Retrofit alternatives for State Houses in Cold Regions of New Zealand

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Funded by
FRST

UNIVERSITY of OTAGO
SAPERE AUDE
Te Whare Wānanga o Otāgo

A research project by
the Energy Management Group
Physics Department - University of Otago
Dunedin - September 2007

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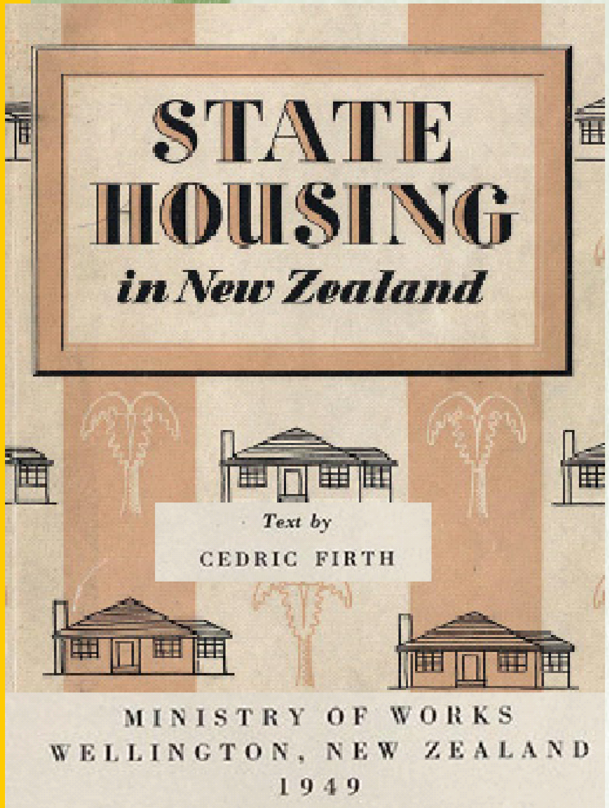
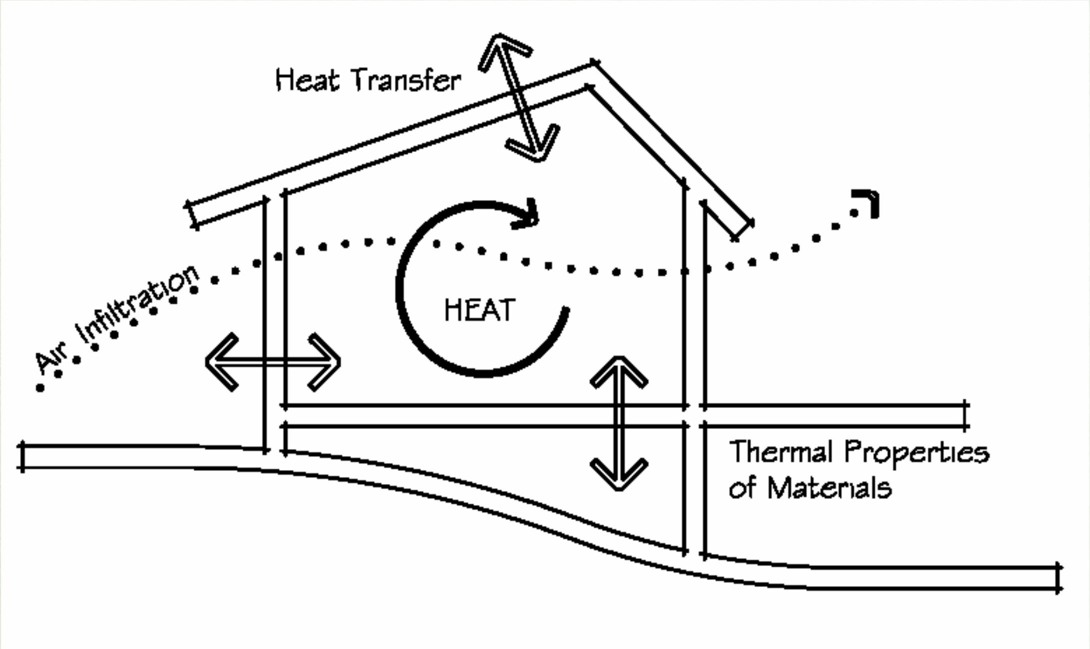
State housing in NZ



"The adequate provision of good housing is regarded as one of NZs most urgent problems. But it should be emphasised good housing does not mean merely houses that are well constructed. They must be well designed for sun and light and air."

Aims



Stage 1

Investigate the efficacy of the HNZC standard energy efficiency upgrade package for the residential sector in southern NZ .

MENU

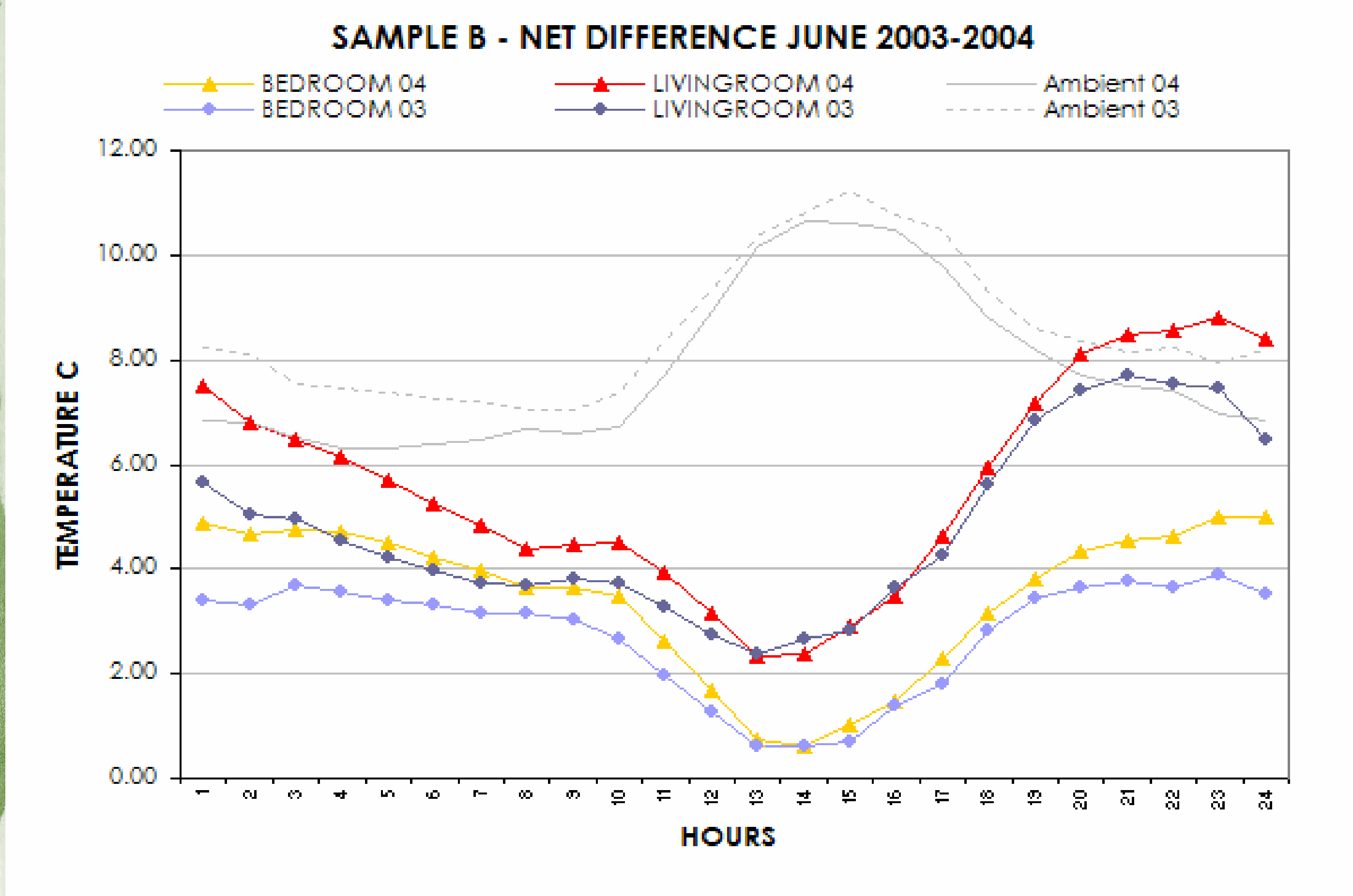
- **Stage 1** Introduction : Bob Lloyd

- **Stage 2** The next step in upgrade options:
  - The research agenda
    Maria Callau
  - Testing & Modelling Results
    Tim Bishop
  - Conclusions and a new modelling package
    HOMES
    Bob Lloyd

Process

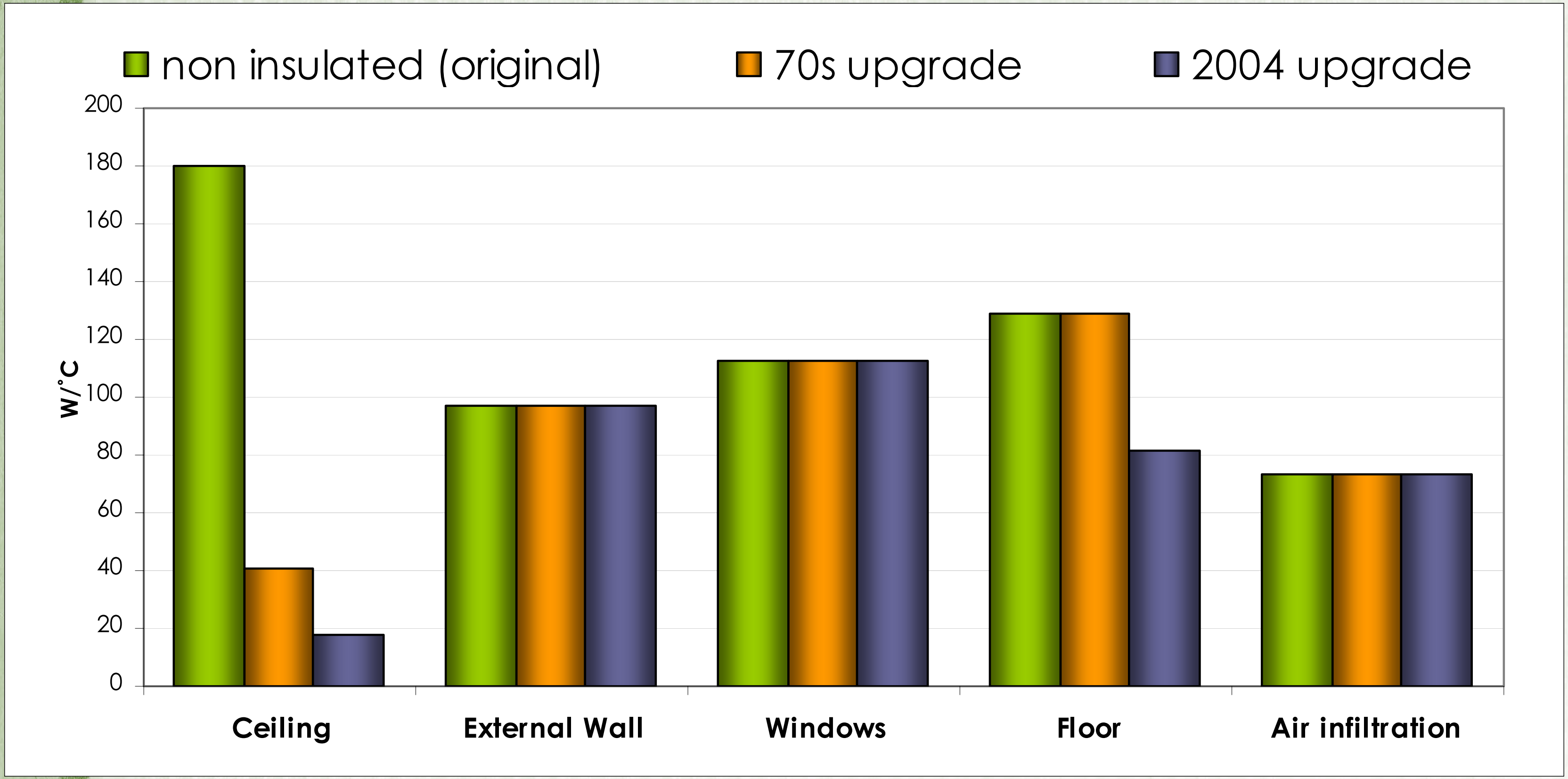
- **Objective**
  - To identify improvements in houses participating in the Energy Efficient Upgrade Programme in southern New Zealand regions.
- **Upgrade Programme**
  - Started in 2002 /Ongoing for 7 years
  - 400 pre 1978 houses per year in southland
  - Focus on the weatherization of the building envelope:
    - FLOOR and CEILING insulation
    - Draughts stopping
    - Insulating the hot water cylinders
  - All houses had been retrofitted with ceiling insulation during'70s (Macerated Paper)
- **Two Samples of 50 houses each were monitored over 2 years period while the programme was being implemented.**

Net Temp Differences - June



- Higher net differences were achieved in living areas after heating was applied to this houses after upgraded
- 5% improvement in the number of hours above 12°C in June

Heat losses through the building envelope



- **Small reduction in % Ceiling losses after last upgrade**

Findings

- **Temperatures**
  - Low indoor temperatures predominated in winter… <12°C for 48% of the time during winter
  - Minimum temperatures between 5 and 5.4°C (sample averages)
  - Some improvement was found in net temperature difference after heating is applied (0.4°C whole year & 0.6°C over winter months).

Findings of first stage

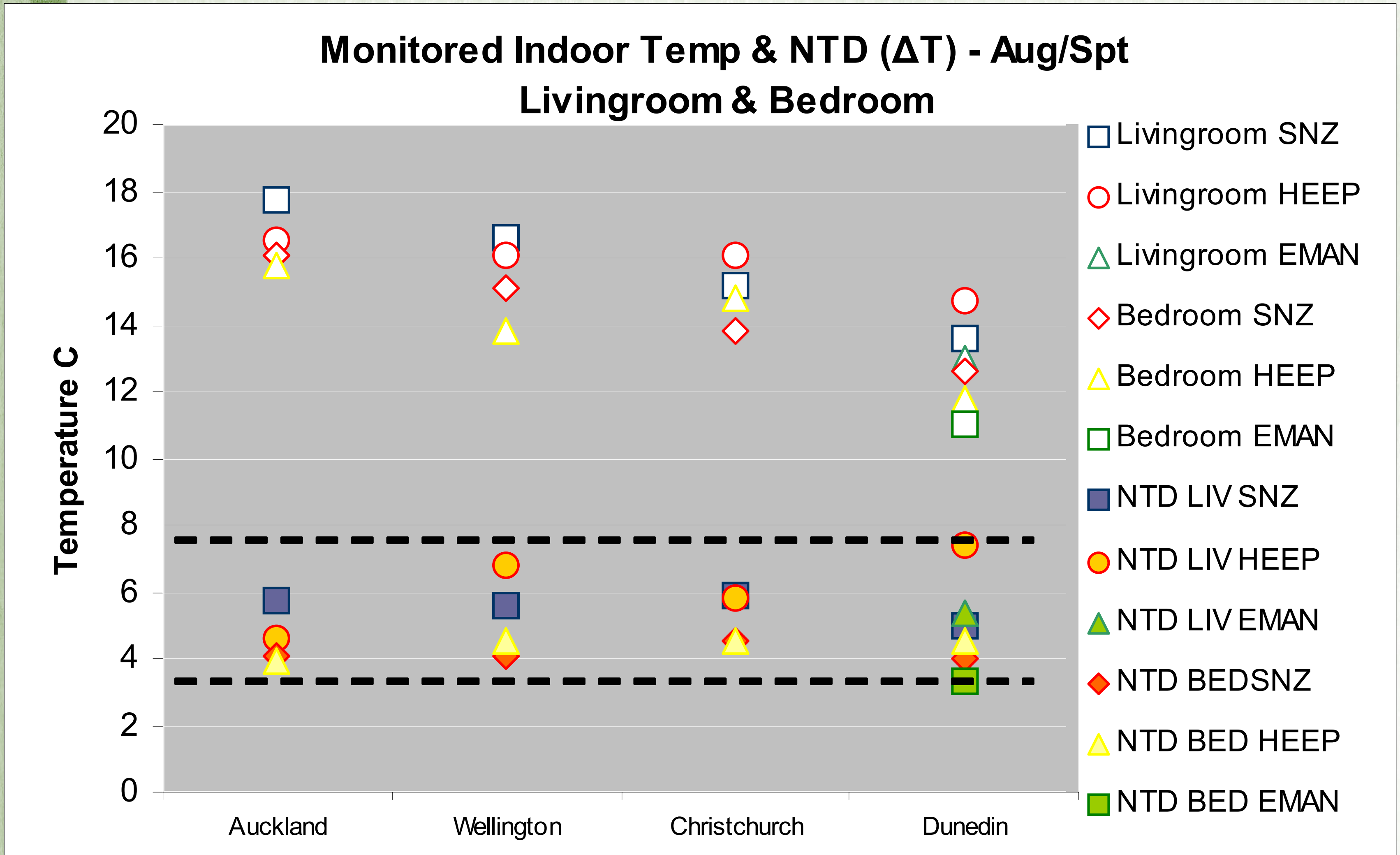
- **Energy Use for Space Heating**
  - Little energy was applied for space heating
  - The occupants tended not to heat the entire house
  - A small reduction in energy consumption was apparent after the upgrade (7%)
  - High losses occurred through uninsulated walls and single glazed windows

Findings of first stage

The HNZC upgrade programme in Dunedin failed to make houses sufficiently warm to satisfy WHO recommendations

- **Reasons were found to be:**
  - The impact of an earlier 70's retrofit did not seem to be taken into account
  - High losses occur through uninsulated walls and single glazing windows.
  - People don't heat enough

