

M MATHS
Y & T H S
M A T H S
BEHIND A LOW
C A R B LO W
A U C K
L A N D

In 2011, Auckland Council commissioned a report to identify how the City could reduce its Carbon emissions. The top 6 recommendations for the built environment included: compact growth, electric vehicles, smart grids, building integrated renewables and standards for both residential and commercial buildings.

All these topics are subject to research at the School of Architecture and Planning, the University of Auckland. The research is empirically based and interrogates some fundamental assumptions that are currently held about the performance of the built environment. The research questions and challenges many issues that appear in policy and good practice documentation concerning compact built form, transport energy, energy standards and the productivity benefits of 'green' buildings.

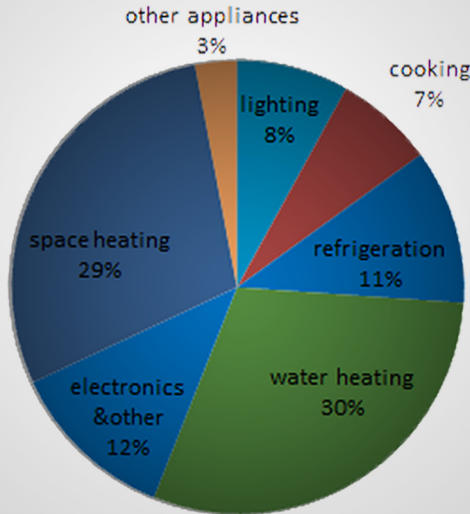
The maths involved in the research has revealed the myths that lie behind the commonly held assumptions of the relationship between built form, energy use and Carbon emissions. As Auckland strives towards sustainability, the importance of independent and robust research on these issues grows in importance. This presentation and exhibition reveals that commonly held views should not necessarily become the basis of policy.

The research presented here was carried out by Hugh Byrd, Anna Ho and Eva Nash at the School of Architecture and Planning. We are grateful for the support of the University for funding this presentation and exhibition.

COMPACT ENERGY;

HOUSING AND AN URBAN MYTH

% Electricity consumption



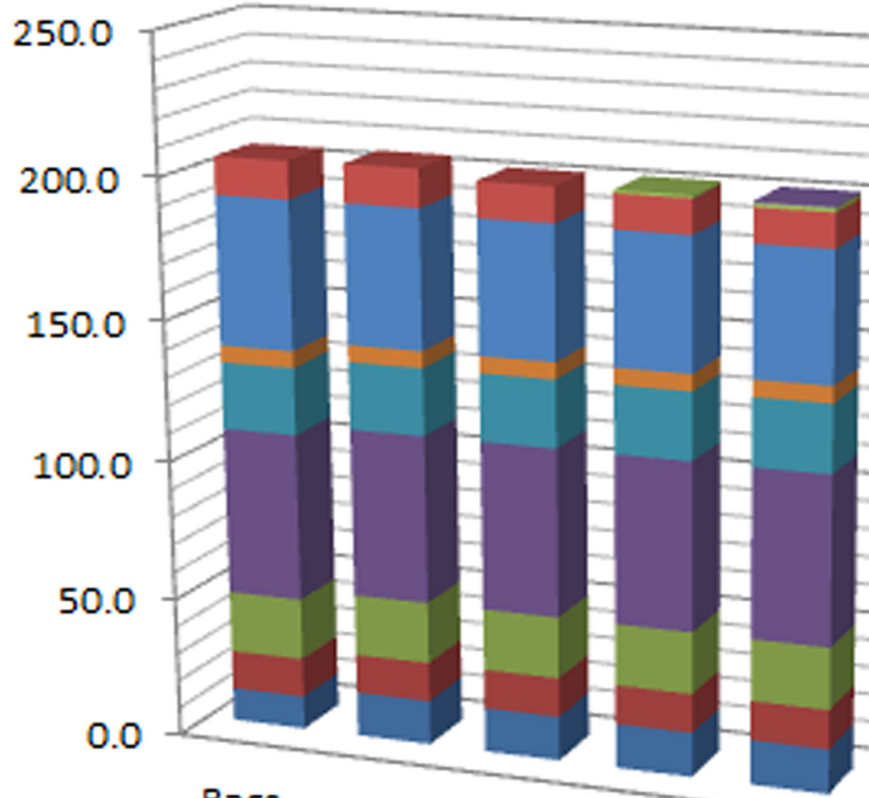
The myth

"In New Zealand, increasing the density of urban residential developments has the potential to reduce domestic energy consumption in relation to transport and home thermal comfort. By joining houses together or otherwise clustering them, the external envelope of each house can be reduced, with consequent reductions in heat losses..."

