.5.
b) For single skin normal weight masonry based wall construction without a cavity, 0.6.
c) For solid timber wall systems no less than 60 mm thick, 0.6.
d) For roof and ceilings of any construction, 1.5.

Details of H1 Compliance

BPI   Maximum: 0.13   Achieved: 0.034

NZS 4218 (Schedule)

	Minimum	Minimum achieved	
Floor:	1.3	3.03	(excl. carpet)
Wall:	1.5	1.78	
Roof:	1.9	2.25	

NZS 4218 (Calculation)

Maximum acceptable heat loss: 441 W/°C
Achieved heat loss: 215 W/°C

For the individual components also applies that the average R-values must also be larger than 60% of those in the Schedule:

	Minimum	Average achieved	
Floor:	0.8	3.03	(excl. carpet)
Wall:	0.9	2.04	
Roof:	1.1	2.25	

Energy

This section gives you an overview of all the heat flows in and out of the designed building. It allows you to evaluate the importance of the thermal performance of individual building components - for example, of particular windows.

	Area m²	Loss kWh/yr	%	Gain kWh/yr	%	Net Gain kWh/yr
Slab Floor:	60.0m²	103	3.2%			
Wall A(E):	33.6m²	93	2.9%			
Wall B(W):	33.6m²	93	2.9%			
Wall C(S):	26.0m²	56	1.8%			
Window C0:	0.5m²	5	0.2%	13	0.3%	8
Window C1:	1.0m²	10	0.3%	26	0.6%	16
Window C2:	0.5m²	5	0.2%	13	0.3%	8
Wall D(N):	11.0m²	32	1.0%			
Window D0:	17.0m²	167	5.2%	1616	34.6%	1449
Wall E(N):	3.8m²	11	0.3%			
Window E0:	24.3m²	238	7.5%	2305	49.3%	2067
Wall F(S):	26.0m²	56	1.8%			
Window F0:	0.5m²	5	0.2%	13	0.3%	8
Window F1:	1.0m²	10	0.3%	26	0.6%	16
Window F2:	0.5m²	5	0.2%	13	0.3%	8
Roof A:	99.8m²	231	7.2%			
Air Leakage:	287.5m³	247	7.8%			
Warm-up:		1814	57.0%			
Internal Gain:		649	13.9%			
Total:		3180	100.0%	4672	100.0%	

Floor Loss:	103 kWh/year
Wall Loss:	342 kWh/year
Window Loss:	444 kWh/year
Roof Loss:	231 kWh/year
Air Leakage:	247 kWh/year
Warm-up:	1814 kWh/year
Total Load:	3180 kWh/year

Solar Gain:	4023 kWh/year
Internal Gain:	649 kWh/year (4 occupants)
Total Gain:	4672 kWh/year

Gain Load Ratio: 147%

Effective Thermal Mass Density (per m² total floor area):   3.03 W/m² °C
Specific Heat Loss Density (per m² total floor area):   2.3 W/m² °C
Usefulness of Gains: 61%
Useful Gains: 2863 kWh/year

Required Heating Energy: 317 kWh/year
PHASE TWO: Heat load <15KWh/m²/yr
                              = 115m² x 15 = 1725kWh

317< 1725 = PASSIVE HOUSE ACHIEVED

Economic Analysis

This section shows the results of the comparison between the current design and the base design.

Base Design: NZS 4218 (default)

Areas of floors, walls and roofs are the same as in the current building design.
Total window area as in the current design (including the skylights); however, one eighth of the total window area is facing each of the 8 major compass orientations (no skylights). The R-value is 0.19, the SHGC 0.83 (clear single glazing) and the Shading is 20%.
R-values: floors:R 3.03, walls:R 1.78 , roofs:R 2.25 and windows:R 0.2 (single glazed windows with aluminium frames).
Local Air Leakage Rate: 1ac/h.
Carpeted floors, external and internal walls: lightweight timber. Ceiling and furniture thermal mass as in the current design.
Internal gains as for the current design.
The same climate and heating conditions apply as in the current design.