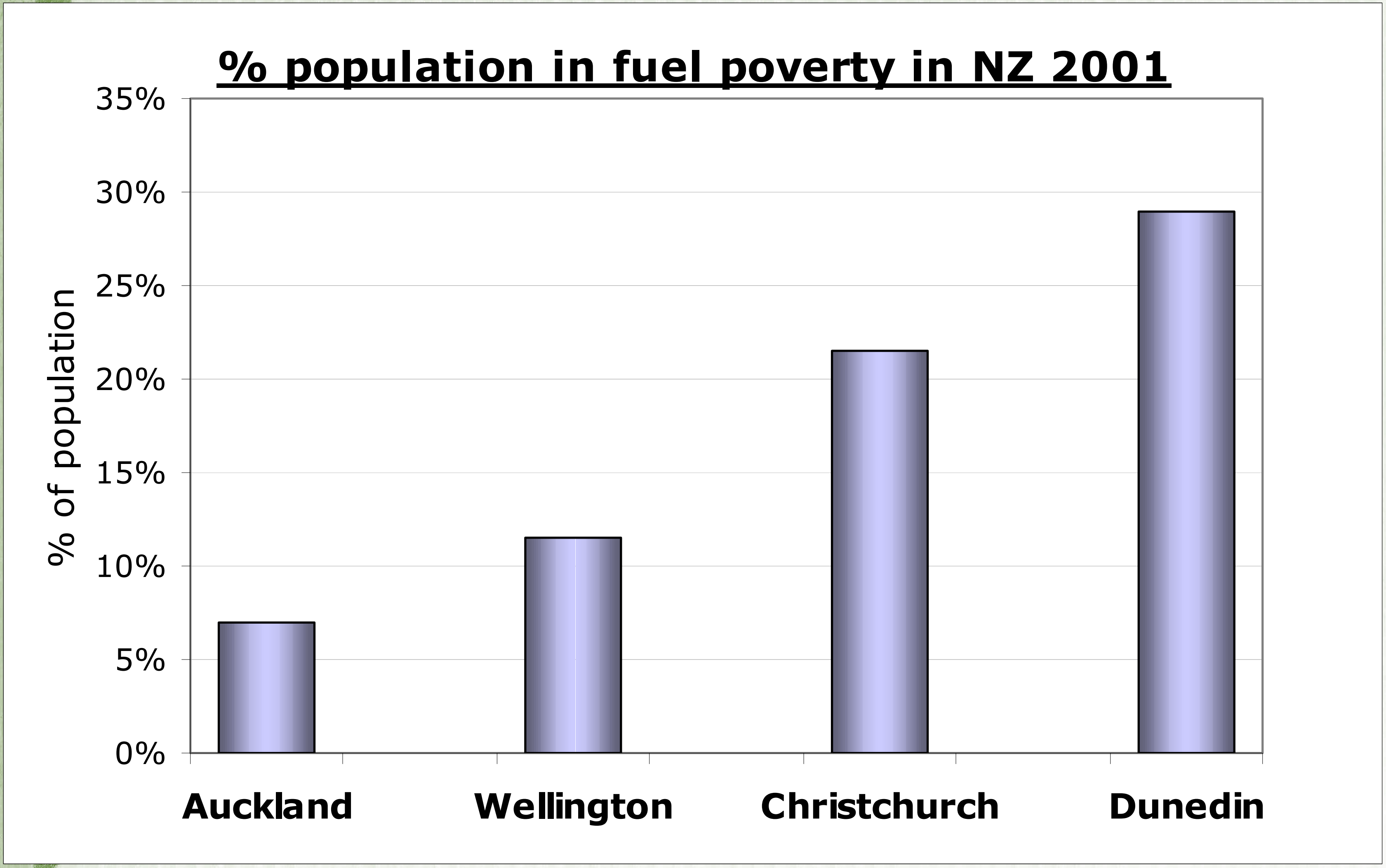
Comparison with other studies



Fuel Poverty

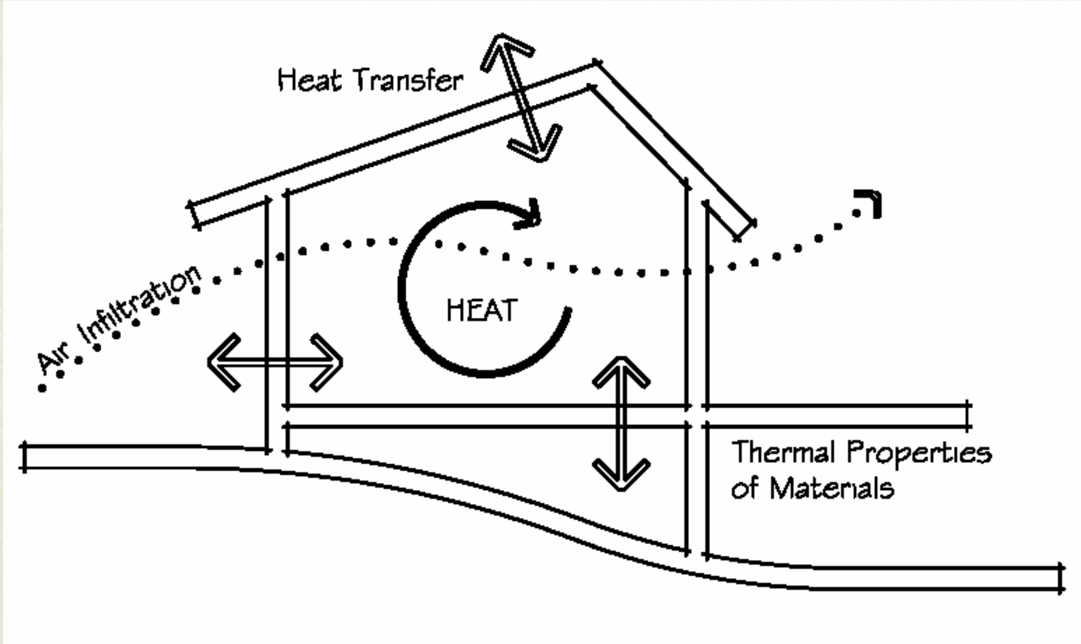
- Household fuel poverty is currently defined in Britain (DEFRA 2003) as the NEED to spend more than 10 per cent of annual household income on ALL household fuel use.
- The heating fuel component of the household fuel use should be sufficient to enable the home to achieve a satisfactory heating regime.
- The UK definition assumes that a satisfactory heating regime is one where the main living area is at 21°C, with 18°C in other occupied rooms.
- It is assumed that heating is available for 16 hours per day for households likely to have occupants home all day, and 9 hours per day for households in work or full time education.

NZ situation in 2001



Urgency of improving the efficiency of NZ housing stock

- *Alleviating fuel poverty* is as priority in NZ,
- The incidence of fuel poverty and low indoor temperatures are directly related to average ambient
- Thus in the cooler parts of the south island we need to go to the next step in terms of energy efficient housing
  - Stage 2
  - **Explore ways to improve the energy efficiency of existing state housing stock.**



Aims

Stage 2:

Explore and implement energy efficiency retrofit options which would help to achieve WHO recommended indoor temperatures for the residential sector in southern NZ .

Stage 2: The research agenda
Maria Callau

I will talk about

- Background
  - Achieving healthy indoor temperatures
  - Heat flow mechanisms
  - R values (elements & houses)
- Our analysis
  - Calculation
  - Testing → heat loss & resistance
  - Modeling → annual heating energy requirements
- Houses description
- Results of calculation of heat loss

Improving the efficiency of existing housing

- The energy efficiency of existing housing can be raised by:
  - Improving the building fabric performance,
  - Improving the heating system efficiency
  - Increasing the solar gains into the house
  - Using high efficiency appliances,
  - Educating occupants on optimal behaviour for energy efficiency.

Modeling
Testing

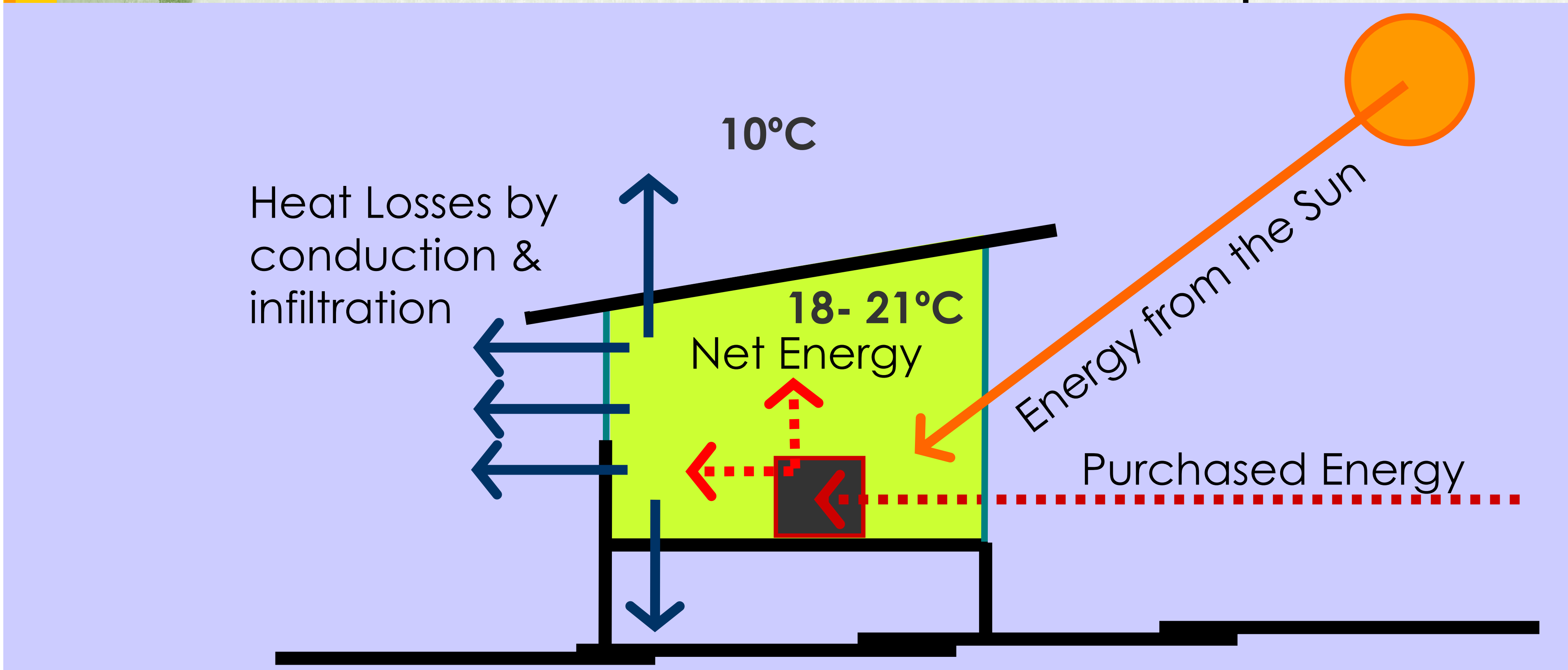
Modeling

Further research

Our research

- We decided to **investigate options** to provide alternative solutions.
- We "borrowed" 2 houses from HNZC for detailed modelling and testing.
- **Houses were upgraded** and monitored to identify the increase in the thermal resistance of the building envelope at each stage.
- We produced models including a computer program *HOMES* based on BRANZ's *ALF3* and NREL's *HOMER* and a spreadsheet based lifecycle analysis also using ALF3.

Keeping houses in cold climates at a comfortable temperature



- The Temperature inside is the result of the balance of heat gains and losses.
- To achieve comfort we need to control this balance.
- Heat losses (w/K): **heating power that must be added continuously to the house to maintain each degree of temperature above ambient.**

Heat transfer mechanisms

- Heat flows from hot to cold
- it can occur through:
  - **Conduction**
    - Heat transfer through bulk material
  - **Convection**
    - Heat transfer by circulation of fluids or gases (air)
    - it can be natural or forced
  - **Radiation**
    - Heat transfer through a transparent medium as electromagnetic radiation (e.g. Solar radiation into the house).
  - **Mass transfer**
    - Heat transfer by bulk materials moving (e.g. air ingress)

Thermal Properties of Materials

- All building materials have **thermal properties**:

Thermal Conductivity (k) = $Wm^{-1}K^{-1}$

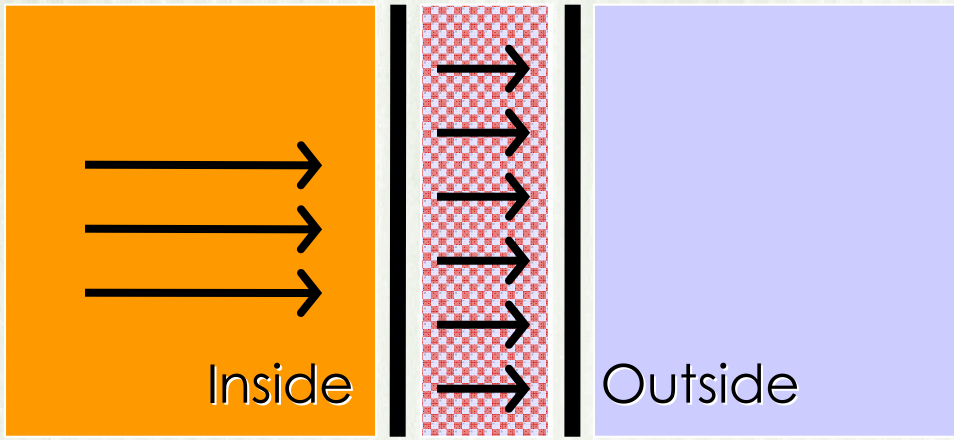
- Elements of the building envelope provide certain resistance to heat transfer per metre of **thickness.**

R Value = m^2K/W

  - The higher the R value the better the insulation
  - R values combine conduction, convection and radiation effects together
  - R values range from 0.15 for an single glazed window to 5.0 for 200 mm of fibre batts

Insulation

- In a cavity wall: Heat will be transferred by conduction through the solid elements and convection and radiation through the air spaces:
  - Still air has poor conductivity
  - But air gaps have high heat transfer due to convection and radiation



- <u>Bulk Insulation:</u> provides small enclosed air pockets which reduce convective heat transfer.

Insulation

- In a cavity wall: Heat will be transferred by conduction through the solid elements and convection and radiation through the air spaces:
  - Still air has poor conductivity
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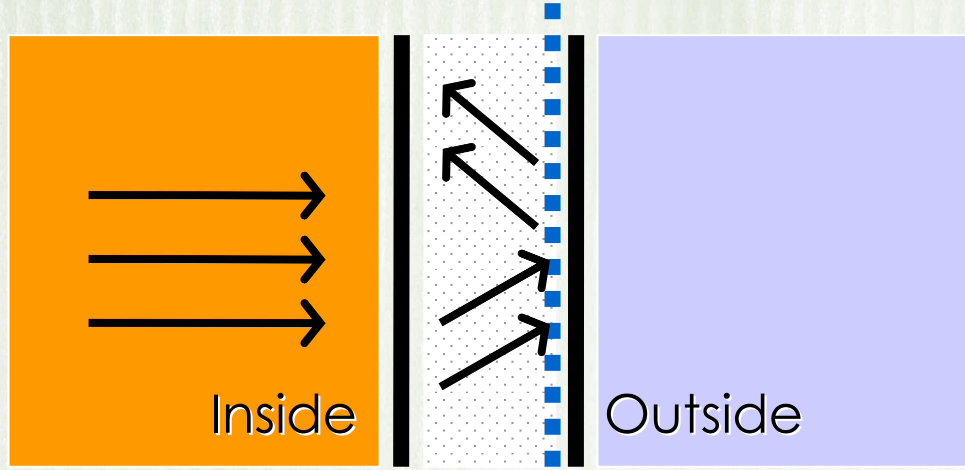
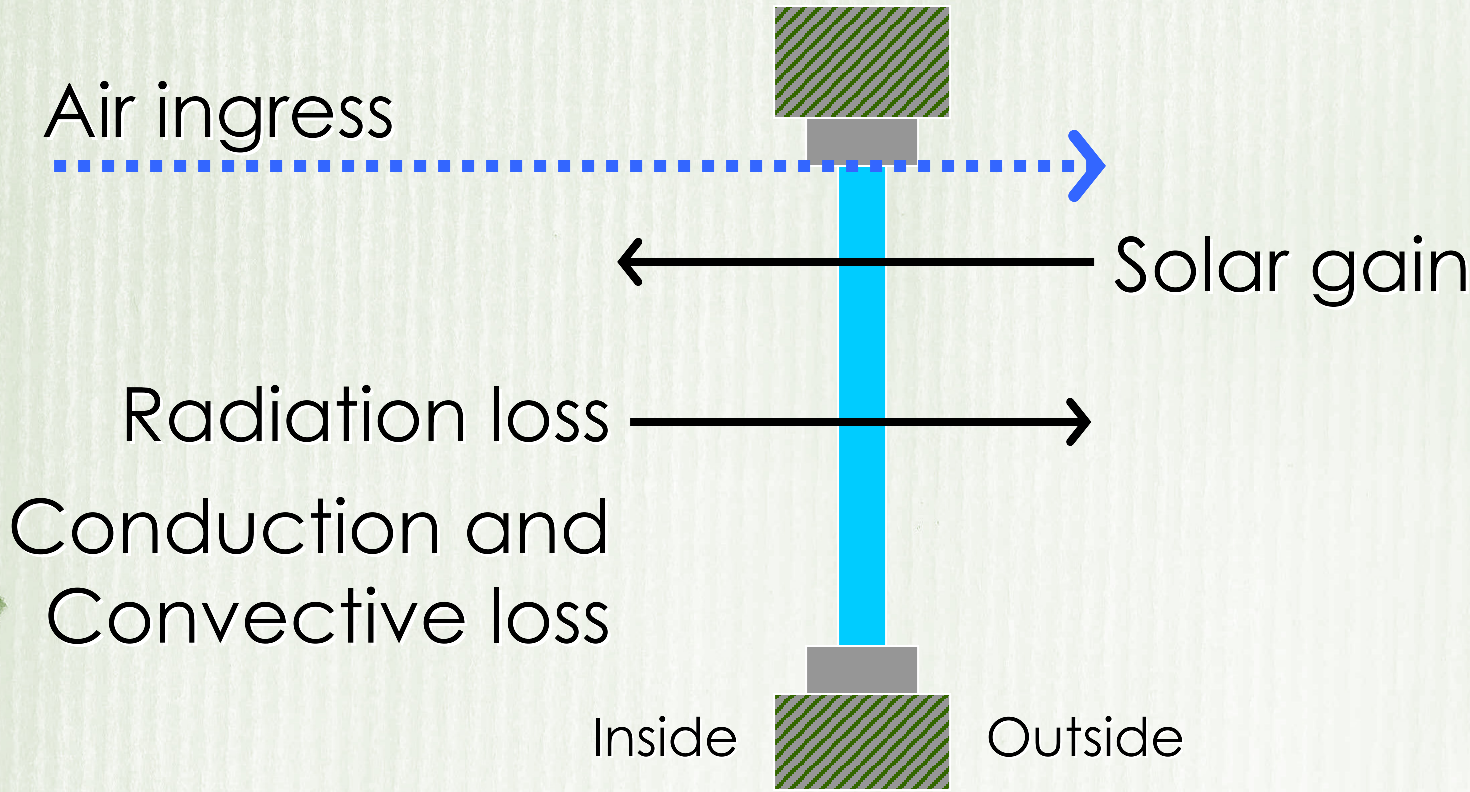


- <u>Reflective foil Insulation:</u> Provides a low emissivity surface which reduces radiation transfer.
- R value for uninsulated brick or timber walls are around 0.4-0.6

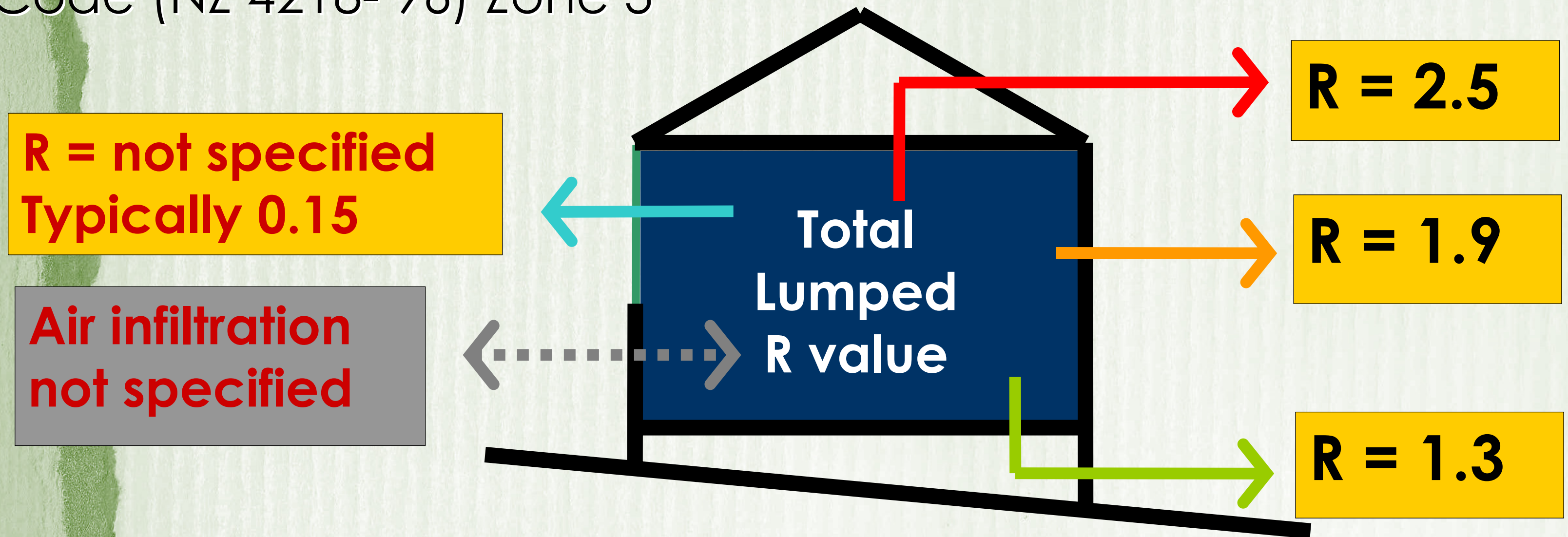
The windows are the weak link in terms of thermal loss in a building



