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Reduction of household CO2 emissions in NSW, Australia: A reference to Central Chile. Case Study: Clovelly House

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En memoria de Humberto Vega Fernández, decano de la Facultad de Ciencias Económicas y Administrativas de la Universidad Central de Chile

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ABSTRACT

Palabras clave: hogares, reducción de carbono y diseño sustentable.

El diseño climático y la eficiencia energética juegan un rol primordial en la reducción de las emisiones de gases de efecto invernadero en los hogares. Esto se ilustra comparando dos zonas climáticas similares de Australia y Chile, países que acordaron reducciones de emisiones de CO_2. En ambas zonas se muestran las condiciones de las viviendas en relación a: principales fuentes de energía usadas, actuales condiciones térmicas, reglamentación de construcción y programas de fondos de los respectivos gobiernos. Además, con el fin de compensar el CO_2 de las viviendas, es presentado el esquema de Carbono Neutro referido a la renovación de una vivienda en la zona Australiana, que reduce las emisiones a la mitad comparada con la vivienda promedio, y también, incluye un pionero sistema de manejo de agua servida, ambos criterios relevantes del diseño sustentable.

Key words: household, carbon reduction and sustainable design.

Climactic design and energy efficiency play a key role in reducing household GHG emissions. This is illustrated by comparing two similar climactic zones in Australia and Chile, countries which agreed on carbon reduction. In both zones, it shows dwelling conditions related to: main energy sources used, current thermal conditions, building regulatory and governmental funds programs. In addition, with the purpose of offsetting the household carbon, the Carbon Neutral scheme is presented with reference to a house renovation in the Australian zone. This reduces emissions by half compared to the average household and it also includes a pioneer grey water management system, both relevant sustainable design criteria.

Reduction of household CO2 emissions in NSW, Australia: A reference to Central Chile. Case Study: Clovelly House

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INTRODUCTION

Both in Australia and in Chile a large majority of city people live in houses that were built with little regard to the climate. These houses are energy inefficient, and comparatively expensive to run in hot and cold climatic conditions. They use far more water than necessary and are often built with materials that damage both occupant's health and the natural environment. These houses also produce greenhouse gases (GHG) which, when released into the atmosphere, have the potential to cause global warming. Activities such as cooling, heating, cooking, lighting, running appliances and rubbish disposal contribute to household emissions. Each Australian household produces more than 14 tons of greenhouse gas emissions every year[1]. Thus 8.4 million households[2] in Australia are producing over 117 million tons annually which contribute to approximately 20% of the 547 million tons GHG emissions produced across Australia[3].

The building industry has a key role to play in influencing the public regarding future energy demands. Using a good design criteria to build houses can save energy, water and money, thus substantially reduce GHG emissions. In addition to this, the sometimes larger upfront cost of implementing greener design into home building can be offset by the long term savings in energy bills as well as an increase in the value of the building.

1 Department of the Environment, Water, Heritage and the Arts, Australia Government, *Greenhouse Gas Emissions Calculator*, Online source http://www.environment.gov.au/settlements/gwci/ calculator.html, Accede on December 2,2008

2 Australia Bureau of Statistic, Australia Government (2006), *A Picture of The Nation*, Australia, Online source http://www.abs.gov.au/ausstats/abs@.nsf/mf/2070.0, Accede December 16,2008

3 Department of Climate Change, Australia Government (2009), *State & Territory Greenhouse Gas Inventories 2007*, Australia, Online source http://www.climatechange.gov.au/inventory/2007/index.html, Acceded on June 7,2009

New South Wales (NSW) Australia Zone 5 has similar climatic conditions to central Chile Zone 3. Reducing GHG emissions now must become a priority for both countries if they are to move towards a more sustainable future. This article compares household energy demands and GHG emissions in the mentioned zones in both countries, taking into account the different stages of each country's development. It also outlines local regulations and procedures to reduce emissions and achieve carbon neutral housing. Finally, it presents a case study of a new residential project in NSW Australia Zone 5, which has actively sought to reduce emissions using contemporary design, via efficient environmental assessment criteria. This project incorporates strategies aimed to reduce energy and potable water demand, while using passive and active solar design. The project, which utilizes climate-specific building materials, also aims to reduce waste levels both during construction and in habitation.

