A Method for Practical Zero Carbon Refurbishments: A Residential Case Study

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(Abridged Version for Publication)

John Shiel[1,2], Professor Steffen Lehmann[3] & Dr Jamie Mackee[1]

[1]University of Newcastle, NSW, Australia

[2]EnviroSustain, NSW, Australia

[3]University of South Australia, SA, Australia

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Introduction

- Part of PhD research

- Building stock of 2020 exists today!
- Few Australian buildings meet BCA thermal provisions
- Urgently need to retrofit existing housing stock
  - To reduce our GhG emissions to zero
    - Climate Change
  - Before oil & other resources get too expensive
    - Peak Resources
- Both issues from population explosion

Importance: Global Warming Evidence

IPCC AR4 SYR (2007)

- Over the last 150 years,
  - Temperature has risen 0.7 degree C
  - Sea level has risen 150 – 200 mm, and
  - Nth Hemisphere snow cover has dropped by 3 million sq km.

Importance: Reaching Peak Resources

"When half of all reserves are extracted"

Mineral	Years left at 50% US consumption rate (New Scientist, 2007)	Years left at 2% increase from 2008 consumption (Brown, 2008)	Years left at current rate of consumption (OECD/IEA, 2008)	Use
Indium	4			LCDs (TVs, Monitors)
Lead	8	17		Lead pipes, batteries
Silver	9			Jewellery, catalytic converters
Antimony	13			Drugs
Tin	17	19		Cans, solder
Uranium	19			Weapons, power stations
Tantalum	20			Mobile phones, camera lenses
Zinc	34			Galvanising
Gold	36			Jewellery, dental
Copper	38	25		Wire, coins, plumbing
Chromium	40			Chrome plating, paint
Oil			~ > 40	Food, energy, plastics, medicine
Platinum	42			Jewellery, catalysts, car fuel cells
Nickel	57			Batteries, turbine blades
Iron Ore		54		Steel – ships, cars, machinery.
Bauxite		68		Produces Alumina, for Aluminium
Phosphorus	142			Fertiliser, animal feed
Aluminium	510			Transport, electricals, durables

New Scientist, 2007. "Earth's Natural Wealth: An Audit", 26 May, p 34
Lester Brown, 2008. "Plan B"

Rare metal prices rising – Siemens, 2008 - http://w1.siemens.com/innovation/en/publikationen/publications_pof/pof_fall_2008/rohstoffe/seltene_rohstoffe.htm
Oil reaching peak production – Aleklett at http://peakoil.net

Importance: Homes – Lifestyle

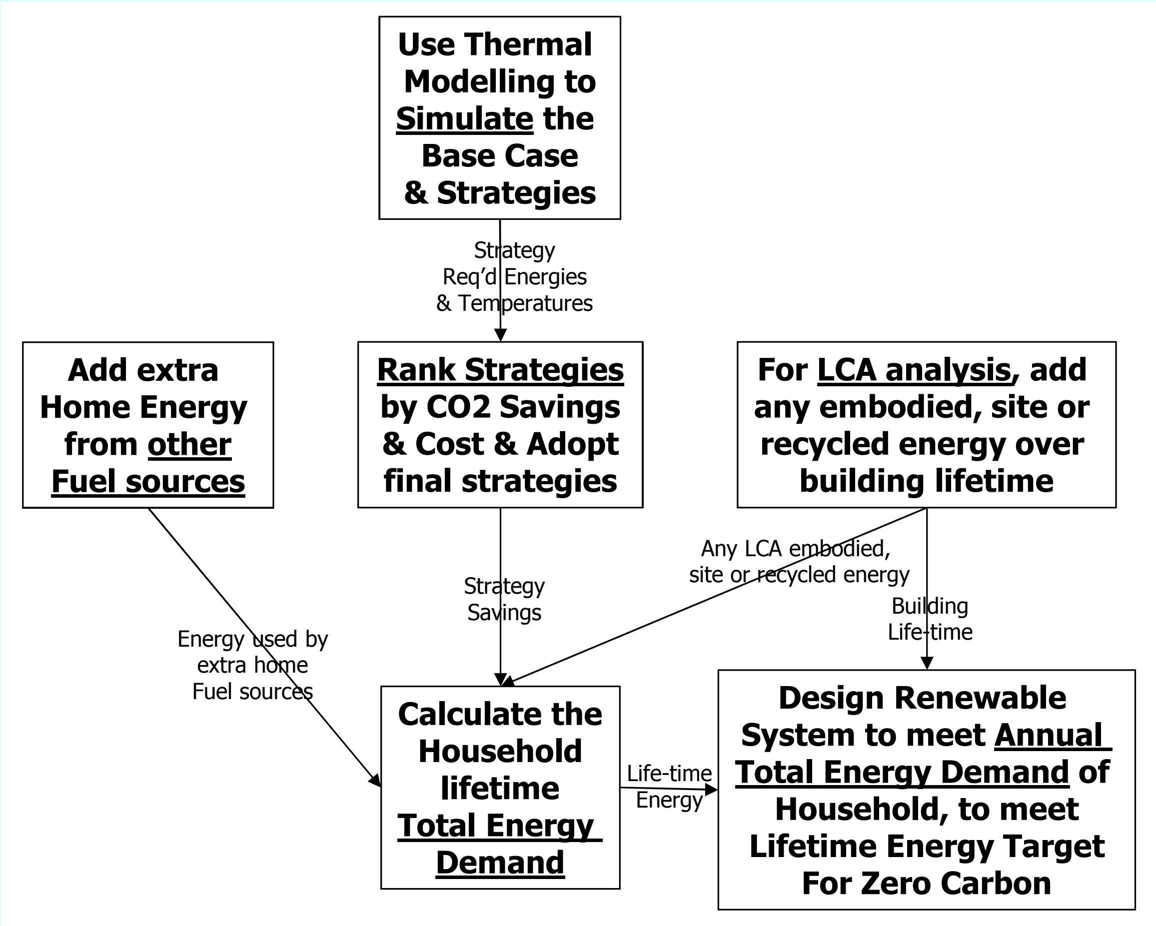
Occupant Behaviour (ACF, 2007) – I/O & LCA CO_2-e