R values for single glazed windows are low: around 0.15

From R values for elements to heat loss and total R value of a house

- Code (NZ 4218- 96) Zone 3



$$\text{Total Heat Loss} = HL_{Win} + HL_{Walls} + HL_{C} + HL_{F} + HL_{Air}$$

$HL = Area/R$

Large Area or Small R value → High Heat Losses

Total Lumped R value = Total Area / Total Heat Loss

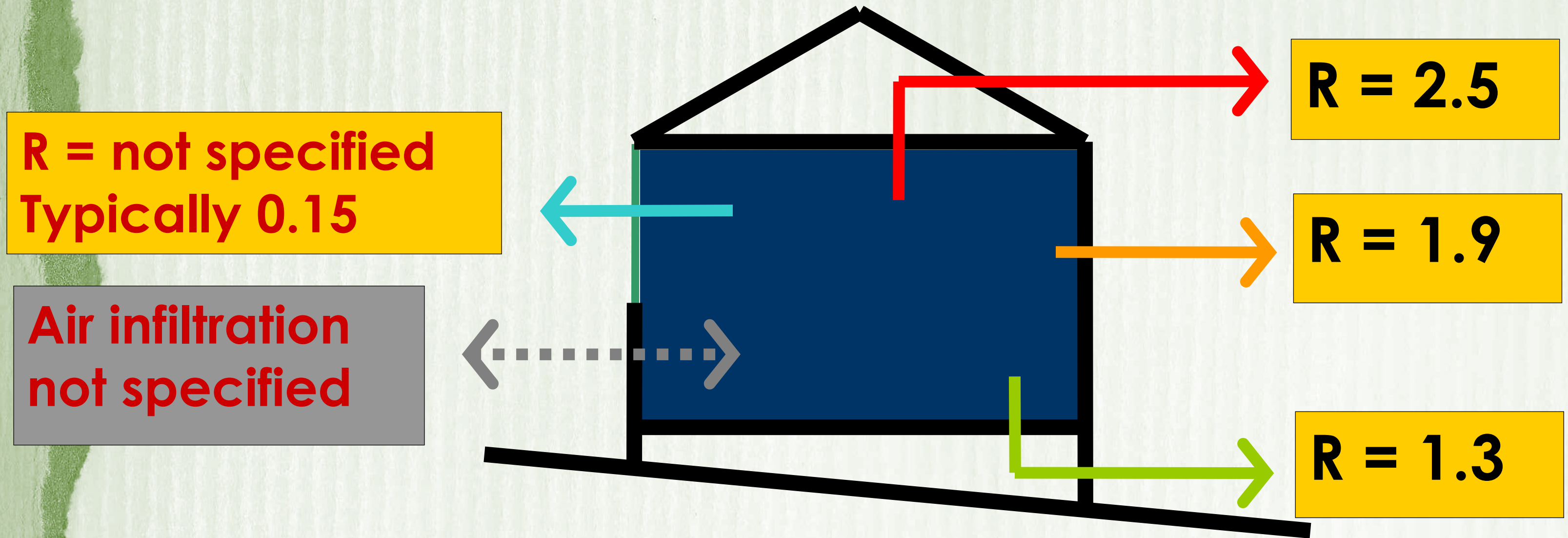
Some typical R values for elements

- R values
  - Brick walls with no insulation 0.4-0.6
  - Weather board with no insulation 0.4-0.6
  - Single glazed windows 0.15
  - Un insulated timber floor 0.4-0.5

  - Insulated walls 2.0-3.0
  - Well insulated Roof 3.0-4.0
  - Double glazed window 0.26
  - Curtains w pelmets 0.2-0.3

Lumped R value for a Dunedin State House built to code

- Code (NZ 4218- 96) Zone 3



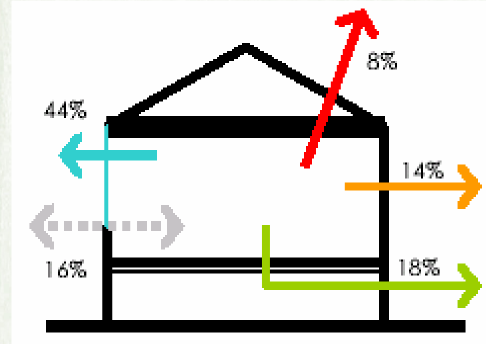
Total Lumped R value **= 0.7 - 0.8 m^2K/W**

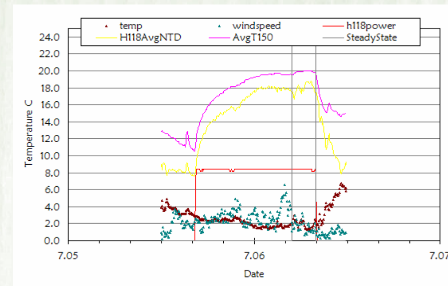
Exploring some heat loss retrofits

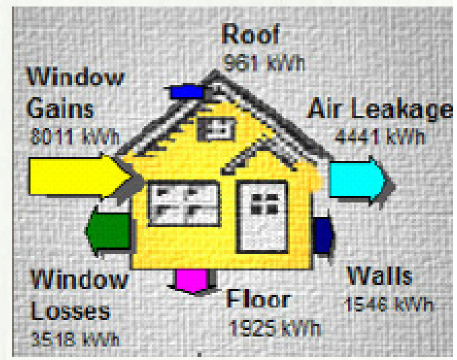
- To gain practical experience we tried several heat loss reduction retrofits and compared calculated and tested performance:
  - insulation
  - windows

Our process

- We explored retrofits options to **reduce heat loss**:
  - Calculate
  - Test
- Modelled the effect of different **heating systems** and heat loss reductions:
  - Annual heating Energy Requirements,
  - Fuel Cost and
  - CO_2 emissions
- We proceeded with a **cost-benefit analysis**.
- An upgrade path was finally suggested.







The Houses: The area

- Houses were located in Brockville (built by HNZC)
- Good sun
- Great exposure to the wind

- Today Brockville is a combination of State Houses and private owned ones, some of which have been renovated.

House 1: 118 Cockerell St.

- Masonry veneer house:
  - concrete block
  - single glazed wooden frame
  - tiled roof
- Multi fuel burner in the living area

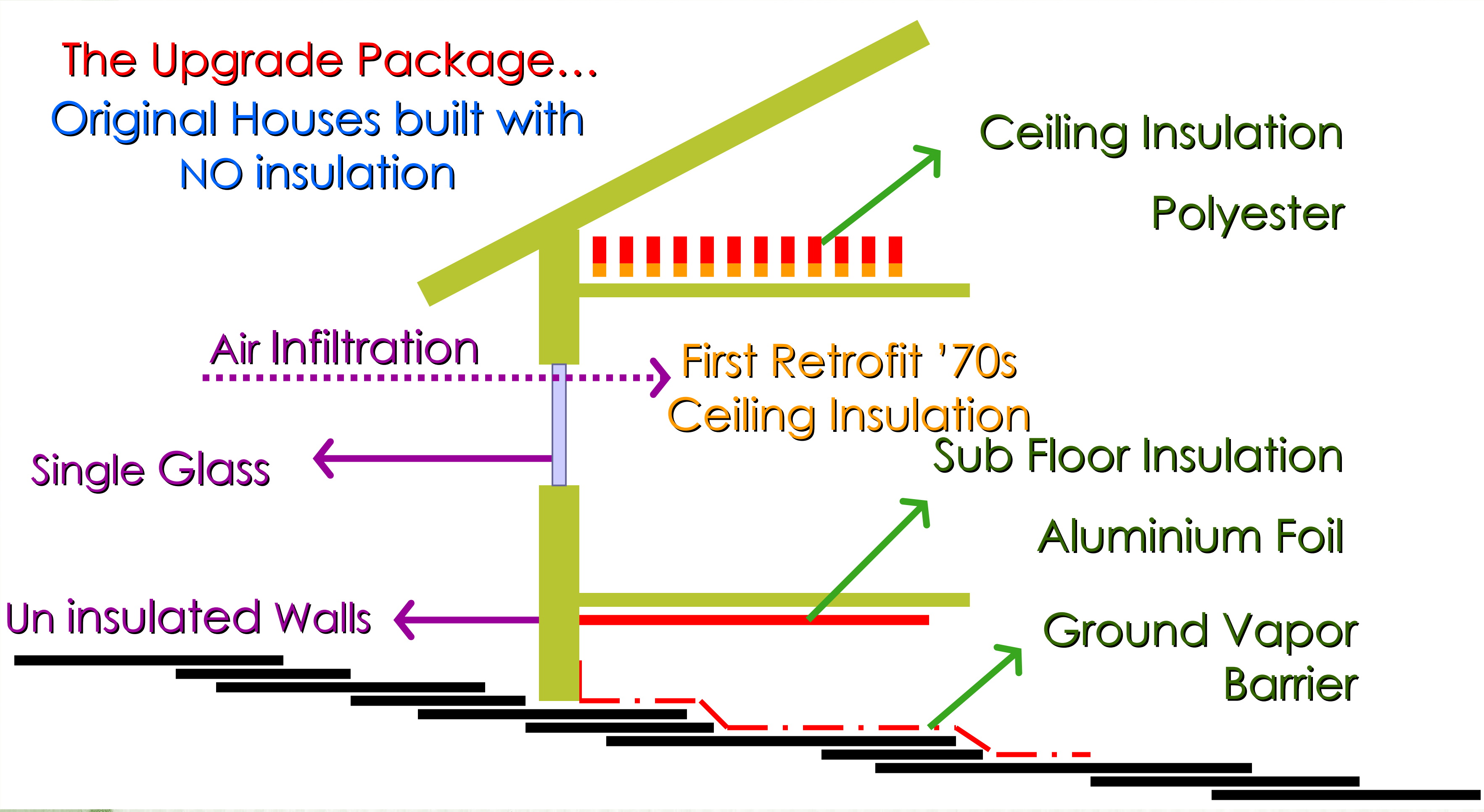
upgraded with the HNZC standard upgrade package

House 2: 83 Cockerell St.

- Weatherboard and brick house:
  - single glazed wooden frame.
  - The roof is metal roof with timber framed attic.
- Multi fuel burner installed in the living area facing north

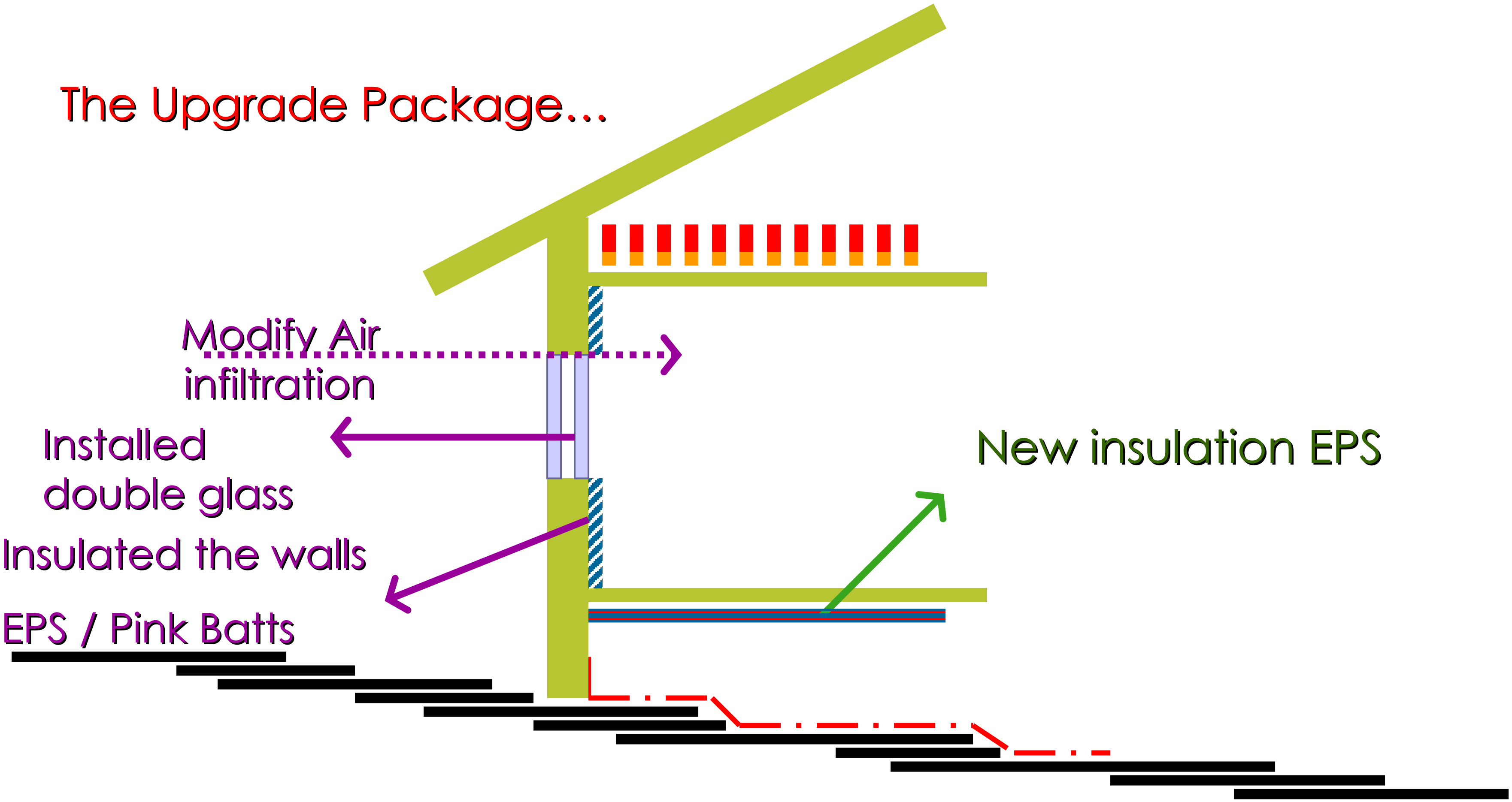
not upgraded with the previous standard upgrade package

The HNZC Upgrade Package



House 1 Upgrade

The Upgrade Package…



House1: Underfloor

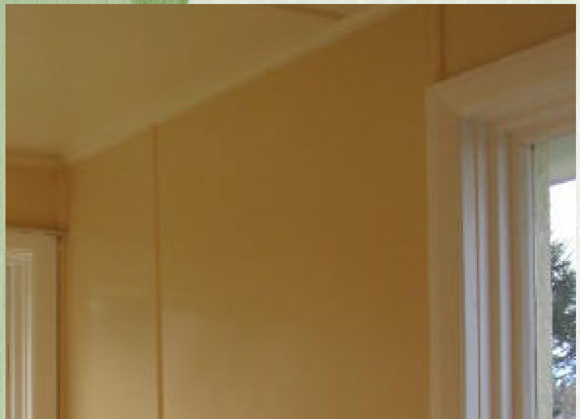
- Aluminium foil was replaced by EPS

House 1: Windows

- Double glazed aluminium framed windows
- Drapes with pelmets

House 1: Walls

- EPS & GIB on top of existing exterior walls.
- Window sill was done with new thickness required.



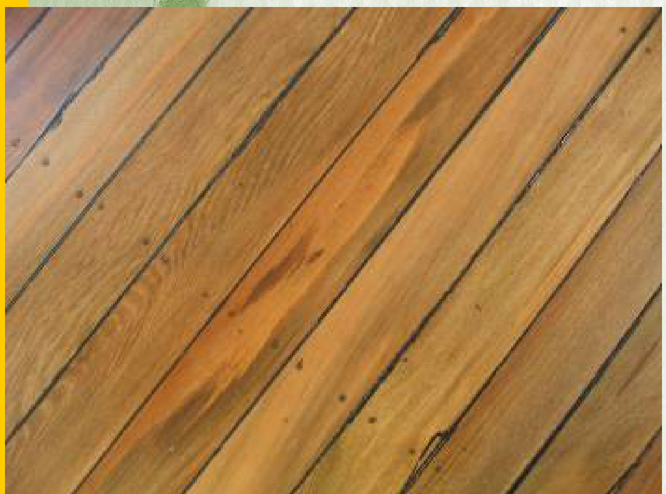
House 1: Walls

- Walls Pink Batts installed in wet areas

House 1: Ceiling

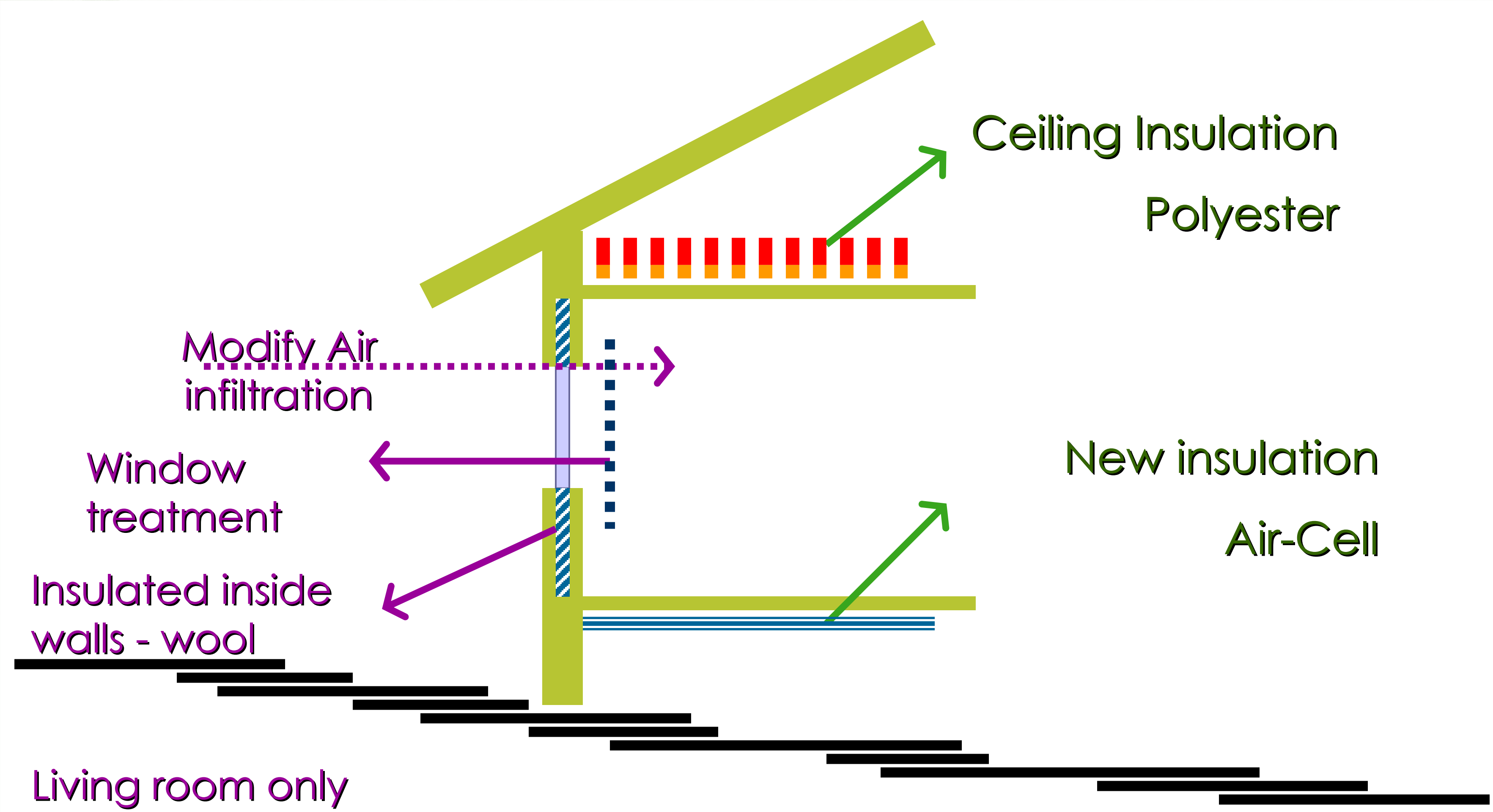
- Already upgraded Polyester Blankets

House 1: The floor



- Old carpet and vinyl was removed
- New finish: polish floors

House 2: Upgrade

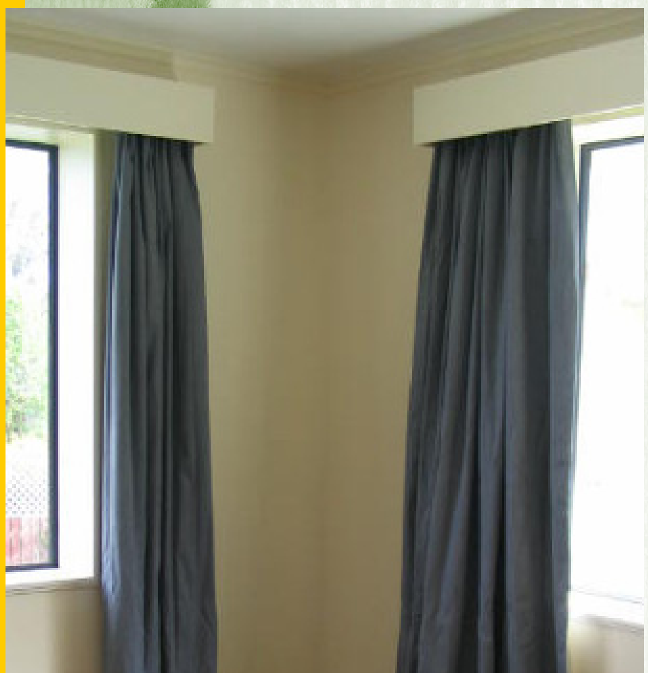


House 2: Underfloor

- Non insulated vs.
- AirCell (Aluminium foil with enclosed air cells)

House 2: Windows

- 3 different tests:
  - Drapes with pelmets
  - Plastic film
  - Acrylic sheets



House 2: Walls

- Wool batts inside walls

House 2: Ceiling

- Polyester blankets on top of macerated paper.