Analysis period: 30 years
Average mortgage rate: 8 %
Modification cost between the base design and the current design: $0
Marginal heating energy cost: 9 c/kWh

Result:

The current design ('Design 1') uses 2149 kWh/year less heating energy than the base design ('NZS 4218 (default)'), and its cost over a lifetime of 30 years is $2991 less than the cost of the base design. This includes the cost of the modification to achieve the energy savings.
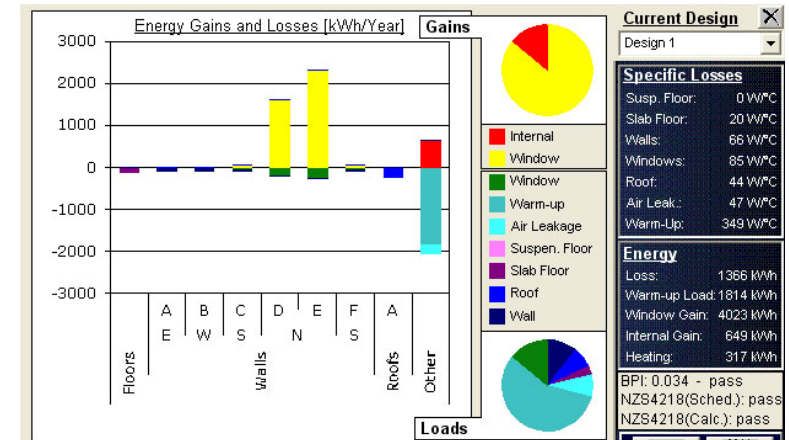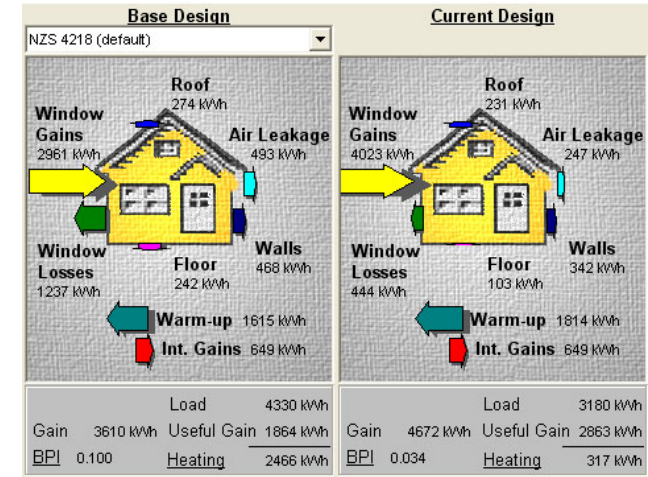
From the result I can conclude...

- Window gains a lot of solar heat and thermal mass absorbs a lot of the solar energy.
- Raising insulation in floor, roof and walls and airtightness minimized heat loss hence reduced heating energy demand.
- Concrete on slab is far better at retaining heat than suspended floor.
- Glazing on the Northern wall proved to be very advantageous.
- The internal heat gains (from people, lighting, cooking etc.) becomes critical to keep stable internal temp.

ALF Calculation Report - Queenstown

NZ Building Code Compliance

In order to comply with the Energy Efficiency Clause H1 (2000) of the New Zealand Building Code a building has to have a BPI of less than 0.13 kWh/m²/Degree Days if it is in a warm location and less than 0.12 kWh/m²/Degree Days if it is in a cool location. Warm locations are locations with an average number of winter (May to August) degree days of less than 920. Cool locations are locations with 920 degree days or more. The currenly selected location (Queenstown) is a cool location. The target BPI is therefore 0.12.

Alternatively, the building complies if it is built to NZS 4218:1996. This standard has three different methods to show compliance: the Schedule Method, the Calculation Method and the Modelling Method.

ALF checks the designed building for a BPI and for the NZS 4218:1996 Schedule and Calculation Methods.

The currently selected NZS 4218 target R-values are for a "non-solid construction".

The current design rates are:
BPI = 0.033		H1 pass
NZS 4218 (Schedule)		H1 pass
NZS 4218 (Calculation)		H1 pass

The current building design complies with Clause H1 of the NZBC because it complies with at least one of the H1 compliance methods. However, in order to comply with the NZBC it also has to comply with Clause E3 (Moisture) of the NZBC.

The acceptable solution of Clause E3 of the NZBC requires that R-values for walls, roofs and ceilings shall be no less than:

a) For light timber frame wall or other framed wall constructions with cavities, 1.5.
b) For single skin normal weight masonry based wall construction without a cavity, 0.6.
c) For solid timber wall systems no less than 60 mm thick, 0.6.
d) For roof and ceilings of any construction, 1.5.

Details of H1 Compliance

BPI   Maximum: 0.12   Achieved: 0.033

NZS 4218 (Schedule)

	Minimum	Minimum achieved	
Floor:	1.3	4.86	(excl. carpet)
Wall:	1.9	3.15	
Roof:	2.5	4.20	

NZS 4218 (Calculation)

Maximum acceptable heat loss: 433 W/°C
Achieved heat loss: 154 W/°C

For the individual components also applies that the average R-values must also be larger than 60% of those in the Schedule:

	Minimum	Average achieved	
Floor:	0.8	4.86	(excl. carpet)
Wall:	1.1	5.05	
Roof:	1.5	4.20	

Energy

This section gives you an overview of all the heat flows in and out of the designed building. It allows you to evaluate the importance of the thermal performance of individual building components - for example, of particular windows.