- If we include embodied emissions, and on an input/output basis

- For the GHG consumption in Australia
  - 60% is behaviour-related **food** & **new goods** and **services**
  - 20% is household energy – Envelope plus **dwelling mgmt behaviour**
  - Half of energy used in houses is **Transport**
  - 12% is **new houses** and renovating to **increase the size of houses**

Results: Practical Zero Carbon Refurbishment

Method - (Assumes house energy assessment is done)

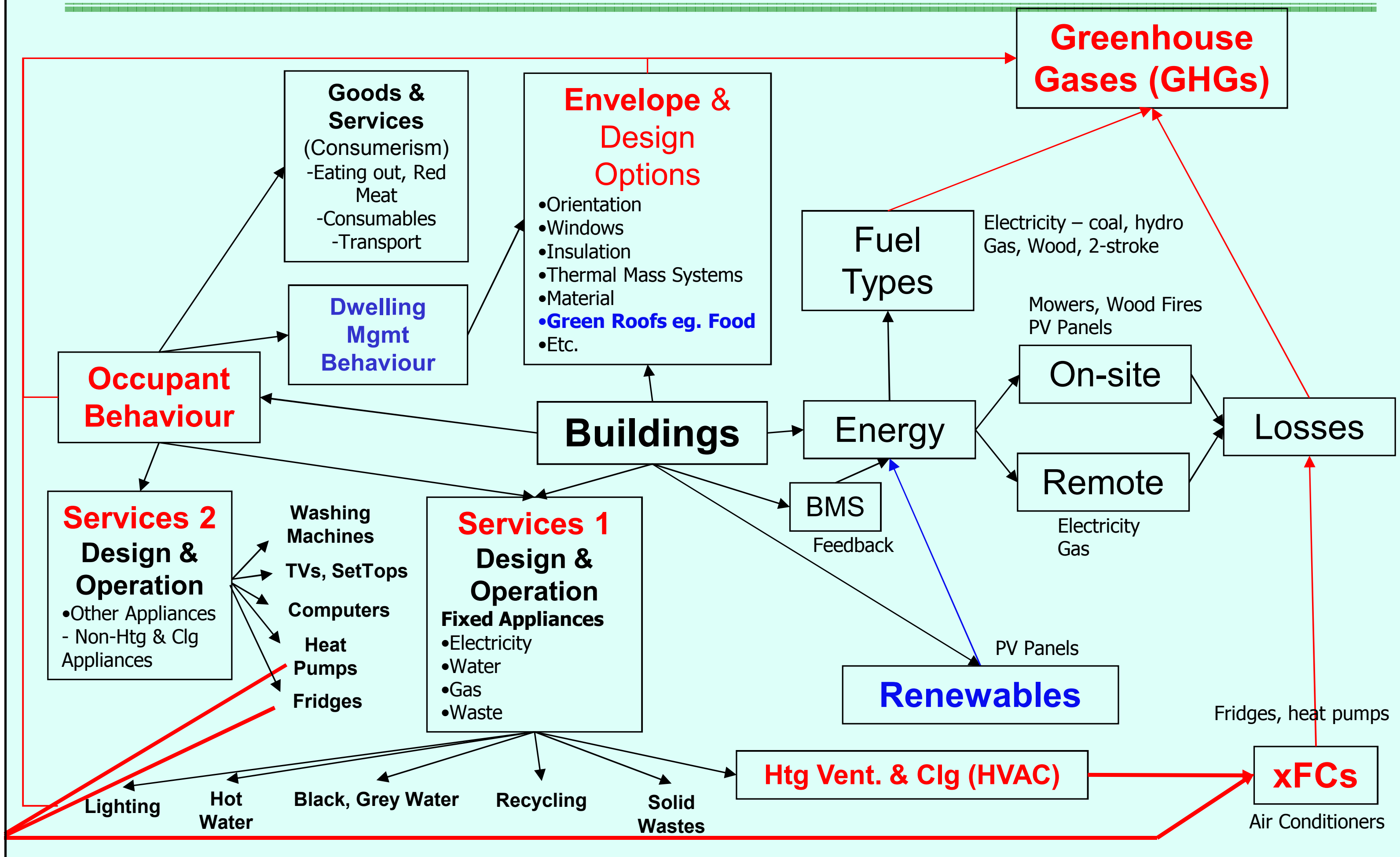


NB:
Thermal modelling only includes space heating & cooling energy

The Operational Householder & Building GHG Problem

Behaviour (60%), Services (15%) & Envelope (5%) – Input/Output & LCA