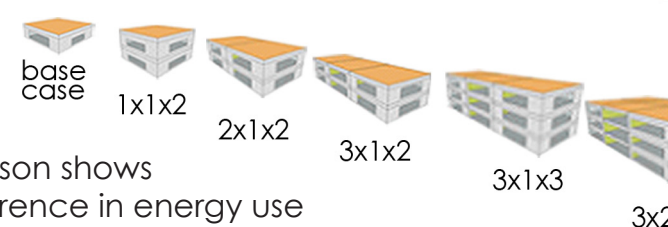
Department of Building and Housing:

Joiner, D. (2010) Sustainable Urban Behaviour. Proceedings of the SB10 conference, Wellington.

Electricity consumption kWh/m²/year



Base case 1x1x2 2x1x2 3x1x2 3x1x3



A fair comparison shows little overall difference in energy use between different house forms when modelled

- lift (3x2x6 only)
- additional cooling
- addition fans & lights
- corridor lighting
- external lighting
- cooling
- heating
- other appliances
- electronics
- water heating
- refrigeration
- cooking
- lighting

Comparison of electricity use assumptions:

All unit have a floor area of 100m²
 All have the same standards of insulation (H1 compliant)

All glazing areas are the same (25% glazing)

All are heated/cooled by heat pumps

Occupancy patterns, orientations, temperature settings are all identical.

Assumed above ground parking

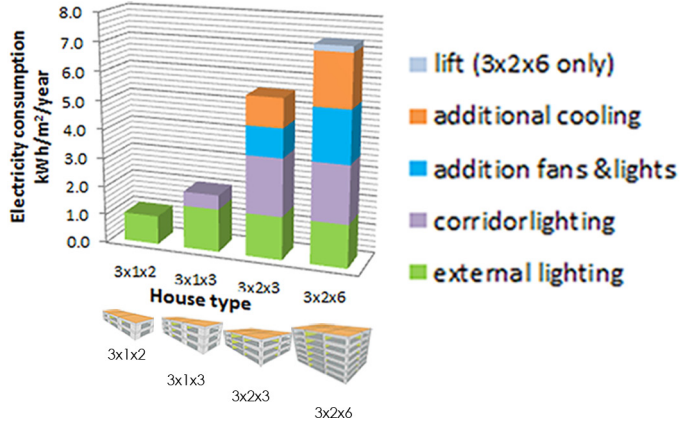
NIWA weather data for Auckland

All modelled using Ecotect.

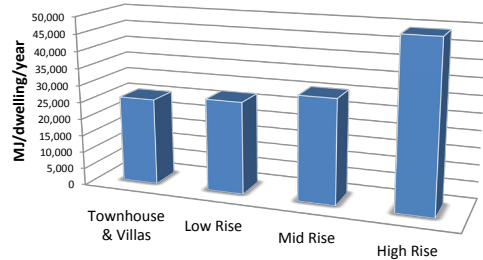
Additional energy use with compact housing

- Cooling load increases with compact plans that have inadequate cross-ventilation
- Lighting load increases when windows are on only one or two sides
- Mechanical air extraction is needed for windowless rooms
- Lighting for corridors and stairs increases with multi units.
- Lifts are required for high rise
- External security lighting for multi units

There are slight energy savings in space heating if houses are more compact. But this is outweighed by the additional energy use for lighting, ventilation, cooling and other electrical uses in common areas. With climate change, more energy will be required for cooling than saved by reduced heating. This will not favour compact housing