Practical experience

- Difficulty getting contractors,
- Retrofitting existing windows,
- Testing causing moisture removal: gaps in timber joints,

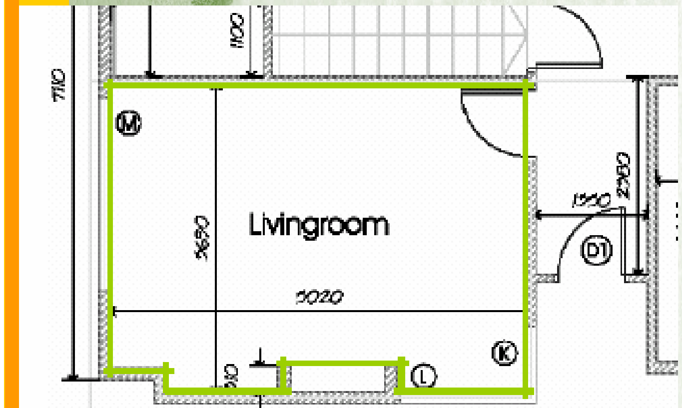
- Drapes were more expensive than expected
- Retrofitting the walls, *Formaliner* v batts,
- Insulating under the floor was easier using *Aircell* comparing to normal foil,

- *Some EPS* under the floor became loose,
- Testing for air infiltration,
- Community approach.

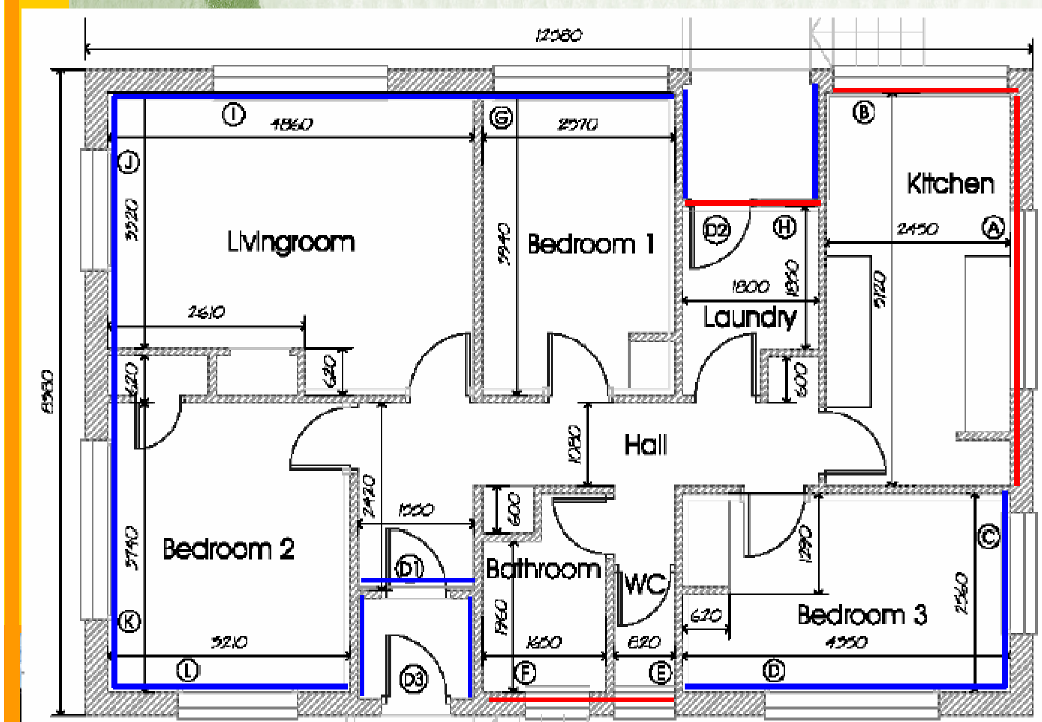
Cost of the Upgrades

House Name	Materials	Materials Cost	Purchased	Labour Cost	Total Cost per house	Total Cost/m^2
House 1						
Insulating the whole building envelope and replacement of new double glazed windows.	EPS underfloor	$600	Private Contractor	$874		
	Pink batts	$100	Contractor			
	Formaliner	$1,886	Forman	$5,489		
	Paint	$1,000*	Contractor			
	Double glass windows	$11,239	Ellisons	$3,316		
	Curtains	$2,778	Active F	$400		
	Pelmets	$334*	University of Otago			
	Paint / Hang Pelmets	$100	Bryan Smail	$400		
	Polished Floors	$3,560	Baker Flooring			
	Sealing	$800	Bryan Smail	$1,500		
	Plumbing work		Bryan Smail	$500		
	Electric work		Bryan Smail	$200		
Total House 1		$22,397		$12,679	$35,076	**$123/$m^2$**
House 2						
Insulating all the floor and ceiling	Air Cell	$906	Negawatt	$458		
	Polyester	$700	Bryan Smail	$786		
	Wool	$320	Bryan Smail	$3,999		
	Paint	$300*	Bryan Smail			
	Paint Windows/Ceiling	$100	Bryan Smail	$922		
	Acrylic	$934*	Designer screens			
	Curtains	$600*	Active furnishes			
	Pelmets	$100*	University of Otago			
	Paint Pelmets	$50	Bryan Smail	$150		
	Plastic Film	$50	Negawatt & CEA			
Total House 2		$4,060		$6,315	$10,375	**$122/$m^2$**

Results for House1 & 2: Lumped resistance model

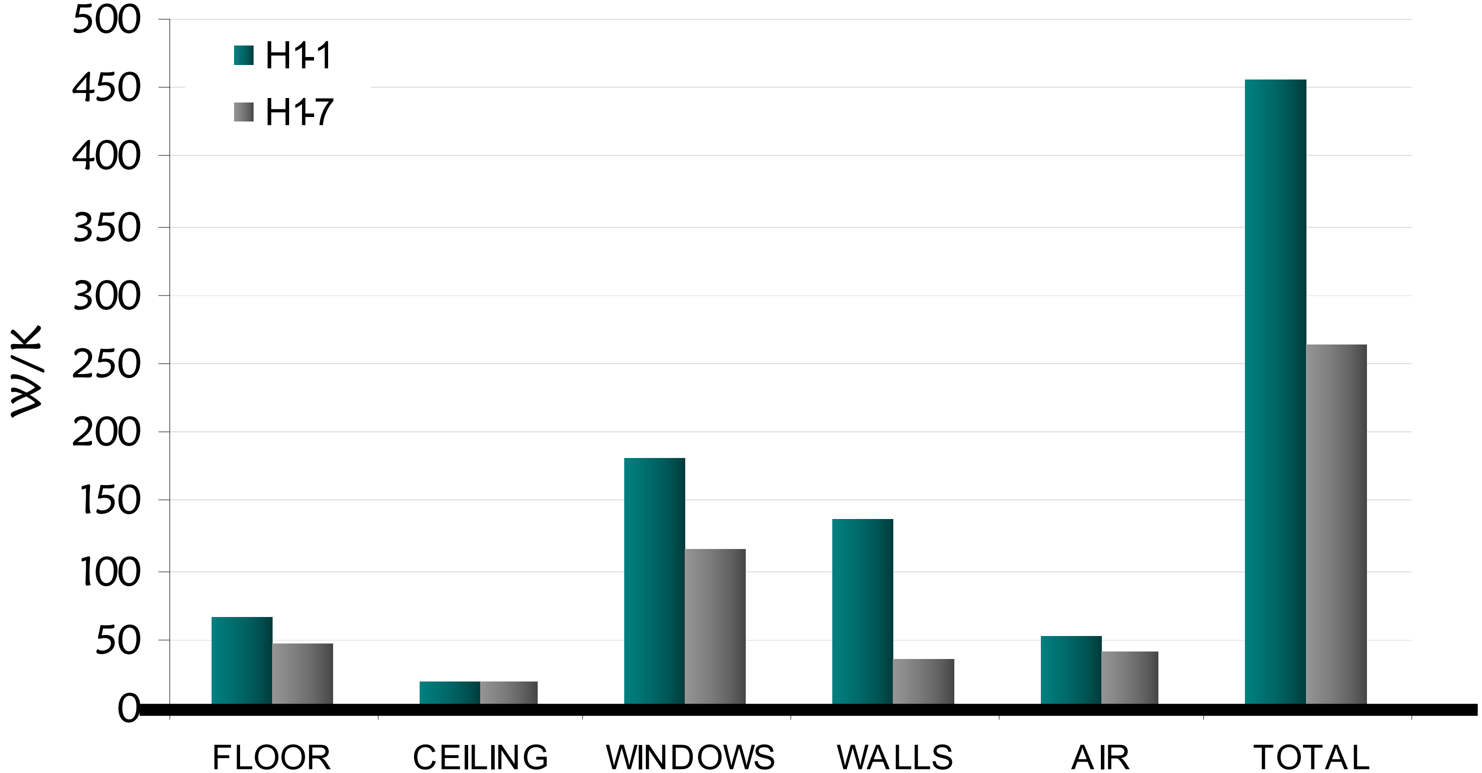


Areas of each component of the building envelope were measured for both houses.



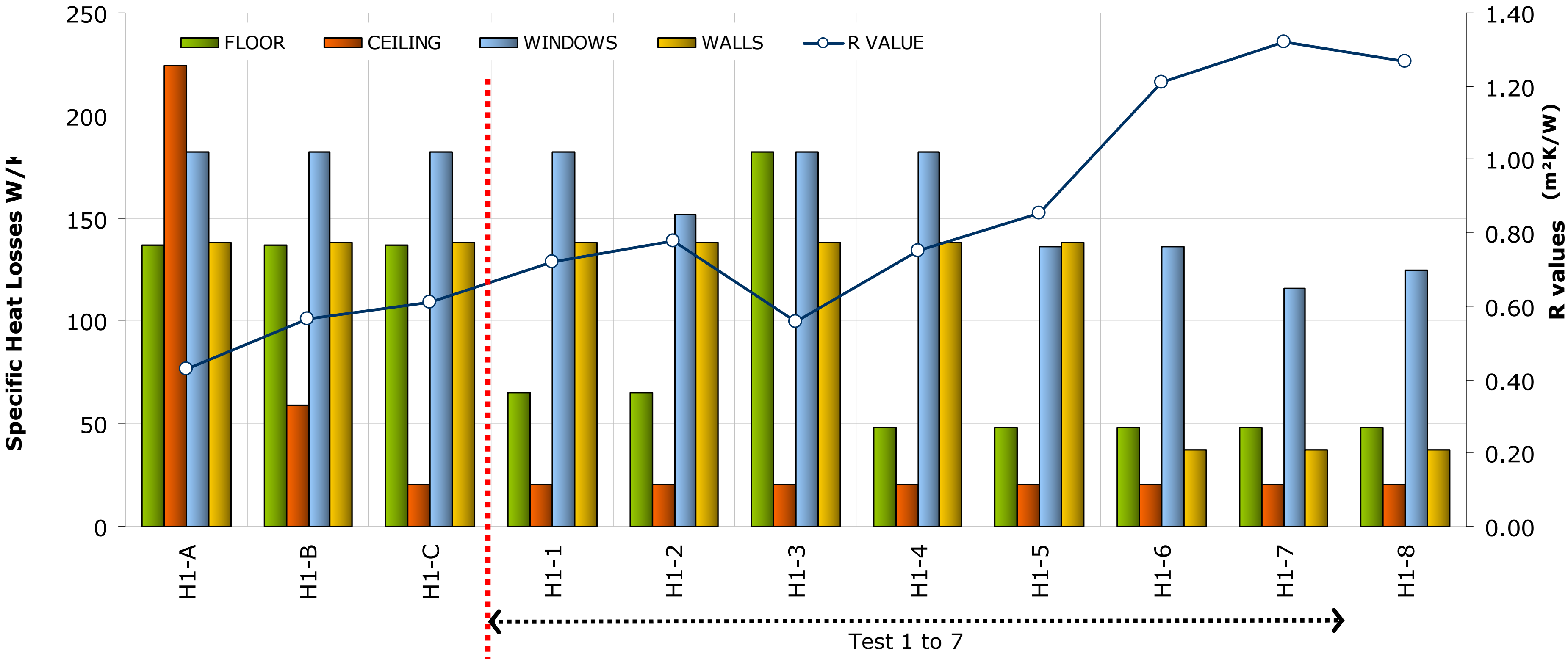
Thermal resistances for each element considering thermal bridges were calculated for each upgrade.

Heat loss model: House 1



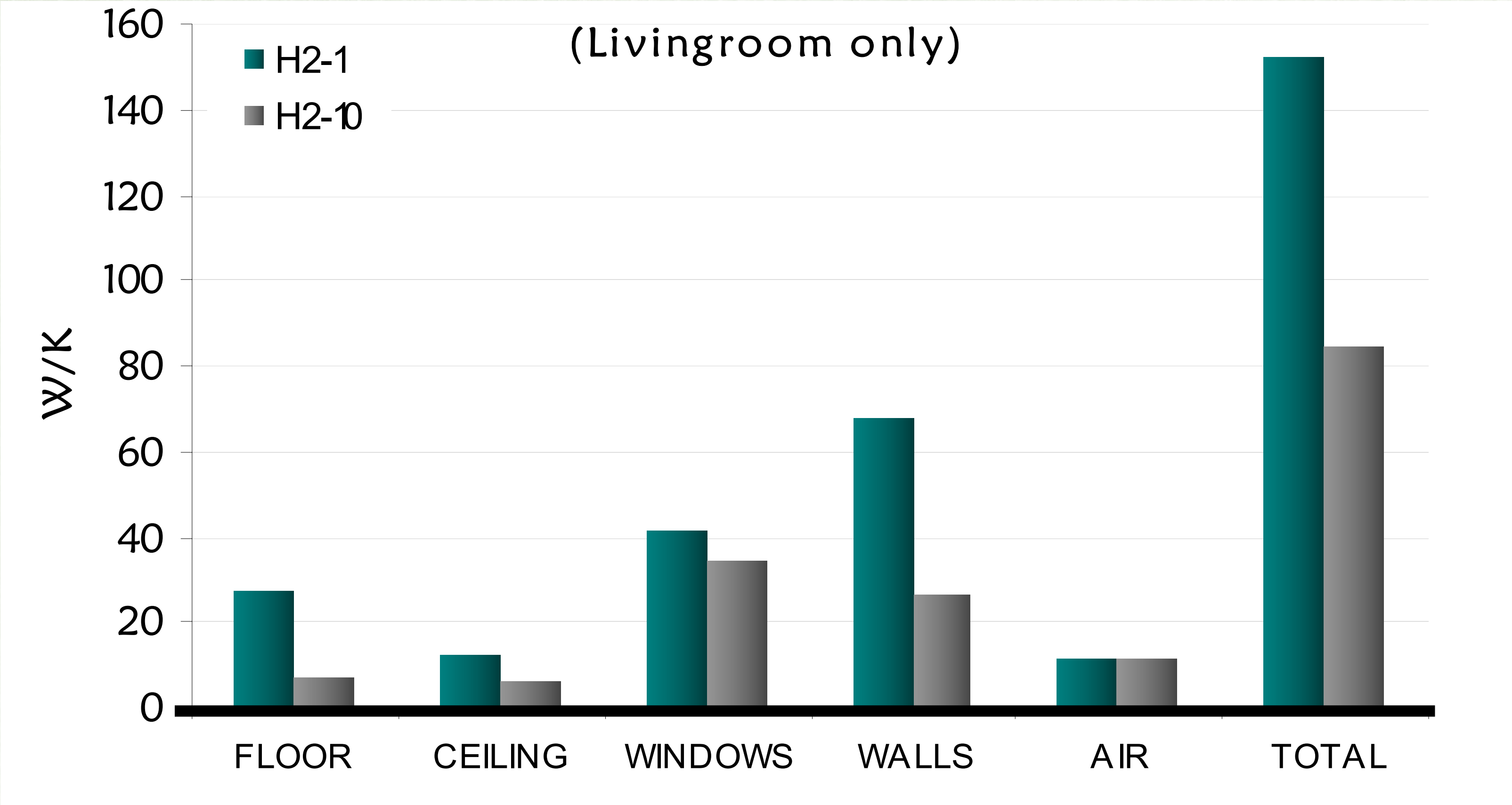
- Specific heat losses reduction for each element before and after the upgrade.