HOUSEHOLD ENERGY DEMANDED AND GHG EMISSIONS

Australia and Chile have diverse climates. In both countries their Building Code divides these climates into zones to establish building requirements in the home shell to achieve thermal performance, so its occupants can use less additional energy for heating or cooling. To compare NSW Australia Zone 5 and Central Chile Zone 3 is relevant because both countries have already ratified The Kyoto Protocol agreement to reduce emissions, and they (Zone 5 in Australia and Zone 3 in Chile) are within similar climatic zones. Both Zone 5 in NSW, Australia[4] (which includes cities such as Sydney and Canberra) and Zone 3 in central Chile[5] (which includes cities such as Santiago and Rancagua) share 35 South latitude, have low temperature variations (day/night) near the coast and high variations in the interior. There are also four distinct seasons: A warm to very hot summer, which can exceed the human comfort range with a moderate humidity, and a cold to mild winter, which also exceeds human comfort range with a low humidity. In contrast, autumn and spring present ideal thermal conditions for human comfort.

GHG emissions produced per household depend on the energy source used. Table 1 shows that the intensity of carbon emissions for electricity is much higher than that for natural gas or wood. (per unit of energy delivered).

Table 1

Australian GHG emissions per unit of different energy types per household[6]

Source	Unit	Factor	GHG emission
Electricity	1 kilowatt-hours	1	1 Kilogram
Natural gas or LPG	1 mega joule	0,007	0,007 Kilogram
LPG if its buying by LT	1 Litre	1,7	1,7 Kilograms
Natural gas in WA (unit in 3,6 mega joule)	1 unit	0,24	0,24 Kilogram
Oil or Kerosene	1 Litre	3	3 Kilograms
Wood (used in slow combustion heating)	1 kilogram	0.23	0.23 Kilogram
Wood (used in an opening fire)	1 kilogram	5	5 Kilogram

In comparing households in Australia and Chile it must be considered that in Australia an average household is occupied by 2,5 persons (2) and in Chile an average household is occupied by 4 persons[7]. This

4 Planning SA, Australia Government, *The Building Code of Australia*, Online source: http://www.abcb.gov.au, Acceded on January 10,2009

5 Ministerio de Vivienda y Urbanismo, Gobierno de Chile (2007), *Reglamentación Térmica*, Ordenanza General de Urbanismo y Construcción, Chile, Online source http://www.mart.cl, Acceded on December 20, 2008

6 www.enviromental.gov.au

7 Bruna, R., Fundación Instituto de Ecología Política, Gobierno de Chile (2008), *Análisis de Datos: Emisión de CO_2 de Hogares de Santiago*, Chile, Online source http://www.radioclima.org/nweb_portal/site/ ver_archivo.php?id=109, Acceded on January 18,2009

