Affordable DIY Retrofits for Rapid Decarbonisation and 21st Century Warming

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Overview

1. Background and Aim
2. Method
3. Results
   A. Climate Change Modelling
   B. 3 House Retrofit Simulations
   C. Net zero house PV design method
4. Findings
5. Acknowledgements
6. References
1. Background and Aim

• Background
  – Australia
    • has one of the world’s worst-performing building stocks
    • committed to zero carbon by 2050 at 2015 Paris COP 21
  – Need to rapidly lower emissions of existing housing
  – Deep retrofits needed to better adapt to 2050 (and tolerate warmer nights) & to lower/mitigate housing stock impact on climate change
    – Upgrades will be adopted if convenient, easy and affordable (Bond, 2011)

• Aim
  – To find affordable and effective low-carbon retrofits for 2050
  – For typical Warm Temperate Australian housing
2. Method

A. Climate Change
- The projected 2050 temperatures and humidity changes
- Used CSIRO Climate Future tool – AR5 GCM models
- 2 Scenarios (RCP8.5, RCP4.5) for only the "Maximum Consensus" climate futures were considered
  - since 2 climate change scenarios were being researched
- Belcher Morphing for 1990 weather data

B. House Model & Retrofits
- Typical 1950s, 1980s, 2010 houses
- Perimeter insulation, sealing, thermal mass
- Adelaide, ducted air conditioner (50% of market)

C. Cost Benefit Analysis
- Money and carbon saved
- Simple Payback Period
- Most affordable and effective retrofits
  - SPP < 3 years (for those renting)
  - SPP < 10 years (for owners and investors)
  - EnviroSustainers – those wishing to be Zero Carbon dwellers
A. Climate Change Modelling
CSIRO “Climate Futures” on-line tool – using AR5

“Climate Futures” settings for 2050 Extreme Climate Change (RCP8.5) scenario

- Used only **Temperature** and **Humidity** parameters for the building simulation
  - other parameters not significant in a Temperate Climate (Chen et. al, 2012)
- Used rainfall as a proxy for **humidity** since:
  - Strong correlation
  - More robust identification of the 'key cases' since every model has data for rainfall, and so a wider range of change.
  - Models without humidity data can be avoided later
- Used 2 scenarios
  - Extreme Climate Change (**RCP8.5**)  
  - Scarce Resources (**RCP4.5**) where growth is lowered by resource pressures (water, soil, conventional oil) **PTO for Anthropocene**
Welcome to the Anthropocene* Geological Era

• Anthropocene image

• We are reaching the limits of freshwater/person, fertiliser, marine fish capture (now eating more farmed fish than wild fish), and domesticated land (farmed and for cities)

• This is due to
  – The great acceleration from 1950 after the end of WWII, with
  – Consumption driven
    • The explosion of the rich middle-classes, greater urban population with one use plastics, cans
    • leads to the research into resource depletion (see water, land, fish indicators)

• So a climate change scenario of Scarce Resources was developed
  – Modelled with RCP4.5
B. Realistic Houses Modelled
With Lot size and house area for that era

House 1
1950s
Weatherboard
Timber floor
(no garage)
No Ceiling insulation
112m² area
Tile roof
2.74m ceiling
45cm eaves
Timber sgl-glzd windows

House 2
1980s
Cavity brick
Timber floor
Single car garage
No Ceiling insulation
187m² area
Tile roof
2.4m ceiling
60cm eaves
Alumin. sgl-glzd windows

House 3
2010s
Brick veneer
Concrete slab
Double car garage
R1 Ceiling insulation
223m² area
Metal roof
2.4m ceiling
60cm eaves
Alumin. sgl-glzd windows
Some of 70 Retrofits researched*

- Partial air-conditioning (partitioned)
- **Insulation** - Ceiling and roof (batts, foil); Underfloor – Sancell, foil, polystyrene batts, AIRCELL; External wall cavity – foam and polystyrene; Zincalume as external wall cladding; Add carpet to timber floor
- **Weather-stripping** - Ultra sealed with HRV; without HRV; and with optimum sealing – no HRV (Lsitburek)
- Add thermal mass (Water in fish tanks & Wine racks; insulated masonry walls; concrete or floor pavers; Remove carpet from concrete floor)
  - Need envelope with low conductivity for least comfort energy for air-conditioning, but need low diffusivity (Diffusivity = Conductivity/Thermal Mass) to maintain comfort temperatures without air-conditioning
  - Low embodied energy (water, 2nd hand bricks)
- Painting roofs and walls (white, reflective)
- Radiation (window sizes, tinting, curtains)
- Ventilation (louvres, ceiling fans)

*Novel retrofits do not need to comply with NatHERS protocol eg. vegetation, water, since we are after the temperature and energy reductions not a better star rating.
Novel Retrofits
Thermal Mass Additions; External Wall shielding

- Challenge is large thermal mass with low embodied energy
  - 2nd hand, zero carbon, water
- Joined 8 wine racks together – 564 bottles (423L).