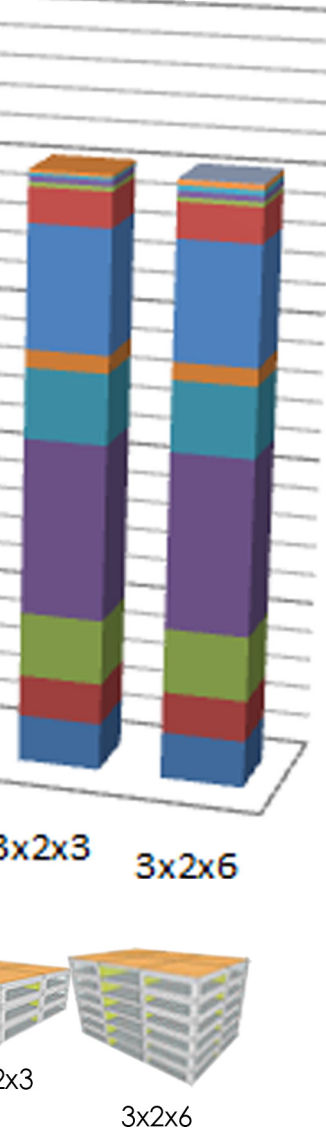
Annual energy use per dwelling
 Energy audit of 3670 apartments in Sydney (1)



(1) Myers, P., O'Leary, R. & Helstrom, R. (2005) Multi unit residential buildings energy and peak demand study. Report for Energy Australia and NSW Dept of Infrastructure, Planning and Natural Resources

This audit also took account of electric clothes dryers (more predominant in multi unit housing) and swimming pools and below ground car parking.

- 1) Space heating does diminish when surface area to volume ratio decreases.
- 2) Cooling load increases with compact plans with inadequate cross-ventilation
- 3) Lighting load increases when daylight distribution is uneven around the perimeter.
- 4) Mechanical air extraction for windowless rooms
- 5) Lighting for corridors and stairs increases with multi units.
- 6) Lifts are required for high rise
- 7) External security lighting for multi units

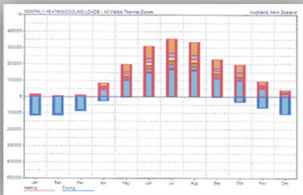


ARE ARCHITECTS MORE DANGEROUS THAN CLIMATE CHANGE ?

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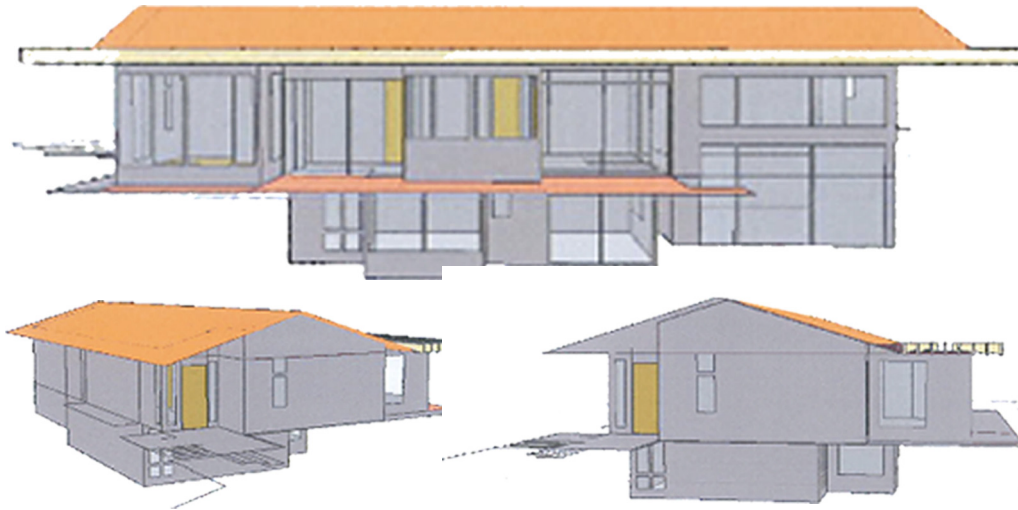
ONE HUNDRED AND ONE award winning houses built over the last 50 years were analysed to see if designers are getting better at producing energy efficient houses.

They may look great but are they good examples of Environmentally Sustainable Design?