House 1: Calculated



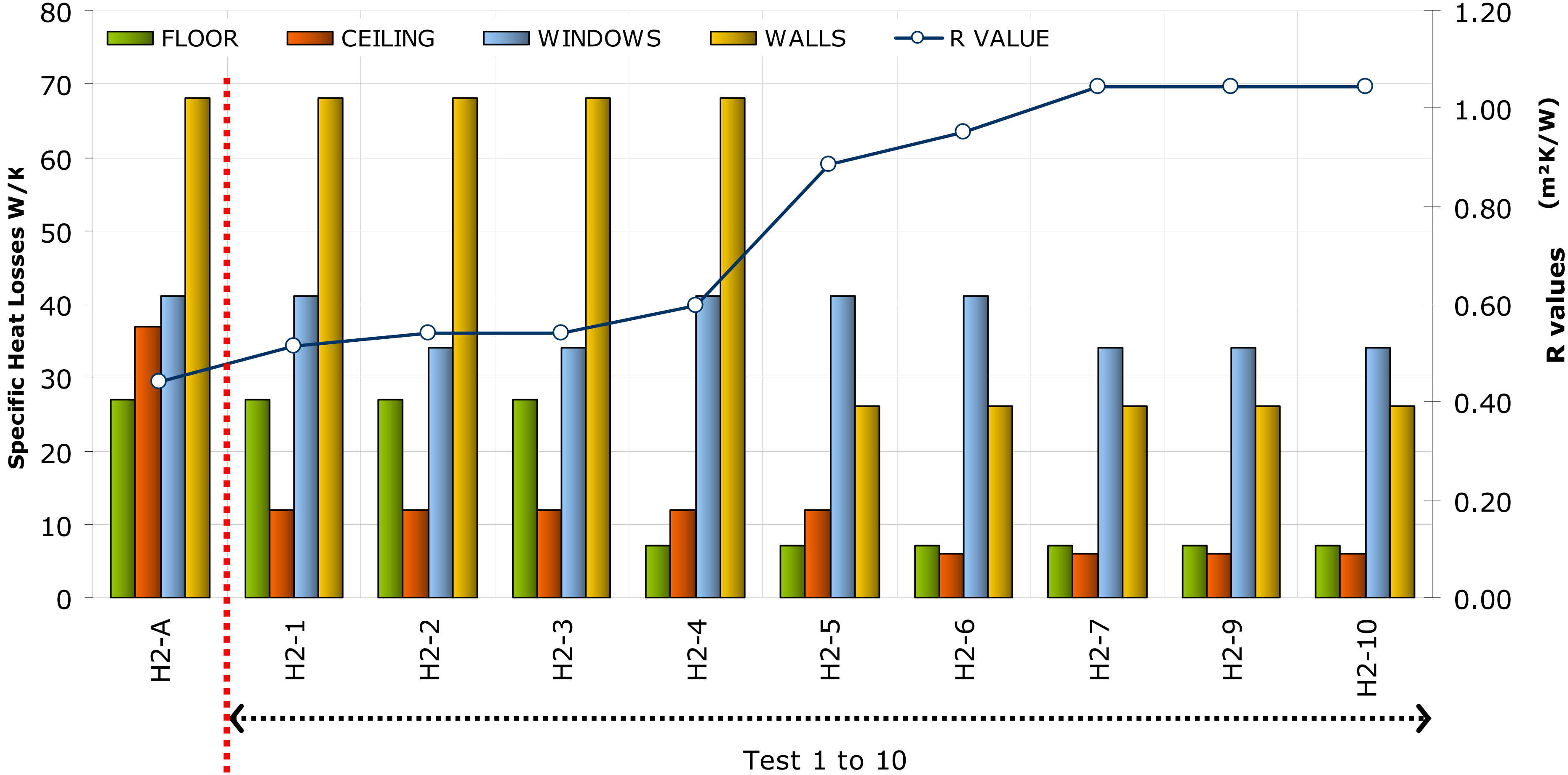
- Specific heat losses decrease
- R values increase

Heat loss model: House 2



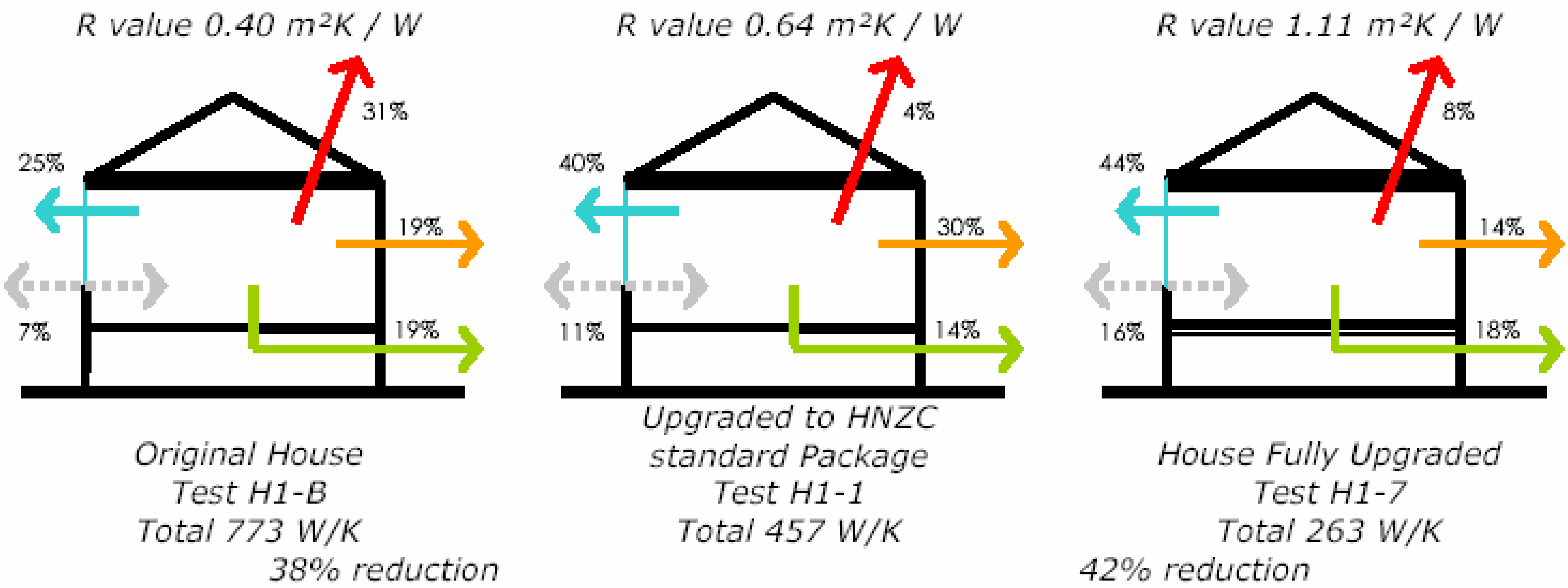
- Specific heat losses reduction for each element before and after the upgrade.

House 2: Calculated



- Specific heat losses decrease
- R values increase

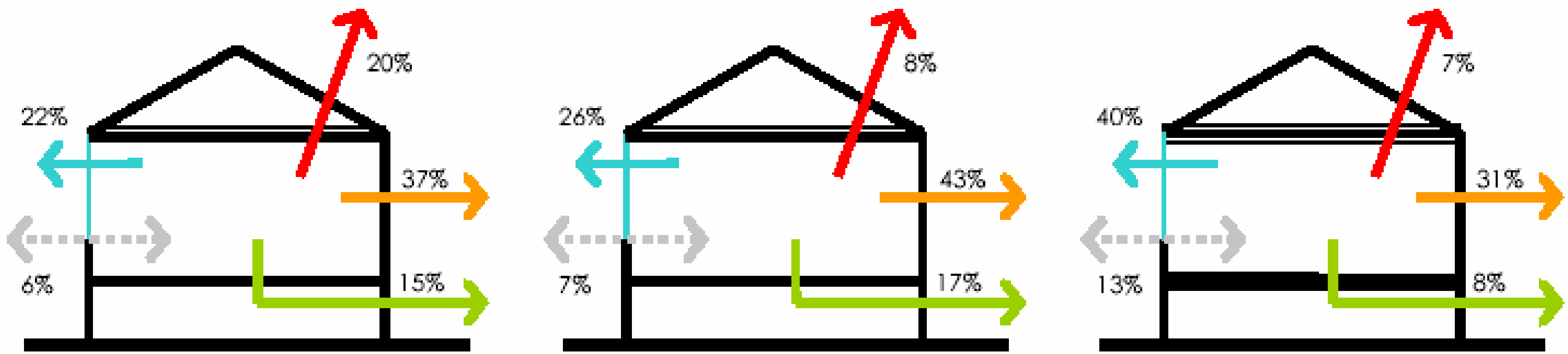
House 1
Total improvement calculated



- 42% heat losses reduction after our upgrade
- Final R value of 1.11 m^2K/W

House 2 (living room) Total improvement calculated

R value 0.41 m^2K / W	R value 0.48 m^2K / W	R value 0.91 m^2K / W



Original Living room Configuration H2-A (As built) Total 184 W/K	Living room Upgraded 70s retrofit Configuration H2-B (Before) Total 159 W/K	Living room Fully Upgraded Configuration H2-10 (After) Total 84 W/K

14% reduction

47% reduction

- 47% heat losses reduction after our upgrade
- Final R value of 0.91 m^2K/W

Testing & Modelling Results

Tim Bishop

Testing & Modelling Results

- Test our retrofits – Heat Loss
  - Simple Method:
    - heat houses,
    - record the power required and temperature achieved,
    - Identify reductions in Heat Loss.
- Estimate annual effects
  - Energy, Cost and Carbon emissions.
- Evaluate many possible upgrades: which are best?

Monitoring Process and R value calculation

- Determine the thermal losses through the building envelope

- Houses were heated to a steady state and the temperature difference (ΔT) was recorded.
- Monitoring was undertaken with the following conditions:
  - Night time (no solar gains)
  - Unoccupied (no internal gains / no evaporative gains)
  - Infiltration estimated from Blower door tests
  - Energy input monitored
  - Δt was monitored
  - Heat Losses = ∑Energy / ∑ ΔT

Monitoring: The equipment

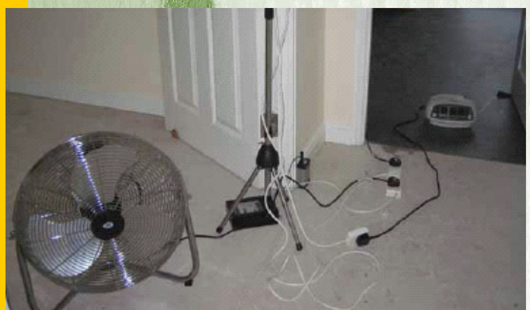
- Indoor temperature monitored with data loggers in each room.
- A weather station was installed on the roof.

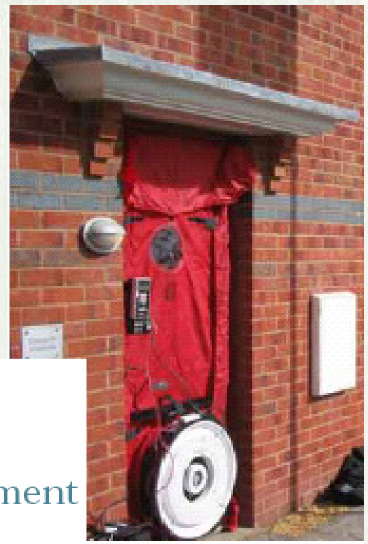
Monitoring Process

- Electric heaters to provide space heating energy.
- Fans were installed to reduce thermal stratification.
- A blower door used to estimate infiltration / air leakage

Whole house calorimetry other research

- Centre for the Built Environment, Leeds Metropolitan University
- STEM tests also carried out by BRANZ and National Renewable Energy Laboratory in the US (NREL)





CeBE
Centre for the Built Environment
April 2003

Side-by-Side Thermal Tests of Modular Offices: A Validation Study of the STEM Method

R. Judkoff, J.D.
G Barker, and K

NREL National Renewable Energy Laboratory

National Renewable Energy Laboratory
Innovation for Our Energy Future

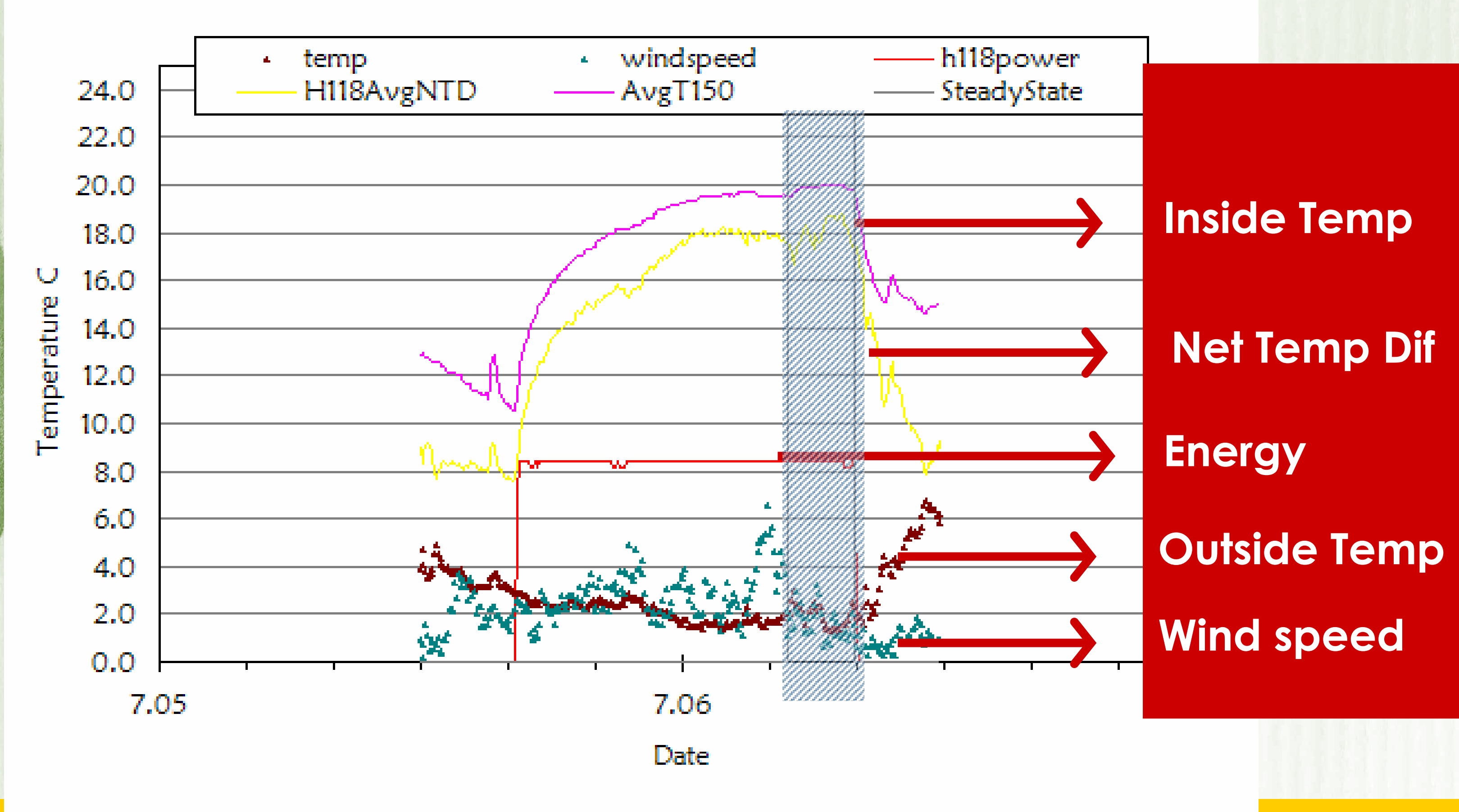
Whole-House Energy Analysis Procedures for Existing Homes

Preprint

R. Hendron

Monitoring: The results

- Wait until indoor temperature reaches reached a steady state
- Some tests discarded because of varying outside temperatures, wind, or precipitation
- ΔT for HL used from last 4 hours of the test



Lumped R values for a code house in ZONE 3 of NZ

Summary		**R VALUES - ZONE 3**								
Regulatioons		BEFORE '77 ESTIMATED	**CODE 1977**	**CODE SOLID POST '96**	RECOMMENDED		**CODE LightW POST '96**	RECOMMENDED		**CODE LightW 07 w Double Glaze**
Element	m^2	NONE	**MINIMUM**		BETTER	BEST	**MIN**	BETTER	BEST	**MIN**
CEILING	**89.50**	0.40	1.9	3.00	3.5	4.6	2.50	3.5	4.6	2.50
GLASS	**32.60**	0.19	0.19	0.19	0.26	0.26	0.19	0.26	0.26	0.26
DOOR	**4.00**	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
WALLS	**76.10**	0.55	1.5	1.00	1.6	1.9	1.90	1.6	1.9	1.90
FLOOR	**89.50**	0.65	0.9	1.30	1.9	3.1	1.30	1.9	3.1	1.30
LUMPED R V		0.40	**0.69**	**0.73**	0.98	1.10	**0.79**	0.98	1.10	**0.91**

- R values are for House 1 configuration modeled for different building code requirements

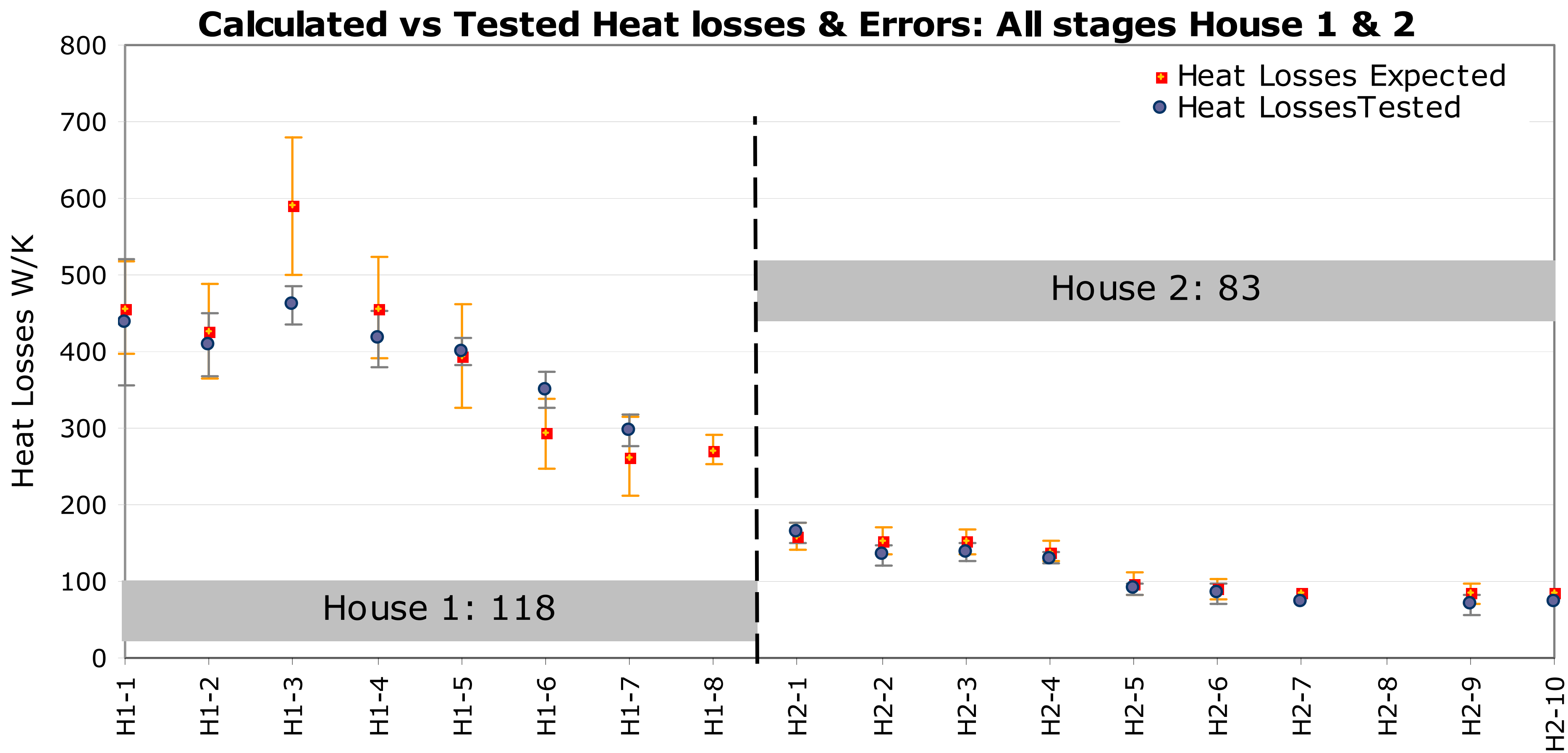
Testing Results: House 1

HOUSE 1	Effective - Measured			Heat Losses				Conduction ONLY	
	U value	R value	ACH	Air infiltration		Conduction		U value	R value
TEST	**W/Km^2**	**Km^2 / W**	**ACH**	**W/K**		**W/K**		**W/Km^2**	**Km^2 / W**
H1-1	1.5	**0.67**	0.71	58	± 17	380	± 85	1.3	0.77
H1-2	1.4	**0.71**	0.71	58	± 17	351	± 44	1.2	0.83
H1-3	1.6	**0.63**	1.03	83	± 25	377	± 35	1.3	0.77
H1-4	1.4	**0.70**	1.21	99	± 30	318	± 47	1.1	0.92
H1-5	1.4	**0.73**	1.04	85	± 25	316	± 31	1.1	0.92
H1-6	1.2	**0.83**	0.90	73	± 22	277	± 32	0.9	1.05
H1-7	1.0	**0.99**	0.78	64	± 19	232	± 28	0.8	1.26