xFCs – 20% of total Building GhGs



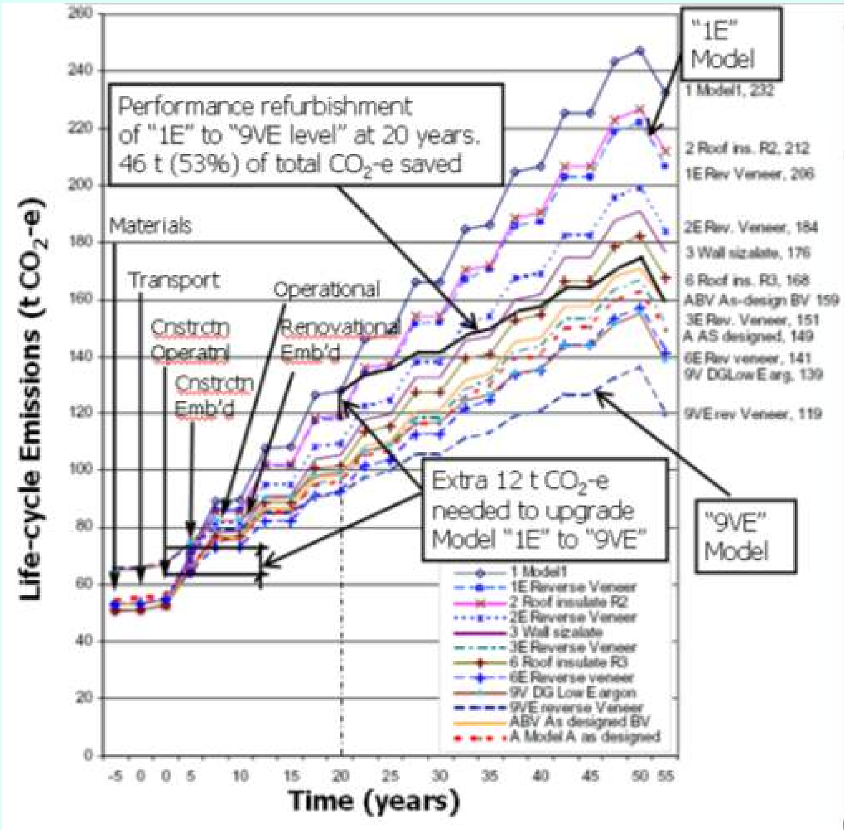
House Carbon Life-Cycle for

Low-Carbon Refurbishment at 20 Years

(Source: Based on Henriksen, 2005)

1. Houses with lowest slopes
   - Are most efficient
   - Use least operational carbon
   - But need more embodied carbon

2. Model 1E house refurbished at 20 years to **super-insulated 9VE Model**



3. Low Carbon Refurbishment
   - Saves 53% CO2
   - Watch embodied CO2 of refurb.

Henriksen method:

1. Use AccuRate to predict indoor temperatures
2. Apply an air-conditioning algorithm to obtain energy
3. Calculate Primary Energy
4. Calculate NSW emissions
5. Add embodied emissions for phases