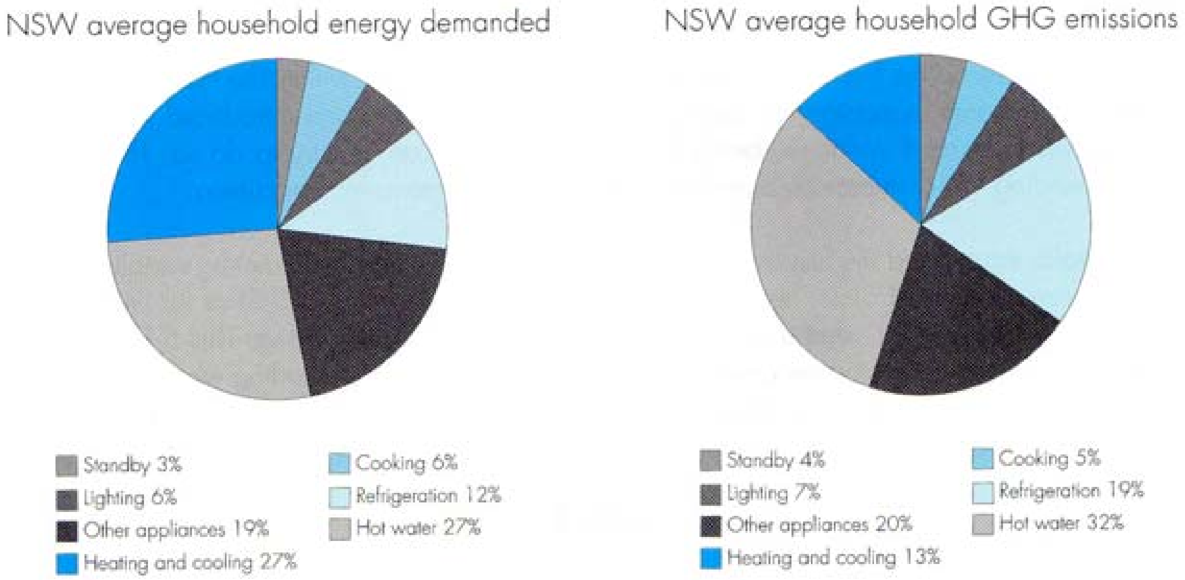
difference is due to Australian families having, on average, fewer children, and to a decreasing prevalence of multi-generational houses (2).

Although natural gas is the main residential energy source in both zones for hot water systems and household heating, electricity constitutes the highest carbon emissions source. In both zones energy from other sources such as wood have significantly low GHG emissions when compared with gas or electricity. Moreover the latest trends show those sources are decreasing further.

More than 50% of the energy used by households in both zones is sourced from electricity, which produces over 50% of the total 8.2 tons in one NSW household (or of the total 3.3 tons per resident)[8] and around 5.7 tons in a similar central Chilean household (or of the total 1.35 tons per resident) (7). In both cases the majority of these emissions are produced by household appliances selected by the residents post construction.

Figure 1

NSW Australia, Energy demanded[9] and GHG emission (8)



As seen in figure 1 in NSW, cooking, water heating and electrical appliances represent about 73% of total energy demands and 87% of residential GHG gas emissions. The other 27% is for heating and cooling (using electricity, natural gas, LPG and wood), which contributes a further 13% to greenhouse emissions. In terms of energy, heating is the second largest item affected by the design and thermal performance of the building's shell. It is also one of the single largest energy items used in houses and the fourth largest producer in GHG emissions activity, after water heating, appliances and refrigeration.

LOCAL REGULATIONS

In terms of household thermal conditions, residential buildings in both NSW and central Chile are generally poor in insulation. A 2005 study into household insulation in NSW shows that about 16% of all residential buildings had both wall and ceiling insulation, and 33% were only insulated in the ceiling[10].

8 NSW Department of Planning, Australia Government (2008), 2005-2008 Single Dwelling Outcomes Basix Ongoing Monitoring Program, Australia, Online source http://basix.nsw.gov.au/information/monitoring.jsp, Acceded on December 25,2008

9 Department of Environment, Heritage and the Art, Australia Government (2008), Energy ,Use in The Australia Residential Sector 1986-2020, Australia, Online source: http://www.enviroment.gov.au/settlements/building/publications/energyuse.html, Acceded on December 12,2008

10 Australia Bureau of Statistics (2005), *Environmental Issue: People's Views and Practice*, Australia, Online source: http://www.abs.

In central Chile a 2008 survey investigated the thermal comfort in winter and summer of social housing residences built between 2002 and 2006. The study found that in both winter and summer seasons these houses were notably outside the effective comfort temperature range[11]. On a winter morning, 90% of these dwellings had additional heating support, (the majority of which were turned on at the time of the survey) and more than 70% of the houses had a temperature below 17_C. In summer, temperatures were notably higher with about 80% of houses measuring over 25_C during the day[12].