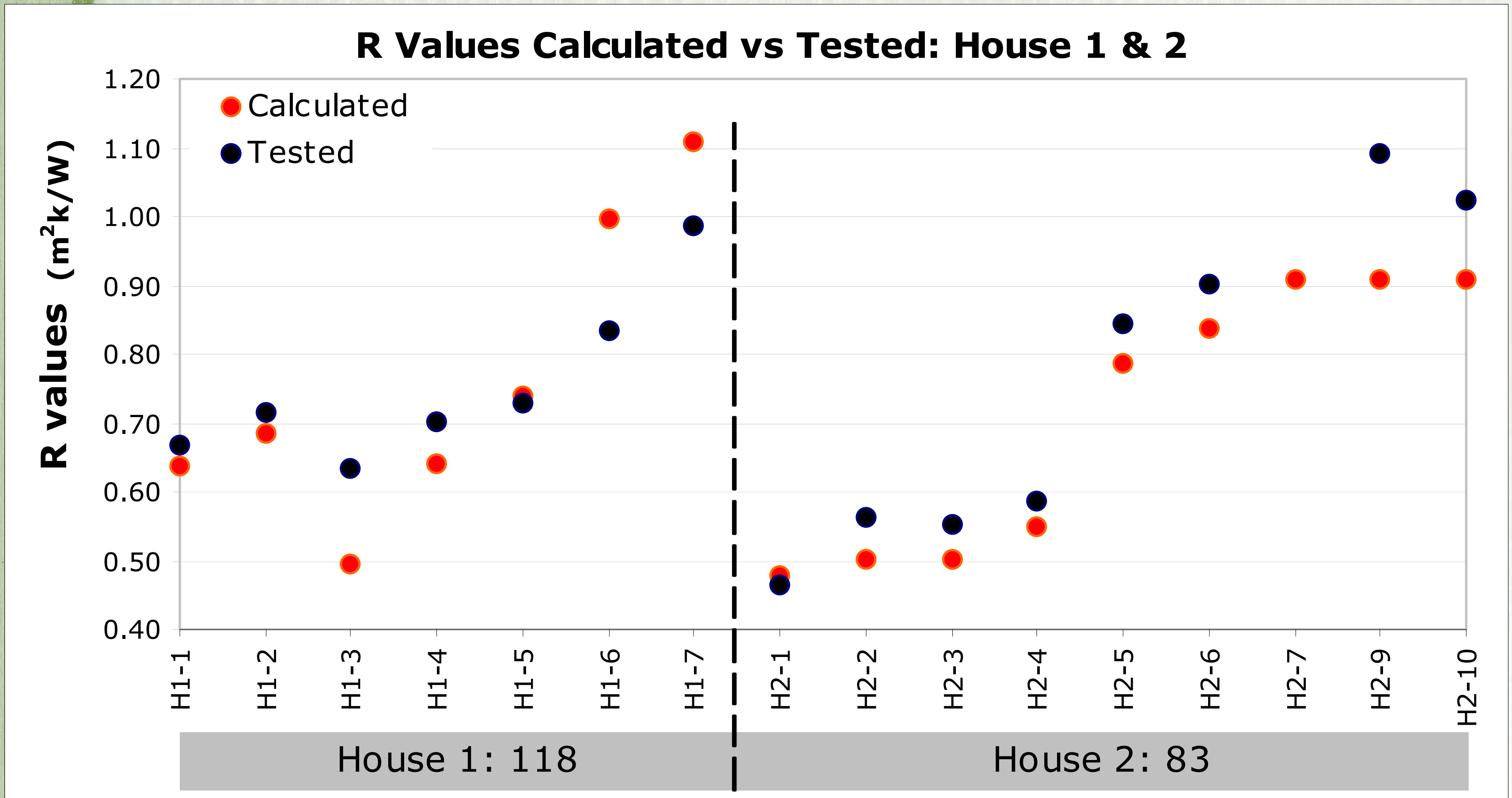
Testing Results: House 2

HOUSE 2	Effective - Measured			Heat Losses				Conduction Only	
	U value	R value	ACH	Air infiltration		Conduction		U value	R value
TEST	W/m²K	m²K/W	ACH	W/K		W/K		W/m²K	m2K/W
H2-1	2.1	**0.47**	0.74	16	± 5	148	± 8	1.9	0.52
H2-2	1.8	**0.56**	0.59	13	± 4	123	± 14	1.6	0.62
H2-3	1.8	**0.55**	0.74	16	± 5	123	± 14	1.6	0.62
H2-4	1.7	**0.59**	0.89	19	± 6	111	± 13	1.5	0.69
H2-5	1.2	**0.84**	1.19	25	± 8	65	± 11	0.9	1.17
H2-6	1.1	**0.90**	1.19	25	± 8	59	± 11	0.8	1.29
H2-9	0.9	**1.09**	1.19	25	± 8	44	± 9	0.6	1.72
H2-10	1.0	**1.02**	1.19	25	± 8	49	± 15	0.6	1.55

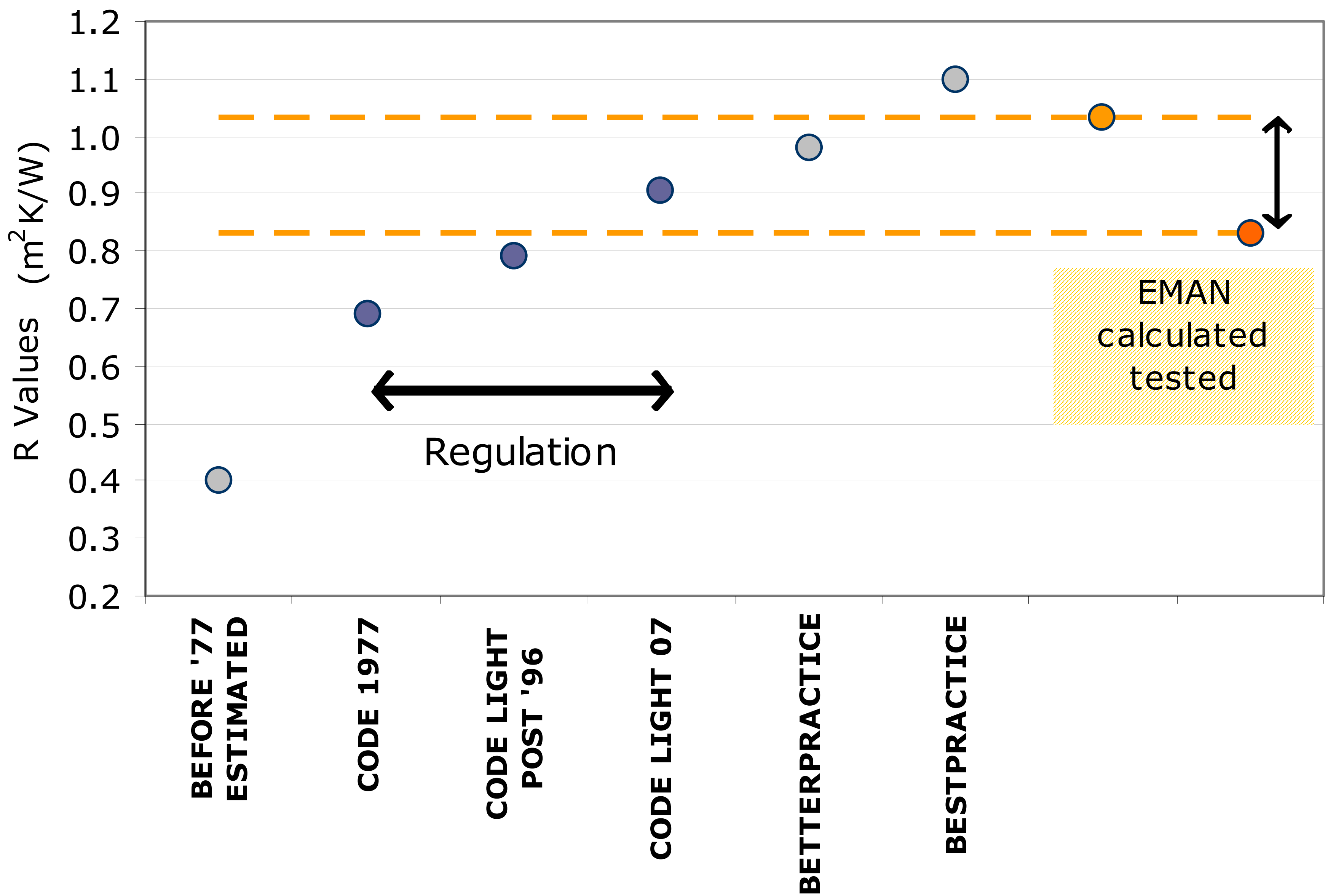
Comparing Heat Losses Calculated vs. Monitored



Comparing R values Calculated vs. Monitored



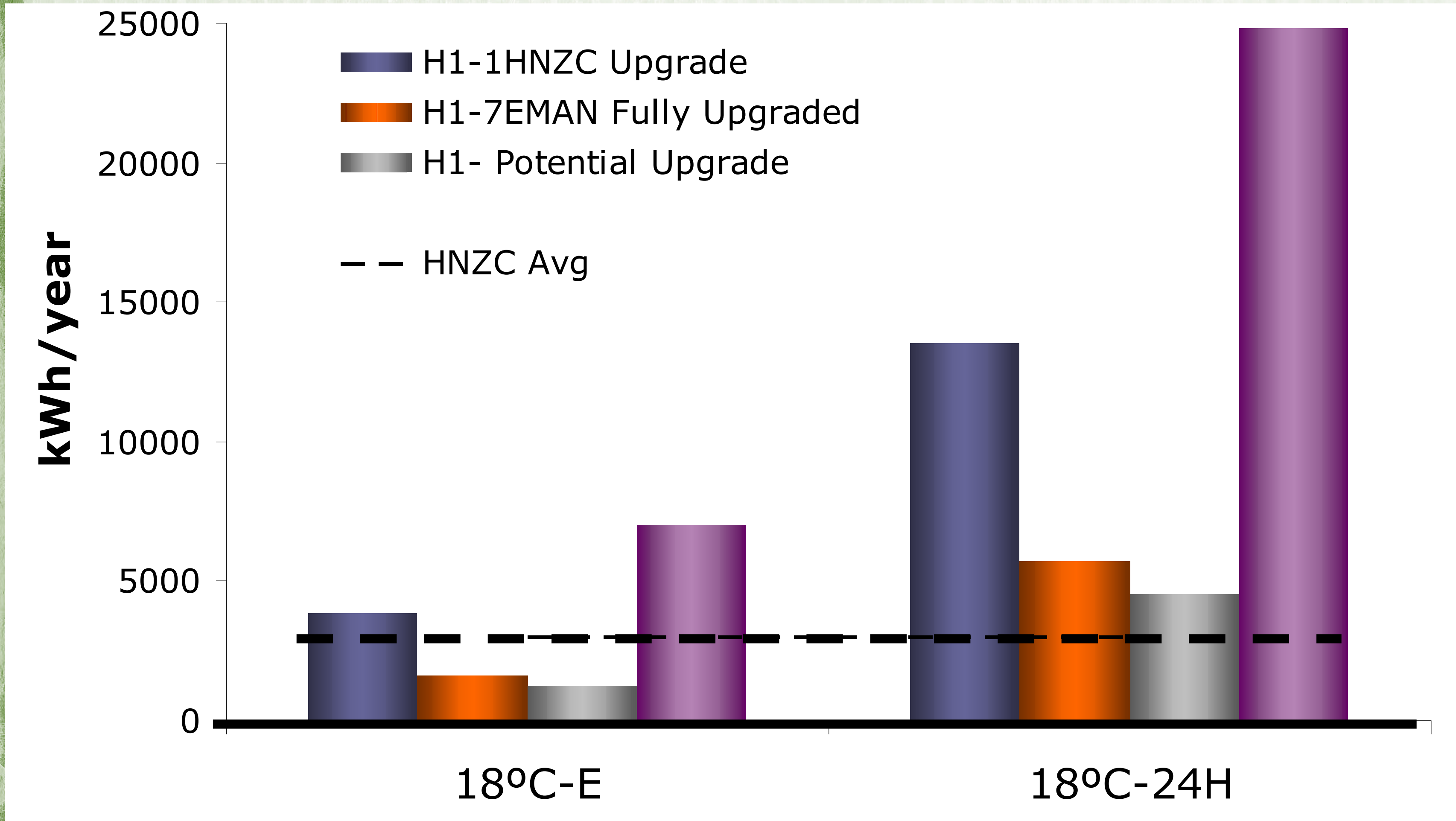
Comparing with the building Code



Annual Heating Energy

- Predict Requirements with ALF3
  - Heat Gains (Sun, Internal) & Heat Losses
  - Estimates Annual Net Heating Energy for a particular house and climate

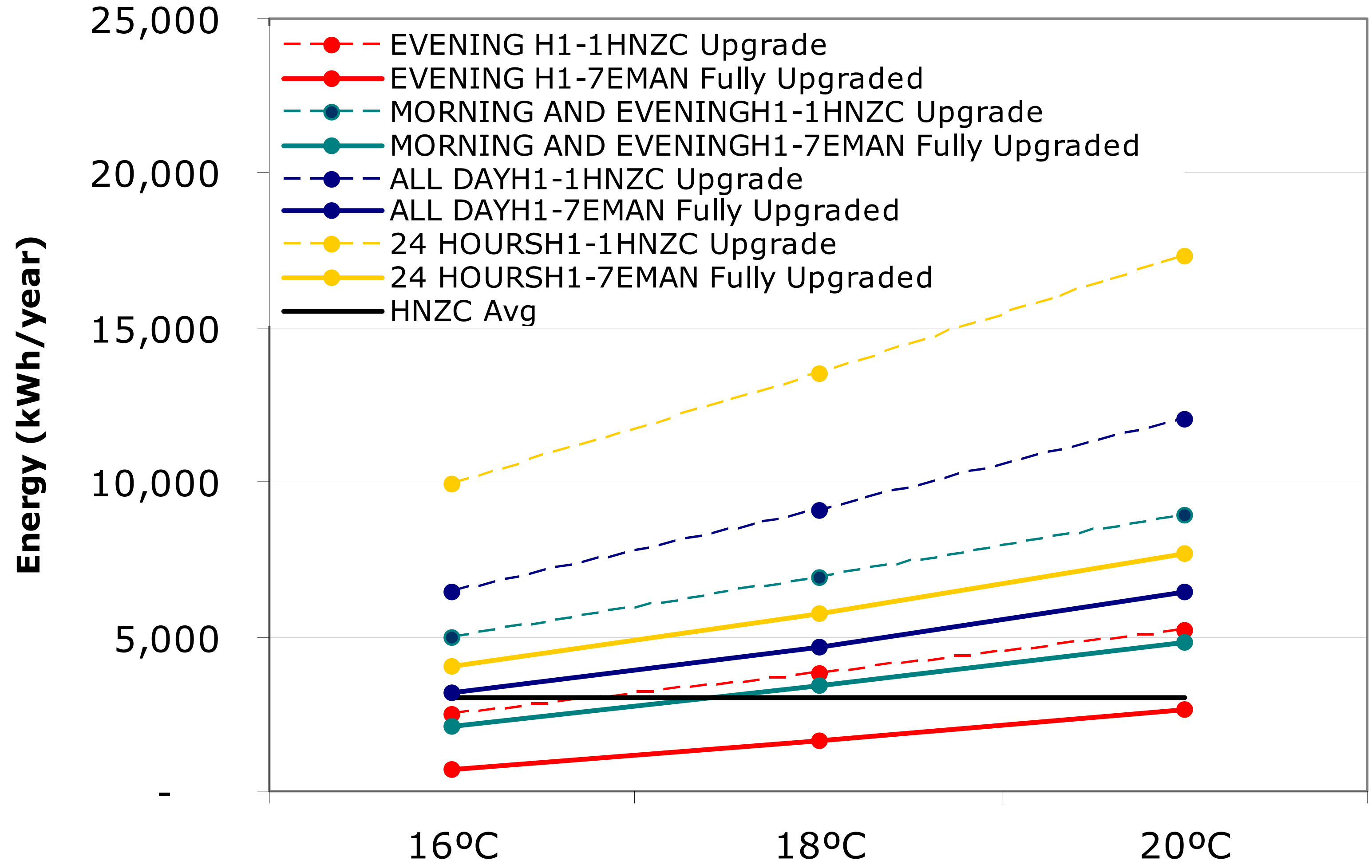
Annual NET heating requirements



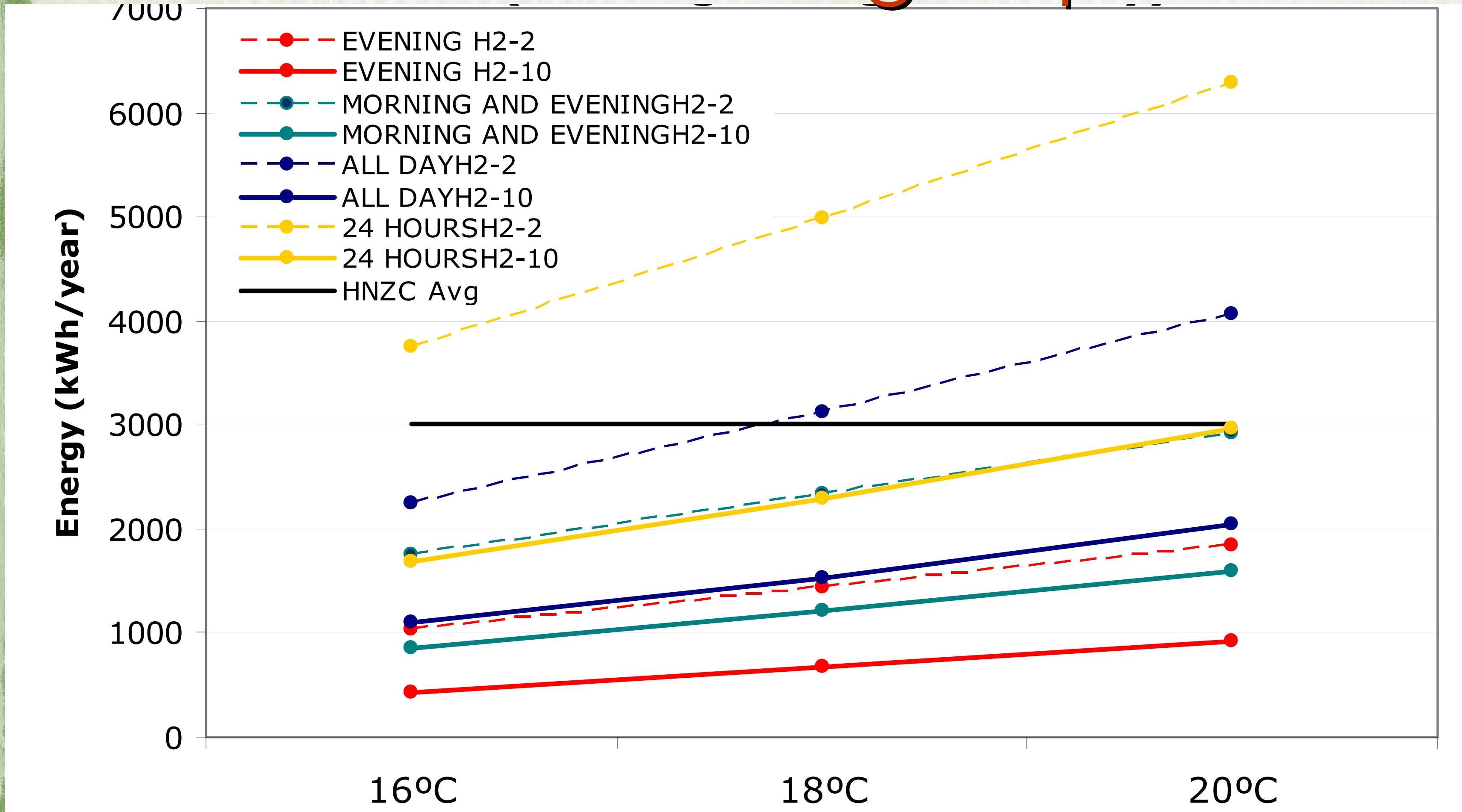
Rebound Effect

- If we insulate a house, or provide more efficient heating, will people:
  - A) Continue to heat to the same temperature, and save energy and cost (0% rebound), or
  - B) Continue to spend the same amount on energy, and be more comfortable? (100% rebound)
- International studies suggest that low income underheated houses will choose B (75-100% rebound)
- >100% rebound has been observed