House Carbon Life-Cycle for

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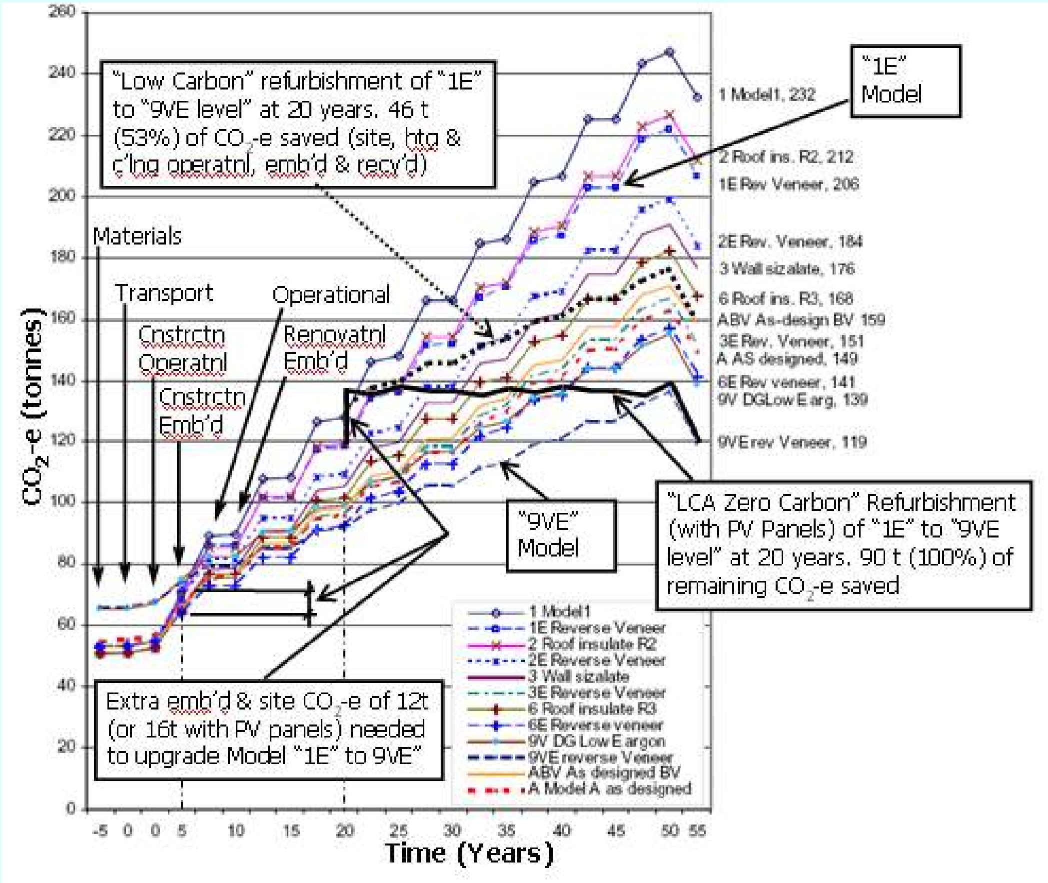
(Source: Based on Henriksen, 2005)