	Area	Loss		Gain		Net Gain
	m²	kWh/yr	%	kWh/yr	%	kWh/yr
Slab Floor:	60.0m²	185	1.9%			
Wall A(E):	33.6m²	187	2.0%			
Wall B(W):	33.6m²	187	2.0%			
Wall C(S):	26.0m²	16	0.2%			
Window C0:	0.5m²	17	0.2%	34	0.3%	17
Window C1:	1.0m²	34	0.4%	69	0.7%	35
Window C2:	0.5m²	17	0.2%	34	0.3%	17
Wall D(N):	5.0m²	29	0.3%			
Window D0:	23.0m²	785	8.2%	4024	41.1%	3239
Wall E(N):	5.0m²	29	0.3%			
Window E0:	23.0m²	785	8.2%	4024	41.1%	3239
Wall F(S):	26.0m²	16	0.2%			
Window F0:	0.5m²	17	0.2%	34	0.3%	17
Window F1:	1.0m²	34	0.4%	69	0.7%	35
Window F2:	0.5m²	17	0.2%	34	0.3%	17
Roof A:	99.8m²	430	4.5%			
Air Leakage:	272.5m³	814	8.5%			
Warm-up:		5986	62.5%			
Internal Gain:				1467	15.0%	
Total:		9584	100.0%	9789	100.0%	

Floor Loss:	185 kWh/year
Wall Loss:	463 kWh/year
Window Loss:	1706 kWh/year
Roof Loss:	430 kWh/year
Air Leakage:	814 kWh/year
Warm-up:	5986 kWh/year
Total Load:	9584 kWh/year

Solar Gain:	8322 kWh/year
Internal Gain:	1467 kWh/year (4 occupants)
Total Gain:	9789 kWh/year

Gain Load Ratio: 102%

Effective Thermal Mass Density (per m² total floor area):   3.03 W/m² °C
Specific Heat Loss Density (per m² total floor area):   1.8 W/m² °C
Usefulness of Gains: 82%
Useful Gains: 7985 kWh/year

Required Heating Energy: 1599 kWh/year
PHASE TWO: Heat load <15kWh/m²/yr
                    = 109m² x 15 = 1635kWh

        1599<1635 = PASSIVE HOUSE ACHIEVED

Economic Analysis

This section shows the results of the comparison between the current design and the base design.

Base Design: NZS 4218 (default)

Areas of floors, walls and roofs are the same as in the current building design.
Total window area as in the current design (including the skylights); however, one eighth of the total window area is facing each of the 8 major compass orientations (no skylights). The R-value is 0.19, the SHGC 0.83 (clear single glazing) and the Shading is 20%.
R-values: floors:R 4.86, walls:R 3.15 , roofs:R 4.20 and windows:R 0.2 (single glazed windows with aluminium frames).
Local Air Leakage Rate: 1ac/h.
Carpeted floors, external and internal walls: lightweight timber. Ceiling and furniture thermal mass as in the current design.
Internal gains as for the current design.
The same climate and heating conditions apply as in the current design.
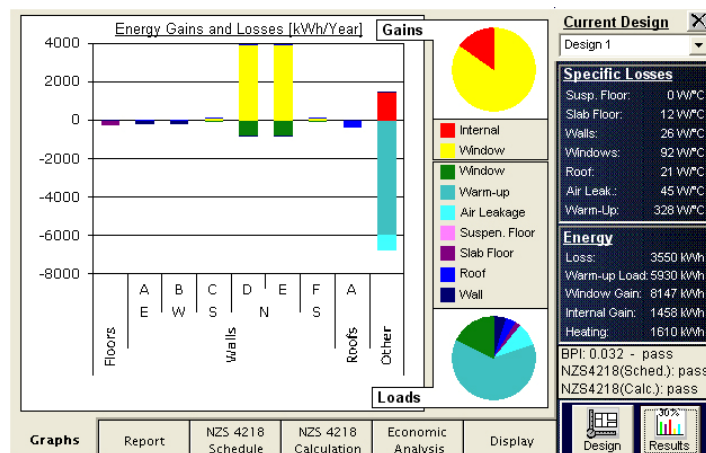
Analysis period: 30 years
Average mortgage rate: 8 %
Modification cost between the base design and the current design: $0
Marginal heating energy cost: 9 c/kWh

Result:

The current design ('Design 1') uses 8090 kWh/year less heating energy than the base design ('NZS 4218 (default)'), and its cost over a lifetime of 30 years is $11256 less than the cost of the base design. This includes the cost of the modification to achieve the energy savings.