All houses were modelled using Ecotect to establish their annual energy consumption. For a fair comparison the model assumed:

- NIWA weather data for the nearest location in NZ
- Occupancy patterns kept the same for all houses
- All houses used heat pumps
- Heating on below 18C. Cooling on above 24C.



From 1978 to 2001, there were no energy Code changes for houses in New Zealand. During that time **award winning houses have increased their energy consumption by 20%** per unit floor area on average. Since 1978, **Code changes in the USA have resulted in halving the energy consumption of buildings.**

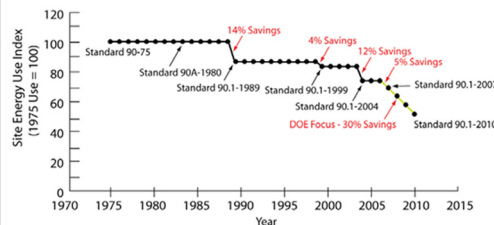
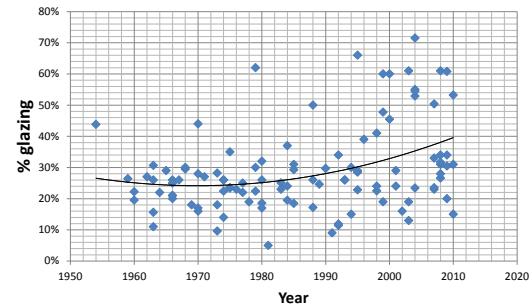


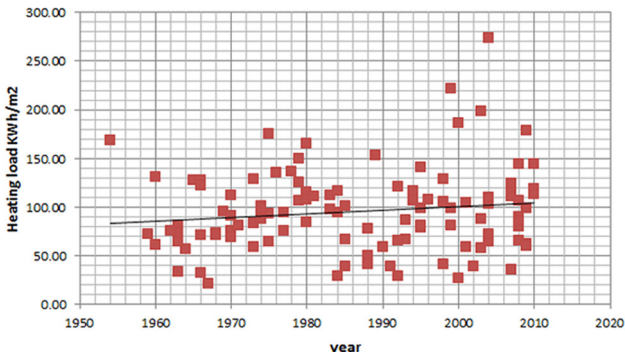
Figure 1. Improvements in the ASHRAE 90.1 code over time. ©2010, ASHRAE (www.ashrae.org). Used with permission from ASHRAE.

% GLAZING TRENDS OVER THE 50 YEAR PERIOD BETWEEN ABOUT 1960-2010



- Best fit curve shows general trend to increase % glazing
- % glazing remained reasonably steady up to around 1985 and has then increased at an average rate of 0.5% per year there after

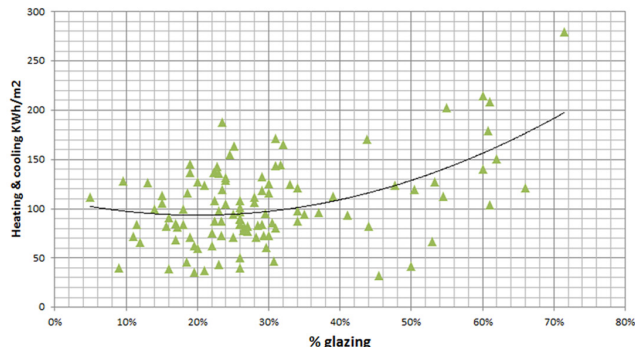
HEATING LOAD (kWh/m²) TRENDS BETWEEN ABOUT 1960 - 2010



Heating load per year

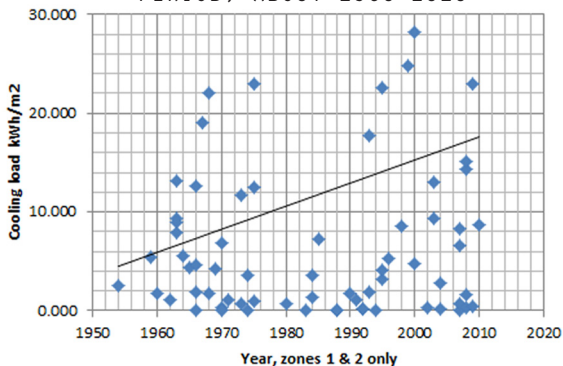
- Very gradual increase of 18kWh/m² over 50 years
- On average less than 0.5% increase per year
- 25% increase over 50 years