Large fish tank – 1200L
Used 3 large fish tanks + 8 wine racks

2nd hand brick wall

Zincalume as external Reflective cladding
House Retrofits
Major Assumptions

- **Costs**
  - DIY costs reported here (supply only) – from Rawlinsons, 2016
  - Some retrofits were assumed zero DIY cost (PV system for shade; aquariums)
  - Simple Payback Period (No future energy price increases; No replacement, repair or refinishing costs; No inflation)

- **Adelaide, SA location**
  - Electric Split system Air Conditioner
  - Carbon
    - Emissions Factor = 0.64kgCO2/kWh, due to natural gas power stations (too low since CH4 GWP100 of 28 is used, not GWP20=84 and don’t have 100 years to reduce to zero carbon)
    - SA electricity rate = $0.35

- **Climate Change**
  - 2050 Scarce Resource Scenario
  - Only Temperature and Humidity parameters used for 2050 projections (for building)

- **Affordable and effective retrofit criteria**
  - Arbitrary < 50 year SPP and > 0.15t/yr CO2-e thresholds

- **Modelling**
  - Realistic based on actual plans, period sizes for house and lots, and neighbour impacts
  - Some energy savings were estimates based on analogous physical modelling and checked by a NatHERS expert
    - Do not strictly comply with NatHERS rules for ratings (aquarium, vegetation etc.)
  - Different retrofits can be compared relatively with AccuRate and the NatHERS assumptions (eg. comfort, temperature ranges, occupancy levels, number of conditioned rooms), although there are room type differences across houses
4. Results
A. Climate Change

The HADGEM2-ES GCM monthly changes from 1995 to 2050 for RCP8.5 and RCP4.5

Temperatures (°C change)  Humidity (% change)
B. DIY Retrofit Carbon Savings ($\Delta C$) for Simple Payback Period (SPP)
2050 Sc. Res. Scenario - Adelaide House 1 - 1950s weatherboard timber floor

Adding water as THERMAL MASS is the most affordable DIY retrofit with small effect, but good CO2 reductions from partitioning the house, followed by insulation (ceiling and roof – in blue, underfloor – in brown, wall cavity insulation – in purple), as well as sealing house – bolded.
Adding water as THERMAL MASS is the most affordable DIY retrofit with small effect, but good CO2 reductions from partitioning the house, followed by perimeter insulation (ceiling and roof – in blue, wall cavity insulation – in purple), sealing the house and adding thermal mass (dark blue).
Adding water as THERMAL MASS is the most affordable DIY retrofit with small effect, but good CO2 reductions from partitioning the house is the most cost-effective, followed by perimeter insulation (ceiling and roof – in blue), as well as sealing house, and adding thermal mass (dark blue).
Comparison of Savings across Houses
Scarce Resource 2050 Scenario

- Large savings in carbon and money to be made for **1950s weatherboard** home
  - Partitioning; insulating ceiling, wall (cavity and external cladding) and **floor**; sealing home
- The **1980s cavity brick** home had fewer retrofits and they were lower in carbon savings
  - Partitioning; ceiling and roof insulation; cavity wall; sealing; **thermal mass wall**; with notably **no floor savings**.
- The modern **2010 brick veneer** home with a concrete slab & R1 in ceiling had fewest retrofits
  - Partitioning; sealing (only Ultra no HRV and HRV); ceiling and roof insulation; **thermal mass wall**; and **no optimum sealing**.
- Interestingly, both the **cavity brick and brick veneer** homes could easily add **thermal mass** by insulating the garage side of the brick garage wall. Adding thermal mass with water was possible for all houses, but carbon savings were low.
Carbon savings for Existing Houses for Era and Construction type
By degree of retrofit (Renters, Owners and Deep Retrofit Households)