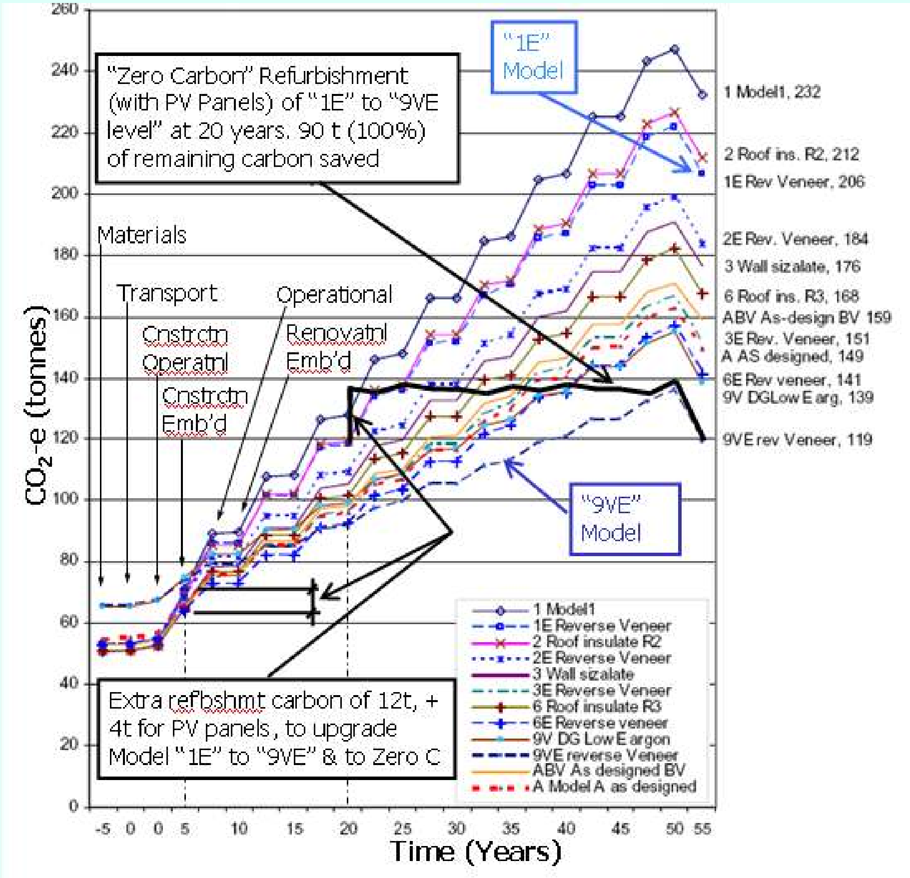


4. Add a 3kW PV system to a Low Carbon Refurbishment to make it a net Zero Carbon house

House Carbon Life-Cycle for

Zero Carbon Refurbishment at 20 Years

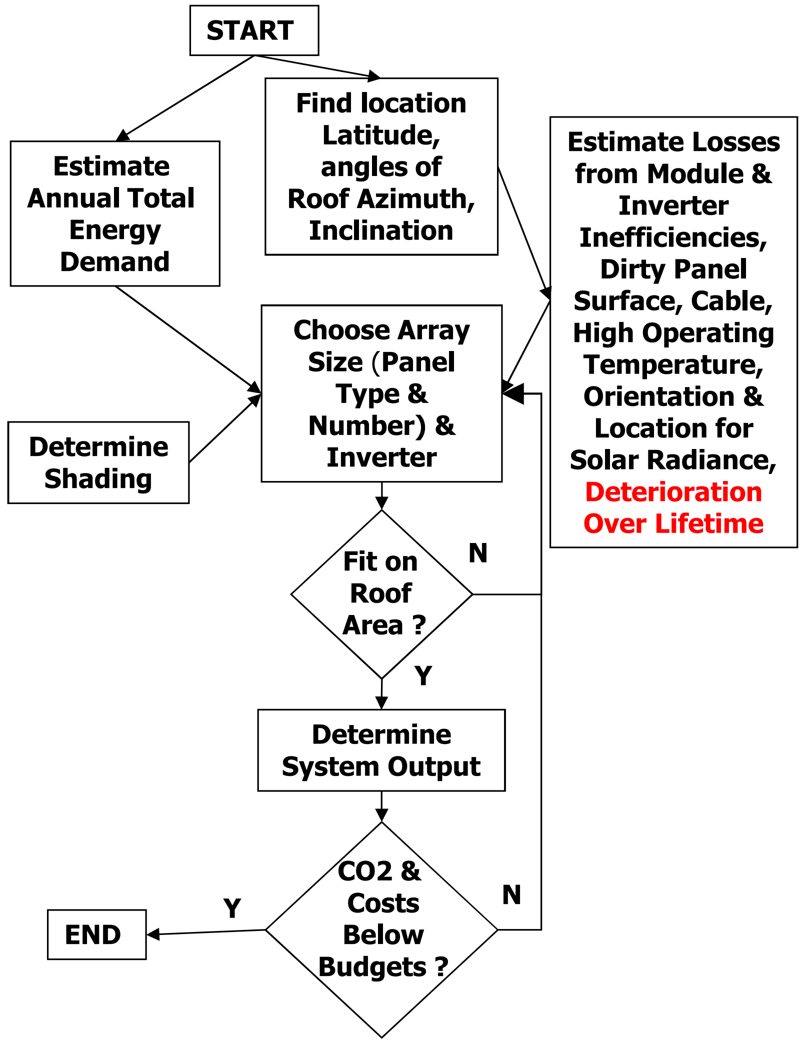
(Source: Based on Henriksen, 2005)



Major assumptions are:

1. There are 30 years to demolition
2. Only heating and cooling carbon is accounted for in the operational stages
3. Additional embodied carbon for the refurbishment at 20 years of **12t** to refurbish Model 1E to Model 9VE (as shown in the Figure as the difference in the initial construction and embodied emissions at "+5 years" for Models 1E and 5E
4. An **extra 4t** for the embodied emissions of the solar PV system itself (assuming approximately 1 year of full operational carbon).

Zero Carbon PV Array Design Method



Iterative design process to find size of panels to reduce household carbon footprint to zero.