HEATING AND COOLING LOAD, ALL ZONES, 1960-2010 AGAINST % GLAZING



- Optimum % glazing between about 10% to 30%
- After 50% glazing, combined heating and cooling load increases at the rate of 30 kWh/m² for every 10% glazing

COOLING LOAD TRENDS OVER 50 YEAR PERIOD, ABOUT 1960-2010



Cooling load for zones 1 and 2 only (these zones tend to have higher temperatures)

- Average increase of 12kWh/m² over 50 years
- 300% increase over that period, an average of 6% increase per year
- Heating increasing by 0.5% per year. Cooling load is increasing 12 times faster than heating

Will the 2007 Code changes make a difference to this trend?

With more and more glass (over 40%), Code compliance can only be achieved by simulation.

1) **Almost 1/5th of these award winning houses were unable to comply with Code** by any method including simulation.

2) **Loophole in NZS 4218.** The default values for simulation (section G1.4) allow the modeller to alter the values if:

"...the designer can demonstrate that different assumptions better characterise the building's use..."

According to BRANZ*, climate change is increasing energy consumption in housing by about 1% per year. Extra energy used for summer cooling is more than that saved for winter heating. **Award winning housing design is also increasing energy use by about 1% per year** (not accounting for climate change).

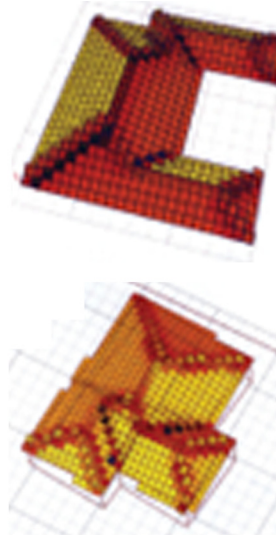
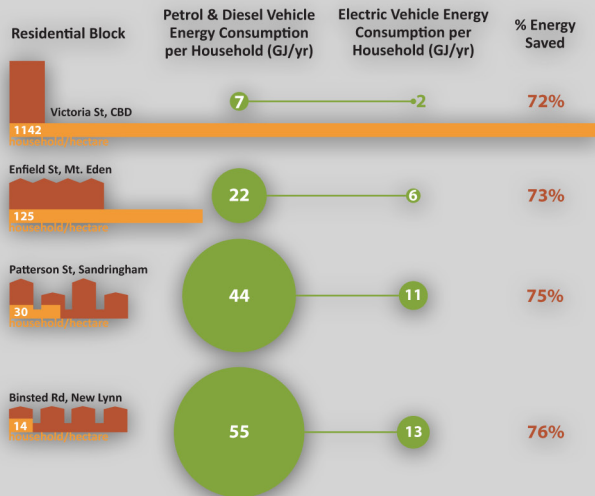
*Page, 1. (2009) 'Regional Heat Pump Energy Loads' BRANZ report No E528

URBAN DENSITY AND TRANSPORT: REVERSING THE CURVE

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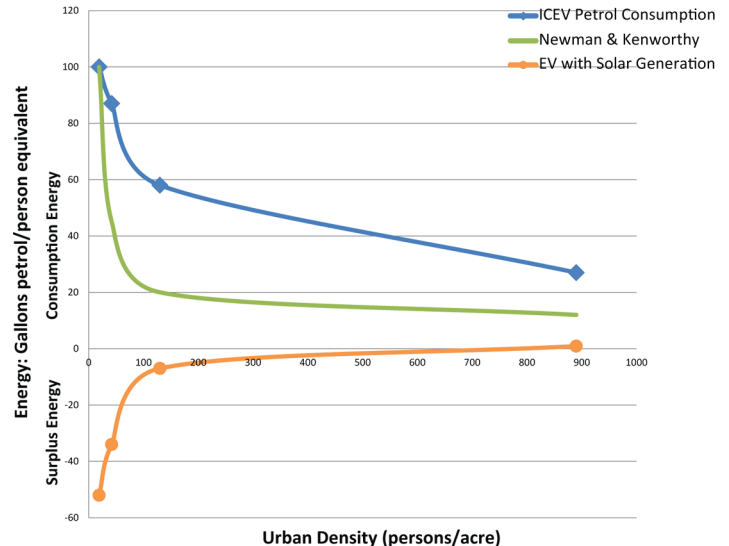
different housing developments with different densities and distances from the CBD were compared based on various data sources such as the 2006 Census NZ and the National Travel Profile by the NZ Transport Agency. It has also been assumed that the travel patterns would remain the same for both Electric Vehicles and Internal Combustion Energy Vehicles. By adopting electric vehicles, for same travel distance, the energy consumption of EVs is 4 times less than of ICEVs.