Renters could negotiate a 3 year lease with no rent increase to retrofit the house
(Landlords could also charge a higher rent in future)
Owners & Landlords have a SPP < 8 years
Energy Positive/EnviroSustainers carry out deeper retrofits
2010 MW house has R1 ceiling insulation, and concrete floor with some thermal mass

Major assumptions – Adelaide location; split system air conditioner; DIY retrofits (supply costs only); Energy costs and carbon savings based on NatHERS occupancy assumptions (may be overly optimistic).
# Deep Retrofit Combinations

## 15 Year SPP – Scarce Resource Scenario

<table>
<thead>
<tr>
<th>House</th>
<th>Retrofits</th>
<th>SPP (yrs)</th>
<th>Carbon Savings CO$_2$-e/yr (t/yr)</th>
<th>Total DIY cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H01 – 1950s Weatherboard, timber floor</td>
<td>501 - 35 - Parasol roof in N an; 42 - 8 wine racks (564 bo; 44 - 2 large Aquariums in; 45 - 1 large Aquarium in ; 3 - Ceiling R4; 16 - Sancell Underfloor 1; 59 - Foil batts in roof u; 62 - Foil batts stapled under floor; 72 - Insulbloc to wall ca; 55 - Green ivy on North &amp;; 76 - Lstiburek optimal infiltration 10ACH$_{50}$; 67 - Add carpet to timber; 53 - Roof R1 insulation (; 26 - 5m high deciduous tr; 49 - 1.4m dia Ceiling fan; 32 - Low-e film applied to windows</td>
<td>8.3</td>
<td>2.7</td>
<td>12,500</td>
</tr>
<tr>
<td>H02 – 1980s Cavity Brick, timber floor</td>
<td>502 - 35 - Parasol roof in N an; 42 - 8 wine racks (564 bo; 44 - 2 large Aquariums in; 45 - 1 large Aquarium in ; 5 - Roof sarking Rfoil &amp;; 10 - Liv/Garage wall R1.5; 72 - Insulbloc to wall ca; 60 - Foil batts in ceilin; 76 - Lstiburek approx. 0.; 59 - Foil batts in roof u; 65 - Zincalume as ext wal; 18 - R2.5 polystyrene bat; 62 - Foil batts stapled u; 58 - Aircell Insulbreak t; 34 - Low-e film tint to ; -</td>
<td>12.9</td>
<td>2.1</td>
<td>15,000</td>
</tr>
<tr>
<td>H03 – 2010 Brick veneer, concrete floor</td>
<td>503 - 35 - Parasol roof in N an; 42 - 8 wine racks (564 bo; 44 - 2 large Aquariums in; 45 - 1 large Aquarium in ; 76 - Lstiburek approx. 0.; 3 - Ceiling R4; 10 - Liv/Garage wall R1.5; 74 - 140mm Insulbloc to f; 65 - Zincalume as ext wal; 59 - Foil batts in roof u</td>
<td>12.5</td>
<td>0.9</td>
<td>6,000</td>
</tr>
</tbody>
</table>
## Owners and Landlord Retrofit Combinations: <10 Year SPP - Scarce Resource Scenario

<table>
<thead>
<tr>
<th>House</th>
<th>Retrofits</th>
<th>SPP (yrs)</th>
<th>Carbon Savings CO$_{2}$e/yr (t/yr)</th>
<th>Total DIY cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H01 – 1950s Weatherboard, timber floor</td>
<td>301 - 35 - Parasol roof in N an; 42 - 8 wine racks (564 bo; 44 - 2 large Aquariums in; 45 - 1 large Aquarium in ; 2 - Ceiling R3; 59 - Foil batts in roof u; 62 - Foil batts under floor; 72 - Insulbloc to wall cavity; 55 - Green ivy on North &amp; West walls; 66 - Zincalume as ext North wall; 76 - Lstiburek approx. 10ACH$_{50}$; 67 - Add carpet to timber; 58 - Aircell Insulbreak to roof</td>
<td>5.4</td>
<td>2.5</td>
<td>7,300</td>
</tr>
<tr>
<td>H02 – 1980s Cavity Brick, timber floor</td>
<td>302 - 35 - Parasol roof in N an; 42 - 8 wine racks (564 bo; 44 - 2 large Aquariums in; 45 - 1 large Aquarium in ; 2 - Ceiling R3; 10 - Liv/Garage wall R1.5; 72 - Insulbloc to wall ca; 60 - Foil batts in ceiling; 76 - Lstiburek approx. 0.; 59 - Foil batts in roof u; 62 - Foil batts stapled u</td>
<td>7.1</td>
<td>1.9</td>
<td>7,500</td>
</tr>
<tr>
<td>H03 – 2010 Brick veneer, concrete floor</td>
<td>303b - 35 - Parasol roof in N an; 42 - 8 wine racks (564 bo; 44 - 2 large Aquariums in; 45 - 1 large Aquarium in ; 76 - Lstiburek approx. 0.; 3 - Ceiling R4; 10 - Liv/Garage wall R2.5</td>
<td>5.4</td>
<td>0.7</td>
<td>2,200</td>
</tr>
</tbody>
</table>
### Rental Retrofit Combinations