Start with

1. Energy (kWh/d) or Carbon target ($kg\ CO_2$-e/d)
2. Cost budget

This was developed to compare quotes from PV system Vendors

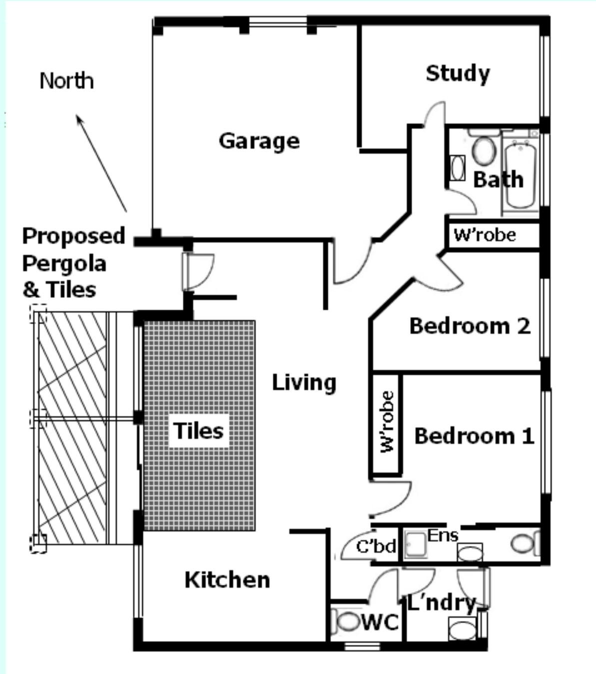
Energy Simulation Modelling

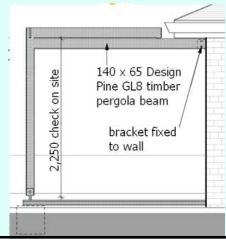
Zero Carbon House Refurbishment - Case Study

- Options modelled
  - R2.5, R3, R4 ceiling insulation
  - Double glazing
  - Pergola
  - Thermal Mass
  - Etc.

- Monitoring – Outside, Bedroom, Lounge
  - Temperature
  - Humidity

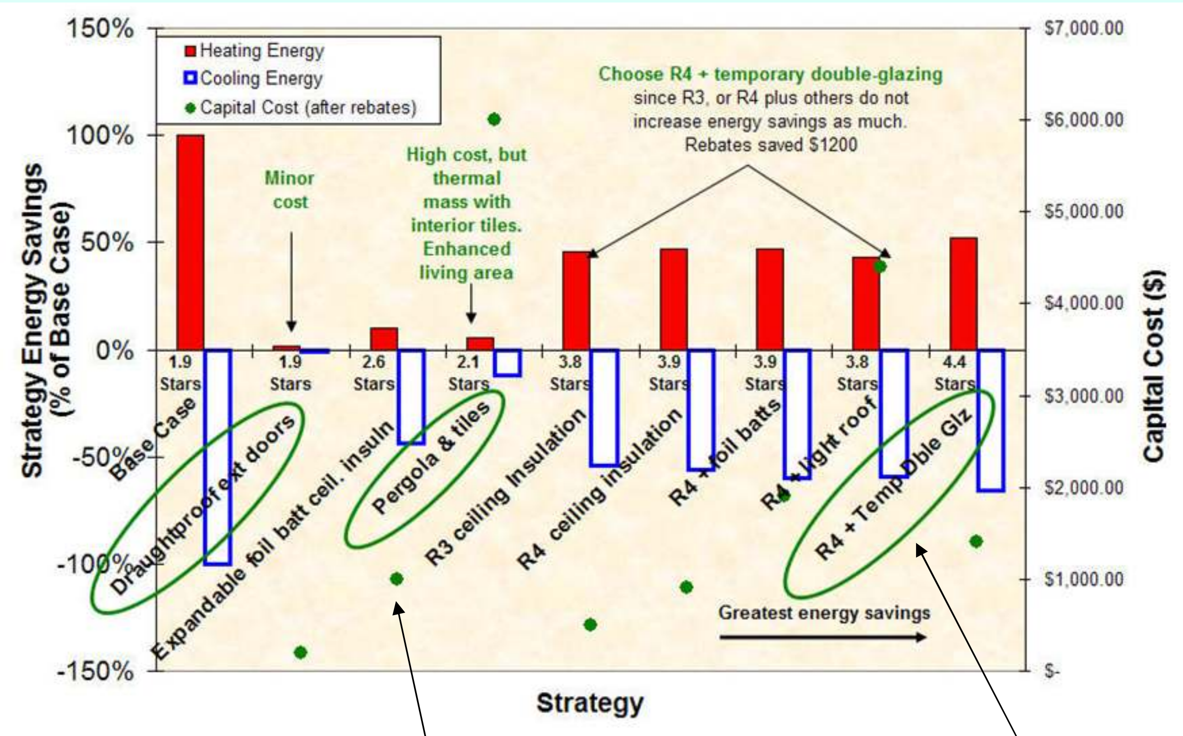
- Rank of most effective, least costly options
  1. R4 ceiling insulation + temp dble glaz.
  2. *Lined & sealed curtains*
  3. *Ceiling fans*
  4. Pergola/ Thermal Mass
  5. Draughtproofing





Pergola Elevation

Percentage of Space Heating & Cooling Energy Savings, Capital Costs & Star Ratings for Refurbishment Strategies



- Effectiveness of various refurbishment strategies
- Improvement in star rating
- Indication of capital cost

Capital Costs

Chosen Strategies in Green Ellipses.