Improving buildings thermal performance results in less use of additional energy being required to keep houses warmer in winter and cooler in summer. Over the past 15 years, both countries have been working on the improvement of home orientation, glazing, insulation and natural lighting. However, improvements have taken too long in the residential sector where the market relies on low cost, profitable housing and hasty construction to meet demands. Improvements will continue to be slow without incentives.

Both zones have thermal regulations in their residential building codes and technical manuals which assist builders with the implementation of effective insulation procedures. These countries have modified their regulations and actively added new standards in order to improve thermal comfort levels.

In 2000 Chile introduced the first of the three stages in thermal regulation within The House Building Code where insulation became mandatory for ceilings. In 2007 the second stage introduced requirements for walls, suspended floors and windows, being the first South American country to do so. The third stage, which is still pending, is set to provide essential household energy performance criteria.

In 2003 Australia established the first mandatory insulation and glazing requirements, establishing a minimum performance rating of 4 Stars. In 2006 it increased the requirements to 5 Stars for walls, roof, suspended floor insulation and included a more comprehensive regulation on glazing. This 5 Star certification also regulates air movement, hot water service and external glazing and/or shading when required. Under these regulations, all new homes must have a rainwater tank to supplement town water supply to be used ideally in the toilet and laundry.

Table 2

Insulation requirements in dwellings for main items, Residential Building Codes per zones and pre country. (4)-(5)

			Suspended	Single glass	Double glass
	Roof	Wall	Floor	Window	Window
	Rt ≥	Rt≥	Rt≥	Rt≥	Total U- value ≤
Zone Code	m2K/W	m2K/W	m2K/W	m2K/W	W/m2K
NSW Australia, Zone 5	3,2	1,9	NR	5,8	3,8
Central Chile, Zone 3	2,13	0,53	1,43	2.8	2,4

In terms of sustainability regulation, in 2004 the NSW Government, through its Department of Planning, introduced the BASIX regulation. BASIX mandates for new residential construction to save 40% more town water and 40% more energy than the average pre-BASIX house. About 42.000 new houses in 2005-08

gov.au/AUSSTAS/abs@.nsf/DetailsPage/4602.oMar%202005?OpenDocument#Publication, Acceded on December 5,2008

11 Between 18 and 24, with air movement less than 1 meter per second and relative humid between 35 and 75, World Health Organisation, www.who.int

12 Proyecto Fomento de la Eficiencia Energética (CNE/GTZ)(2008), *Determinación de Línea Base "Anual" para la evaluación de la inversión en Eficiencia Energética en el Sector Residencia, Invierno 2007-Verano 2008*, Chile, Online source: //www.iconstruccion.cl/files/Invierno%20-%20Verano%20GTZ.pdf, Acceded on February 15, 2009

Programa País de Eficiencia Energética (PPEE): www.ppee.cl

This governmental program managed by the *Comision Nacional Energetica* (CNE) assists the government strategies to achieve energy efficiency across diverse areas. Within the residential area in 2007 it supported the central Chilean zone with The Replacing Light Bulb Program supplying 124,000 energy efficient lighting bulbs (20W fluorescent globe) to 40% of the poorest population (750,000 households). It reduced 80% of energy demand by each bulb replaced, saving money and avoiding 258,000 tons of GHG. Now the government is tendering the first public selling project of GHG reductions for those light bulbs already replaced in the international GHG emission market, being again the first South American country to do this.