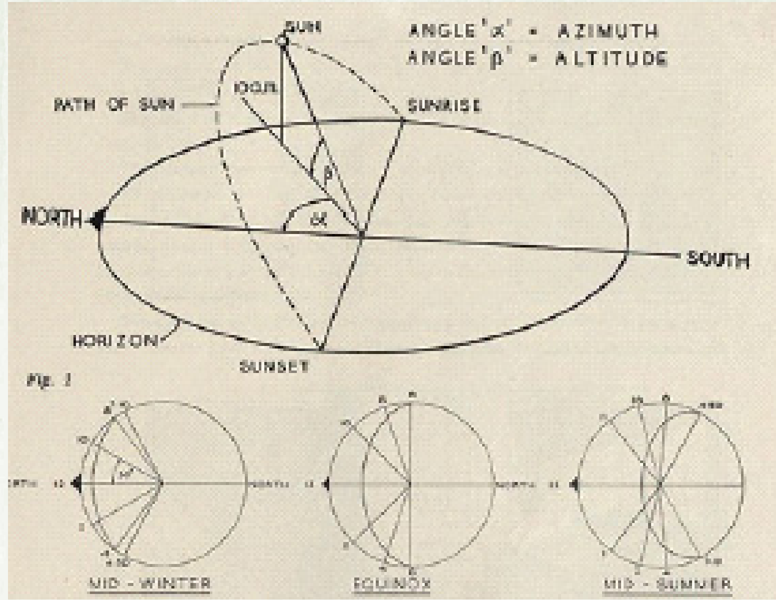
House 1: Computer Modeling Annual heating requirements



House 2 (living room) : Computer Modeling Annual heating requirements



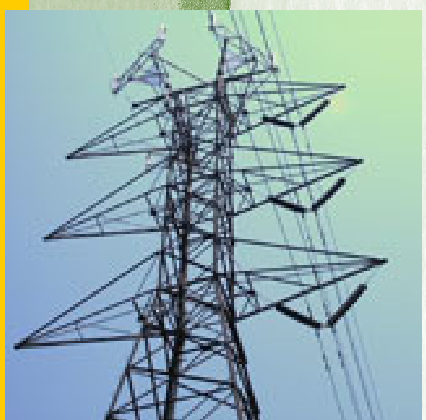
- Even though HNZC houses are designed for the sun the passive design cannot deliver WHO recommended temperatures



- Thus the houses need heating

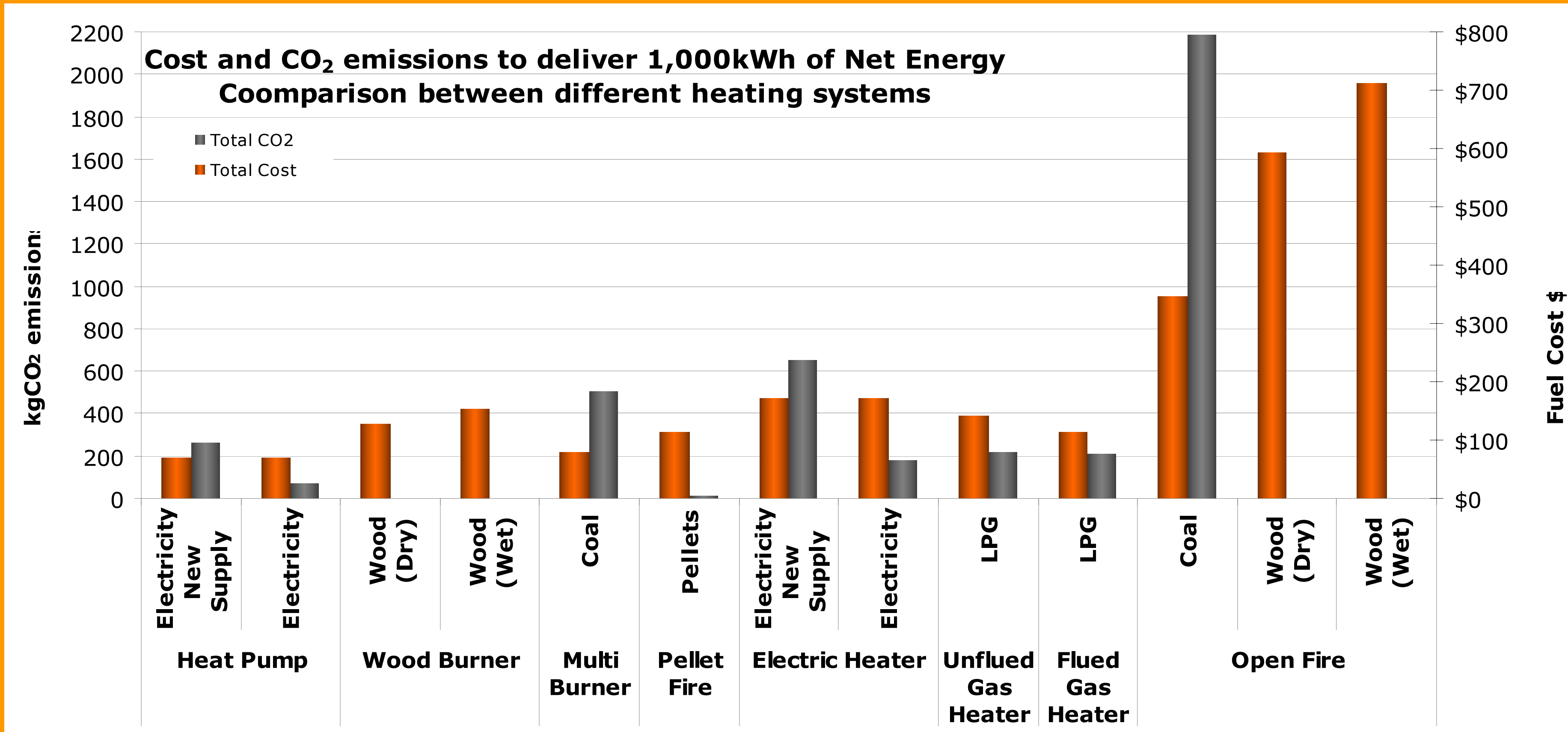
Purchased heat v net heat

- The ***net energy*** is the heat energy usefully emitted from the heating appliance (kWh of heat)
- The ***purchased energy*** is what we buy. (m3 of firewood, kWh of electricity). The amount of net energy released depends on the efficiency of the heating system.
- The ***primary energy*** required will depend on the efficiency of supply of the purchased energy.




70% Efficiency

Space Heating Appliances







What you get for $1000

Heating System		Net Heat kWh	Net kg CO2	Thermal Comfort: Heating Scheculle achieved											
				EVE16	EVE18	ME16	EVE20	ALL16	ME18	ME20	ALL18	24H16	ALL20	24H18	24H20
Electric Heater	Electricity	5,784	342												
	Electricity New Demand	5,784	3,759												
Heat Pump/Electricity	Electricity	14,459	342												
	Electricity New Demand	14,459	3,759												
Multi Burner	Coal	10,201	5,153												
	Wood (Dry)	6,825	-												
	Wood (Wet)	6,094	-												
Open Fire	Coal	2,354	5,153												
	Wood (Dry)	1,575	-	none											
	Wood (Wet)	1,406	-	none											
Pellet Fire/Pellets	Pellets	8,824	120												
Unflued Gas Heater/LPG	LPG	7,099	1,544												
Flued Gas Heater/LPG	LPG	6,318	1,544												
Wood Burner	Wood (Dry)	7,350	-												
	Wood (Wet)	6,563	-												
Wood Burner + Electric Heater	Wood/Elect 50/50	6,452	190												
Wood Burner + Heat Pump	Wood/HP 50/50	9,524	114												

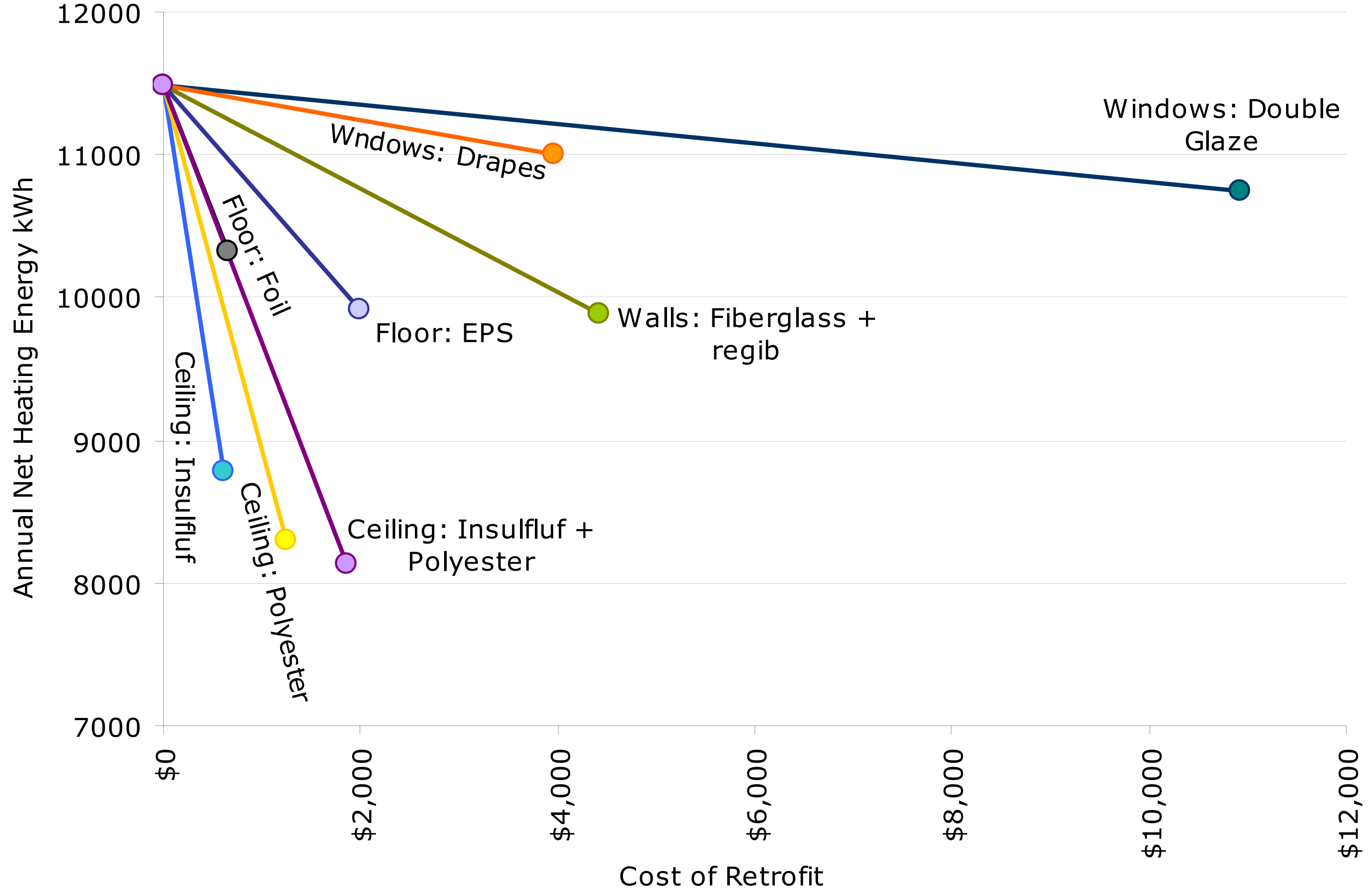
EVExx	= Evening Heating to xx ºC
Mexx	= Morning and Evening Heating to xx ºC
ALLxx	= All Day Heating from to xx ºC
24xx	= 24 Hours Heating to xx ºC

Improvement strategies

- 1) Look for most effective heat loss retrofits
- 2) Look for most effective heating system retrofit
- Effective means the most heat loss reduction or heating system efficiency improvement for least cost

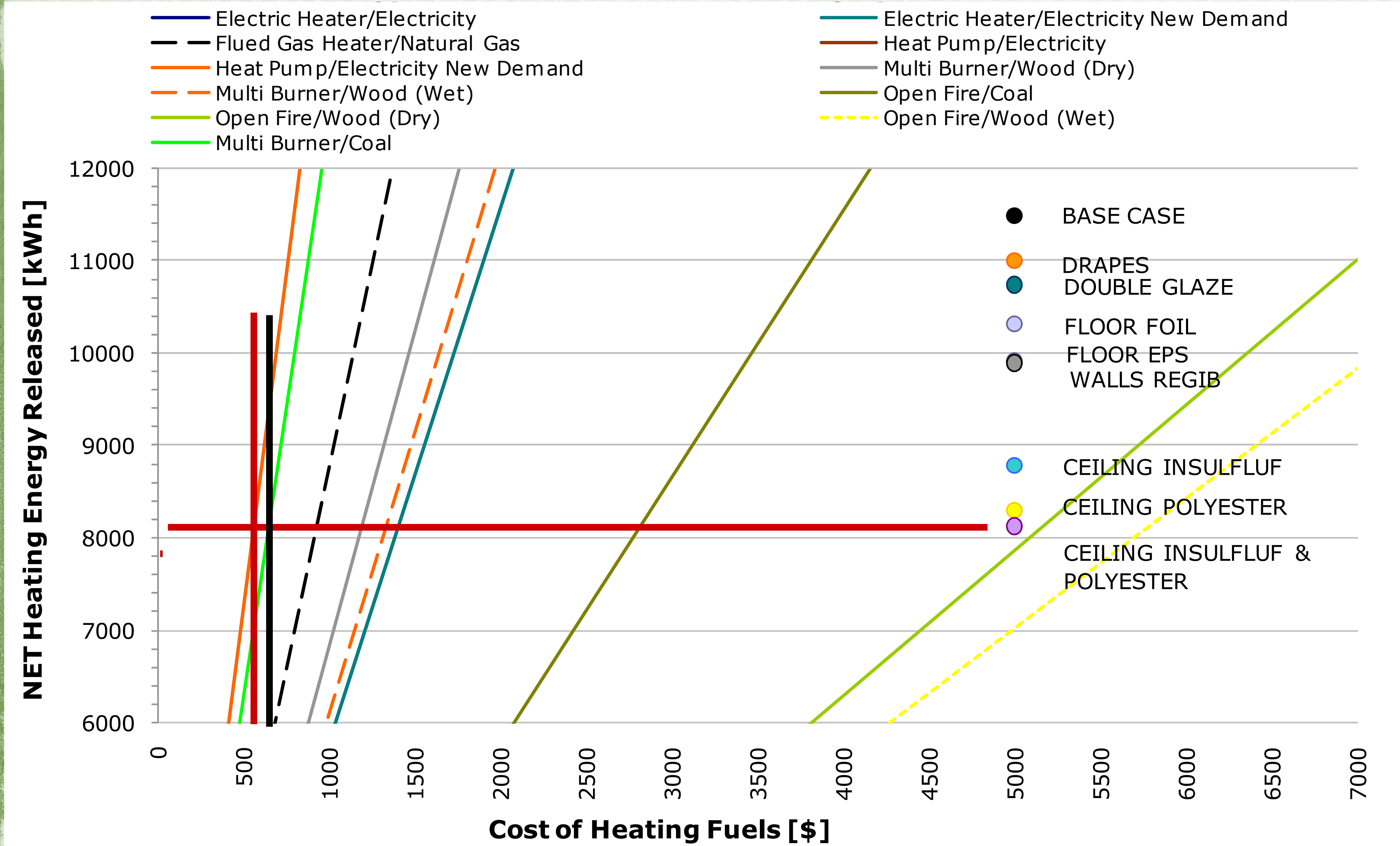
Heat Loss Retrofit Choices

for a non insulated state house in Dunedin (H1-A)



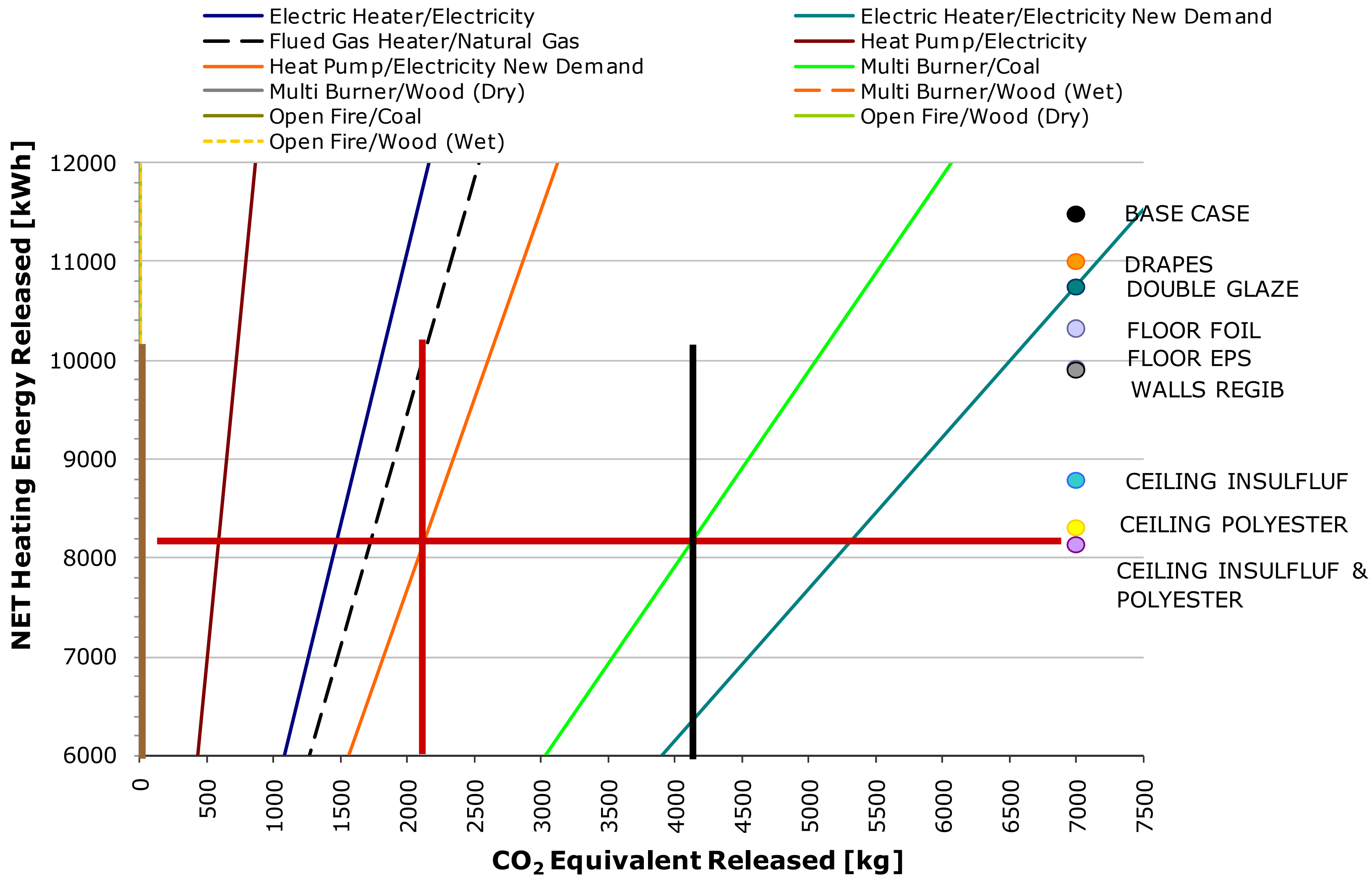
Heating System Upgrade

Improvements – Fuel Cost Reduction

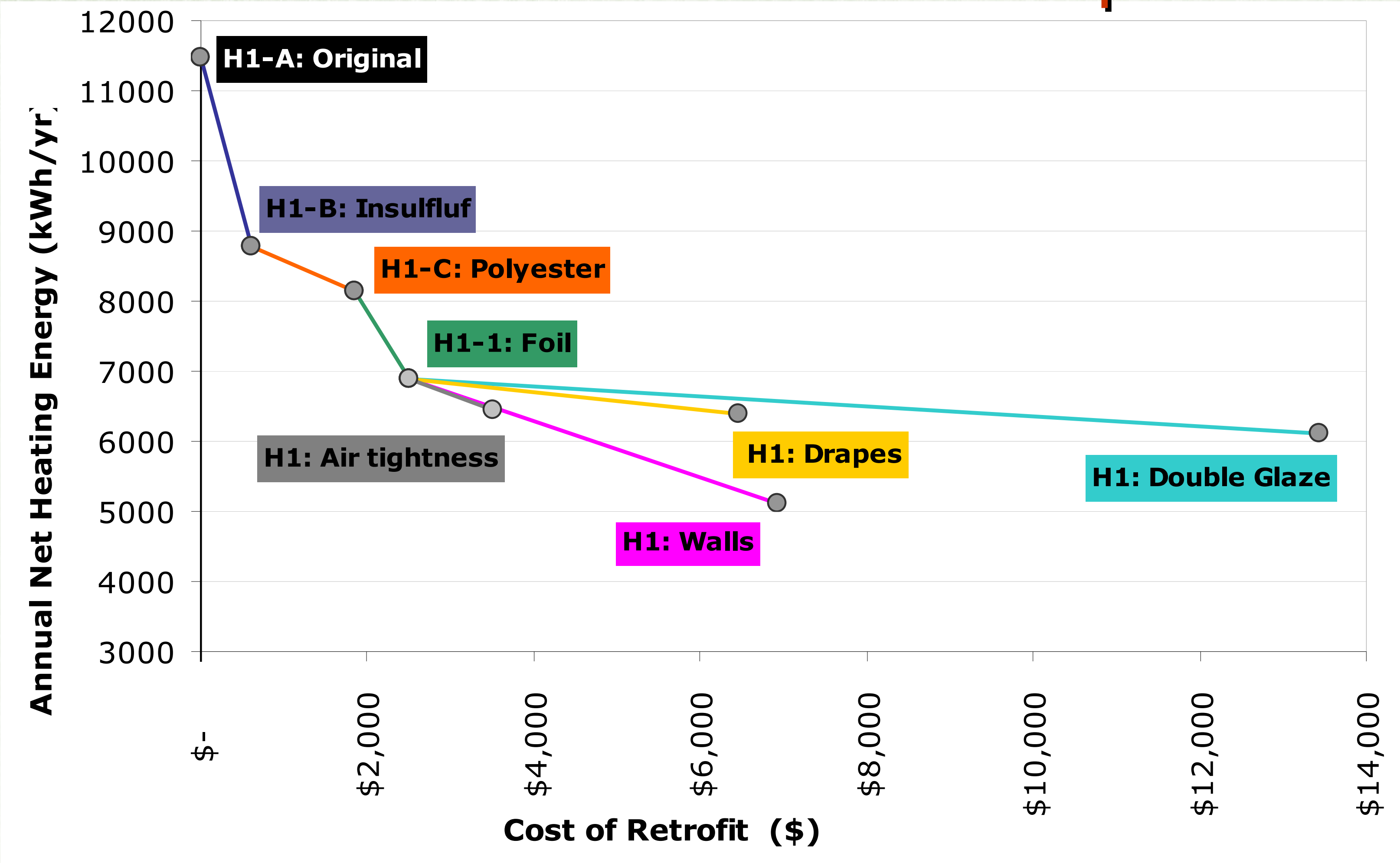


Heating System Upgrade

Improvements – Heating systems



History of Improvements and Future options



Upgrade paths for the future

- We ranked upgrade options: including heat loss reduction and heating systems upgrades.
  - Our ranking consisted of:
    - Annual savings ($) / Cost of the upgrade ($)
    - We gave preference to options that reduced recurrent CO_2 emissions.
- Then: a combined upgrade path was suggested