Discussion (1)

- AccuRate
  - Standard rating tool rather than modelling reality
    - Assumed occupant behaviour
    - Standard reference year for climate
  - Has some deficiencies
    - In free running mode (Kodjamshidi *et al.* 2007), that is used to calculate temperatures
    - Humid tropics
    - Subfloor humidity etc.

Discussion (2)

- 100% GreenPower
  - An alternative method of supplying renewable energy
  - Creates an operationally zero carbon house
  - Only the delivered energy is usually offset
    - Not the primary energy.
  - It does not cancel electricity price rises

Discussion (3)

- Carbon and Gross and Net Feed-In Tariff Metering
  - Grid connect
    - Energy will go directly to the grid
    - The house will use Primary Energy from the grid with additional large emissions from losses (70%) at power station and transmission
  - Net Metering
    - House will receive energy directly from PV system, and so the grid with Primary Energy will be used at night and in times of heavy demand or poor solar radiation
  - So we need to factor in additional losses than those estimated in the PV Design method to get Carbon Neutral

Annual House Energy Budget Before & After Refurbishment

Item	Before Refurb. Equiv. kWh/d	After Refurb. Equiv. kWh/d
House Total Demand	11.00	**7.32**
PV System*		**-10.90**

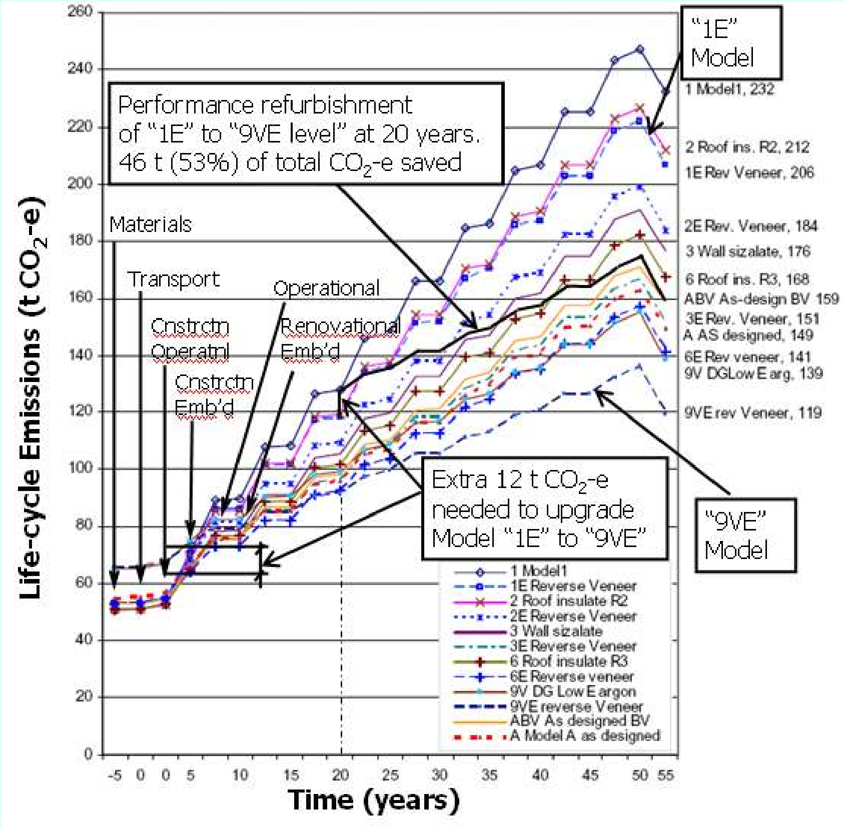
*Vendor estimate of average yearly output of 3kW system installed.

House delivered energy totals need to be adjusted for losses as per

1. PV Design Method &
2. Gross or Nett Metering losses

Discussion (4) – Demolish/Build new or Refurbish?
House Carbon Life-Cycle for Zero Carbon Refurbishment at 20 Years

(Source: Based on Henriksen, 2005)



Demolish/Build New or Refurbish?