TRAVEL ENERGY CONSUMPTION COMPARISON PER HOUSEHOLD PER YEAR BY VEHICLE TYPE

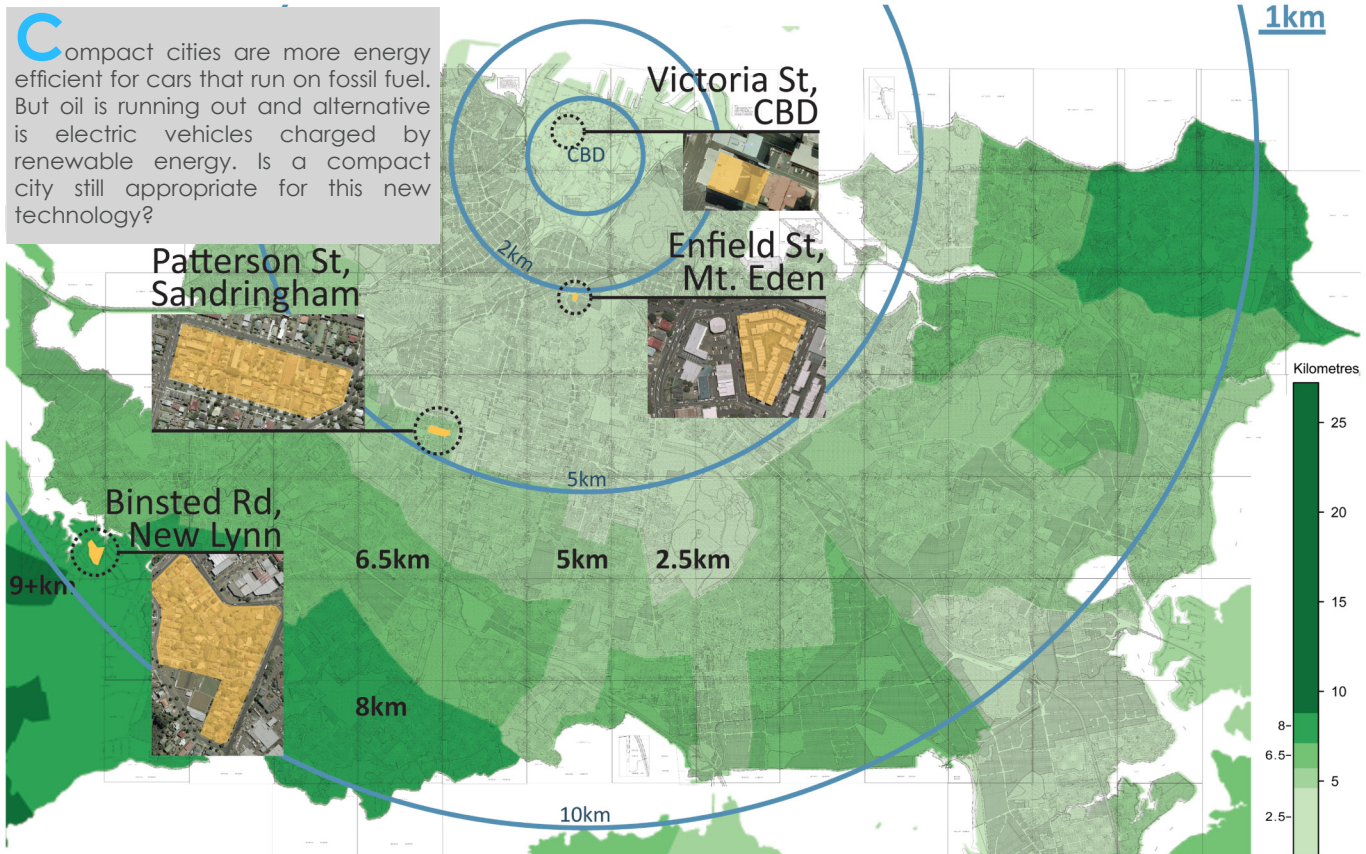


The roofs for all the houses were assessed for PVs. Only roofs with the optimum orientation and tilt were selected. 4m² was reserved for solar water heating. Assuming all four residential sites utilize their full solar potential, the energy generated will be sufficient to provide all their daily travel energy consumption. However, of equal importance is the amount of surplus energy that can be generated depending on the density of the site.

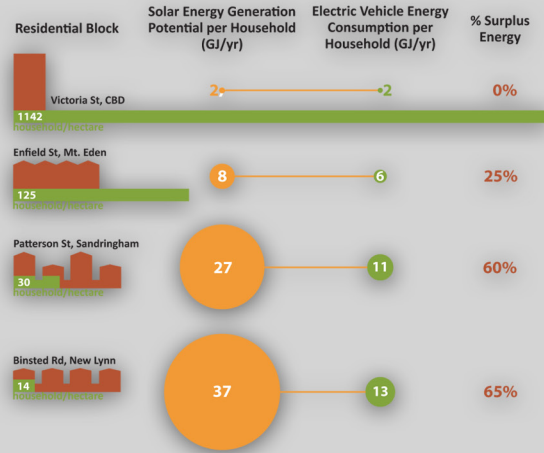
Transport Consumption with Energy Generation Potentials



Compact cities are more energy efficient for cars that run on fossil fuel. But oil is running out and alternative is electric vehicles charged by renewable energy. Is a compact city still appropriate for this new technology?



SOLAR ENERGY POTENTIAL & EV TRAVEL CONSUMPTION COMPARISON
(PER HOUSEHOLD PER YEAR)