From the result I can conclude… (Other than mentioned in Auckland report)

- Window gains a lot of solar heat and thermal mass absorbs a lot of the solar energy. Minimizing heat loss through glazing is critical for colder conditions.
- Glazing on the Northern wall proved to be very advantageous. – For Queenstown this is especially important for passive solar house to retain maximum the solar energy present during the day and store as thermal mass to be re-radiated at night.
- Maximize and store solar energy VS Minimize heat loss
- Using VIP to increase R value without drastically increasing thickness

Comparison

Despite the higher/thicker insulation, (thicker walls mean smaller sq. meter) more northern glazing, Queenstown still requires 1600kWh of energy per year. This can easily be supplemented by a PV panel, but idealistically it won't function as 100% passive house. On the other hand, Auckland has managed to reduce its heating load by 317kWh/yr. This load is so minimal it is almost dismissed. To get an equivalent heating load of around 1600kWh/yr like Queenstown, Auckland can increase their heating temperature by 20 degrees and schedule to all day heating.

Due to the significant amount of heat being lost through the glazing it is perhaps desirable to resort to higher efficiency such as triple glazing. This will decrease the heating load.

For the Auckland House, insulation values has been increased (more than the NZBC standard), by less than x2 of the minimum R values. It has almost achieved to be a passive house. It has proven that just by increasing insulation and using double glazing with protective coating, and airtightness is the only action required to drastically reduce the heat load.

Queenstown is much trickier case, with a consideration of super insulation (or V.I.P as mentioned above) and triple glazing (or even using new technological inventions such as GlassX – www.glassx.ch) to achieve the passive house standard. Compared to European countries with a similar climate, Queenstown does have higher annual sunshine hours and this can be utilized to provide passive heating through the use of thermal mass.
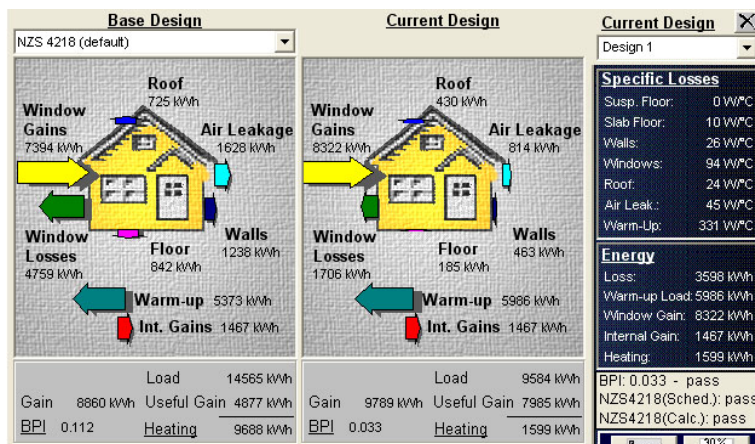
Conclusion

Limitations of ALF

Due to the nature of the program there were several limitations which prevented the full advancement of exploring different possibilities of designing a passive house in Auckland and Queenstown.

1) Custom materials were difficult to add: i.e. exact values need to be known. There is a limited range of standard construction materials. It doesn't consider the new technological inventions. (such as V.I.P)
2) It is unclear as to how much insulation could be added in a given construction details of a specific dimension. There is no ways of changing the thickness of the construction detail given in the program.
3) Due to the program being calculative in nature, 3D consideration is absent. It cannot cater for organic designs, out-of-the-ordinary details or joinery. (i.e. Green roof, Glass X etc…)
4) It is also unclear as to how the thermal performance is calculated between the different levels.
5) It is not very accurate. Many broad assumptions are made. (i.e. doesn't take into account site specific factors)
6) It is not client-friendly. It needs to consider a visual language to communicate the results.
7) It cannot add interior thermal walls. The distinction between interior and exterior is unclear.
8) It doesn't indicate overheating due to lack of solar shading. It also doesn't consider the solar shading as a component in the calculation.
9) The thermal distribution is unclear. The importance of radiant temp with less vertical temp gradient in a space is unknown.

Reformation of the current NZBC

Through this analysis, it is clear that through simple implementation, great energy savings can be made. (Not just in terms of electricity but also water). As the energy demand increases and the production decreases, it is critical to implement regulations and rules to encourage more self-sufficient housing. Through the use of passive design techniques and utilization of renewable technology, more energy efficient, sustainable houses can be designed and built to improve the current New Zealand houses that are inefficient, cold, damp and moldy. The program ALF should also be revised to integrate "smarter" materials and also encourage more "freedom" in the design. This as a result will ultimately help the current practicing architects to design better houses and in turn improve the quality of New Zealand homes, keeping in mind the cost issues.

References

All the facts, stats based on New Zealand/Australian figures not overseas to enhance credibility and relevance of the data.

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