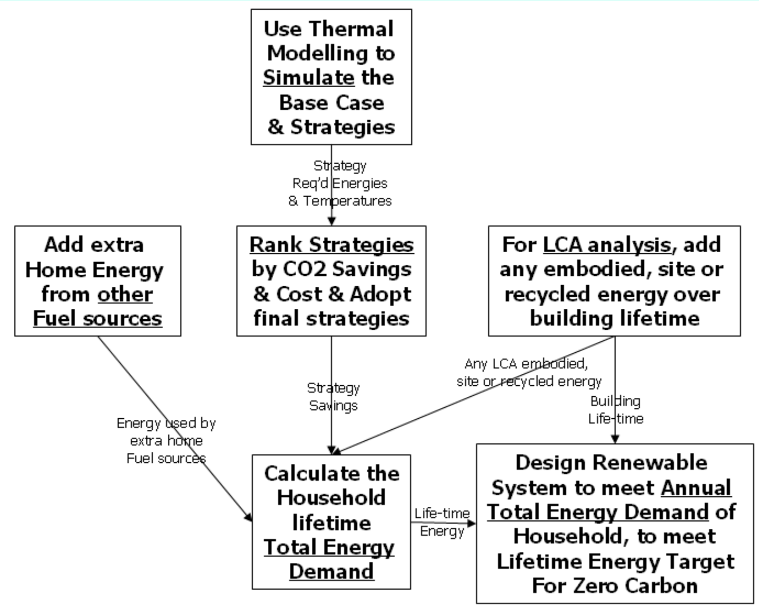
- A new 9VE Model house using **20t of recycled Carbon** recycled would emit **around 85 t** CO2-e in 30 years due to embodied high emissions (105 – 20 = 85t)
- The refurbished 1E Model building only used **40 t** CO2-e in 30 years (160 – 120 = 40t)
  - Reuses the embodied emissions of the 1E Model house
  - But has a shorter longevity
- **Better to refurbish if possible**

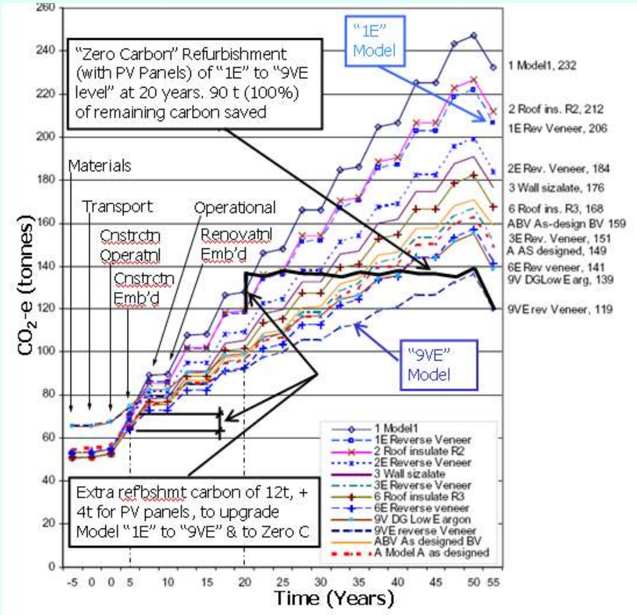
Conclusion (1)

- Building stock of 2020 exists today!
- Few Australian buildings meet BCA thermal provisions
- Urgently need to retrofit existing housing stock
  - To help meet our Climate Change targets
  - To get ready for Peak Resource challenge

Conclusion (2)

- Method for practical zero carbon refurbishment strategies
  - Obtain a house energy assessment;
  - Rank strategies using <u>thermal simulation</u> for energy savings and temperature impacts and <u>Simple Payback Period</u> to find the impact of the return of the investment against the investment outlay
  - Calculate Total Household Energy Demand (all fuel sources)
  - Design a renewable system to meet the reduced energy demand





Conclusion (3)

- Gross vs Nett Meters
  - Gross metering
    - Taking energy from grid (power station "heaters" with 70% energy losses)
  - Nett metering
    - Still taking some energy from grid
    - So not just looking at house demand – there may be some net grid losses
    - Need to factor these losses in
      - Before you can be sure you have designed a zero carbon house

Conclusion (4)

- A taxonomy of types of building carbon emissions
  - Across stages (time) in the building lifecycle
    - Embodied carbon for materials,
    - Materials transport carbon,
    - Site construction carbon
    - Site embodied carbon.
    - Operational carbon (only takes into account spatial heating and cooling energy, and not any other appliances etc.)
    - Regular component replacement (renovation) embodied carbon
    - Demolition carbon
    - Recycled embodied carbon (credit)
  - Spatial scope
    - Refurbishments,
    - Complete buildings
    - Districts
  - Metering
    - Gross (more grid losses)
    - Nett
  - Behaviour
  - FluoroCarbons

Thank you