For Electric Vehicles powered by PVs on the roofs of houses, lower dense suburbia becomes more energy efficient.

EVs powered by PVs have not only adequate energy for transport but also a surplus. (Hence the graph indicates negative values.) An intensive urban form may be more energy efficient, in terms of transport energy use, for ICEVs.

T O O M U C H G L A S S

: SHEDDING LIGHT ON ENERGY AND PRODUCTIVITY



A common characteristic of many recent buildings is a high proportion of glazing. One assumption is that the greater the Daylight Factor (DF), the greater the IEQ and the greater the productivity.

This is based on research carried out in the US.

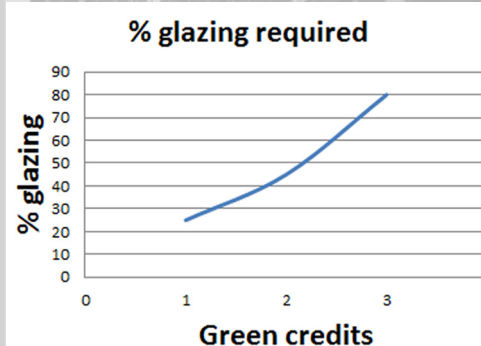
"The analysis indicates that for every 10% increase in daylight illuminance on the log scale, there was a 0.45% increase in performance"

California Energy Commission (2003) Windows and Offices: A Study of Office Worker Performance and the Indoor Environment.

"There is also evidence that daylight and views have positive impacts on work attitudes and experiences"