Fondo Vivienda Solidario and Vive con Buena Energía: www.minvu.cl

Both programs are managed by the local Housing and Planning Ministry (Ministerio de Vivienda y Urbanismo - MINVU). The Fondo Vivienda Solidario Program offers funding support for the continued need for social housing and it also creates incentives to provide innovation in terms of energy efficiency such as architectural open competitions in this field. The new proposals will form the main policy outlines for the third stage of residential regulations. Additionally, the Vive con Buena Energia Program is a planned initiative in collaboration with PPEE which will begin by supplying funding to improve thermal isolation of 10.000 existing social houses.

ACHIEVING A CARBON NEUTRAL HOME

This term is used for a house that reduces the equivalent amount of GHG emissions produced by its internal household activities during a year, which is possible by improving energy efficiency and using renewable energy sources on-site; after a year the net energy generated on-site offsets the amount of GHG emissions the house produces. Therefore the overall amount of carbon-dioxide emitted can be effectively cancelled out, resulting in a carbon neutral household. The scheme to balance or offset household GHG emissions encompasses three basic steps:

1. Calculating the amount of carbon-dioxide emissions produced by each activity.
2. Calculating how much it will cost to carry out a project that is specifically set up to provide greenhouse savings or benefits (for example planting new trees)
3. To give a final cost to offset the activity, the cost calculated in Step 2 is added to Step 1

Table 3

Table shows the scheme of offset household GHG[14]

CO_2 produced for an Activity		Carbon Offsets are purchased		Neutral overall CO_2
1 CO_2 Tone per year is emited	+	CO_2 Tone per year is absordeb by planting trees	=	Zero CO2 activity emissions

The household behavior is essential to a home becoming carbon neutral, and it is also necessary for the household to assess its conditions before undertaking the scheme i.e. physical condition, temporal condition and house life cycle conditions. Physical condition refers to aspects such as orientation or climatic benefits that affect the shell, temporal condition refers to the period assigned to achieve the scheme, and life cycle conditions refer to the house's actual useful lifespan. This formula assists households in maintaining a self-

14 Department of the Environment, Water, Heritage and the Arts, Australia Government (2000), *Your Home*, Australia, Online source: http://www.yourhome.com.au

sustainable existence, with a full understanding of the benefits from renewable energy as well as how space and cost is required to provide renewable energy solutions on-site.

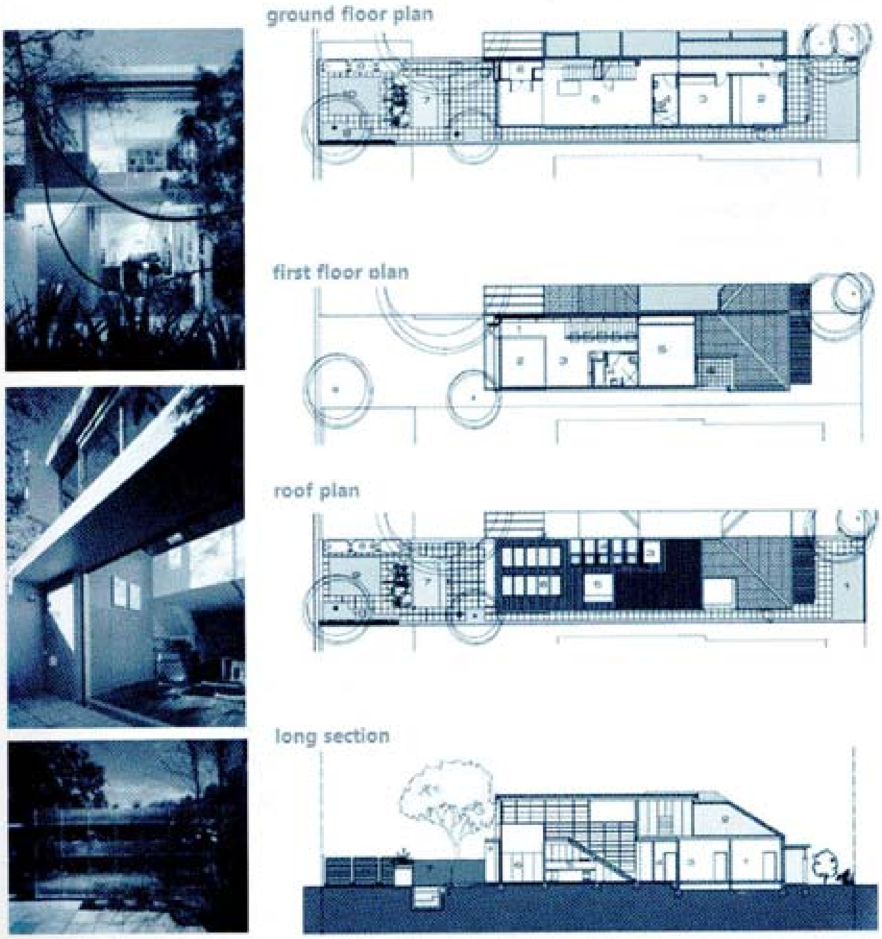
Zero Emission House (ZEH), designed by CSIRO projects, over construction, will be the first carbon neutral house in NSW. CSIRO project leader, Dr Greg Foliente said:

"The goal is a home that does not release any CO_2, or other greenhouse gas, into the atmosphere as a result of producing or consuming energy on the entire site. The first step is to reduce energy consumption to the lowest possible level through careful building design, considering the climate, the hot water system, how the building is heated and cooled, as well as the appliances which will be used. This new house is expected to use up to 70 per cent less energy than a traditional home of similar size"[15]

CASE STUDY: CLOVELLY HOUSE (Sydney, NSW, Australia)

Kennedy Associates Architects in association with ENVDS Consulting Engineers
2006 Randwick City Council Urban Design Awards, Awards for Best Alterations and Additions and Best Sustainable Design
2005 RAIA (Royal Australian Institute of Architects) Award for Sustainable Architecture Award
2004 Green Building Awards, Gold Medal

Figure 2



Ground floor plan:
1. Entry
2. bedroom 3
3. bedroom 2
4. bathdroom 2
5. Living and Kitchen
6. Laundry
7. Pool
8. Rainwater tanks
9. Stormwater absorption
10. Parking and storm water absorption.

First floor plan:
1. Library
2. Void
3. Study
4. bathdroom 1
5. Master bedroom
6. Deck

Roof plan:
1. Storm water infiltration zone
2. Solar pool heating
3. Skylight
4. Sun Lizard
5. Solar water heater
6. future solar array
7. pool
8. 9000L rainwater tanks
9. storm water absorptionn

Long section:
1. Bedroom 3
2. Bedroom 1
3. Bedroom 2
4. Bedroom 2
5. living, Kitchen and Laundry
6. Void
8. Rainwater tanks

Source: The Clovelly House, Kennedy Associates Architects.

15 CIRIO Projects,(2008),Zero Emission House (ZEH), Australia, Online source: http://www.csirio.au/news/ZeroEmissionsHouse.html. Acceded on February 13, 2009

This house in NSW Zone 5 is a three-bedroom south-facing semi-detached residence, which was renovated for two people into a two story building, with pool and off-street car parking. One significant environmental design criterion utilized in this example is the use of passive solar design techniques which are relevant due to its east-west orientation that offers limited potential for easy solar access; the same occurs in Chilean houses which have the same orientation. The other design criterion is the innovative water management plan with a green wall for grey water treatment, the first of its kind in Australia.