Ranking the options

From Non insulated + Open Fire (H1-A)

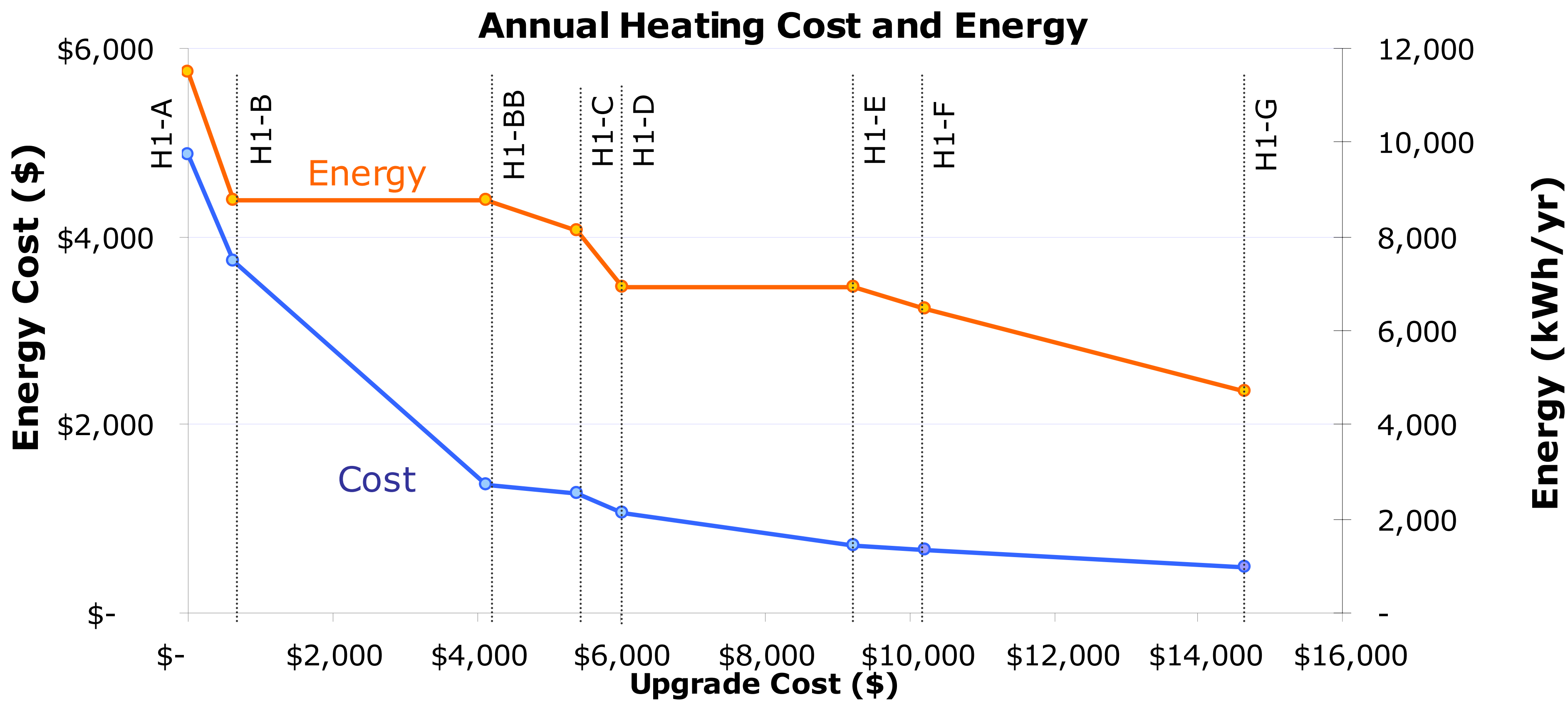
Ranking Options by COST $ *		Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
		H1-A	**H1-B**	**H1-BB**	**H1-C**	**H1-D**	**H1-E**	**H1-F**	**H1-G**
AIRTIGHTNESS		1.37	1.43	0.52	0.53	0.54	**0.37**	choose	
CEILING	**Insulfluf**	**14.36**	choose						
	Insulfluf & Polyester	5.93	reject						
	Polyester	8.44	1.73	**0.63**	choose				
FLOOR	**EPS**	2.60	2.71	0.99	1.00	reject			
	Foil	5.88	6.14	2.24	**2.27**	choose			
HEATING SYSTEM	**Flued Gas**	7.12	5.44	-0.07	-0.06	-0.05	-0.86	-0.80	-0.58
	Heat Pump	9.86	7.54	1.82	1.68	1.43	0.60	0.56	0.41
	Multi fuel Burner	8.21	6.28	1.10	1.01	0.86	0.11	0.10	0.07
	Pelletfire	6.84	5.24	0.70	0.65	0.55	-0.11	-0.10	-0.08
	Wood burner + Electric H**	7.25	**5.19**	choose					
	Wood burner + Heat Pump**	n/a	n/a	1.06	0.98	**0.83**	choose		
WALLS	**Formaliner**	1.01	1.05	0.38	0.39	0.40	0.27	0.27	reject
	Fiberglass + Regib	1.18	1.23	0.45	0.45	0.47	0.32	**0.32**	choose
WINDOWS	**Double Glaze**	0.22	0.23	0.08	0.09	0.09	0.06	0.06	**0.06**
	Drapes	0.40	0.42	0.15	0.15	0.16	0.11	0.11	**0.11**
Heating Kg CO_2 reduction (%) **from base to chosen option***		**23%**	**99%**	**7%**	**15%**	**59%**	**7%**	**27%**	**12%**

** Wood burner + Electric Heater or Heat pump assumes 50% net energy delivered by each system.

A Suggested Upgrade Path for House 1 (H1)

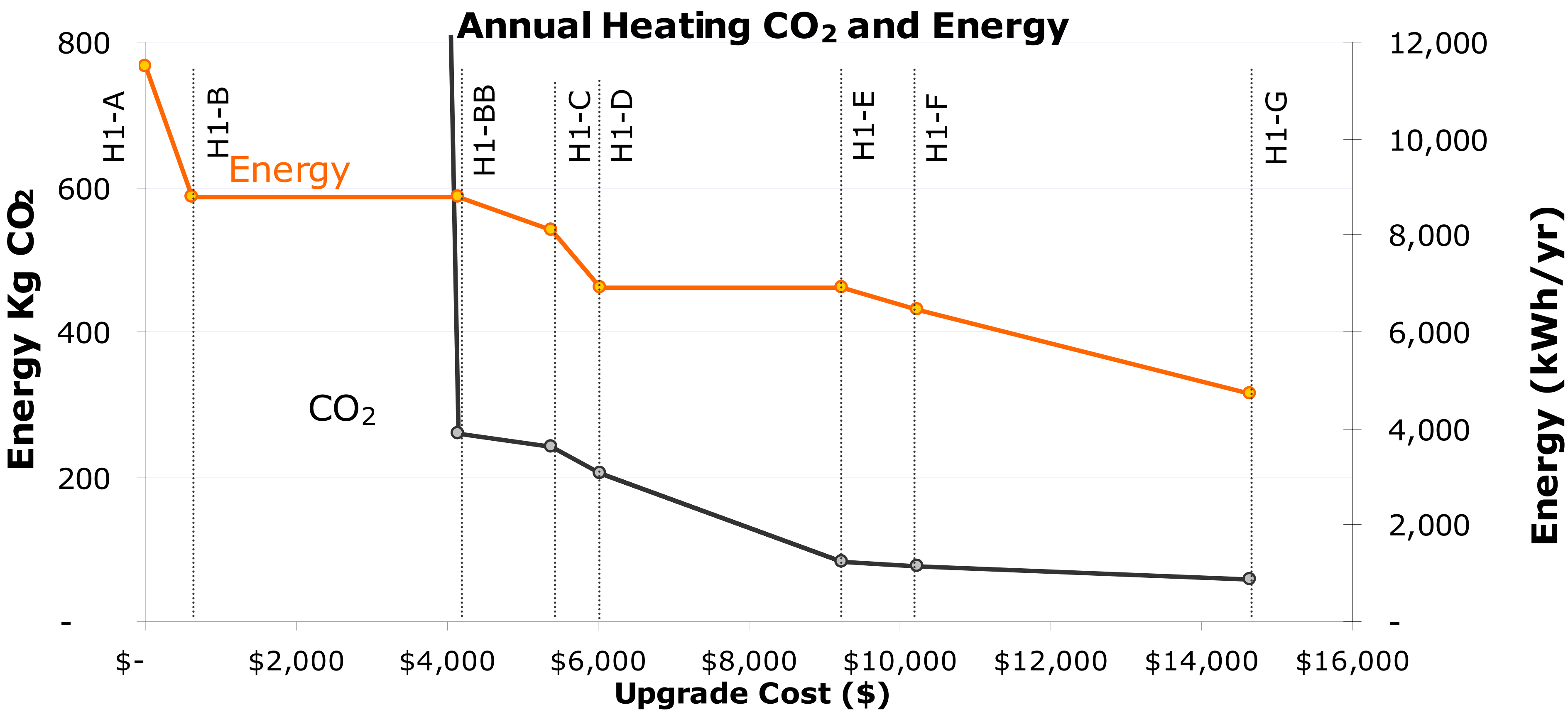
- H1-A Original As Built
- H1-B Ceiling insulation (Insulfluf)
- H1-BB Heating system: Wood Burner to replace open fires
- H1-C Ceiling insulation (Polyester)
- H1-D Floor insulation (Foil)
- H1-E Heating system: Heat Pump to replace Electric Heaters
- H1-F Improving Air tightness
- H1-G Insulating the Walls
- Next step: Upgrading the Windows

Future upgrade path
Costs and Energy

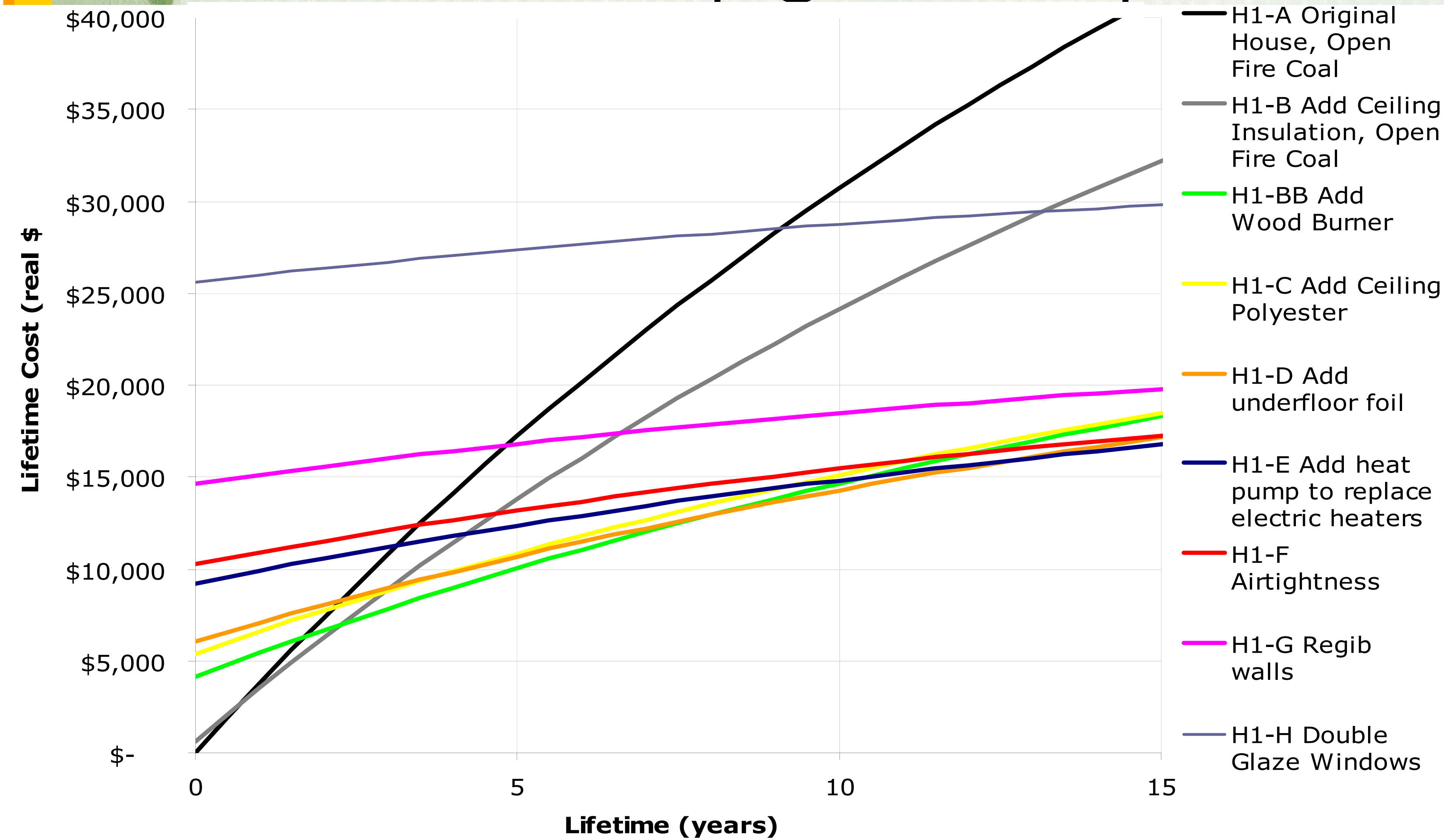


Future upgrade path

CO_2 and Energy



Lifetime cost for various upgrade options



Conclusions & Further work
Bob Lloyd

Conclusions & Further work

- The original HNZC upgrade was simple to implement and reasonably cheap to fund, going the next step will be more difficult and more expensive
- Each upgrade step will incur significant monetary costs but can lead to reductions in gas emissions /reduction in energy consumption and an increase in thermal comfort.
- Funding the costs will be a challenge but a challenge that will have a payoff over the long term.

Conclusions & Further work

- Improving building fabric alone will not provide WHO recommended indoor temperatures
- A path is needed for efficient space heating at a cost commensurate with the occupant circumstances and the environment

Conclusions & Further work

- Importantly, information should be provided to tenants on how to realise energy efficient healthy housing form a behavioural point of view.
- Information packs could be provided to all HNZC tenants on how to manage the indoor environment and provide the health and comfort for all age groups.

Conclusions & Further work

- Insulate the ceiling (Completed)
- Insulate the floor (Completed)
- Install a low emissions woodburner or pellet fire (if not done yet)
- Install a heat pump if it will replace electric heaters used elsewhere in the house.
- Improve air-tightness
- Insulate walls
- Install double glazing/drapes

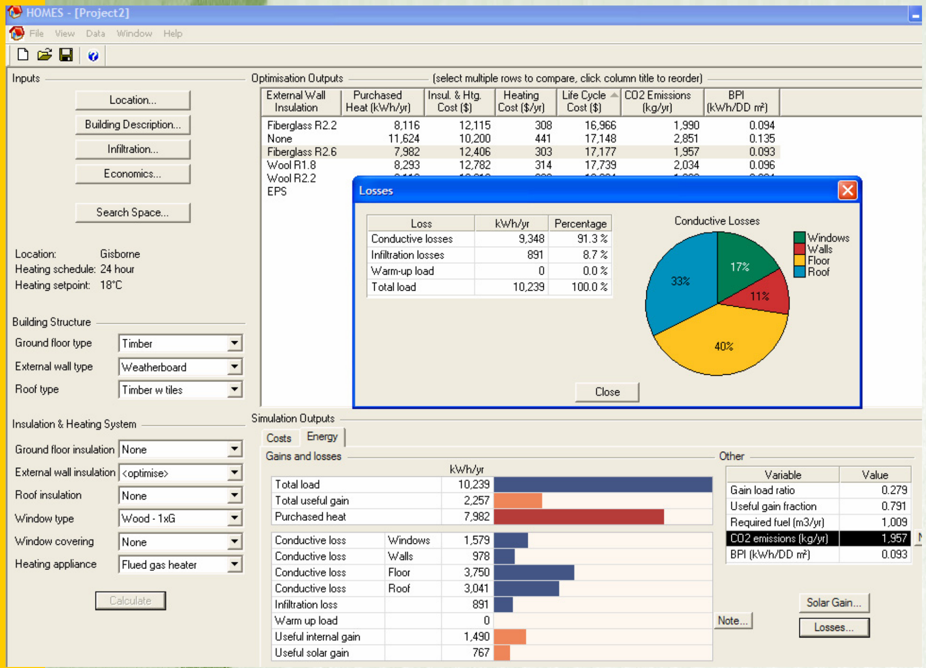
A useful Tool: HOMES

Home **O**ptimization **M**odelling **E**nergy **S**imulation

HOMES is a new optimization program developed for New Zealand based on BRANZ's ALF3.

- Estimate the annual heating energy requirement for houses.
- Explore how different heating schedules, set points and orientation affect heating energy requirements.
- Calculate the energy savings benefit of increasing building insulation, window double glazing and choosing a different heating system.

A useful Tool: HOMES



- Compares costs and savings of upgrade options.
- Determine the Building Performance Index (BPI) o a house.
- Compare CO_2 emissions from different heating choices.
- Quantifies operational CO_2 emissions and cost over a the lifetime of a building.
- Evaluate energy efficiency retrofit options for existing buildings.

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- F.R.S.T of New Zealand for funding this research
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