Heerwagen, J. (2000), Green Buildings,

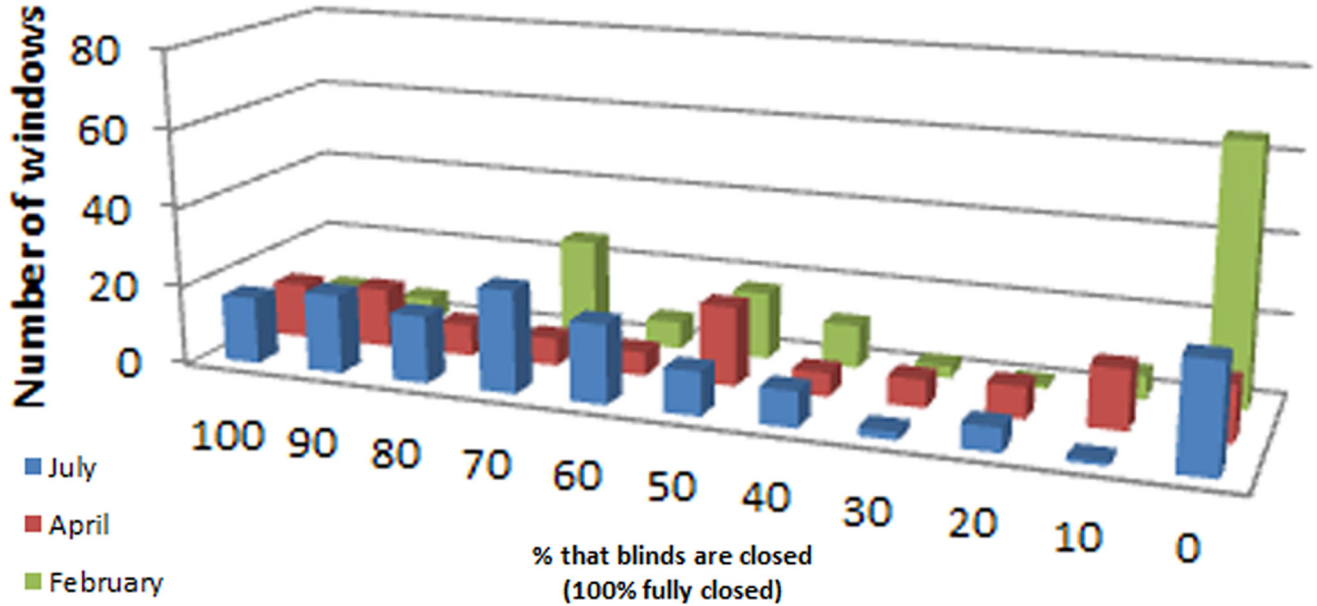
Rating tools for 'green' buildings may be inadvertently prescribing high energy consuming buildings with low IEQs. While the corporate image of a highly glazed building is seductive, there is now evidence that they are not necessarily productive.



Green rating tools induce too much glass

The relationship between the amount of glass and green credits is exponential. To obtain the maximum accreditation points requires at least 80% glazing for a 2.5% Daylight Factor for typical room depths, heights and reflectances.

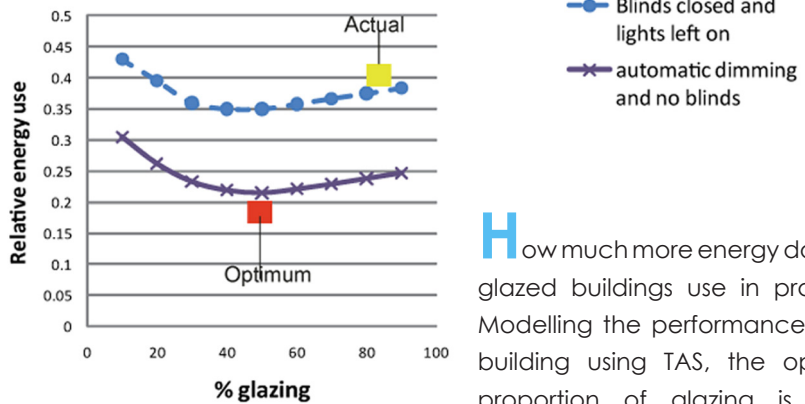
SEASONAL HABITS OF CLOSING BLINDS



Measured observations on buildings, such as the one illustrated, shows that on average, 60% of the windows are covered. **Occupants do not like too much glass. They vote with the blinds and leave the lights on to compensate.**

Too much glass means a high cooling load. But when the blinds are closed it makes it even worse. Most of the solar energy still gets in but there is less daylight. So occupants turn on the lights which increases lighting energy consumption as well as the cooling load.

Comparative energy use of building with & without the use of blinds



How much more energy do highly glazed buildings use in practice? Modelling the performance of the building using TAS, the optimum proportion of glazing is about 50%. However, when the blinds are closed and the lights left on, **a building with over 80% glazing uses almost twice as much energy.**