Table 4 (14)

Reduction electricity demanded in Clovelly House

Energy uesd for an average NSW homehold each year	initial load (kWh)	Approx cost assuming $AUS 0.15 cents per kWh	Average NSW 2 residences GHG emission (%) tonnes		Energy efficiency measures Clovelly house 2 occupants	Approx energy efficiency saving (%)	New load (kWh)	Approx saving assuming $AUS 0.15cents per kWh	GHG emssion achieved tonnes
Heating/ Cooling 27%	1900	$285.00	13	0.858	Passive systems: Void, solar fans and air colec	100	0	$285	-0.122
Hot water 27%	1250	$187.50	32	2.112	Change to solar hot water systems	50	625	$93.75	1.056
Others electrical appliancies 19%	800	$120.00	20	1.32	Improve efficiency and reduce use	10	720	$12	1.188
Lighting 6%	350	$52.50	7	0.462	Change to compact fluorescent lighting	75	87.5	$39.375	0.1155
Cooking 6%	200	$30.00	5	0.33	Improve efficiency by using microwave	30	140	$9	0.231
Refrigera-tion 12%	350	$52.50	19	1.254	Improve efficiency bu 5 star	30	245	$15.75	0.8778
Standly 3%	150	$22.50	4	0.264	Turn off most appliances at the plug	90	15	$20.25	0.0264
Total	5000	$750.00		6.6			1833	$475.13	3.3727

DESIGN CRITERIA

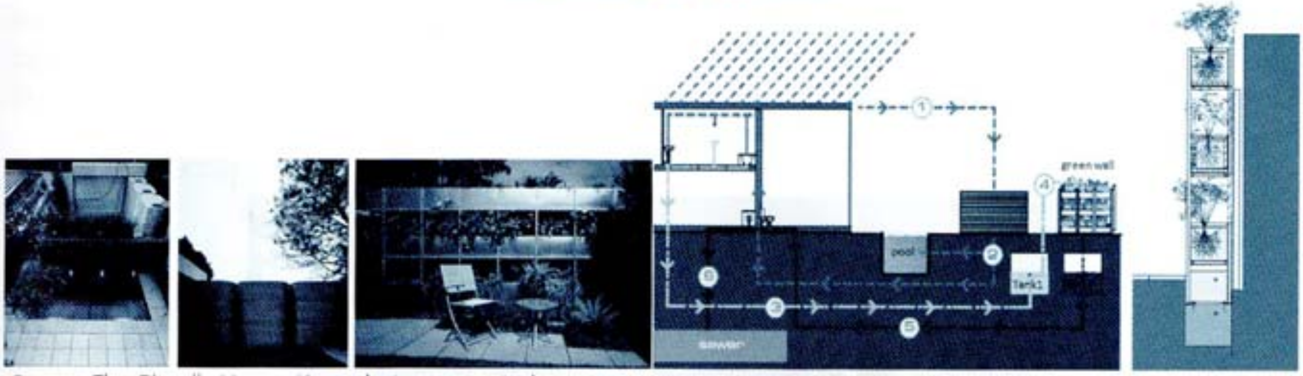
Passive heating / cooling: Without air-conditioning or auxiliary heating, the house bases its internal thermal comfort in two systems:

Void: A double height space placed at the rear of the house achieves natural cooling in summer as well as heating in winter. In summer it acts as a chimney by closing external louvers blocking the western sun. Warm air is exhausted through high-level windows and at the same time the void pulls fresh cool air into the house at ground level by convection. In contrast, during winter external louvers are kept open to allow the sun inside heating a timber covered concrete floor at ground level to warm the living areas.

Solar fans and collector: This system uses the same principles as a solar hot water system. In summer, two solar-powered fans draw air at ceiling level through an opening flap on the collector and extract it externally. In winter the fans draw air from ceiling level, heating the air to about 50_C in the collector, and pumping it back to ground floor level via insulated ducts. Insulation is placed in the walls and roof with draught protection on doors and windows to retain heat.

Water management:

Figure 2
Water system and green wall



Source: The Clovelly House, Kennedy Associates Architects.