**<3 Year Simple Payback Period (SPP) - Scarce Resource Scenario**

<table>
<thead>
<tr>
<th>House</th>
<th>Retrofits</th>
<th>SPP (yrs)</th>
<th>Carbon Savings CO$_2$e/yr (t/yr)</th>
<th>Total DIY cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H01 – 1950s Weatherboard, timber floor</strong></td>
<td>201 - 35 - Parasol roof in N an; 42 - 8 wine racks (564 bo; 44 - 2 large Aquariums in; 45 - 1 large Aquarium in ; 3 - Ceiling R4; 76 - Lstiburek approx. 0.</td>
<td>1.0</td>
<td>1.5</td>
<td>900</td>
</tr>
<tr>
<td><strong>H02 – 1980s Cavity Brick, timber floor</strong></td>
<td>202 - 35 - Parasol roof in N an; 42 - 8 wine racks (564 bo; 44 - 2 large Aquariums in; 45 - 1 large Aquarium in ; 76 - Lstiburek approx. 0.; 10 - Liv/Garage wall R1.5</td>
<td>1.9</td>
<td>1.5</td>
<td>1,500</td>
</tr>
<tr>
<td><strong>H03 – 2010 Brick veneer, concrete floor</strong></td>
<td>203 - 35 - Parasol roof in N an; 42 - 8 wine racks (564 bo; 44 - 2 large Aquariums in; 45 - 1 large Aquarium in ; 2 - Ceiling R3; 76 - Lstiburek approx. 0.</td>
<td>2.7</td>
<td>0.7</td>
<td>900</td>
</tr>
</tbody>
</table>
C. Zero carbon method for existing dwellings

1. Find all energy used by appliances
2. Educate occupants to be “active” in conserving household energy
3. Reduce appliance loads
4. Find the most cost-effective retrofits e.g. by simulation
5. Estimate the reduced total household operational energy per year (kWh/a)
6. Find the household energy load per day (kWh/d)
7. Estimate the size of the house solar photovoltaic (PV) system after losses and shading etc
   • \( W_p = \text{Energy per day} \times \frac{1.2}{4} \text{ approx} \)
8. Estimate the size of battery
   • kWh/2d if two cycles can be charged by battery eg. the 2kWh Enphase for $2,500 (get 4kWh charge from it).
5. Findings

• Upgrades will be adopted if convenient, easy and affordable (Bond, 2011)
• Affordable and effective low-carbon retrofits can be found for lightweight and heavyweight housing types in Australia
  – They don’t need to have star ratings, so we can use the temperature and energy comparisons in simulation engines to model novel retrofits
• The Extreme Climate Change scenario projection for 2050 by GCM projects temperatures to rise by 1.8 Kelvin from 1995 to 2050
• However, Scarce Resource scenario indicators may be more likely
• For security in Global Warming
  – Need optimal thermal mass for free-running conditions (Baverstock, 1986)
    • Watch power blackouts – storms, fuel shortages, grid accidents (eg. Tas Bass Straits), so should not rely on Passiv Haus, or Energy Recovery Ventilation systems (need resilience)
7. Acknowledgments

• My supervisors
  – Behdad Moghtaderi, Richard Aynsley, Adrian Page

• CSIRO’s
  – John Clarke, Leanne Webb, Jack Katzfey
  – Dong Chen

• Architect Graham Hunt

• IT Analyst/programmer Allan Leslie
Thank you

Questions?

Significance of parameters in Climate Change Modelling

• Used only Temperature and Humidity parameters for the building simulation
  – Other parameters not significant in a Temperate Climate (Chen et. al, 2012)
  • Even if there were other parameters that were significant, the strong correlations with temperature & precipitation (excluding wind) means that robust data can still be obtained for those variables using this 2-way classification.