1. Rain water collected from 100 sqm roof area is directed to 3x300L storage tanks
2. Water from rainwater storage tanks supplies: pool, shower, bath, washing machines & toilets.
3. Grey water collected from shower, bath and basin is directed to tank 1 (treatment system)
4. Water from holding tank 1 is pumped to top of the green wall treatment system
5. Polished water supplies washing machines & toilets.
6. Green water collected from shower, bath and basin is directed to treatment to tank 1 for Green wall treatment system

This is a net water system which retains and reuses all water on-site excluding grey water. Taking into account the average water consumption for a two person NSW household is 180,680 litres per year (8). The Clovelly House system achieves a minimum of 75% usage reduction and a saving of approximately 115,000 liters of water per year. This system supplies water from three sources: town water, rainwater harvesting and grey water. Town water is connected only to the kitchen and roof collector. The rainwater harvested from the 100sqm of roof is stored in three 3,000 liter tanks to supply the swimming pool, showers, baths and hand basins. Excess storm water is directed to an onsite aquifer. Grey water is filtered and processed through a vertical 'green wall' and stored to be used in the toilets and washing machine. The green wall is basically a large water filter *(6m long, 2.1m high and 350mm wide)*. It has three containers stacked on top of each other. Each container has different diameter grains of sand (from coarse to fine) which purify the water, removing bacteria and suspended solids. Two times a day, the gray water in Tank 1 (a 300 litre tank buried under the paved courtyard) is pumped to the plants in the top container. The water then naturally gravitates down through the filters to the bottom storage Tank 2 (600 litre), from where it is pumped back into the house for reuse. A UV filter provides a final stage of disinfection for the water as it is being pumped between Tank 2 and the house.

The plants grown in the Green Wall were selected for their suitability to grow in water and to handle certain levels of acidity and absorb nutrients extracted from the grey water. Cannas and Liriopes are grown in the containers on top, Arum Lillies the intermediate level and Ferns the lower level. In periods without residential occupation, the pump re-circulates the water in Tank 2 to the filters to keep the plants alive. The system operates with common detergents without the need for special products, though the fewer chemicals used will extend the life of the filter material in the Green Wall.

Water heating: This encompasses an electrically boosted solar hot water system, set on top of the roof. The therapeutic pool is heated by a solar heating system which uses a series of heat-absorbing collector pipes, also located on the roof.

Appliances: 5 Star refrigeration, induction heating to stove, solar systems (hot water fans and collector). Clothes line prevents the need for an energy consuming clothes drier.

Power and lighting: Provision for solar power generation, low wattage lighting including PL and LED (light emitting diode). Light-coloured internal walls, skylight and clerestory glazing minimize the need for artificial lighting during the day

Construction Materials: To improve indoor air quality, plant-based biological paints are used for internal walls and ceilings, as well as vegetable-based oils for floors. Neither of these materials emit volatile organic compounds (VOCs). Processed sustainable timber, including gum timber flooring is used, along with polypropylene pipes (rather than copper pipes) for water supply and plumbing.

CONCLUSION

In NSW, Australia Zone 5 and central Chile Zone 3, household GHG emissions are mainly produced by energy associated with fossil fuels for heating, lighting, hot water and other electricity/appliances. Therefore it is essential during renovation or design of new homes to include a set of energy efficient criterions to achieve the best conditions of comfort and reduce GHG emissions. Although the Australian Zone is further advanced than the Chilean Zone due to a more developed context, its households are producing more emissions than the Chilean equivalents. Nevertheless both agree with the aforementioned criterion and are approaching the development process in the same manner. They have shown significant progress during recent years, including new requirements in their local regulations, such as BASIX Certificates in NSW, and in addition to this, both have supported existing and new households with programs and funds such as the PPEE program in Chile, to reduce their energy demands and the GHGs emitted

Cases like The Clovelly House in NSW confirm that residential projects designed with a set of energy efficient criteria, such as materials used, passive heating/cooling system and water management, are leading examples for energy-efficient households. It demonstrates how, by reducing energy demands and GHG emissions by half, it allows its occupants to begin achieving a carbon neutral home. Sharing similar climatic conditions and the primary target of reducing GHG emission, the environmental management included in this project could easily be referenced for both future social and private housing in the central Chilean Zone.

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